MAINTENANCE AND REPAIR OF CIVIL STRUCTURES

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STANDARD PUBLISHERS DISTRIBUTORS

1705-B, NAI SARAK, POST BOX No.: 1066, DELHI-110006
Phones : 3262700, 3285798, Fax: 3243180
email: stpub@vsnl.com www.standardpublishers.com

Published by :
A. K. Jain
For Standard Publishers Distributors
1705-B, Nai Sarak, Delhi-110006.

First Edition, 2007
Reprint Edition : 2009

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Price : Rs. 200-00

ISBN : 81-8014-102-0

Laser Typesetting by : Bhargave Laser Printers, Delhi.
Printed by : Prabhat Offset Press, Delhi.

PREFACE TO THE FIRST EDITION

The construction activities in all fields of Civil Engineering are increasing by leap and bounds, but no proper attention has been paid to the maintenance and repairs of these structures. No good books are available in the market on the subject of maintenance and repairs of civil structures. The age of super structures of concrete structures is assumed as 70 years and for sub structures as 100 years, but it has been observed that, what so ever well designed and carefully constructed structures failed much earlier than their intended life, due to improper upkeep and maintenance.

Thus keeping the importance of proper maintenance and repairs of structures and the needs of students and field Engineers in mind, authors have tried to present the scattered information on the subject in concised form at one place in this text in a simple and lucid language. In preparing this text authors have taken help from various codes and standard works. We express our gratitude to their authors. If the book proves to be useful to the students and field engineers we shall consider our labour fruitful.

Though every effort has been made to eliminate the errors of all types, yet some errors might have been left un noticed. Authors sincerely request the readers to bring such errors to the notice of publishers for the improvement of the book. Any constructive critisim for the improvement of the book is welcome. At the end authors express their gratitude to M/s Standard Publishers & Distributors, who have brought out this book in such a nice get up in a very short time.

Ellenabad (Haryana)
Ist, January, 2007.

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Introduction to Maintenance and Repairs

1.1. INTRODUCTION

We all know that to up keep the natural human body structure nutritious food is essential, so that it can carry out necessary duties of the human being. In case of any minor trouble in the body we take medicine to cure it. Thus taking of nutritious food is maintenance and use of medicines is the repair of the body. Similarly artificially constructed structures by human being need maintenance and repair to keep them in good condition to render the services for the purpose they are constructed or intended for. In case of minor defects they are removed by proper repair. Though the age of sub structures and super structures is estimated as 100 and 70 years in most of the concrete structures, but in most cases it depends on proper up keep and maintenance of the structure. It has been observed that a well designed and carefully executed structure failed much earlier than intended age due to improper up keep and maintenance.

Though essests are created of crors of rupees, but their maintenance is neglected, which reduced these essests to junks and ultimately have to be demolished and removed at a large expenditure.

1.2. DEFINITIONS

1. **Maintenance.** The term maintenance has been coined from the French word "MAINTENIR" which means to hold, keep and preserve a equipment or building structure to an acceptable standard of serviceability. In other words maintenance is the activities carried out to improve or to restore the facility in every part of the building to a accepted standard.
2. **Repair.** Work or activities carried out for the removal of any decay or defect or damage developed or caused due to constructional defect or due to natural decay of the structure is called repair.
3. **Operation.** The term operation relates to a plant as sugar mill or any activity required to run a plant. Thus the activity to run the plant is called operation. The operation, maintenance and repair are post constructed activities and there is a distinct difference between them.
4. **Services.** The provision of utilities such as power, water, lift etc. in a building are called services. Without essential services a building is useless.
5. **Servicing.** The work done or activities carried out to keep a plant or vehicle in a running condition is called servicing.
6. **Distress in structure.** The wear and tear developed in the structure due to aging or aggressive environmental conditions is called distress in structures.
7. **Defect.** When a structure or its member is subjected permanently to some unforeseen stresses exceeding its load bearing capacity, then structure is said to have developed a defect.
8. **Decay.** The development of a defect in a structure either due to aging or otherwise is said to have decayed. A building is considered decayed when it becomes incapable to sustain the designed stresses and its early failure is anticipated.

1.3. OBJECTIVES OF MAINTENANCE

The objectives of maintenance of a building or plant etc. are to ensure that the building or plant can perform their designed functions for the intended period of time with a high degree of reliability. Following are the main objectives of maintenance.

1. To preserve buildings alongwith their services, and plants in good serviceable condition.
2. To restore buildings along with their services and plants in their original standards after any deterioration occurred due to any reason.
3. To improve the serviceability of buildings and plants when ever required.
4. To sustain their utility value by slowing down the rate of deterioration of structures and plants.

1.4. FACTORS INFLUENCING THE MAINTENANCE

Though there are various factors which influence the decision of taking maintenance of a structure. However following are the main factors which influence the maintenance.

1. Cost. The cost of maintenance may be divided into the following categories:

(*a*) **Direct cost.** Direct cost comprises the cost of material, labour, rent and cartage of equipment etc. Usually this cost varies from 70 to 90% of the total repair cost.

(*b*) **Indirect cost.** Under this head cost of stoppage of work, money spent on safety measures, availability of time, over head expenses, restricted access etc. are grouped. This cost may vary from 10 to 30% or even more.

2. Age of building. Every element of a structure has a definite life span. All materials and components start aging from the moment they are used in the structure. Hence a comprehensive program of inspection and maintenance of structure should be prepared as soon as the construction of building or structure has been completed.

3. Availability of physical resources. At the time of planning maintenance of an element of the building all the materials, components, services and equipment needed should be available. If they are not available maintenance is not possible.

4. Urgency. In case of failure of some services as failure of water supply, the repair needs immediate attention. If it is not repaired immediately, it will cause a lot of inconvenitence.

5. Future use. At the time of considering of carrying out maintenance, future use of building as a whole must be kept in view.

6. Social considerations. While carrying out maintenance work, the disturbance to the society should be minimum. Pleasing environment should be created by regular and planned maintenance.

1.5. NECESSITY OF MAINTENANCE

Maintenance of structures is essential for the following causes.

1. Prevention of damages and decay caused due to natural agencies, wear and tear and keep them in good working condition and appearance for the intended job.
2. Repair of defects developed in the structure and strengthen them.

1.6. CLASSIFICATION OF MAINTENANCE

Maintenance of structures can be classified into the following categories:

1. Preventive maintenance
2. Remedial maintenance
3. Routine maintenance
4. Special maintenance
5. Corrective maintenance

1.6.1. Preventive maintenance

Activities or work done before the development of defects or damage in the structure is called preventive maintenance.

This operation includes thorough inspection, and planning the programme of maintenance and its execution. It depends upon the condition, use and specifications of the structure.

Under this maintenance, following actions may be taken to arrest decay or damage to the structure.

1. Stopping of leakage in roof, walls, sanitary, plumbing and waste water pipe lines and rain water pipe lines by regular and proper maintenance.
2. Use of specified materials and adoption of good workmanship during construction.
3. Adoption of correct specifications for items during construction.
4. Protecting the structures from physical influences and weathering agencies.
5. Protection of structure from aggressive environmental influences.
6. Proper use of structure.

1.6.2. Remedial Maintenance

This maintenance is adopted or done after the occurrence of damage in the structure. Under this maintenance following steps are involved:

(*a*) Determination of the extent of deterioration or damage.
(*b*) Determination of the causes of the decay or deterioration.
(*c*) Determining the strength of the existing structure.
(*d*) Assessing or evaluating the needs of the structure *i.e.* what is to be done to save the structure.
(*e*) Selection of proper procedure of repair and its implementation.

1.6.3. Routine Maintenance

It is a service maintenance attended to the structures periodically as decided by the public works department. For this maintenance generally 1½% amount is fixed of the cost of construction. The interval of routine maintenance of different items also has been fixed as a guide line. These standard maintenance cost and interval of maintenance may vary from state to state.

The routine maintenance is carried out to attend the problems of normal nature. It includes inspection, planning and execution of the maintenance plan. Generally works included are white washing of building, patch repair of plaster work, replacement of faulty fittings and fixtures, binding of road surfaces etc. The interval of routine maintenance of some items is shown in table belows as laid down by public works department.

Table 1.1. Interval for routine maintenance of some items

Name of periodic repair	*Exposed surface*		*Un exposed surface*	*Remark*
	Important buildings	*Other buildings*		
External white wash	Annually	Normally every two years	Every two to three years	The periods shown are a guide line, but repair should be done when ever required. Some structures need frequent maintenance than others due to various reasons
External colour washing	Every two years	Every two and three years	Every three years	
External painting	As per need	—	—	
Internal painting	Every three years	Every four years	As required	
Renewal of approach road	3 to 10 years	According to traffic and material used	—	
Renewal of tanis court	5 years	—	—	
Thatching	8 cms coat every year	Renewal after 9 years and 8 cms coating every 3 to 4 years	—	

1.6.4. Special Maintenance

This maintenance is carried out under special conditions. It is not covered in routine or annual repairs. It requires sanction from the competent authority. Special maintenance are required for strengthening the structure to increase its serviceability as in case of foundation settlement. It may include a particular part or complete removal of floors and roofs etc. In this case estimate of repairs is prepared. Financial and technical approvals are obtained before starting the work (also refer chapter 5 page 56-57.

1.6.5. Corrective Maintenance

It is the most common method of maintenance. When an element or item fails or falls below the level of acceptable standard, corrective maintenance is resorted as repair of cracks or corrosion maintenance etc.

1.7. MECHANISM OF DETERIORATION

Deterioration of a building is the gradual disintegration of its component materials due to any destructive action from aggressive soils, and waters, exposure conditions to weathering agents and relative movements of components. The rate of deterioration of a structure or building varies with the resistance of the materials used in the structure. Permeability of the construction materials is one of the critical characteristics which influence the durability. The causes of deterioration may be external or internal. The deterioration process can be classified into the following categories.

1. **Mechanical.** Under this head, effect of overload of structure, impact of loads, fatigue of materials and wear and tear can be included.
2. **Physical.** Under this head, effects of thermal and volume changes due to temperature variations, cracking, deformation, freezing and thawing may be grouped.
3. **Chemical.** Under this category, reaction of aggressive substances in contact with structure and reaction of harmful chemicals present in the construction materials and electro-chemical process like corrosion can be classified.
4. **Biological.** Under this category bacteriological growth can be classified.

1.8. FACTORS RESPONSIBLE FOR THE INITIATION OF THE PROCESS OF DETERIORATION OR DECAY

Following factors are responsible for the initiation of determination process.

1. **Human factors.** This factor can be divided in two groups as

(*a*) **Misuse of building by the occupants.** Use of building for purposes other than those it is intended is an act of blatant misuse of the building. Failure to timely repair of damaged services, lack of proper cleaning of services, resulting in deposition of injurious materials and act of deliberate damage to the building are some of the factors which cause deterioration of the building.

(*b*) **Lack of maintenance culture in maintenance staff.** If the persons responsible for maintenance have no appreciation for timely and proper maintenance, may lead to deterioration of buildings. No timely maintenance further deteriorates the building. Under this head following factors may also be included.

(*i*) Failure to carryout routine maintenance well in time.
(*ii*) Poor security against misuse of the building.
(*iii*) Lack of knowledge, regarding factors leading to deterioration.
(*iv*) Lack of awareness of maintenance needs among the users.
(*v*) Having casual approach to repairs etc.

2. Chemical factors. The interaction of building materials with the surrounding environmental agencies such as rain, temperature variation, atmospheric gases and fumes etc. is one of the main causes of deterioration. When metals come in contact with moisture or water, air, sulphates and carbon dioxide etc.

they corrode. Thus corrosion is the main factor for causing instability in metals. Thus it is essential to know the causes and its protective measures to over come the problem of corrosion.

3. Furring. Deposition of mineral scales in pipes and vessels in which lime and magnesium bearing water is heated or conveyed is called Furring. It depends on temporary hardness of water. The mineral particles are known as *fur*. Mineral particles precipitated at temperature above 60°C deposit on the walls of the vessel or pipe in the absence of evaporation. This process makes the pipe or vessel poor conductor of heat, and reduces its diameter resulting lower flow of water. To over come this problem either treated water should be used or over sized pipe diameter may be used.

4. Environmental Aspects. The exposure of building components to the atmospheric agencies such as rain, moisture, air, gases and surrounding soils is called environmental effect. Generally environment results in weathering. Weathering is the process of decomposition due to weather components as mentioned above. In addition to weathering effect, Biological agencies, ground water and salts also affect the durability of construction materials. The effect of various factors is dissuced as follows:

(*a*) **Solar radiation.** Solar radiation is received by all elements of the earth surface. Most building materials absorb radiation depending upon their nature and colour of the surface. As we known that black colour absorbs maximum radiation. The absorption of radiation leads to degradation of some materials as paints, plastics and bitumen based materials.

(*b*) **Temperature effects.** The variation in temperature causes dimensional changes or variation in their lengths and volumes. This effect is more pronounced in case of materials whose coefficient of expansion is high. The restraint to this change causes internal disruption of the material resulting in the rupture and failure of the material.

5. Effect of Moisture. Moisture in any form as solid, liquid or gaseous state is the main agent of deterioration of all kind of materials. Moisture is always present in the atmosphere. Moisture freezing in pores of concrete, stone and bricks etc. exerts esscessive pressure on the structure causing its spalling and cracking. Moisture also reacts with iron elements causing its corrosion, which results in the reduction of its strength and ultimate failure.

6. Biological Agencies. Many construction materials such as timber, concrete and bricks etc. get affected by biological agencies. Bricks and concrete are affected by the growth of algae and moss etc. They grow in damp conditions and affect the aesthetic look of the building. Timber is badly affected by wet rot, which reduces its strength to a great extent. Wet rot generally develops in wet conditions, when moisture content in the timber is more than 20% and temperature of its surroundings is above 20°C. In wet rot, timber loses its cellulose, which results in loss of strength, shape and development of shrinkage, cracking, and loose fittings etc.

7. Effect of Gaseous Constituents of air. Sulphur dioxide is the most aggressive gaseous pollutant. It forms sulphuric acid by absorbing moisture from atmosphere or structural elements. It promotes corrosion to steel of reinforcement and also erodes some stones causing blister and spalling. Carbon dioxide also forms carbonic acid which erodes lime stone and concrete slowly. The extent of carbonation in concrete has a marked influence on the rate of corrosion of reinforcement. Thus the increasing pollution is a source of deterioration of structures.

8. Solid Contaminants. Solid contaminants as dirt gets deposited on building surface. It contains some soluble salts. It absorbs moisture from atmosphere and makes some acidic solution by dissolving salts with in it. This acidic solution accelerates the process of corrosion by maintaing moisture contact. Dirt not only affects the aesthetic look of the building but also deteriorates some stone surfaces.

9. Ground salts. Salts present in ground, get dissolved in water present on the ground surface or under ground. These salts rise above the ground level in the pores of the masonry by capillary action. On evaporation of solvent water, there salts remain deposited on the surface of the wall and spoil its look. This salt deposition is called efflorescence.

10. Efflorescence. If magnesium sulphate is present in ground water, it is most aggressive deterrent. It disintegrates the rendering and masonry surfaces more aggressively. Acidic ground water disintegrates concrete more vigorously.

11. Fire hazzards. Fire is a potent source of deterioration of all types of structures. All materials and components can be adversely affected by fire. They themselves can burn fully or partially or can lose some of their properties. Concrete and steel both are affected by fire. The heat of fire along with water used for fire fighting usually leads to distortion, cracking, spalling and swelling of nearly all components. Duration and temperature of fire are most important factor causing hazzards to the buildings. (Please also refer chapter 27, page 473).

12. Faulty design. Faulty design is the most critical factor in deterioration of the structure. Use of inadequate size of structural members and use of material of unknown characteristics will result in the failure of the structure.

13. Faulty construction. It is one of the most important factor responsible for the deterioration of the buildings. Following factors contribute to deterioration due to faulty construction.

1. Lack of supervision and failure to monitor the work adequately during the period of construction.
2. Failure to follow the specifications of the work and failure to get rebuilt defective work and get replaced defective material.
3. Lack of employing skilled labour.

14. Use of faulty materials. Following factors results in poor quality construction work:

(*a*) Ue of sub standard materials

(*b*) Wrong selection of materials and specification.

(*c*) Inadequate inspection of materials and inadequate facility of storage of materials at site.

(*d*) Use of expired mortar/concrete.

(*e*) Inconsistent mixing of materials.

(*f*) Inappropriate use of materials etc.

15. Inappropriate upkeep. Actually the process of maintenance starts with the cleaning of the building. Improper cleaning may affect the life of the building considerably. Inadequate cleaning may be due to the following factors:

(*a*) Use of incorrect-cleaning techniques

(*b*) Failure to carry out routine cleaning

(*c*) Inadequate supervision for effective cleaning

(*d*) Use of incorrect equipment for cleaning

(*e*) Failure to appoint proper and efficient workers for cleaning special fittings and equipments etc.

16. Misuse of building. Lack of awareness among the occupants of the building of the consequences of deliberate damaging the building (vandalism) and failure to repair the damaged area by vandalism and lack of security are some of the causes which deteriorate the buildings. Misuse of building, its fittings, furnishing etc. may further result in the deterioration of the building.

1.9. EFFECTS OF DETERIORATION ON CONSTRUCTIONAL MATERIALS

To plan prevention of fast deterioration of structures, the knowledge of various causes and sources responsible for the deterioration is essential. It is also essential to understand the effects of various agencies responsible for causing deterioration of the structural materials to protect them from these agencies. Constructional materials should be selected on the following basis:

1. The material should be able to withstand the climatic effects.
2. The material should be able to fulfill the intended functions.
3. It should be easy to maintain and replace if need be.
4. It should not be reactive with surrounding materials.
5. Its use should be economical.

Thus the materials having physical, chemical and economical advantages should be selected. The effect of deteriorating agencies on some building construction materials is discussed below:

1. Effect on Clay products and Bricks. Clay products include roofing tiles, terra cotta tiles, coping and bricks. Generally all clay products and bricks have been found quite durable. The most common effect of weathering on these products has been found as change in appearance known as EFFLORESCENCE. The soluble salts come out with moisture on the surface. When the moisture evaporates, the dissolved salts deposit on the surface forming white patches on the surface, which destroy the pleasant look of the surface. On crystallization of these soluble salts in the body of the brick work exert pressure causing spalling of surface. They also weaken or decompose the mortar in joints resulting in failure of the wall.

2. Natural stones. Stones are taken out from natural rocks by disintegration or fragmentation. Natural rocks can be classified into three categories as Igenerous rocks, Sedimentary rocks and Metamorphic rocks.

Igneous rocks. These rocks are formed by solidification of molten Lava inside or out side the earth crust. The rock formed in side the earth is called granite and outside rock is called basalt. Granite is crystalline where as Basalt is glossy. Thus granite, basalt, dolerite and pumice are examples of Igneous rocks. These stones are highly resistant to all the weathering agencies.

Sedimentary rocks. These rocks are formed by gradual deposition of particles of pre existing rocks carried by the flowing water along with it. Lime stone and sand stones are the main examples of sedimentary rocks. Sedimentary rocks provide most of the building stone. The atmospheric weathering agencies cause considerable deterioration to sedimery stones. Due to rainfall, frequent-drying and wetting the surface of the sediment rock gets slowly eroded as calcium sulphate gets continuously removed. In sheltered conditions, the calcium sulphate builds up to form a hard skin which gives a unsightly appearance to the surface. On blistering and breaking off this skin, it tries to pull away the lime stone with it. Dissolved sulphuric gases in rain water weaken the bonding of calcium carbonate in the calcareous sand stone and severely weahen the stone. Magnesium carbonate is also attacked by sulphuric gases in the similar way and deteriorates the magnesium lime stone and sand stone. Ground salts on penetration in lime stone and calcareous sand stones cause expansion in them and damage severely. Calcium sulphate derived from lime stone by the reaction of sulphuric gases gets penetrated into sand stone surface and causes internal stresses in the surface crust. These internal stresses are developed due to differential thermal expansion or moisture movement between the sand stone and crust block of calcium sulphate. Usually this crust breaks at a depth varying from 5 mm to 20 mm following contours of the surface. This phenomenon is called as contour scalling.

The deterioration by pollution and frost action becomes more pronounced if sedimentary stones are laid with the natural bed parallel to the vertical face of the wall. The greatest durability can be obtained by keeping the natural bedding plane of stones parallel to the horizontal courses in a wall.

Metamorphic rocks. These rocks are formed from sedimentary or Igneous rocks by the alteration of their original structure due to the action of great heat and high pressure arising from the movement of the earth's crust. From building considerations the significant metamorphic rocks are MARBLE and SLATE. Usually marble is used for cladding (face work) and has been found very durable. It is also not immune from the attack of sulphuric gases. Usually slates are used for roofing, cladding and damp proof course. The roofing slates are exposed to the most severe conditions of frost and temperature variation. They are likely to be affected by sulphuric gases.

It has been observed that corrosion of embedded fixtures has caused greatest damage to all types of stones. From the statistics of post stone building damages, it is found that rusting of iron and steel cramps and dowls caused extensive damage particularly to sand and lime stone structures.

Concrete. Cement concrete is a mixture of cement, aggregate (fine and course) and water. Its properties mainly depend on the quality of its ingredients and its water-cement ratio. Compaction and curing affect its permeability. Higher the water-cement ratio, batter the workability and higher the permeability. Concrete is liable to physical and chemical attacks of the atmospheric agencies.

Temperature effect. The variation of temperature causes thermal and moisture movements in concretes, resulting shrinkage and settlement cracks. These cracks become a major source of ingress of water, moisture and gases, which react with the ingredients of concrete, causing different reactions and changes. Some of the effect of atmospheric agencies are discussed below in brief.

(*a*) **Effect of water.** Running water contains impurities and dirt in it. When this water runs in contact with concrete surface, these impurities and dirt get deposited on it. On drying, the moisture evaporates, leaving behind these salts deposited on the surface, which give unsightly look to the surface.

(*b*) **Growth of vegetation.** Due to constant dampness of the surface, usually algae, mosses and lichens develop on the surface. They are usually green or brown in colour. They give unsightly look to the surface. They can be washed by using toxic washes.

(*c*) **Corrosion of reinforcement.** Corrosion of reinforcement occurs due to the oxidation of iron in the presence of oxygen and moisture. This can be checked by providing adequate cover to the reinforcement and using dense and high strength concrete.

For sub soil salts attack, alkali-aggregate reactions etc. Please refer chapter 7, page 84.

Timber. It has been fully dealt in chapter 21.

Paints. Paints is one of the most vulnerable building material which needs regular maintenance.

1.10. FACTORS CAUSING DETERIORATION OF PAINTS

Usually following factors are responsible for the development of defects in paints.

1. **Incorrect selection of paint.** paints should be selected on the basis of their exposure condition and backing material.
2. **Application of paint on damp surface**. Dampness of the surface destroys the adhesion of the paint with the surface of the component causing flaking and cracking from the surface.
3. **Poor workman ship.** It is one of the main causes of paint deterioration and defects. Poor workman ship can be attributed to (*i*) incorrect and inadequate surface preparation. (*ii*) Over thinning of paint, (*iii*) Improper selection of brush, (*iv*) Poor brushing techniques, (*v*) Failure to apply specified number of coats etc. may result in deterioration of paint.

The deterioration of paint may be visual or the break down of the aterial it self. The loss of gloss or loss of colour is the first visible sign of weathering of the paint. If weathering is allowed to continue, the paint film eventually will become brittle, resulting in loss of bond and its cracking. If possible, the base surface should be prepared by simply rubbing before applying the new coat of paint. If the surface is not prepared, the deterioration of paint will spread to the lower layers and repanting of the whole surface has to be done which will be costly and time consuming.

If the contact faces between the backing material and the paint is good, then paint will deteriorate by surface erosion often called chalking and not due to loss of adhesion and cracking or flaking.

Source of deterioration. The main source of deterioration of a paint is the presence of moisture or damp- ness. The deterioration of paint may be minimised by (*i*) selection of good quality paint, (*ii*) By adequate and proper preparation of surface before applying paint.

To increase the overall life of the building, it is very essential to maintain the painted surfaces of the various components nicely.

1.11. ASPHALT AND BITUMEN

Asphalt. It is found naturally in pure state and called natural asphalt. It may also be manufactured artificially having substantial quantity of inert mineral material. This is known as rock asphalt. On heating the asphalt becomes plastic and can be moulded into any shape.

Properties. The main properties of asphalt are as follows:

(*i*) It is available in solid or semi solid state.

(*ii*) It is black in colour.
(*iii*) It burns only above 250°C temperature
(*iv*) It is elastic and resists acid action
(*v*) It is good water repellent
(*vi*) It is soluble in carbon disulphide
(*vii*) It is good insulator for electricity, heat and sound.
(*viii*) It becomes plastic on heating and possesses good binding properties.

1.11.1. Bitumen

It is the product obtained from the residue of the crude during petroleum distillation.

Properties:

(*i*) Its colour is black
(*ii*) It is sticky
(*iii*) It softens and melts on heating
(*iv*) It is completely soluble in carbon disulphide
(*v*) It is obtained in semi solid state.

Thus bitumen has water proofing as well as adhesive properties.

Bituminous based materials have a very long natural life, but they are affected by acids, sun light and by impact etc. However they are not affected by biological agencies and by pollution. Moisture also has no direct adverse effect on asphalt and bitumen. How ever trapped moisture vapour pressure can cause blistering in bitumen and asphalt layer. These products also can be damaged by the contact of oil.

On exposure to heat and light, bitumen and asphalt get oxidized, resulting slow hardening of these materials. This give rise to cracking through thermal movements. As bitumen is a thermoplastic material, it will soften on heating with a tendency to flow. When used in horizontal situations, an insulating water proof film should be provided in between the asphalt and supporting structure to allow the differential movements. If insulated layer is not provided, the continuous expansion and contraction could result in cracking of the asphalt allowing moisture to penetrate. In vertical situations adequate keying arrangements with the surface should be provided at a close interval to prevent flow of asphalt as it softens with the variation of the temperature. To reduce the effect of solar heat and light, a reflective cover should be provided. Usually a cover of light coloured stone aggregate may be provided.

In set condition, the mastic asphalt is brittle and can be easily damaged by impact of loading. In such situations where there is a risk of damage by the impact of loading, a suitable protective cover as that of screed should be provided to support the load.

1.12. PLASTICS

Plastics are compounds of carbon with other elements such as hydrogen, nitrogen and oxygen etc. They can be moulded easily into any desired shape. Various types of plastics can be made by replacing one or more hydrogen atoms in ethane and polymerising the monomer thus obtained. Non availability of good building timber and high cost of timber and metals has given rise to the use of plastics in building industry. In the last twenty years, the use of plastics in building industry has increased many fold. A wide range of plastics are used in buildings. The use of some of them is discussed briefly as under.

1. Poly Vinyl chloride (P.V.C.). It is the most popularly accepted plastic in the building industry either in plasticised or un plasticised form. The plasticised P.V.C. is extensively used as false ceiling under pitched roofs, floor covering, membrane covering in flat roofs and plastic membrane for water proofing. By modifying the properties of P.V.C. rigid un plasticised P.V.C. is used mainly for domestic soil and vent system, rain water disposal pipes, drainage, wall cladding, opaque corrugated roof sheeting, ducting and skirting etc. Rigid P.V.C. also has been used on a modest scale for window frames in combination with timber or metal. It is also used as thermal insulation material. Glass reinforced plastics also have been used for structural purposes.

Properties of P.V.C. P.V.C. is more popular and widely used due to the following properties:

(*i*) P.V.C. is not affected by rust, rot, termite and dust etc. *i.e.* it is rust proof, rot proof, termite proof and water proof material.

(*ii*) P.V.C. products retain their shape in dry heat, sub zero temperature and tropical rains.

(*iii*) They are not affected by coastal saline air.

(*iv*) They do not need any costly maintenance as they are washable with ordinary water and soap.

(*v*) P.V.C. door and window frames provide thermal insulated opening. Thus they are most suitable for air conditioned and heated rooms.

(*vi*) They do not allow dust penetration. Thus they are used for operation theatres, computer rooms and electronic factories.

(*vii*) They are eco friendly.

Polymer resins. Polymer resins reinforced with glass fibres are used mainly for cladding. They can also be used for cold water cistern and floats. Cold water tubes and pipes, basins and bath tubs and sink. In the form of sheets, polymer resins can be used as damp proof membrane and for covering concrete and hard core surfaces.

Acrylic resins. These resins are mainly used for drains, bath tubs, and sinks etc. They are also used for making corrugated sheets and for roof light coverings. Special plastics as Butadiene syrene etc. are used for large drainage chambers, plumbing, drainage fittings and wall ties etc.

Poly carbonates. They are mainly used for glazing.

Phenol formaldehyde resins. These resions are used to impregnate paper and fabric to provide wall and roof sheets.

Epoxy resins. They are used for concrete repair work and insitu flooring etc.

Polystyrene and urea formaldehyde resins. These resions in expanded from are used for thermal insulation purposes.

Foamed plastics. They provide a cellular material, used for thermal insulation.

Further there may be other plastics which are used in one from or the other in the building industry.

Properties. Plastics have been found quite durable. Though moisture has little effect on the properties of plastics as a whole, but it can reduce the bond strength between the glass fibre and polyester resin. In general, plastics are not harmed by the contact with other building materials, though cracking of polyethylene in cold water cistern have been found by the use of oil based joining compounds. P.V.C. and poly carbonates have high thermal expansion. Hence they need proper joint treatment. If their joints are not properly treated or sealed, the joints in pipes may open causing joint failure and leakage. Plastics creep under continued loads. Special precautions are necessary in case stresses are high.

1.13. METALS

Most commonly used metals in buildings are steel, aluminium, copper, lead and zinc. The most deteriorating atmospheric agencies to the performance of metals are those which cause corrosion of the metal. These agencies may be moisture, gaseous, liquid or solid pollutants. In most situations in buildings moisture is always present and corrosion is a potential risk. When some metals are in contact with other building materials, such as bricks or plaster in the presence of moisture, the galvanic cell is created. In this reaction moisture acts as an electrolyte for the formation of galvanic cell which leads to the loss of metal, forming the anode of the cell *i.e.* metal forms the anode of cell.

Galvanic action may also occur in single metal elements when a difference in oxygen concentration occurs at the surface. Thus corrosion is a complex electro-chemical reaction, which is developed in the presence of dissolved atmospheric gaseous pollutants, and dirt etc. The sensitiveness to corrosion of common metals used in buildings has been discussed below in brief.

1. Steel. It is the most widely used metal in buildings as reinforcement in concrete, plumbing system, window frames, rain water fittings or a protective covering (cladding). Mild steel with out alloying material in substantial quantity rusts readily when exposed to atmospheric conditions. Mild steel seldom exposed directly to atmospheric agencies with out a coating of paint, bitumen, zinc or cover of concrete etc. The protective cover or coating reduces the rate of corrosion to a great extent. Steel protected by zinc galvanising has been found good resistant to corrosion. By adding about 0.25% copper in steel by weight the rate of corrosion in air is reduced to 50%. Alloying improves weathered appearance with tenacious coating. If steel is alloyed with at least 10% chromium together with one or more alloying elements, the steel can be made corrosion resistant. Such a steel is known as stainless steel.

2. Aluminium. Aluminium is attacked readily by copper, and lead, but it is not attacked by zinc, galvanized steel and stainless steel.

Aluminium mainly is used in buildings for window frames, providing hard covering and flashing. Aluminium in contact with copper and its alloys gets readily attacked, resulting in severe damage due to chemical corrosion. The chemical corrosion even may take place from a distance. It has been observed that when rain water from roofs, covered with aluminium with small particles of copper in aluminum, drainage flashes fell on aluminium window frames, they suffered severe pitting corrosion. Similar action has been observed from lead. Thus it is essential that a correct aluminium alloy should be used for a specific purpose.

Many high strength aluminium copper magnesium alloy products used in the past got severely corroded due to the presence of copper in aluminium in damp conditions. Even wood preserved with copper containing preservatives attacked aluminium on coming in contact with it. Thus un protected aluminium should never be embedded in cement mortar or concrete. Direct exposure to sea water also cause corrosion.

Aluminium can be anodised by treating it by electrochemically to thicken the natural oxide film formed during normal atmospheric exposure. The thicker film formed enhances the appearance of the aluminium surface and its resistance to corrosion. The anodised layer is readily disfigured by the splashes of lime or cement. Thus it needs protection from lime or cement at site during repair or construction work.

Copper. It is very resistant to corrosion. It is mainly used in building work for roofing, cladding and plumbing. When copper is used in building in combination with other metals, it forms a non corroding cathode. It can be attacked by flue gasses containing sulphur dioxide, if it is provided in the close vicinity of the chimneys. This can be easily prevented by good chimney design or by the use of copper silicon alloy. Copper is easily corroded by ammonia and some other mineral acids, but such occurrence or combinations are not common in buildings. How ever it will be better not to allow copper to come in direct contact of latex cements used for fixing some kinds of flooring. Water containing high concentration of carbon dioxide may dissolve copper, but the rate of loss of copper will be small.

Lead. Mainly lead is used for roofing for flashings, in main water supply and as damp proof course in building works. It is highly resistant to corrosion by forming a dense protective film of lead carbonate or lead sulphate. How ever it is not wholly immune to corrosion attack as organic acids released from damp oak and some other substances can cause corrosion. Lead can also be attacked by free alkali present in cement sand mortars. Severe corrosion had been observed with in 10 years duration in case D.P.C. is constructed with cement sand mortar having free alkali. Thus in such situations lead sheet should be provided an protective cover.

Zinc. In buildings zinc is used for roofing, cladding and flashing, but usually zinc is used for providing protective coating to steel by hot dipped galvanizing. Zinc coating may also be provided by metal spraying. Thick coating can be achieved by either method at reasonable cost, but hot dipped galvanizing method is the most common. The corrosion rate of zinc in unpolluted environment is slow but increases markedly when it is exposed to sea environment or sulphur gases or compounds. When the galvanized wall ties are embedded in black ash mortar, rapid corrosion of these ties may take place. Zinc is attacked slightly by wet concrete. Thus the resistance of concrete to galvanised steel has enabled the use of galvanised steel as reinforcement in situations where more protection to reinforcement is necessary and providing concrete cover to full depth is not possible due to certain difficulties. How ever it should be kept in mind that due to the liberation of hydrogen bubbles due to the reaction between alkalis and zinc the bond strength between concrete and reinforcement may be reduced. To check this reduction in bond strength galvanised reinforcement should be used which has been passivated by a chromium based treatment.

Galvanised steel also has been used in cold water cisterns. Soft water containing dissolved oxygen and carbon dioxide attacks zinc. In such situations the steel be protected by providing a bituminous paint coating. Inside ungalvanised cisterns source pitting corrosion takes place due to copper and brass debris developed from the plumbing installation operations. This always should be prevented. There are many zinc and copper alloys. One of them is known as alpha-beta brass, which is commonly used for fittings in water services. If the water is alkaline with high chloride contents or acidic, then zinc will be removed from the copper leaving a spongy copper residue. This will lead either to blockage by zinc corrosion compounds or making the body of the fitting loose causing leakage of water. If the temporary hardness of the water is not possible to be removed then in such waters hot pressed alpha-beta brass fitting should not be used.

Effects of Creep and fatigue on metals

Though corrosion of metals is a main cause of deterioration of metals, yet creep and fatigue have some effect on metals. Creep is deformation caused by loading. if the loading continue beyond the elastic range of the metal, permanent creep will be developed. Fatigue is a phenomenon developed due to large number of cycles of loading and un loading causing reversal of stresses. Creep in metals is developed due to sustained loading. It is a slow process and is influenced by the temperature at the time of loading and range of loading. This phenomenon does not pose a serious problem. However failure of lead flashing have occurred, partly due to its low resistance to creep, and partly due to low resistance to fatigue and high thermal movements. This defect can be checked by good design or by the use of lead, containing a small proportion of copper.

1.14. GLASS

Glass is immune to the deterioration caused by atmospheric deteriorating agency. It is seldom affected by any such agency. It is a very durable material. If under damp conditions glass sheets are stacked very closely then surface etching can occur. If alkalis from paint remover splashes on the glass plates and is not removed, causes scratches. Thermal stresses developed in frame materials may cause cracks in glass panels. Hence sufficient space should be left in between the glass panel and frames to avoid cracking of glass.

1.15. MORTARS AND RENDERINGS

Now a days mostly mortars used have cement or lime as binding material. Usually mortars are prepared and used with out an air entraining agent. The proportion of cement and sand depends upon the type of masonry work and conditions of exposure. Usually 1:6 proportion of cement and sand is used for construction and plastering internal as well external walls. Generally the effect of carbonation and drying shrinkage on mortars is negligible. How ever mortars can be affected by frost, but its effect can be reduced by using the air entraining agents.

Mortars are severely damaged when soluble sulphates present in bricks react with tricalcium aluminate of portland cement mortar, which is one of the most important compound of cement. Sulphates can dissolve in water. Sulphates found in most of the soils are calcium, potassium, sodium and magnesium. The solubility of calcium sulphite is low, hence least reactive. Out of the above sulphates magnesium sulphate is found more reactive and causes maximum damage to mortars and concrete. Magnesium sulphite decomposes hydrated calcium silicate as well as calcium hydroxide $Ca(OH)_2$ and hydrated tricalcium aluminate (C_3A), forming hydrated magnesium silicate, which has no binding properties. Sulphate reaction is indicated by the characteristic whitish appearance on the surface. This reaction causes about 225%

increase in the volume, which causes disintegration. Similar sulpho-aluminate reaction can take place when mortar is exposed to condensed water vapour containing sulphates obtained from flue gases. This hazard is developed when slow combustion fuel appliances are used in unlined chimneys.

1.15.1. External Renderings

Generally the mix proportions of external renderings are same as that of mortar and have similar properties. Here also sulphate attack can take place when dissolved sulphates in bricks come out through pores and react with rendering cement compound C_3A. Drying shrinkage may be a serious problem in case of rich mixes as 1:2 or 1:3 proportion which can develop fine cracks, particularly in dry and warm weather. A good quality rendering is not affected by frost action.

1.16. DIVISION OF MAINTENANCE

Maintenance of all kinds of structures may be divided in two groups, namely:

1. Pre monsoon
2. Post monsoon

1. Pre monsoon

Before taking up of any maintenance work in hand inspection of structure is necessary to estimate the extent of damage and to draw up the plan of action to rectify the defect. Pre monsoon inspection is carried out to draw up the plan of maintenance to be done before the on set of monsoon. Pre monsoon maintenance includes works as clearing of drains, checking of leakage of roofs etc. and collection of material and equipment needed for repair works. Bridges and other works which are difficult to inspect during monsoon should be inspected before monsoon and repair done as per requirements.

2. Post monsoon maintenance

During rainy season due to the floods or heavy rains, many structures are damaged and washed away, as railway track and highway may be washed away. Canals, and dams may breach, house roofs may collapse and failure of walls may take place. All these damages require emergency repair. Thus in post monsoon maintenance all replacement, removal and rehabilitation works are carried out. Post monsoon inspection should be made to assess the damage caused.

QUESTIONS

1. Define maintenance and repair.
2. State the causes which necessitate the maintenance of Civil Engineering works.
3. Explain the followings, giving two examples of each.
   (*a*) Routine maintenance (*b*) Special maintenance
   (*c*) Preventive maintenance (*d*) Remedial maintenance
   (*e*) Pre monsoon maintenance (*f*) Post monsoon maintenance
4. Discuss the causes of failure of structures.
5. The main aim of maintaining of structure is
   (*a*) To i prove its aesthetic appearance
   (*b*) To stabilise the structure to carry out its functions for which it is intended or constructed
   (*c*) To utilise the funds provided for the maintenance
   (*d*) To utilise the services of the maintenance incharge
6. Identify the correct statement/statements
   (*a*) Repair of pot holes of a road is the preventive maintenance
   (*b*) Painting of doors and windows is the preventive maintenance
   (*c*) Renewal of flooring is the preventive maintenance
   (*d*) Filling up of cracks is the preventive maintenance

7. Identify the correct statement/statements
   (*a*) Renewal coat to W.B. road surface is a special repair
   (*b*) White and colour washing of a building is a special repair
   (*c*) Painting of steel roof trusses of a work shop is a special repair
   (*d*) Replacing of door frame damaged by white ants is a special repair
8. Causes of failure of a structure are
   (*a*) Improper design
   (*b*) Defective construction
   (*c*) Improper use of the structure
   (*d*) Lack of maintenance
   (*e*) All the above
9. Identify the correct statement/statements
   (*a*) The post monsoon inspection is done to assess the damage to structures by rain fall and draw programme of their repair
   (*b*) The post monsoon inspection is done to get 1st hand information of damages
   (*c*) The post monsoon inspection is done to know the causes of damage
   (*d*) In post monsoon maintenance work, clearing of drains, checking of roof leakages etc. is taken up
10. Repair of a falling down of a roof in rainy season is classified as
   (*a*) Pre monsoon maintenance
   (*b*) Routine maintenance
   (*c*) Special repair
   (*d*) All are correct

ANSWERS

5. (*b*)	7. (*d*)	9. (*a*)
6. (*b*)	8. (*e*)	10. (*c*)

2

Foundation Maintenance

2.1. INTRODUCTION

Foundation of any structure is the most important part of that structure. It bears the load of the structure itself and the load to be placed on it.

Foundation generally is built below ground level, upon which the super structure of the building is constructed. The foundation is built below ground due to the following reasons:

(*a*) To protect the foundation from environmental effects.

(*b*) To protect the structure from over turning moment developed in the structure due to atmospheric air.

(*c*) To provide a good natural surface to the foundation.

2.2. DIMENSIONS OF FOUNDATION CONCRETE BLOCK

The depth of foundation below the ground level may be obtained by the following formula:

(*i*)
$$D = \frac{p}{w}\left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)^2 \qquad \ldots(2.1)$$

where

D = Depth of foundation below ground level

p = Safe weight coming on the foundation in kg/m^2

w = Weight of soil kg/m^3

ϕ = Angle of repose of soil

In ordinary soils it should not be less than 90 cms.

(*ii*) Length of lower concrete layer

$$L = 2T + 2J \qquad \ldots(2.2)$$

where

T = Thickness of wall

J = Length of each projection from wall face. 15 cms length of projection is sufficient

(*iii*) Thickness of concrete blocks may be taken as

(*a*)
$$d = \frac{5}{6} \times t \qquad \ldots(2.3)$$

where t is wall thickness in cms above plinth level.

(*b*)
$$d = \left(\frac{3\,pj^2}{m}\right)^{1/2} \qquad \ldots(2.4)$$

where

p = weight on foundation in kg/m^2

j = length of projection as above

m = modulus of rupture of concrete. For 1:2:4 concrete it is taken as 5.27.

2.3. CLASSIFICATION OF FOUNDATION

Foundations can be grouped in the following three main groups:

1. **Spread foundation.** Under this head following foundations are grouped:
   - (*a*) Wall foundations
   - (*b*) Isolated footings
   - (*c*) Combined footing
   - (*d*) Inverted arch footing
   - (*e*) Cantilever footing
   - (*f*) Continuous footing
   - (*g*) Raft foundation
   - (*h*) Grillage foundation
2. Deep or Pile foundation
3. Pier foundation

2.4. REPAIR OF FOUNDATIONS

Decay, damage and repair of foundations are not very common occurrence in buildings if constructed properly. Actually foundations like grillage foundations which are of isolated type foundations, pile, raft and under reamed piles etc. if damaged, entire building gets affected and repairs to these foundations are rarely possible as they are very costly. Hence maintenance of such foundations for up keeping can not be generalised. The maintenance in such cases in taken in special circumstances, when a part of the foundation might have damaged and required restoration.

2.5. SHALLOW FOUNDATIONS REPAIRS

Shallow foundations are liable to damages and decay in full or part, hence require maintenance and repair.

2.6. CAUSES OF FAILURE OF FOUNDATIONS

Usually building foundations are found to be damaged due to the following causes:

1. Uniform settlement
2. Unequal or differential settlement
3. Sinking of foundations etc.

2.6.1. Uniform settlement of foundations

Settlement of foundations may occur due to the following causes:

(*a*) In adequate bearing capacity of soil below the foundation.

(*b*) Over stressing of foundation brick work due to crushing, resulting in settlement.

(*c*) Local weaknesses due to gaps in joints during construction process.

(*d*) Exposure of foundation to weather agencies due to excavation close to foundation for laying drainage pipe line, telephone lines etc. and back filling not done property.

(*e*) Seepage from sub soil water from ground water table or some external source through foundation or seepage from drainage or water supply pipes.

(*f*) Leaching out of lime used in foundation lime concrete and forming cavities. Some times rodents thrive in these cavities.

(*g*) Repeatedly rising and lowering ground water table.

(*h*) Movements due to earthquake or vibrations caused in soil due to any activity in the vicinity.

2.6.2. Differential settlement

When the settlement of different portions of the foundation of the building is of different magnitude, then this settlement is called unequal or differential settlement. If the magnitude of the differential settlement is more than 0.003 cms/m to 0.007 cms/m, then it causes cracks in the building. Cracks have been discussed in details in Chapter 6 and 7.

Occurrence of differential settlement. Differential settlement occurs due to the following reasons:

(*a*) Unequal load distribution on the soil strata below the foundation.

(*b*) Eccentric loading of the structure on the soil strata.

(*c*) Non homogeneous nature of the soil.

2.6.3. Sinking of foundation

Sinking of foundation is a rare case of foundation failure. It may take place to either faulty construction or inadequate bearing capacity of the soil below the foundation. The foundation may be saved by streng- thening it by underpinning as discussed on page 405. If the sinking is of few centimeters, then the floor may be adjusted by raising its level by adding stone slab or concrete tiles etc. In case the sinking is sufficient, then the roof has to be removed, walls rasid to the required height and roof relaid. The floors are also relaid. It is very costly and time consuming activity. Usually foundation will sink if the bearing capacity of soil is less than the load coming on it. The soil bearing capacity can be increased by distributing the load on the greater area of the soil by increasing the dimension of the existing foundation and deepening it by the method of under pinning. Fig. 2.1.

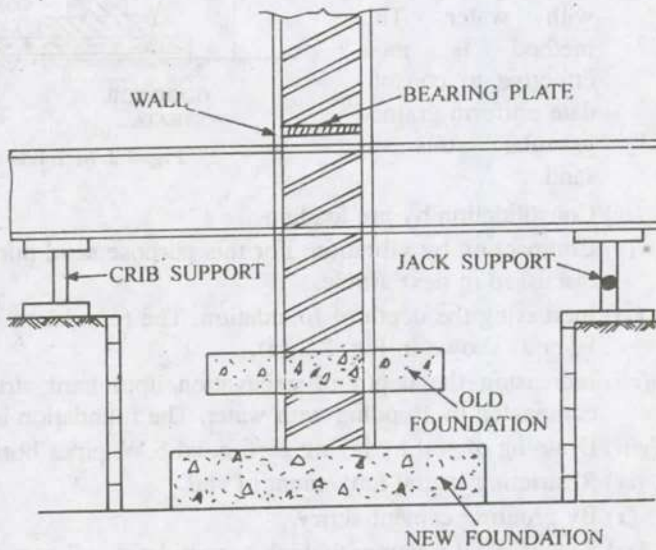


Fig. 2.1. Strengthening of existing foundation

2.7. FOUNDATIONS ON MADE UP SOILS

A filled up soil which neither naturally or artificially has consolidated is called made up soil. some times low tying areas, ponds and tanks etc. are filled up for construction of buildings. Thus in this way soil built up is called made up soil.

Usually materials used for filling are heterogeneous in nature. In most of the cases, what ever waste materials are available are dumped in the depression for filling it.

Usually soil with less clay contents consolidates naturally in 20 to 30 years period. In case brick bats, rubbish, organic materials, liable to decomposition cause delay in consolidation. On the other hand granular material such as sand, fly ash etc. consolidate early. While constructing building on made up soils, utmost care need to be taken in construction of foundations in such soils.

Before carrying out construction, the bearing capacity of the made up soil and depth of fill must be as- certained carefully. If the soil has not attained desired bearing capacity and the depth of filling varies at different points and the fill material also is of different nature, then the super imposed load on foundation will develop differential settlement of the foundation. Further, if the area of the made up soil is small and foundation is laid partly on made soil and partly on virgin soil, in that case also the foundation is liable to develop differential settlement.

2.8. METHODS OF IMPROVING THE BEARING CAPACITY OF MADE UP SOIL

Following methods may be adopted to improve the bearing capacity of made up soil:

(*i*) Removing of air voids from the soil by mechanical compaction. This method is effective if the depth of fill is not more than 1 m.

(*ii*) Compacting 30 cm to 40 cm thick layers of rubble. This method is effective upto 45 cms filling.

(*iii*) Flooding up soil with water. This method is most effective to consolidate uniform grained granular soils as sand.

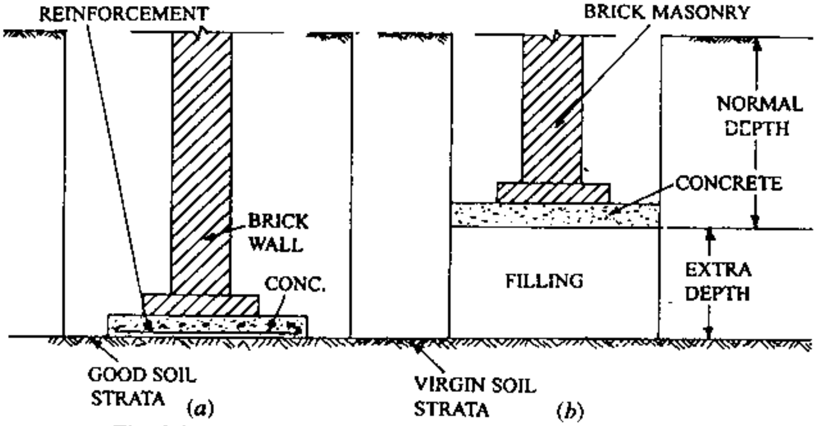


Fig. 2.2. Methods of improving bearing capacity of soil

(*iv*) Consolidation by pre loading.

(*v*) Compaction by vibration. For this purpose sand piles are most effective but costly. Sand piles are discussed in next article.

(*vi*) Increasing the depth of foundation. The foundation should rest on a virgin or hard and strong soil layer as shown in Fig. 2.2 (*a*).

(*vii*) Increasing the depth of excavation upto hard strata and filling the extra depth by sand and compacted by flooding with water. The foundation is laid on consolidated sand fill. Fig. 2.2 (*b*).

(*viii*) Draining of soil by laying perforated S.W. pipes horizontally.

(*ix*) Restricting lateral movement of soil.

(*x*) By grouting cement slurry.

(*xi*) By chemical treatment which consolidates soil particles.

(*b*) Sand piles

It is the process of compaction of granular soil by vibration. In this method about 200 mm to 300 mm diameter piles are driven in soil upto a depth of 3 to 4 m as per need upto the pervious strata. Due to the pile driving, the adjoining sand will get compacted. After wards the piles are withdrawn and the holes are filled with sand.

(*c*) Sand wick pile

If in place of filling sand directly in the hole, sand filled jute bags are placed in holes, then it is known as sand wick piles. The gunny bag walls protect the soil wall from crumbling and also serves as wicks and expedite water movement up wards due to capillary action.

2.9. DETERMINATION OF APPROXIMATE AGE OF A STRUCTURE

To determine the present strength of a structural member, we need the approximate age of the member as all materials lose strength with age. Though completion or "as built" drawing is the best tool for determing the approximate age of the structure, but it is always not possible to lay hands on these drawings. In the absence of such authentic record of age of the structure, the approximate age may be determined by adopting a common line from the three results discussed below:

2.9.1. From local inquiries

Information collected from local inquiries may vary widely. Some times plaques (piece of stone or metal) inscribing the name of the person who got it constructed, with date and purpose of construction are found in the neighbour hood of the structure from which some information may be obtained.

2.9.2. Architecture and architectural features

Architecture and architectural features of a structure or building may provide some indication of the approximate construction period of the structure. In India the development of architectural style may be divided into the following four periods with prominent style and architectural motifs.

(*a*) **4th Century B.C. to 5th century A.D.** During this period Buddhist architecture dominates the scene with the advent of Hinduism and native inspiration. During this period the structures were built by the Persian craftsman. In these structures the column type elements known as Ionic elements, Greek ornamental decorative designs or patterns (Motifs, and symmetry) in the distribution of the complex is found. The structures of this period found are Mauryan foundations, stone structures, columns decorated in gold and silver. Courts admist garden, monolithic column shafts polished in Persian style and decorative designs and patterns (motifs). Pillars of low foundation of stupas to enshine, the relics of Buddhist monasteries, chaita griha, barrel vaulted halls carved parallel to the rock face leading to roughly circular domed shrine are also found.

(*b*) **6th Century A.D. to 13th Century A.D.** During this period Buddhist influence gradually diminished and Hinduism became predominant with GUPTA inscription. Temples with ornamental works, padma pattern (molifs) on the back of walls or ceilings, lintels and brackets have been located. Circular or octagonal form with magnificent entrance portals have been seen. Soft stone Raths, free standing temples, use of timber in structures, as joists, rafters, and cross beams are other features of this period.

(*c*) **13th Century A.D. to 18th Century A.D.** This period is dominated by Muslim type buildings. In this type of buildings, erection or building of enclosure for defending sanctity of the complex can be seen. Mosques facing Macca having reception vertical elements, tower, ablution tends (ceremonial washing) of the body and hands etc. have been found. Walls decorated with plaster, and elaborately patterned by brick works are found. Semi circular arches, large halls having arch roof over massive transverse arches, multiple domes and multiple columns were in use in this period. A blending with the "Hindu architecture in columns with decorative and structural brick and tile tradition may also be seen. Hybrid style forts, fine stone work having motif of Gujrat style and cross fertilisation of indigenous and imported tradition can also be seen. The main features of this period are imperial mosques and temples painted stucco, decoration of domes and stones in the walls.

(*d*) **8th Century A.D. (After death of christe) and later.** In the early period, rivalry amongst British, French and Portuguese may be seen, but the product is a mix of imported European architecture and local Persian, Hindu and Muslim architecture. How ever the new style of European architecture pattern remained dominant. In this period, elegantly moulded stucco, ribbed domes, posts, bracket, beams, chatri, and balcony etc. can be seen. The main features of this period are,

(*i*) Tall columns of predominant influence of Greek architecture
(*ii*) Halls with flat roofs on timber beams and joists
(*iii*) Lavishly decorated receptions.
(*iv*) Grand stairs with balustrade and extensive use of coloured marble.
(*v*) Exterior walls with exposed bricks decoratively pointed.

2.9.3. Materials used

The approximate age of the structure can also be estimated by visual examination of the materials used in the structure. How ever it must be ensured that the materials examined were actually used in the original construction.

From the study of the construction technology, it is found that the stone predominantly was not only used in constructing walls but equally used for roofs and floors. This tradition continued till the Persian craftsman introduced new techniques of construction. In the later part of the 15th century flat roofs with timber beams and joists came into existence and dominated the scene till the arrival of European nations to India. The European nations brought some new techniques of construction with them. In muslim period door and window shutters were not used. For privacy finely carved marble stone screens were used.

In the later part of 18th century, Britishers introduced use of bricks and Engineering technology. Earlier also brick of smaller size were in use. The size of the brick was approximately $100 \times 75 \times 40$ mm. The use of such bricks can be traced in Buddhist period. In the initial stages, Britishers introduced bricks of smaller size which gradually changed to the present size, due to economy and convenience in handling.

Later Britishers introduced use of steel structural members as RS Joists, angles, flats and tee etc. These elements were used in the construction of flat roofs. Later jack arch roofs with lime concrete were introduced. They also introduced the use of shutters for door and window frames. During this period stone block floorings were replaced by stone slabs of lesser thickness followed by mosaic and terrazzo floors.

With the introduction of cement concrete and R.C.C. the construction technology under went a sea change. All flat-roofs with timber beams and joists or steel elements were replaced by R.C.C. work. The use of R.C.C. roofs, and columns gave pleasing and elegant look to the buildings and saved space as R.C.C. columns being slender than brick or stone columns.

Around 1950, the use of twisted steel bars and deformed steel bars was tried and it was found that the deformed bars of mild steel have much advantage over plain steel bars as reinforcement in R.C.C. work. Now deformed bars have completely replaced the use of plain steel bars as reinforcement.

Due to non availability of good timber and economy, steel and aluminium door and window frames are replacing wood work. The use of plastic in building industry is increasing day by day. P.V.C. is quite popular material for floors and pipes etc.

By knowing the use of important building materials, the construction period of the structure may be approximately estimated by comparing the three estimates.

2.10. EXAMINATION OF THE EXISTING FOUNDATION TO CHECK ITS CAPACITY

In order to determine the strength of a building, it would be necessary to examine the foundation of the existing building. The strength of the existing foundation of the building would be determined as follows.

For determining the strength of the structure, it is necessary to have its plans. In this respect the best thing would be to have either the completion or "as built" drawing of the structure, prepared immediately after the completion of the structure giving details of actual construction. The completion drawing is prepared marking on the construction drawing the deviations done during construction by red ink or pencil.

In case the completion drawing is available, task becomes easy, other wise a plan of structural members will have to be drawn by actual measurements at site. The foundation is excavated and measurements taken. The present condition of the building and nature of construction is noted on the drawing. In case of super structure also, the detailed measurements of members are taken to prepare a authentic drawing. The age of the building shall be ascertained either from record and built drawings or by any of the methods discussed later in this chapter.

After knowing all the data and record, the calculations are made to ascertain the age of the structural members.

In case of R.C.C. slabs, beams, and columns the over all sizes of the members can be known by measurement. The details of reinforcement can be known by "as built" drawings. In case "as built" drawing is not available, then details can be determined by cutting grooves in the cover and exposing the reinforcement. By knowing the details of measurement and details of reinforcement, the moment of resistance of concrete and steel can be calculated by usual method of design. However allowance for the age of structure and steel in particular must be made.

In case of brick work in load bearing walls and columns calculations are made for the desired thickness on the basis of dead load of the floors and walls and live load as per use of the building. Reduction in strength is made due to age of the brick work and a high factor of safety ranging from 6 to 12, preferably

10 is adopted. Timber works usually are assumed to lose 40% strength in 50 years of use. Further effect of deformation and creep also should be taken into account.

In case of steel members, thickness of these parts of the members which are liable to corrosion need to be determined. After this, the strength of the member should be determined after taking due allowance of age factor of the structure and effects of creep and deformations etc. Salient features of the procedure are shown below:

(*a*) **Strength of wall.** The crushing strength of brick work may be taken as 55 kg/cm^2 and a factor of safety may be adopted as 10.

(*b*) **Strength of timber beam**

$$B.M. = \frac{Wl^2}{8}$$

Flexture stress $$f = \frac{\text{B.M.}}{\text{modulus section}} = \frac{M}{Z}$$

It may be reduced as per age factor. After a age of about 50 years, it may be assumed as 60% of the original.

Strength of cement concrete and steel may be calculated from the principles of R.C.C. design.

2.11. FOUNDATIONS IN EXPANSIVE SOILS

In expansive soils best type of foundation is that of under reamed piles foundation.

2.11.1. Under Reamed piles (IS-2911 Part-3-1980)

In India the use of under reamed piles was advocated by scientists at Central Building Research Institute, Roorkee in fifties. Since then it is widely used in India. These piles are made of reinforced cement concrete. These piles may have one bulb or more bulbs formed by enlarging the bore hole of the stem of the pile. By the provision of bulbs sufficient bearing or enchorage is available. The details are shown in Fig. 2.3.

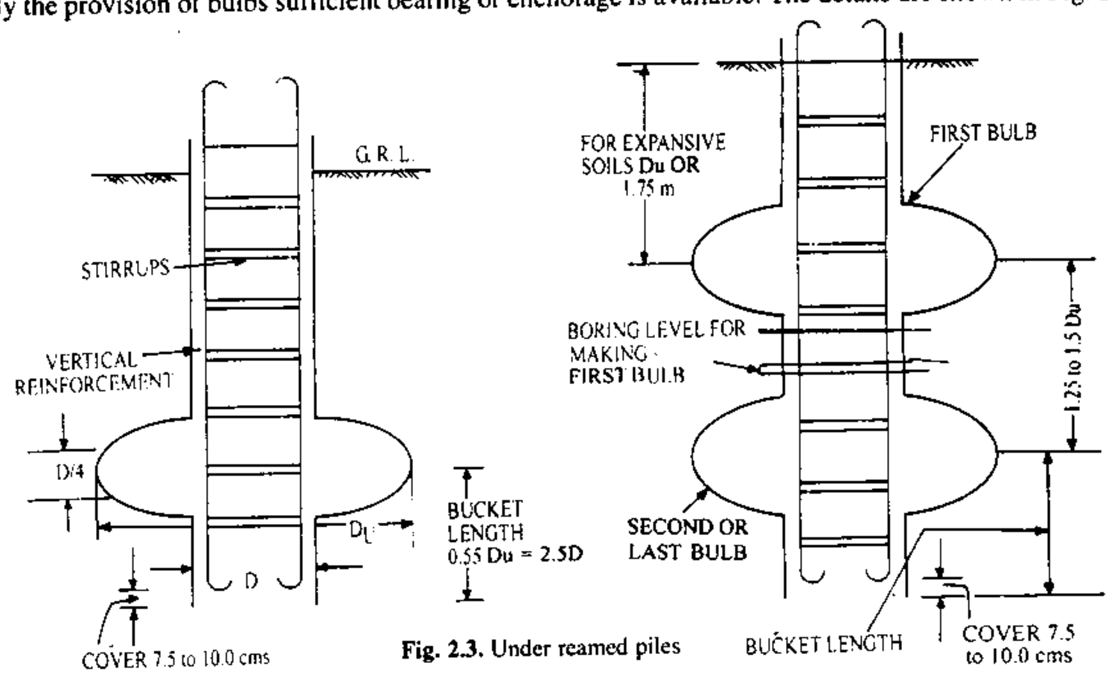


Fig. 2.3. Under reamed piles

2.11.2. Application of under reamed piles

Under reamed pile foundations are found useful in the following situations:

1. The under reamed pile foundations have been found useful in expansive soils, where the seasonal

moisture content changes cause wide spread damage to the buildings. Thus under reamed pile foundations have been found effective to check the undesirable effect of seasonal moisture content changes in expansive soils.

2. Under reamed foundation may be taken upto a firm strata.
3. Adequate capacity of load bearing can be obtained in all directions as vertically down ward, upward or lateral loads and moment resisting capacity can be obtained by the use of this type of foundation.
4. Under reamed foundation even can be taken upto below scour level.
5. Under reamed pile foundation may also be used in situations where noise and vibrations caused during the construction of piles is objectionable. The provision of bulbs in under reamed piles resist the up lift thrust as they act as anchors. They also provide increased bearing surface.

Under reamed piles with more than two bulbs have not be found much effective, hence their use should be made after due investigations.

2.11.3. Design Considerations

The diameter of the bulb of under reamed pile usually may vary from 2 to 3 times the diameter of the stem of the pile depending on the feasibility of construction and design requirements. Normally the bulb diameter is adopted 2.5 times the diameter of the stem.

Spacing of the two bulbs. For piles upto 30 cm diameter, the spacing of the two bulbs should not be more than 1.5 times the diameter of the bulb. For piles greater than 30 cm diameter, the spacing should be reduced to 1.25 times the diameter of the bulb.

Diameter of the stem. The minimum diameter of stem for bore holes which need stabilization by drilling should be 25 cms.

Position of top bulb. The distance between the top of the pile and top most bulb should not be less than two times the diameter of the bulb. (Du) where Du is diameter of the bulb. In expansive soils it should not be less than 1.75 m below the ground level. The minimum distance below the under side of the pile cap embedded in the ground and the bulb should not be less than 1.5 times the diameter of the bulb.

Spacing of two piles. The centre to centre spacing for bored under reamed piles in a group normally should be two times the diameter of the bulb (Du) How ever it should not be less than 1.5 Du. For under grade beams the spacing of piles generally should not exceed 3.0 m. In case of under reamed compaction piles, the spacing should not be less than 1.5 Du.

2.11.4. Equipment

For manual operations normally following equipment is required:

(*i*) A augur (*ii*) Under reamer
(*iii*) Boring guide (*iv*) Accessories

For piles of larger size than 30 cm and deeper a portable tripod hoist with manually operated winch is required. For compaction of piles, additional equipment is required.

2.11.5. Construction operations

Following operations are involved in the construction of under reamed piles:

(*i*) Bore holes are made with earth augurs. In manual boring, an augur boring guide is used to keep the bore vertical or at desired inclination etc.

(*ii*) At site with higher water table, drilling mud (bentonite) may be used for boring and under reaming.

(*iii*) In very loose strata at top, a casing pipe of suitable length may be used to avoid irregular shape and widening of the bore hole.

(*iv*) The reinforcement cage should be placed with the help of a guiding chute etc.

(*v*) In order to get a proper under reamed bulb, the depth of bore hole should be checked before starting under reaming. It should also be checked during under reaming. An extra soil at the bottom of the bore hole should be removed by augur before reinserting the under reaming tool.

(*vi*) The completion of desired under reamed bulb can be ascertained by vertical movement of the handle. If the under reamed is full no further soil will be cut.

(*vii*) In case of multi reamed piles, the boring is first completed upto the depth of the first bulb (top bulb). After completing the under reamed bulb, the boring is extended further down to the second bulb and so on.

(*viii*) The pile is to be installed as correctly as possible with respect to the correct location and true verticality. The deviation of piles should not be more then 7.5 cms or one fourth of the diameter of the stem which ever is less. For piles greater than 60 cm in diameter, the deviation may be upto 7.5 cms or 10% of the diameter of the stem.

Any deviation beyond permissible limit should be noted and adequate measures should be taken before concreting the pile cap and plinth beams. When defective piles are formed either they should be removed or left in place which ever is convenient with out affecting the performance of the adjacent piles or cap all of them.

(*ix*) To allow the removal of the laitance and weak concrete of the top of the pile, the top concrete of the pile should be brought above the cut off level before capping. It is also important to ensure good concrete at the cut off level for proper embedment into the pile cap.

(*x*) In case the cut off level is less than 1.5 m below working level, the concrete should be cast upto a minimum of 30 cms above cut off level. For every excess of 30 cms over 1.5 m, additional 5 cm should be cast over and above 30 cms.

(*xi*) The pile should project 5.0 cms into the cap concrete.

QUESTIONS

1. Emumerate the causes of settlement of foundation.
2. Discuss the process of strengthening of existing building foundation with neat sketch.
3. Define made up soil. Enumente the causes of unequal settlement.
4. Define sand piles? How are they made? Discuss their functions also.
5. Sand piles can be used primarily for consolidation of soil of the type.
   (*a*) Black cotton soil (*b*) Boulders
   (*c*) Cohesive soil (*d*) Granular soils like sand
   (*e*) Gravels
6. The bearing capacity of a soil can be increased by
   (*a*) By removing air voids from the soil by mechanical compaction
   (*b*) By increasing the depth of foundation (*c*) By compaction with vibrofloats
   (*e*) By chemical treatment (*e*) By any of the above
7. Identify the incorrect statement/statements
   (*a*) Foundation is built below ground level to save money.
   (*b*) Foundation is built below ground level to protect it from environmental effects.
   (*c*) To protect the structure from over turning moment
   (*e*) To provide a good natural level surface to the building
8. The footing of a single column is classified as
   (*a*) Spread foundation (*b*) Isolated footing
   (*c*) Combined footing (*d*) Any of the above
9. Differential or unequal settlement of a foundation occurs due to except
   (*a*) Uniformly distributed load (*b*) Eccentric loading
   (*c*) Non uniformly distributed load (*d*) Unequal load distribution

ANSWERS

5. (*d*) 6. (*e*) 7. (*a*) 8. (*b*) 9. (*a*)

3
Anti-termite Measures

3.1. INTRODUCTION

Termite is a white coloured insect like an Ant. Due to its colour it is also called white Ant. The damage caused by termite is very huge. Termites attack cellulosic as well as non cellulosic materials. They also damage materials of organic origion with cellalosic base as wood, rubber, leather, plastic, neoprene as well as lead coating materials used for covering under ground cables. Termite thrives or grows in moist conditions under cover of a tall tale tube. It dies as it comes in contact with atmospheric air.

3.2. CLASSIFICATION OF TERMITES

Termites can be classified on the basis of their habitat into two classes, namely (*a*) subterranean or under ground nesting termite and (*b*) non subterranean or wood nesting termites having no contact with soil. Sub terranean termites are responsible for most of the termite damage in buildings. Typically they form nests or colonies under ground in the soil near the ground level in a stump or other suitable pieces of timber in a conical or domed shaped mound.

3.3. SOURCE OF INGRESS OF TERMITES

The termites enter the building through the timber buried in the ground or by means of mud sheltre tubes constructed over unprotected foundations. They advance upwards along side the walls of the building. They may also enter the building through cracks and crevices in the masonry. Once the termites find a foot hold in or near a building, they start spreading very fast and can damage the wooden members of the building and other house hold articles as furniture, stationary, clothings etc. in a very short time. Hence termite treatment in existing as well as new buildings is very important. The termite treatment in existing buildings is very difficult and elaborate. Hence it is always better to provide anti-termite treatment during its construction.

3.4. TYPES OF TREATMENT

The commonly adopted method of anti termite treatment is to treat the soil beneath the foundations with soil insecticides. A chemical barrier is created between the ground and the masonry of the foundation, preventing the termites from approaching or attacking the building. Anti termite treatments can be classified as:

(*a*) Pre constructional chemical treatment during the construction period.

(*b*) Treatment of existing buildings after construction of the buildings.

3.5. CHEMICALS

Tremiticide pretreatment is a cost effective approach to protect the structure from termite attack. Earlier

Aldrin emulsifiable concentrate was the most popular insecticide in the market. But now it has been banned and no longer is available in the market. For treating soils beneath a building following chemicals have been found very effective.

(*a*) 0.5% by weight Heptachlor emulsifiable concentrate (IS 6439-1978).

(*b*) 1 % by weight chlordane emulsifiable concentrate (IS-2682-1984).

(*c*) 1.0% by weight chloropyrifos emulsifiable concentrate (IS-8944-1978).

The active ingredient of the commonly available termiticide is chloropyrifos. It is manufactured by DE-NOCIL, MONTARI industries and others. Many other companies prepare their own formulations from chlorophyriphos and market under different brand name in the market. Before use of these chemicals latest recommendations of Central Board and regulation committee, Ministry of Agriculture FARIDABAD should be referred. Further before the application of the chemicals, it should be ensured that no well or any source of drinking water is contaminated with chemicals.

3.6. DILUTION OF CHEMICALS

In the market the chemicals are available in the concentrated form. The concentration is indicated on the sealed container. To achieve the specified % and concentration, chemical should be diluted with water in required quantity before it is used. For example DUSTBAN-TC (a chloropyrifos formation manufactured by DE-NOCIL) should be diluted in water in the ratio of 1 litre of chemical and 19 litres of water to get a 1.0% chloropyrifos emulsion. For dilution of chemicals graduated containers should be used to get the desired concentration.

3.7. SAFETY PRE CAUTIONS

As these chemicals are poisonous, they can have adverse effect on the health of the worker when absorbed through skin, inhaled as vapours or spray mist or swallowed. Hence proper precautions should be taken to prevent skin contact with concentrates and prolonged exposure to dilute emulsion. After using concentrates or dilute emulsions, workers should wash themselves with soap and water and wear clean clothing, specially before eating and smoking.

3.8. PRE CONSTRUCTION CHEMICAL TREATMENT (IS-6313-Part-II-1981)

General. Chemical treatment of soil should be got done only from approved specialized agency. The chemicals also should be purchased from authorized dealers. Spraying chemical should be done using hand operated pressure pumps.

3.9. TIME OF APPLICATION

Soil treatment should be started when the foundation trenches and pits are ready to take bed concrete or levelling course in the foundation. Laying of bed concrete should start when the chemical emulsion has been absorbed by the soil and the soil is reasonably dry. Treatment should be stopped when it is raining or when soil is wet with rain or sub soil water. This also applies to the fill up soil with in plinth area before laying the sub grade for flooring.

The treated soil barrier should not be disturbed. If due to some reasons the treated soil barriers are disturbed, immediate steps should be taken to restore the continuity and completeness of the barrier system.

3.10. TREATMENT OF MASONRY FOUNDATIONS AND BASEMENT

Stage 1. Trenches. The bottom and sides upto 30 cms height of the excavated trench should be treated with the chemical emulsion at the rate of 5 lit per m^2 of the surface area as shown in Fig. 3.1 marked A. The foundation concrete should be laid after the treatment with chemical.

Stage 2. After building the foundation and the retaining wall of the basement, the back fill in the immediate contact with the foundation structure should be treated at the rate of 7.5 lit per m^2 area of the vertical surface of the sub structure for each side.

If water is used for ramming the back fill, the chemical treatment should be carried out after the ramming operation is completed. For this compaction rodding of earth close to the wall should be done at 15 cm centres. The rod should move to and fro parallel to the wall before applying the chemical emulsion in the specified dozes.

The earth fill should be done in layers. Chemical treatment should be carried out for each layer. The chemical emulsion should be directed to wards the concrete or masonry surfaces of the column and walls in contact with earth marked by B as shown in Fig. 3.1 (*a*). All foundations and surface in close contact alongwith external parimeter of the building should be surrounded with the chemical treated soil barrier as shown by E in Fig. 3.1 (*a*).

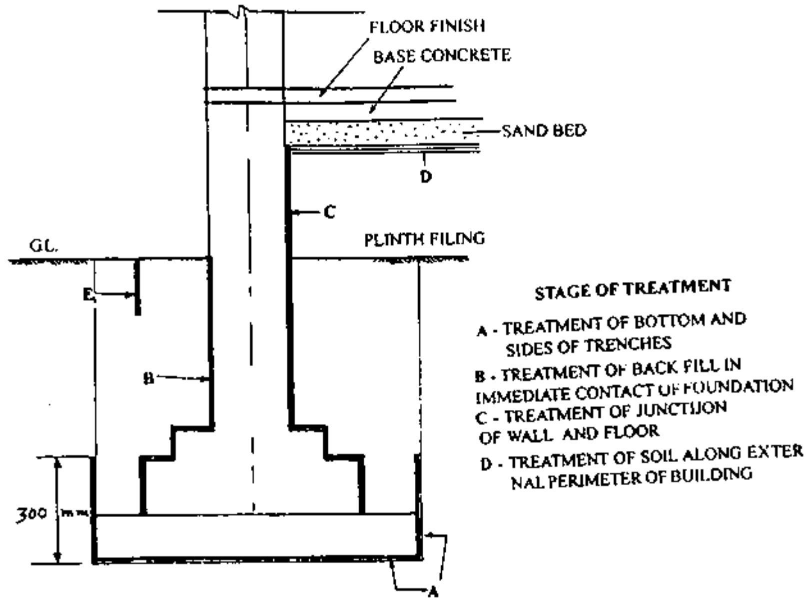


Fig. 3.1. (*a*)

3.11. TREATMENT FOR R.C.C. FOUNDATIONS AND BASEMENT

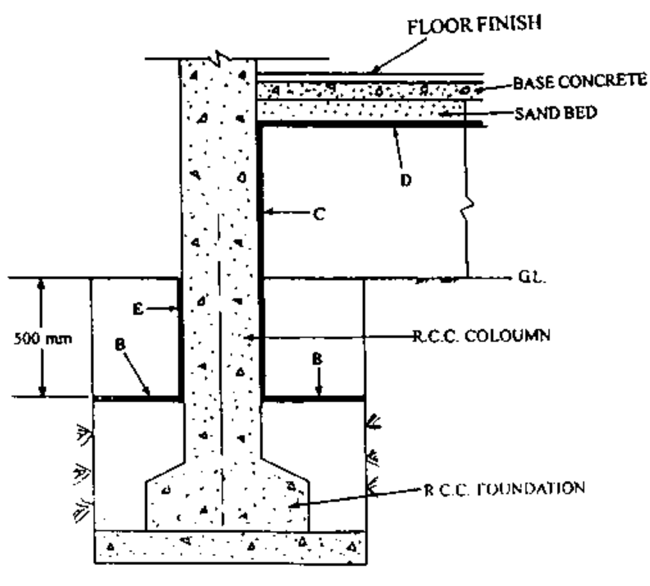
In case of R.C.C. foundations, concrete mix used is 1:2:4 or richer. Hence concrete is quite dense and the treatment of the bottom of foundations is not nessary. The treatment should start from 50 cms below the ground level and the soil in immediate contact with the vertical surfaces of R.C.C. foundations is treated. The chemical should be used at the rate of 7.5 lit/m^2 of the vertical surface as shown in Fig. 3.1. (*b*). The other details are similar as discussed under stage 2 treatment above.

3.12. TREATMENT OF TOP SURFACE OF PLINTH FILLING

The top surfaces of the filled earth with in plinth walls is treated with chemical emulsion at the rate of 5 lit/m^2 of the surface before the sand or sub grade for the flooring is laid. Holes upto a depth of 50 to 75 mm and at 150 mm centres both ways are made with crow bars on the surface to facilitate the saturation of soil with chemical emulsion as shown by (D) in Fig. 3.1 (*b*).

3.13. TREATMENT AT JUNCTIONS OF WALLS AND THE FLOOR

In order to achieve continuity of the vertical chemical barrier on the surface of the inner walls from ground level a small channel of 30 × 30 mm



(*b*)

Fig. 3.1. R.C.C. Column Footing

should be made at the junction of vertical walls and columns with the floor before laying the sub grade. Rod holes are made 150 mm apart upto the ground level in the channel. In the channel, chemical emulsion is poured at the rate of 7.5 lit/in^2 of the vertical wall surface, so that soil upto the bottom is soaked with chemical. After this operation, the soil is filled and tamped back in to the place.

3.14. TREATMENT OF SOIL ALONG THE EXTERNAL PERIMETER OF BUILDING

After completion of the building, 300 mm deep holes are made in the soil with iron rods along the external parimeter of the building about 150 mm apart and filled with chemical emulsion at the rate of 7.5 litres/m^2 of vertical surfaces in contact with earth.

In case the depth of filling is more than 300 mm, the external perimeter treatment should extend to the full depth of filling upto the ground level to ensure the continuity of the chemical barrier.

3.15. PLINTH PROTECTION OR TREATMENT OF SOIL UNDER APRON

The top surface of the consolidated earth over which the apron (the protective hard layers is to be laid) should be treated with chemical emulsion at the rate of 5 lit/m^2 of the surface before laying the apron. If the consolidated soil does not allow the penetration of the chemical emulsion through it, the holes upto a depth of 50 to 75 mm at 150 mm apart both ways should be made with 12 mm diameter mild steel bar on the surface to facilitate the saturation with chemical emulsion.

3.16. TREATMENT OF EXPANSION JOINTS

Expansion joints at ground level are one of the worst hazzards for termite infection. The soil below these joints should be given special attention as discussed under R.C.C. foundation for plinth filling. This treatment should be supplemented by treating the expansion joints after the sub grade has been laid at the rate of 2 lit per liner metre.

3.17. TREATMENT OF SOIL SURROUNDING PIPES, CONDUITS ETC.

When waste pipes, and conduits enter the foundations, the soil surrounding each point of entry should be loosened around each such pipe for a distance of about 150 mm and to a depth of 75 mm and the soil should be treated as discussed under stage 2 treatment. When pipes enter the soil external to the foundation, they should be similarly treated with the chemicals emulsions for a distance of 300 mm unless they are clear of the walls by about 75 mm.

3.18. TREATMENTS OF CHOKHATS

The chokhats should be treated with anti termite chemicals before fixing in the building. The termiticide should be mixed with kerosene oil in the proportion of 1:20 and the emulsion should be applied with brush to the surface of the chokhat in contact with the masonry. After drying one more coat may be applied.

3.19. TREATMENTS FOR EXISTING BUILDINGS (IS 6313 Part-2-1981)

Before taking any type of treatment, the building should be inspected thoroughly and the routes of entry of termite into the building are determined. Portions of building in contact or adjacent to soil should be inspected. Damp locations such as bathrooms, toilets etc. and points where wood work is embedded in the floor are more susceptible to termite attack.

The sign of presence of termite is indicated by the tell tale tubes. (A muddy colour cover for termite easily distinguishable by eye). Termite travel in these tubes and eat away wood work leaving the film of the paint on the surface, making it difficult to locate the termite. To determine the presence of termite, wood work should be tapped. The hollow sound indicates the termite attack. The new tubes of termite are moist, where as old tubes are dry and break easily. These tubes should be raked out with knife or sharp edge article and destroy the termite.

3.20. EXTERMINATION OF TERMITES IN BUILDINGS

After thorough study of termite infestation in the building, step should be taken to eliminate it in a thorough and systematic manner. They would be sought out in their habitats or hide outs, such as ceilings, behind wooden paneling, inside electric battens, conduits, switch boards and similar locations. These should be treated with chemicals as discuss under pre construction treatment. To facilitate the proper penetration of chemicals into the surface to be treated, hand operated pressure pumps may be used. All traces of termite tubes should be removed, so that any fresh infestation that may occur at an later date may be detected easily. While injecting the chemicals same precautions should be adopted as discussed above.

3.21. TREATMENT ALONG OUT SIDE OF FOUNDATIONS

The soil in contact with the external wall of the building should be treated with the chemical emulsion at the rate of 7.5 litres/m^2 of the vertical surface of the sub structure to a depth of 300 mm. To facilitate this treatment a shallow channel along and close to the wall face should be excavated. The chemical emulsion should be directed to wards the wall at 1.75 litre per running metre of the channel. For uniform dispersal of the chemical to 300 mm depth from the ground level 12 mm holes at 150 mm apart should be formed from rod and chemical rodded. The back fill earth should be treated with the remaining chemical at the rate of 0.5 litre per running metre of the channel and returned to the channel after spraying the wall.

In case of concrete or masonry apron around the building about 12 mm diameter holes about 300 mm apart should be drilled as close as possible to the plinth wall. These holes should be deep enough to reach the soil below. The chemical emulsion is pumped into these holes at the rate of 2.25 litres per linear metre.

In case of R.C.C. framed structures, the soil in contact with the column side and plinth beams along external perimeter of the building is treated with the chemical emulsion at the rate of 7.5 litre/m^2 of the vertical surface of the structure. To facilitate the treatment, trenches equal to the width of the shovel are excavated exposing the side of columns and plinth beams upto a depth of 300 mm or upto the bottom of the plinth beams if this level is less than 300 mm.

The chemical emulsion is sprayed on the back fill soil as it is returned into the trench directing the spray against the concrete surface of the beam or column as the case may be.

3.22. TREATMENT OF SOIL UNDER FLOORS

In this case the treatment is done by drilling 12 mm diameter holes at the junction of wall and floor along the crack on the floor and along the construction joints at an interval of 300 mm upto soil below. Chemical emulation is injected in these holes with the help of hand operated pressure pump to soak the soil below until refusal or upto a maximum of 1 lit per hole. Then the holes are sealed properly with 1:2 cement mortar and finished to match the existing floors. The cement mortar applied should be cured at least for 10 days.

3.23. TREATMENT OF VOIDS IN MASONRY

The movement of termites through masonry walls may be arrested by drilling holes in the masonry wall at plinth level and filling chemical emulsion into them. The holes should be drilled at an angle of 45° from both sides of the plinth wall at 300 mm intervals and chemical emulsion injected through these holes into the masonry using a hand operated pump The treatment should also be extended to internal walls having foundations in the soil.

Holes should also be drilled at wall corners and where a door and window frames are embedded into the masonry or floor at ground. Chemical emulsion should also be injected into the holes till the saturation of soil or to a maximum of 1 lit per hole. After treatment holes should be sealed.

3.24. TREATMENT OF POINTS OF CONTACT WITH WOOD WORK

The termite infested wood work in the building should be treated carefully by spraying chemical emulsion at the points of contacts with the adjoining masonry. 6 mm diameter holes are drilled at about 45°

angle down wards at the junction of the wood work and masonry. Chemical emulsion is filled in these holes till saturation or to a maximum of 1/2 lit per hole. The treated holes are sealed properly.

3.25. TREATMENT OF WOOD WORK

Wood work damaged beyond repair should be replaced after proper treatment.

Infested wood work which can be used after treatment should be protected with chemical treatment. In this case inclined holes upto the core on uninfested side should be drilled and chemical emulsion injected in these holes. if need be the wood work may be painted with one or two coats of chemicals.

3.26. TREATMENT OF TYPICAL STRUCTURES

Forest Research Institute Dehradum has recommended the treatment of typical structures. Fig. 3.2 illustrate the process of laying termite proof wooden floor on cement concrete bass while Fig. 3.3 shows

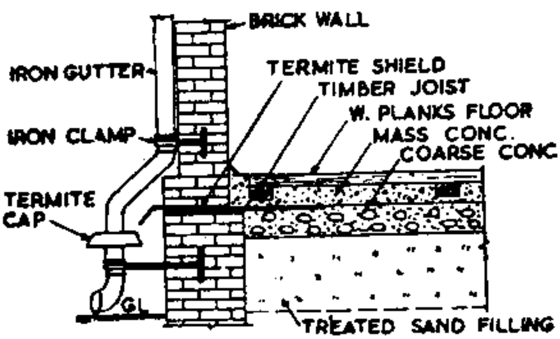


Fig. 3.2. Wooden floor on concrete base

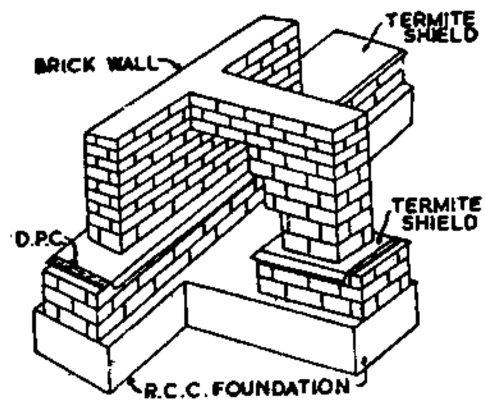


Fig. 3.3. Junction of main wall and other walls

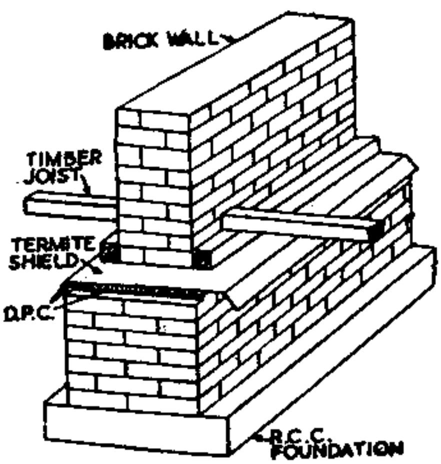


Fig. 3.4. Junction of external wall

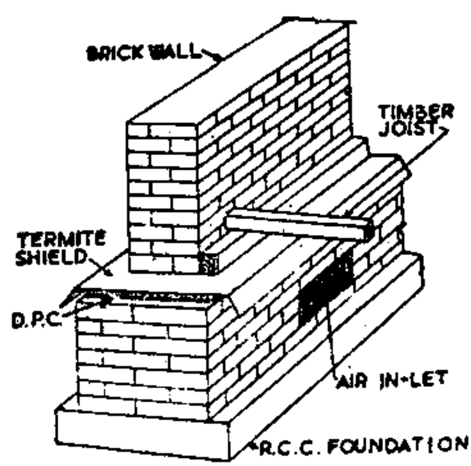


Fig. 3.5. Junction of internal wall

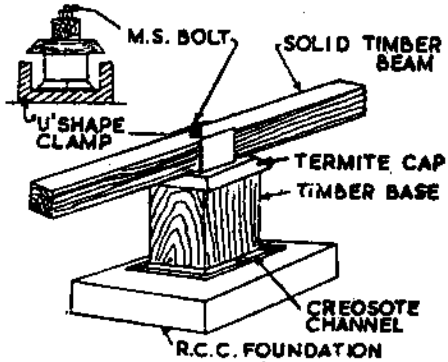


Fig. 3.6. Anti termite layer between concrete base and timber column

termite proofed junction of main wall with other walls. Fig. 3.4 and 3.5 show the construction of termite proof external and internal walls respectively. Fig 3.6 shows the anti termite layer between concrete base and timber column.

QUESTIONS

1. What is termite? How it causes harm to the building.
2. Name different chemicals used in anti termite treatment.
3. What precautions should be observed while using chemicals for anti termite treatment.
4. Discuss the process of treatment for
   (*a*) Treatment of soil under floor (*b*) voids in masonry
   (*c*) Treatment along out side of foundation
5. Write a note on the anti termite treatment of existing buildings
6. Identify the incorrect statement/statements.
   (*a*) Anti termite soil treatment should be done when the foundation and pits are ready to take the levelling course in the foundation.
   (*b*) Bed concrete should be laid when the chemical emulsion has been absorbed by the soil and it is dry.
   (*c*) Anti termite chemical treatment can be carried during rains as well with advantage
   (*d*) Treated soil barrier should not be disturbed
   (*e*) The bottom and sides of trenches should be treated upto a height of 30 cms from bottom with chemical emulsion
7. The depth of holes for injecting chemical emulsion into the floor should be
   (*a*) 50 cms (*b*) 25 cms
   (*c*) 75 cms (*d*) 15 cms
8. To treat voids in masonry, the holes are drilled at angle of
   (*a*) 90° (*b*) 110°
   (*c*) 60° (*d*) 45°
9. Holes drilled under floor are filled after treatment with
   (*a*) 1:2:4 cement concrete (*b*) 1:3:6 cement concrete
   (*c*) 1:2 cement concrete (*d*) Any of the above may be used

ANSWERS

6. (*c*) 7. (*d*) 8. (*d*) 9. (*c*)

4

Maintenance of Brick and Stone Masonry

4.1. INTRODUCTION

The brick and stone masonry is a an important part of all Civil Engineering works as buildings, bridges, culvests etc. For day to day requirements of human beings, habitat dwellings *i.e.* houses are very important. The inhabited buildings should be hygienic, and comfortable for the inhabitants.

4.2. FUNCTIONS OF MASONRY

Followings are the main functions of the masonry:

(*a*) It encloses the area

(*b*) It protects the enclosed space from atmospheric effects

(*c*) It bears the load and the thrust

4.3. INSPECTION OF MASONRY WORK

To provide healthy and hygienic living conditions to the inhabitant the dwellings should be free from all defects and damages Thus inspection of masonry is essential to determine the defects and damages and its extent to take remedial measures. At the time of inspection following points should be given special consideration.

1. Dampness
2. Cracks in building
3. Condition of painting and plastering
4. Growth of vegetation
5. Structural failure (as settlement and bulging etc.)

4.4. INVESTIGATIONS OF DEFECTS

To ensure proper functioning of all elements of a building it requires proper and timely maintenance. All the damaged structures develop visual signs of cracks of different pattern and size resulting in peeling of plaster, spalling of concrete and other surface finishes. Hence before taking up necessary repairs, it is necessary to carry out systematic detailed investigations to identify the exact cause of deterioration.

4.5. STEPS INVOLVED IN THE INVESTIGATIONS OF CAUSES OF DETERIORATION

Following steps are involved in the investigation of causes of deterioration:

(*a*) Preliminary investigation

(*b*) Physical investigation

(*c*) Material tests

(*d*) Non destructive tests

(*e*) Detailed diagnosis of defects

(*f*) Study of available documents

(*g*) Checking of errors in the design

(*h*) Estimation of actual loads and environmental effect

(*i*) Strengthening requirements
(*j*) Relevant approach to repair
(*k*) Retrospective analysis

4.5.1. Preliminary (visual observations) Investigation

In this investigation following points should be recorded:

(*a*) Position, extent, direction and nature of cracks in R.C.C. slabs, beams, floors, columns and walls etc.
(*b*) Position of honey combing in R.C.C. works
(*c*) Sinking of floors
(*d*) Extent and position of damage
(*e*) Type and quality of masonry
(*f*) Excessive voids and hollows in R.C.C. works.
(*g*) Loads on building
(*h*) Inspection of adjoining building to ascertain whether they also have gone such damages.

The inspection should be done atleast once a year. Periodic inspections may also be carried out as per need.

4.6. BASIC KIT FOR DIAGNOSIS

For all investigations a kit is required for recording length, level and depth etc. The investigation kits may be of two types.

1. Basic kit
2. Specialised kit

1. Basic kit. Basic kit should have the following articles in it:

(*a*) Note book, sketch pad, clip board, pencil, scale and eraser for recording and noting.
(*b*) For measuring over all dimensions and profile of defects, rulers and tapes should be available. A caliper gauge, and micrometer will be useful to measure the dimensions of cracks.
(*c*) Adhesive tape or other adhesive material for temporary fixing of rulers etc.
(*d*) Camera can be useful for taking photographs of important features during visual inspection. A video camera will be more useful.
(*e*) Torch or other source of light.
(*g*) Mirror with appropriate source of light will be highly useful.
(*h*) Magnifying glass for observing the very fine cracks.
(*i*) Binoculars will be useful for studying surface defects and details of inaccessible defects.
(*j*) Small hammer, screw driver, plier and such tools useful for scrapping surface finishes.
(*k*) Small spirit level and angle indicator for assessing surface levels.
(*l*) Moisture meter to indicate the moisture average depth of dampness in the structure.
(*m*) Thermometer to record the temperature of the surface etc.

2. Specialised kit. It contains all the equipment needed for Specialised job.

4.7. DAMPNESS

It is a state in between wet and dry condition. Dampness gives rise to the growth of bacteria of many deceases and insects which cause damage to the health of inhabitants and house hold articles. Hence dampness should be removed as early as possible from the dwellings.

4.7.1. Causes of dampness

Though water is a essential element for the construction of the structure, but presence of moisture in the buildings is very harmful element for causing damage to them.

4.7.2. Sources of ingresss of moisture

Followings are the sources of ingress of moisture:

(*a*) **Defective design.** Leakage from roof is a major source of ingress of moisture in the buildings.

(*b*) **Use of defective or substandard materials.** Use of porous bricks is a permanent source of dampness. The use of other sub standard or defective materials also is a source of dampness.

(*c*) **Improper execution.** Use of defective rain water pipes, mortar joints not constructed properly and uniformly, cavities and holes are left in the walls due to negligence.

(*d*) **Defective damp proof course.** It is the worst source of ingress of moisture in buildings to cause dampness.

(*e*) **Growth of vegetation.** Growth of vegetation develops cracks in buildings which are a major source of ingress of moisture into the buildings.

(*f*) **Splashing of water from the ground.** Splashing of rain water from the ground on the wall above D.P.C. causes dampness in the building. It happens, when the plinth height is low or building level is at lower level from the adjoining ground.

(*g*) **Defective window sills.** Defective construction of window sils would allow stagnation of water on it.

(*h*) **Leaking pipes.** Rain, soil, waste water or water supply leaking pipes may be a major source of moisture ingress.

(*i*) **Earth banks.** Construction of earth banks by the side of the building side slopes covering some height of the wall above D.P.C. would cause dampness in the building.

(*j*) **Sloping ground.** It applies to hilly areas where buildings are constructed on slopes of the hill.

(*k*) **Ground water.** Moisture ingresses into the building through walls and floor by capillary action and causes dampness in walls and floor.

4.8. EFFECTS OF DAMPNESS

Followings are the common ill effects of the dampness:

1. *Discoloration.* Dampness develops unsightly patches on the walls and ceiling surfaces.
2. *Weathering of materials.* Dampness causes dry rots to the wooden members and corrosion to the steel members in the building.
3. *Decay of materials.* Moisture causes decay and disintegration of materials as bricks, stone, steel and timber.
4. Dampness causes peeling off and crumbling of plaster.
5. Damage to electrical installations and short circuiting.
6. Deterioration of floor coverings as carpets.
7. *Damage of paints.* Paint on walls get bleached, flaked and blistered.
8. *Growth of vegetation.* It develops unaesthetic look to the building.
9. *Un hygienic conditions.* Dampness causes un healthy environment for the inhabitants as bacteria of many deseases thrives in damp conditions.

4.9. EFFLORESCENCE

All building materials as bricks or stone, cement etc. Contain various soluble salts. When moisture ingresses through any source in these materials, it dissolves these salts, forming a solution. This solution comes to the surface through the pores of the material as brick. As the moisture from the solution is evaporated, these salts crystallize on the surface producing white patches on the surface, which look ugly. This may also disintegrate the brick work.

Remedial measures. Efflorescence can be removed by rubbing the surface of brick masonry with wire brush and thoroughly washing with water.

4.10. REMEDIAL MEASURES FOR PREVENTING DAMPNESS

Different measures are adopted for preventing dampness depending upon the source of dampness and position of dampness as internal or external.

4.10.1. Measures to prevent dampness due to ground water or sub soil water

To check seepage through walls and floor of the building from subsoil water, following measures may be taken.

(*a*) Reduction in sub soil level by pumping out sub soil water by providing relief well.

(*b*) Opening out of masonry joints for evaporation of seeping moisture.

(*c*) Providing effective damp proof course (It has been discussed fully in subsequent paras).

4.10.2. Measures to prevent dampness due to rain water

Dampness due to rain water may ingress through walls and roof.

1. **Through walls.** Dampness can be prevented by applying suitable treatment.
2. **Leak through roofs.** For dampness through roof, damp proof course is applied. It has been discussed in detail in article 4.9.

4.11. CLASSIFICATION BASED ON PERMANENCY

Dampness prevention measures can also be classified as:

(*a*) Temporary measures (*b*) Permanent measures

4.11.1. Temporary measures for preventing internal wall dampness

In this case following measures can be adopted:

1. **Application of water proofing solution.** In this case either commercially available solutions or locally prepared solutions may be applied.
2. **Application of cement wash**. In this method a solution of cement in water of thin consistency is prepared with adhesive gum. This solution is applied after cleaning the surface. This treatment is easy to apply.
3. **Application of bituminous paints.** In this case the affected area is cleaned and allowed to be dried. After drying a coat of hot bitumen or available emulsion is applied uniformly.

4.11.2. Temporary measures for external walls

Under this head following measures may be adopted:

1. Use of water proofing solutions as in the case of internal walls.
2. Coating with hot linseed oil after cleaning the surface.
3. Applying cement wash as above.
4. Painting with paraffin.
5. Application of bituminous paint as above.
6. Sylvester's process. In this case alternate coats of soap and alum solution is applied to the affected wall. The solution will fill up pores forming a hard surface on the wall.

The first coat should be applied after clearing the surface. Subsequent coats should be applied after the previous coat has dried up.

4.11.3. Permanent measures

These measures are discussed in details in the following pages.

4.12. DAMP PROOF COURSE (IS-3667-1988)

Foundations of all structures are laid on soil. Bricks being porous in structures, all brick masonry below ground level absorb moisture from the adjacent ground. This moisture travels upwards by capillary action from one course to an other making wall damp upto a certain height. Rise in ground water table in rainy season also helps the ingress of moisture into the wall and floor, hence the need of damp proof course.

To prevent the rise of absorbed water from the soil and causing dampness in the wall, plaster and adjacent wood work is provided with, a continuous layer of an impervious material. This impervious layer is known as a *damp proof course*. If this layer is provided horizontally, then it is called horizontal damp proof course, and if laid vertically, then it is called vertical damp proof course.

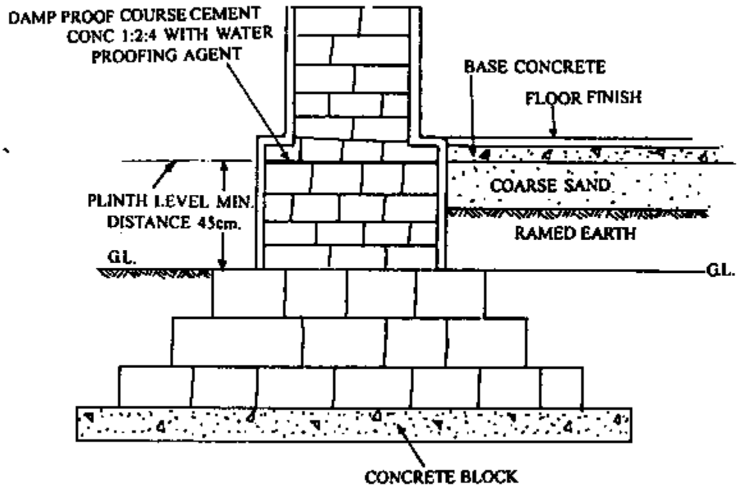


Fig. 4.1 (*a*). D.P.C. at plinth level

4.12.1. Location of damp proof course

The damp proof course is provided in all buildings at the plinth level. Plinth level should always be 15 cms above the highest point of the finished ground level. National Building code specifies the height of the plinth to be not less than 45 cm above the surrounding ground level. Typical D.P.C. details are shown in Fig. 4.1 for new buildings above ground level.

4.12.2. Composition of damp proof course (IS-2645-1975)

For residential buildings D.P.C. consists of a layer of the followings:

1. 40 mm thick 1:2:4 cement concrete layer. The coarse aggregate should be graded with the maximum nominal size of 12.5 mm. (1 cement, 2 coarse sand, 4 graded coarse aggregate).
2. 50 mm thick 1:2:4 cement concrete with graded aggregate of nominal max size of 20 mm. These mix should contain some water proofing compounds.

The D.P.C. must extend upto the full width of the wall. It must be continuous for the whole length of the building. In the damp proof course there must be no construction joint. D.P.C. is not carried across door ways, verendha, arches and like openings.

4.12.3. Laying Procedure of D.P.C.

Before laying the cement concrete layer of D.P.C. the surface of brick or stone masonry should be properly leveled. The edge of D.P.C. should be straight, even and vertical. Side shuttering should be made of steel. It should be strong enough and should be fixed properly so that it does not get disturbed during compaction and mortar does not leak through it. The concrete mix should be of workable consistency to be compacted fully to make the dense mass of concrete. On removing the sides, the surface should be smooth with out honey combing. It should be cured for 7 days before applying bitumen coat to the surface. The surface should be allowed to dry for at least 24 hours before applying the bitumen coat.

4.12.4. Application of hot bitumen

Before the application of the bitumen, the concrete surface is properly cleaned with brush and finally with cloth socked in kerosene oil. Bitumen of 80/100 penetration or equivalent is heated to a temperature of 160° ± 5°C. The hot bitumen is applied in two coats uniformly at the rate of 1.7 kg/m^2 surface area. No blank spaces should be left any where on the dried up concrete surface of the DPC.

4.13. DAMP PROOFING OF FLOORS

4.13.1. Dry areas having low water table

In areas where rainfall is scanty and ground water table also is low, in such areas usually 75 mm thick layer of sand for damp proofing of floor is adopted as shown in Fig. 4.1 (*a*). The sand layer is spread uniformly over the entire area of the flooring on the prepared bed of compacted earth. In granular soils the rise of water due to capillary action is almost negligible, where as in fine grained soils it may go upto 90 cms. This course is known as base course and should be thoroughly compacted. On this base course a layer of 75 mm or 100 mm of lean concrete (1:3:6 to 1:4:8 proportion) is laid. This layer forms the base for the floor topping. The floor topping may be of terrazzo, tile, marble or cement concrete.

4.13.2. Areas having high water table

In areas of high ground water table or in damp and humid areas, the capillary rise of water is likely to be very high, which will damp the walls as well the ground floor. In such situations it becomes essential to provide damp proof course of flexible material like bitumen felt over the entire area of ground floor including walls as shown in Fig. 4.1. (*b*).

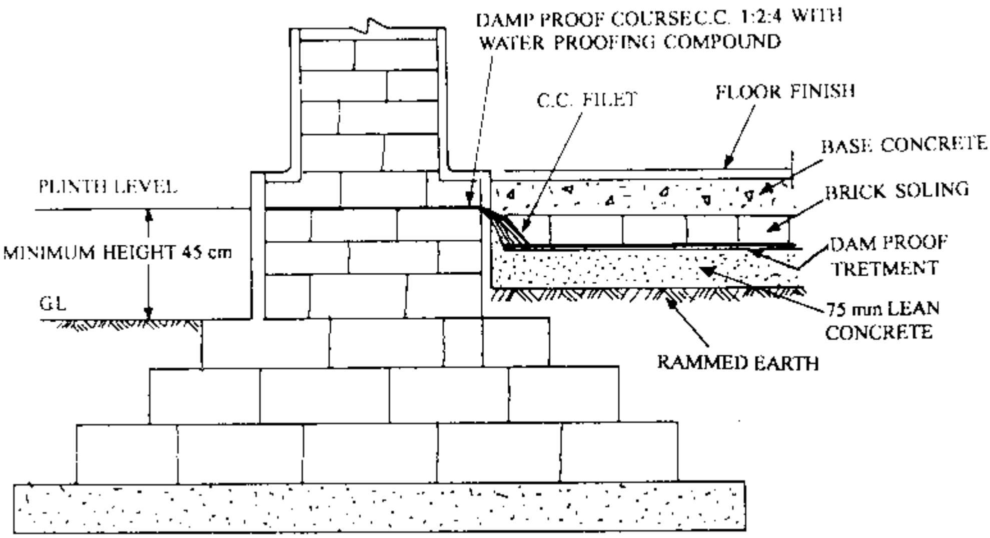


Fig. 4.1 (*b*). Damp proofing floors in high water table areas

When a horizontal damp proof treatment is carried over a vertical face as from floor to vertical wall, a 1:4 cement mortar fillet of 75 mm radius should be provided at the junction of horizontal and vertical surface. Both the vertical and horizontal surfaces should be finished smooth. Immediately after laying D.P.C. it should be protected with a course of brick soling laid flat, so that D.P.C. is not damaged during subsequent operations by the movements of workers over it.

4.14. TREATMENT OF EXTERNAL WALLS FOR DAMP PROOFING

Walls get damp due to the penetration of moisture from external face of wall to internal face due to porosity of bricks and mortar joints during rainy season. To prevent dampness to walls, various treatments given to exposed surface of the wall are as follows:

1. Plastering
2. Pointing
3. Painting etc.

Plastering. Plaster made out of ordinary cement of 1:6 cement sand proportion is much more prone to surface cracks due to temperature variation and shrinkage effect than 1:1:6 cement, lime, fine sand proportion. Thus 1:1:6 proportion plaster serves as a fairly effective rending to protect the wall against dampness in normal weather conditions.

Non water proof cladding such as stone tiles with open joints should not be used. Water pool against external walls on balconies, chajjas and porch etc. should not be allowed to be formed. They should be so constructed that no water should accumulate on them, but drain off quickly into rain water drains.

4.15. DAMP PROOFING FOR WET AREAS

Due to their functional requirements water closet, bath room, kitchen, are the main wet areas of a building. These wet areas are one of the main source of leakage and dampness in a building. To some extent, verendha, balcony, sun shade, over head water tank also are responsible for leakage and dampness in a building. Use of sub standard materials or poor workmanship is one of the main causes of leakage and dampness in a building. Hence all plumbing fixtures and sanitary appliances should be of specified standard and the workmanship of their installation should be of high quality. In addition to this following points should be kept in view at the time of damp proofing of the wet areas.

1. Finishing floor of wet areas should be kept 25 mm lower than the adjoining floor. Walls in wet areas above finished level should be made of impervious material as glazzed tiles or insitu terrazzo to a height as follows:
   (*a*) Water closed 30 cms (*b*) Bath room without shower 1 m
   (*c*) Bath room with shower 2 m
2. Floor slope. Minimum slope from door towards the outlet drain should be 1 in 60.
3. Soil and waste pipes should be kept away from the wall to avoid dampness in wall, in case of leakage. There should be proper provision for access to all pipe work. As far as possible joints should not be embedded into the wall.

4.16. DAMP PROOFING OF JOINTS BETWEEN SKIRTING AND FLOOR TILES

As far as possible, floors should be laid joint less. How ever in case of tile floors, the tiles should be laid on bed of water proof mortar and the joints should be filled effectively. Floor tiles are laid at a specified slope and it is not easy to cut the skirting tiles exactly matching the slope of the floor tiles as laid. Thus the joint formed between the skirting tile and floor tile is vulnerable to moisture penetration if the workman ship of floorings is not proper. In this case following precautions are suggested:

(*a*) To minimize the possibility of moisture penetration through the joint, the floor tiles must extend fully to the walls and the skirting tile must have full beaning on the floor tile.

(*b*) In case of marble flooring and skirting, it is extremely important that 2% water proofing compound is mixed to the cement mortar used for packing the skirting and floor tiles. The joint is fully topped up and lightly tapped to eliminate of voids in the joints. During normal use, these voids may act as passage to the seeping moisture.

4.17. WATER PROOFING SYSTEM FOR FLAT ROOFS

Commonly adopted water proofing systems for flat roofs are as follows:

(*a*) Mud phuska terracing and paving with brick tiles (IS-2115-1980).

(*b*) Lime concrete terracing and paving with brick tiles (IS-3036-1992).

(*c*) Polymer modified bitumen polyester membrane treatment (IS 1609-1991).

(*d*) Application of bitumen mastic (4365-1967).

The choice of water proofing system depends upon climatic conditions, size of the roof, importance of the building and cost of treatment etc.

4.17.1. Preparatory work before application of water proofing treatment

(*a*) Slope of roof for drainage of rain water. For efficient draining a slope of 1 in 60 is sufficient.

(*b*) Size of rain water pipe (IS-2527-1984). For every 40 m^2 area of the roof surface one 100 mm diameter pipe is sufficient.

4.17.2. Mud Phuska Terracing with Brick tile paving (IS-2115-1980)

This system of water proofing of flat roofs is most suitable for hot and arid regions of North India, where annual rain fall is not high. Mud phuska is also a good thermal insulation layer for maintaining fairly comfortable temperature inside the dwelling.

The durability of mud phuska water proofing treatment depends on the maintenance of brick layer and slope for draining water from the surface. If cracks develop in the joints of the brick tiles, water seeps through these joints to the mud phuska layer resulting in the failure of water proofing system. Construction details of mud phuska terracing are shown in Fig. 4.2.

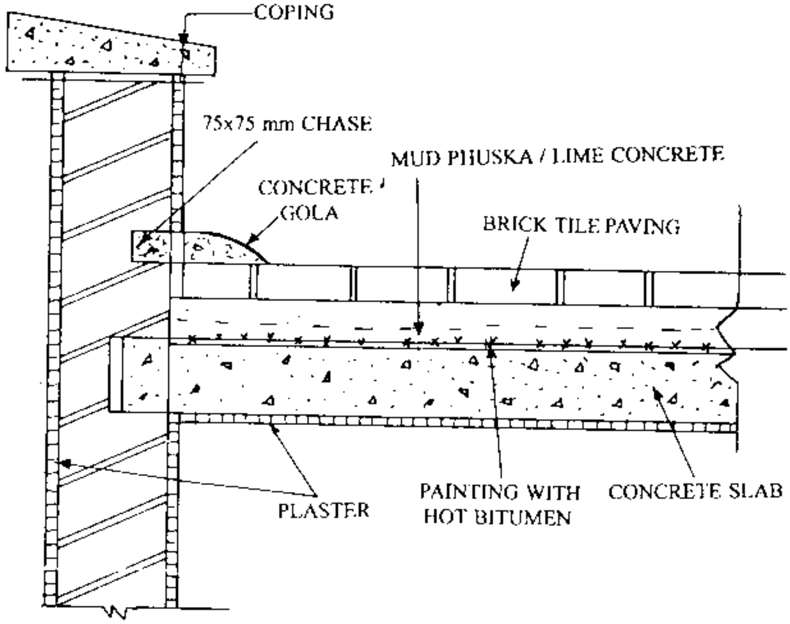


Fig. 4.2. Mud Phuska/lime Terracing for water proofing

4.17.3. Procedure

Before laying mud phuska on the roof, the concrete surface is given a thin coat of bitumen. The bitumen coat should be applied only after the surface has thoroughly dried, other wise trapped moisture will blister the painted surface after evaporation.

Bitumen of grade 80/100 is heated upto about 180°C to make it of pourable consistency. Bitumen should be applied at the rate of 1.75 kg/m^2 of the surface area. Bitumen should be applied in a thin and uniform manner ensuring that no blank patches are left. The bitumen coat should continue upto at least 15 cm along all the vertical surface in contact with the horizontal roof as parapet, pipes etc. Immediately after applying bitumen coat, clean coarse sand should be spread evenly on the surface at the rate of 0.6 m^3 of sand per 100 m^2 of surface to protect the bitumen laryer from damage during subsequent construction operations.

4.17.4. Mud Phuska terracing

Soil suitable for brick manufacture is also suitable for mud phuska. The soil to be laid as mud phuska should contain optimum moisture content. If the soil is not at optimum moisture content, then water should be sprinkled over it at least 12 hours before laying on roof and turned over with phawar to break clods and to pulverize the soil.

The plasticity index of the soil should be between 10 to 15%. The moisture content in the soil can be determined by pressing the soil in hand in the form of a ball. If the ball retains its shape after releasing pressure, it contains desired *i.e.* optimum, moisture content. On the other hand if the ball fails to maintain its shape, then moisture is insufficient. In case the ball deforms on pressing with hand, then moisture content is in excess than desired. Generally 145 lit of water per cubic metre of soil is necessary for having optimum moisture content.

The damp soil should be laid on the roof to the required thickness and slope. The slope may be kept between 1 in 50 to 1 in 60. The minimum thickness near the rain water outlet pipe should be 25 mm. The soil should be compacted with wooden rammers and thappies to get a even surface to correct slope. Now the surface should be allowed to dry for 24 hours.

Over the mud phuska surface, a layer of mud plaster of 25 mm thick should be provided and allowed to be dried. Hair cracks if any developed should be grouted with binder material.

4.17.5. Preparation of mud plaster

Mud plaster is prepared from the same soil used for mud phuska. The soil is dumped in a pit with sufficient water. Wheat bhusa at the rate of 35 kg per m^3 of soil is added in the pit soil and the mixture is left for 7 days to mature. During this period the mixture is pugged manually at interval with feet and phawras to form a homogeneous mass, free from lumps and clods. This mud mass is made of proper consistency for mud plaster.

To fill any hair cracks left, the mud plaster surface should be given a coat of gobri leaping after the mud plaster has dried. The thickness of gobri leaping should not be less than 3 mm. The quentity of gobre in the gobri leaping layer should be about 0.03 m^3 per m^2 of plaster area. It should be prepared by mixing equal parts of gobre and finely sieved clay with 5% cut back of 80/100 bitumen.

4.17.6. Paving with brick tiles (IS-2915-1990)

Brick paving finish becomes necessary where the roof is used for living and sleeping purposes. Provision of brick tiles, provides additional durability and thermal insulation. Tiles finish may be laid directly over the mud plaster.

After drying the mud plaster, flat brick tiles are laid using minimum amount of plain mud mortar (with out bhusa). The mud mortar is used as bedding layer to get a correct slope and even surface of the tile floor. The mud mortar should not rise into the vertical joints not more the 12 mm. The thickness of the joints should not be less than 6 mm and width not more than 12 mm.

After the mud bedding and mortar has dried, the joints should be grouted with 1:3 cement sand mortar. In the grouting cement, water proofing compound should be added at the rate of 2% *i.e.* (1 kg water proofing compound per 50 kg bag of cement). The joints should be finished neat. The surface should be checked for evenness and slope with straight edge and sprit level.

Curing. After finishing the surface, it should be covered with moist gunny bags for about 12 hours. Then water should be sprinkled frequently over the surface for a period of 7 days to avoid evaporation of moisture from the cement mortar.

4.18. KHURRAS

The spot near the rain water outlet made water proof of 1:2:4 cement concrete with 2% water proofing agent is called Khurra. The size of khurra usually is 45 × 45cm. It is provided to guide the rain water from the roof terrance into the down pipe. The thickness of the concrete is kept as 5.0 cm and its top level is finished a little lower than the adjoining roof surface. The lowering of khurra's level depends upon the surface finish as indicated below.

(*a*) About 20 mm lower than adjoining surface in case, roof surface is finished with lime concrete terracing.

(*b*) 70 mm in case the roof surface is finished with lime concrete terracing covered with brick tiles.

(*c*) 50 mm in case of mud phuska and brick tiles covering.

The concrete is laid over a little larger area than the finished size of the khurra in such a way that the adjoining terracing should lap it on the three sides at least by 7.5 cm. The slope of the concrete from edges to the out let should be kept uniform. The minimum thickness of concrete at the outlet should not be less than 20 mm and the joint should be water tight as shown in Fig. 4.3.

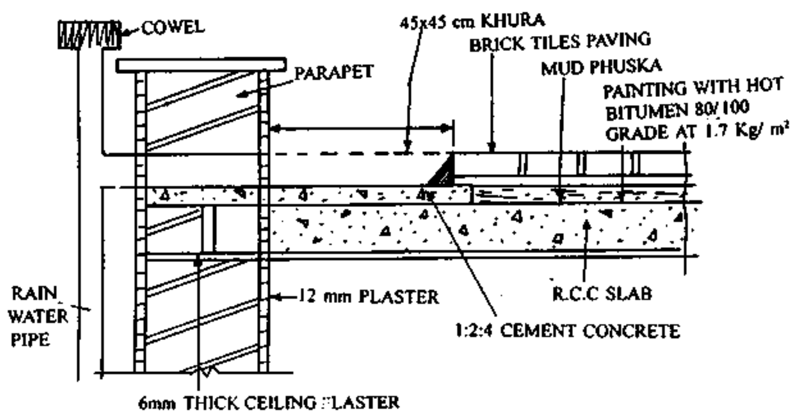


Fig. 4.3. Details of Khurras

The khurras and the side of the out let should be rendered with 12 mm coat of 1:3 cement plaster, while the concrete is still plastic or green. The sides should be well rounded. The size of the finished out let opening should be 10 cm wide and 20 cm high. To safe guard against chocking of opening, iron grating may be provided at the mouth of the opening.

4.19. LIME CONCRETE TERRACING (IS-3036-1992)

This method of water proofing is suitable for hot and humid regions of India. For lime concrete, good quality lime and surkhi is required. The execution of lime concrete work should be of high quality workmanship. The procedure of preparing the surface and painting with a coat of hot bitumen is the same as discussed under 7.11.

4.19.1. Preparation of lime concrete

Lime concrete mix consists of brick aggregate of nominal size 25 mm, lime and surkhi. Lime mortar is made in the ratio of 1 lime putty and 2 surkhi. The volume of wet mortar is 50% of the volume of the brick aggregate.

1st lime putty and surkhi are mixed thoroughly on a masonry platform in the ratio of 1:2. The brick aggregate should be soaked with water for a period not less than 6 hours before use in the lime concrete.

The moistened brick aggregate is spread on the masonry platform and on the top of the brick aggregate lime surkhi mortar is laid. The proportion of lime surkhi mortar and brick aggregate is 1:2 *i.e.* 1 part of lime surkhi mortar and 2 parts of brick aggregate. The lime surkhi mortar and brick aggregate are worked over and again with addition of necessary quantity of water till a uniform mix of desired consistency is obtained. The consistency should be such that mortar dues not separates from the brick aggregates.

4.19.2. Laying of lime concrete

Lime concrete is laid in a single layer. The concrete is spread and rammed with 2 kg weight wooden rammers to the desired level and slope. The average thickness of lime concrete terracing is 10 cms. The concrete is consolidated by beating it with wooden thappies across the entire surface for 7 days or till the mortar is almost set and wooden thappies rebound from the surface when struck on it.

While beating is in progress, then a mixture of Gur and boiled solution of bael fruit is sprinkled liberally. The mixture is prepared by adding 1.75 kg of Gur and 1 kg bael fruit in 60 litre of water and boiled. After beating is completed, the mortar that has come on the surface is softened by adding the Gur and bael mixture and smoothened with a trowel to a fine polish. No plaster is required to be done on the rammed and compacted concrete. The concrete should be kept wet after each day's work. It is cured for 10 days.

4.20. BRICK TILING

If brick tiles are to be laid over the lime concrete, terrace concrete should be finished rough and not fine finished. The concrete at the junctions of terrace with parapet walls etc. should also not be rounded as it would interfere with the tile paving.

Brick tiles are laid in 1:3 cement sand mortar. The tiles should be soaked in water at least for one hour before laying. The 1:3 cement mortar is spread in 12 mm thick layer evenly over the surface with the required slope. The tiles are laid flat over the mortar layer with open joints and pressed lightly to the proper slope. The width of joints should not be more than 10 mm. The tiles should be laid at right angle to the sloping edges of the roof. Transverse joints in alternate rows should be in line with one another. Transverse joints in adjacent rows never be in one line, but should break.

After the paving is completed, the joints are grouted with 1:3 cement sand mortar. 2% water proofing compound should be added in the cement grout *i.e.* (1 kg water proof compound in every 50 kg cement bag). The joints should be finished flush with brick surface and cured for 7 days. During curing period the surface should be protected from damage.

4.21. BITUMEN/MEMBRANE WATER PROOFING SYSTEM (IS-1346-1991)

Bitumen felt (IS-1322-1993). Traditionally, hession based roofing felts impregnated with industrial bitumen have been used for the manufacture of bitumen felts. Hession fibres restrain the flow of bitumen in hot weather and resist contraction stresses and cracking in winter. They stabilize and reinforce the membrane. Though during manufacturing process, the hessian cloth gets saturated with low grade bitumen, yet in due course of time progressive degradation sets in due to oxidation of the impregnated bitumen and it gets brittle. Oxidized bitumen becomes prone to ultra violet radiation and hessian is prone to organic degradation. It may tear off due to expansion and contraction caused by variation of temperature. In actual use the life of bitumen felt is found 5 to 7 years. Due to this reason, bitumen felt-no longer is considered useful as water proofing material.

4.22. POLYMERIC WATER PROOFING MEMBRANE

The built up water proofing membrane consists of two elements, one polymer mat and polymer modified bitumen combined into a laminate. Non woven polyester fibre comprises randomly distributed fibre bonded thermally and chemically. The dense over lapping arrangement of the fibres provides greater resistance to tear, higher flexibility, better resistance to puncture, lower rates of oxidation and embrittlement. They have much higher resistance to biodegration and aging. Now a days they have largely replaced traditional bitumen felts for water proofing purposes.

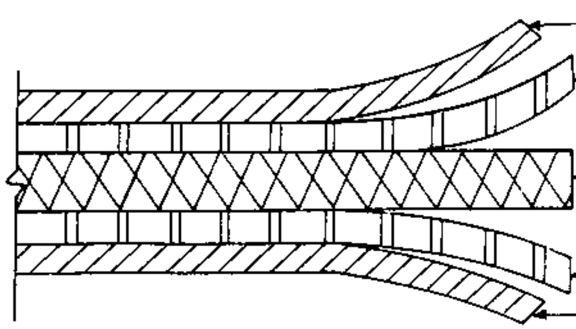


Fig. 4.4. Polymer water proofing membrane

The polyester core consisting of non woven polyester fibre mat is coated on both sides with polymer modified bitumen as shown in Fig. 4.4. The membrane has a softening point above 140°C and is stabilized equivalent to about 10 years exposure. Normal thickness of the membrane is in the range of 3 to 4 mm. The polyester cover gives the membrane high tensile strength. They can withstand normal structural movement with out breaking and cracking. The life of these membrane varies from 20 to 30 years and are available in 10 m × 1 m rolls.

4.22.1. Application Methodology

Before laying bitumen felt over the roof, a bitumen based primer is applied with brush in cold state as per IS 3384 at the rate of 0.24 lit/m^2 of the surface to assist the adhesion of the bonding material.

4.22.2. Laying of bitumen felt/membrane

There are following two methods of laying the bitumen felt or membrane:

1. Pour and roll method 2. Torch on water proofing membrane

1. Pour and roll method. Following steps are involved in this method:

(*a*) *Applying priming coat.* For improving the adhesion of bonding material with the roof and vertical surfaces as well, a priming coat of bitumen primer is applied with brush on the roof and vertical surface as parapet wall at the rate of 0.24 lit/m^2 of surface.

(*b*) The bitumen felt/membrane is cut in the required length and cleaned with brush to remove the dusting material. Then it is laid flat on the roof to eliminate curls and subsequent stretching. The laying of bitumen felt should be started from the lowest level, *i.e.* from near the rain water out lets to the crest. Normally the felt is laid at right angle to the direction of slope. This treatment of laying felt does not obstruct the flow of rain water *i.e.* over lap of adjacent layers of felt does not obstruct the flow of rain water. A single length of felt more the 6 to 8 m should not be laid as long length is likely to shrink.

(c) Each length of bitumen felt or membrane is laid in position and rolled up for half its length. The bonding material is heated to a temperature of 180°C and is poured at the rate of 1.5 kg/m^2 of surface across the full width of the rolled membrane. This rolled membrane is then steadily rolled out and pressed down. The bonding material should be so poured that the correct weight of bonding material is spread uniformly over the surface. The extra material that get squeezed out at ends should be leveled up as the laying proceeds.

(d) After bonding the first half of the bitumen felt/membrane to the roof, the other half is rolled up, hot binder spread and rolled out and pressed as above.

(e) Subsequent strips are laid in the same way as above. Each strip should over lap the preceding strip by 75 mm at longitudinal edges and 100 mm at the ends. All overlaps should be bonded fully with the hot bitumen. Streaks and traillings of bitumen near edges of laps should be levelled by heating the overlaps with blow lamps and unevenness levelled down. The details of construction are shown in Fig. 4.5.

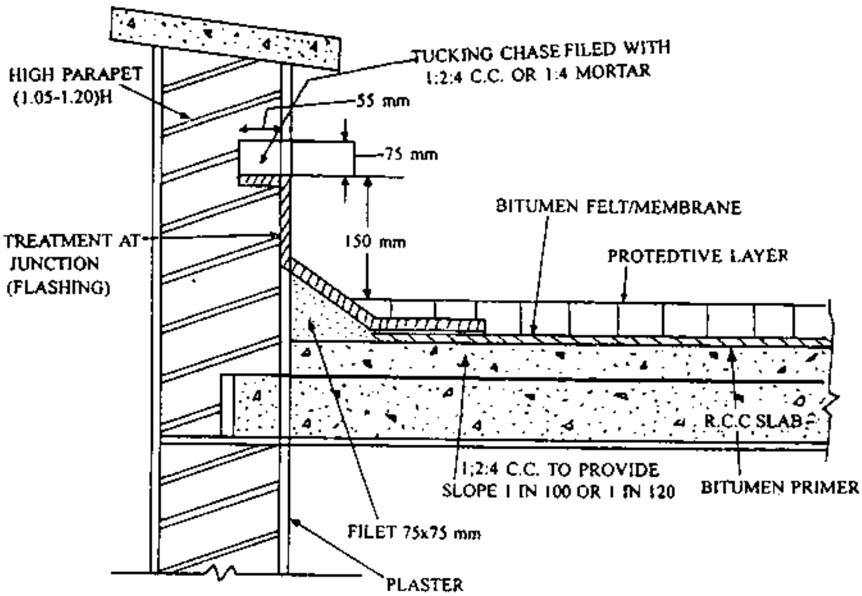


Fig. 4.5. Bitumen felt membrane water proofing system for flat roofs

4.22.3. Torch on water proofing membrane

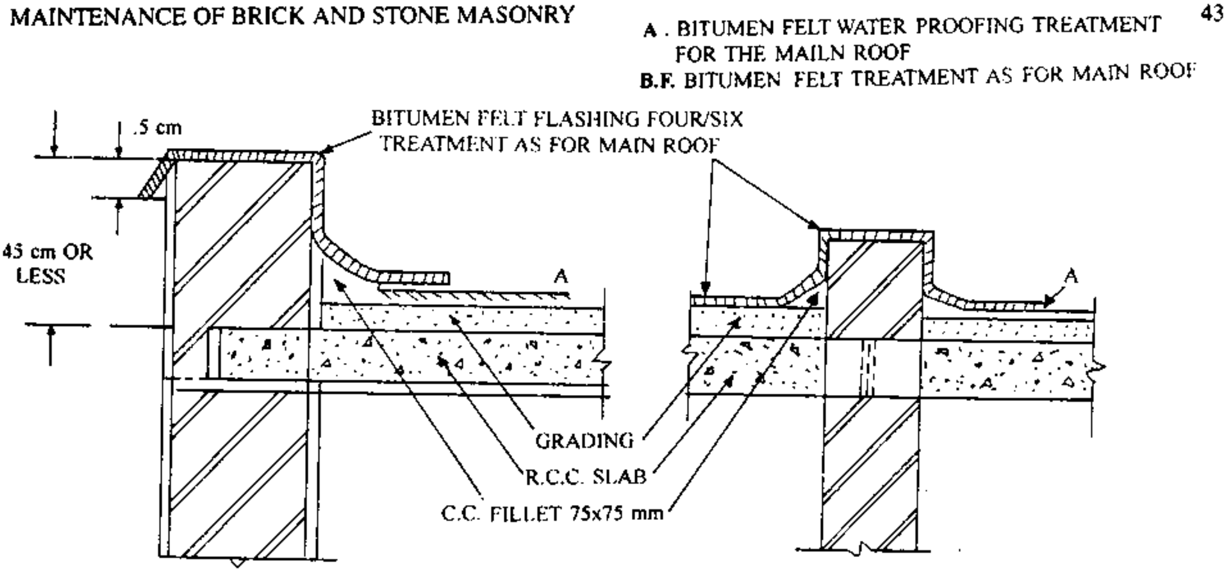
In this method the initial layer of bonding material is not required. For laying the membrane the under side of the membrane is heated with a pressure regulated LPG gas torch. As soon as bitumen on the coated surface starts to bleed, the membrane is laid out and pressed. Rest of the procedure of overlap and other precautions are same as in pour and Roll method.

4.22.4. Flashing

The treatment of roof junction with vertical surfaces as that of parapet walls or pipes etc. is called flashing. The minimum over lap of the flashing over the roof felt should be 10 cms. The upper end of the flashing should be fixed in a groove in the vertical wall to a depth of not less the 65 mm. This groove is called CHASE. Its dimension may be 75 × 75 mm or 75 × 65 mm. The treatment is firmly held in position in the groove by wooden blocks at intervals. The groove is filled up with 1:4 cement mortar or 1:2:4 cement concrete. The surface is finished smooth with the rest of the surface of wall. Cement work should be cured for 7 days. On drying, the exposed joints of grooves should be painted with bitumen.

4.23. TREATMENT OF LOW PARAPET WALLS

In case of parapet walls upto 45 cm in height, no tucking groove is required as discussed above. In this case the upper edge of the bitumen felt flashing is carried upto the full height of the wall and right across the top of the parapet wall and down on the external vertical side of the wall to a minimum distance of 5



(*a*) Low parapet wall (*b*) Inverted beam or short dividing wall

Fig. 4.6. Flashing treatment of projections

cm as shown in Fig. 4.4 (*a*).

In case of low dividing walls or inverted T beams same treatment of water proofing will be given to them as given to the main roof. The bitumen felt/membrane shall be carried down on both sides of the wall or beam and overlap the roofing treatment atleast for a length of 20 cm as shown in Fig. 4.6 (*b*).

4.23.1. Treatment of pipes

In case of vertical out let pipes a fillet of cement concrete or lime concrete of size 7.5 × 7.5 cm should be provided as shown in Fig. 4.6 (*c*). These pipes also should be given same treatment as to the main roof. They should be given flashing as usual. The upper edge of the flashing should be laid sloping down forward and butted against the pipe and annular depression so formed should be filled with hot bitumen. To throw away the rain water from flashing a circular metal collar in the shape of inverted truncated cone should be provided.

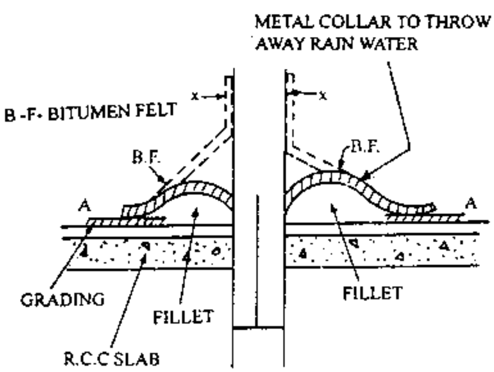


Fig. 4.6 (*c*). Projecting pipe

4.23.2. Water Proofing of drain outlet

Same treatment as for main roof and should be carried into the out let by at least 100 mm.

4.24. DAMP PROOF TREATMENT FOR BASEMENTS (IS-1609-1991)

4.24.1. Basements where adequate space for excavation is available

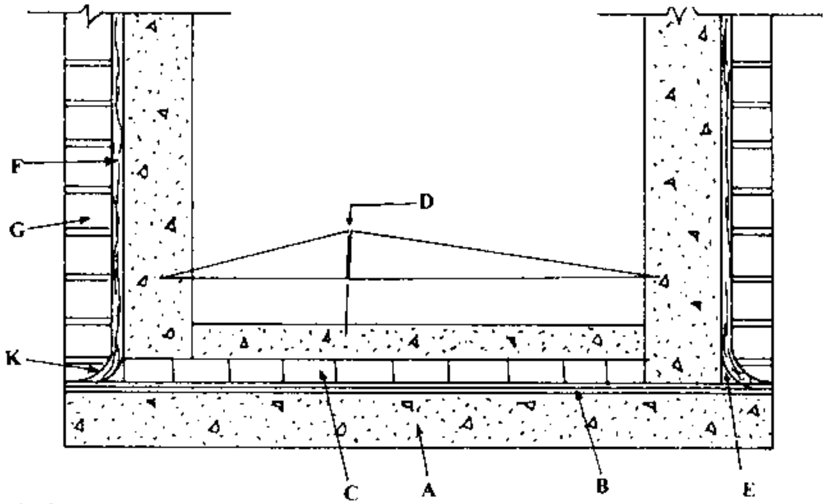
In basements, the damp proofing work should be taken up during dry season when the sub soil water table is at its lowest level. For all new buildings damp proofing should be done externally. For doing damp proofing work at least 60 cms working space must be available all-round the periphery of the external walls. If the water tables is high, it should be lowered by applying well point system and the area to be excavated should be kept dry.

4.24.2. Methods to be used

For water proofing of vertical walls of the foundation, self adhesive water proofing membrane system should be adopted. The membrane system is easy and quick to install. They can be cold applied. The membranes made from SBS modified bitumen compounds are strong and resistant to chlorides, sulphates and alkalies etc. The thickness of the membrane is 1.5 to 2.0 mm and is available in 15 to 20 m roll.

4.24.3. Method of application

In the water proofing of the basement following operations are involved.



A - BASE SLAB OF LEAN CONCRETE
B - HORIZONTAL DAMP PROOF TREATMENT
C - C.C. 1:2:4 OR FLAT BRICK
D - STRUCTURAL WALLS AND FLOOR
E - C.C. FILLET
F - VERTICALDAMP PROOF TREATMENT ON OUTSIDE FACE OF STRUCTURAL WALL
G - OUTER PROTECTIVE WALL
K - JOINT OF HORIZONTAL AND VERTICAL WATER PROOFING

Fig. 4.7. Damp proof treatment for basement with adequste out side space

1. A 7.5 to 10 cm thick layer of lean concrete (1:4:8 or 1:5:10) proportion is laid over the dry and leveled ground. This layer serves as the leveling course for the water proofing membrane. The lean cement concrete layer should project by about 150 mm beyond the outer faces of the structural walls of the basement when completed as shown in Fig. 4.7.
2. The concrete surface to be treated or water proofed should be cleaned with wire brushes and gunny cloth. All loose material and scales etc. should be removed and the surface is allowed to dry thoroughly.
3. To assist the adhesion of the water proofing membrane, bitumen based primer is cold applied over the levelling course at the rate of 0.24 to 0.3 lit/m^2 of the surface area.
4. Bitumen compound polyester membrane is laid over the levelling course. This membrane is fixed in hot bitumen of grade 85/25 uniformly applied over the surface at the rate of 1.5 kg/m^2 of surface.
5. Horizontal surface of the membrane is protected during subsequent operations of the work by laying flat bricks or cement concrete over it.
6. Water proofing on the external face of basement walls is done after the construction of structural slab and walls. The treatment of basement walls is called external tanking. The basement walls will remain in contact with earth. The outer face of the structural walls should be vertical and free from protrusions.
7. After cleaning the surface thoroughly, bitumen based primer is cold applied on the entire surface with brush to enhance the adhesion of the water proofing membrane at the rate of 0.24 lit/m^2.
8. To the vertical basement walls, self adhesive SBS bitumen rubber membrane with cross laminated high density polyethylene film is cold applied. Proper length of overlap at the vertical joint with the bitumen membrane of the bottom slab must be ensured. The over lap should not be less than 20 cms in any case.
9. Before back filling the soil in the space, the water proofing membrane should be protected by constructing a outer wall leaving a space of about 10 cms all-round. This space is filled subsequently by grouting. Alternately for protecting the water proofing membrane, thermocole slabs may be fixed in bitumen against the water proofing membrane before back filling the soil.
10. Before constructing the flooring, a self adhesive bitumen compound membrane on the horizontal surface of the basement is laid. The membrane is carried on the internal face vertical upto a height

of 45 cms. This membrane is protected by 20 mm plaster with chicken wire mesh. This treatment is known as post construction treatment.

4.25. EXTERNAL TANKING OF BASEMENT WITH LIMITED SPACE FOR EXCAVATION

When space around the basement for excavation is limited, the details of damp proofing treatment and sequence of operation is shown in Fig. 4.8. First the base slab of lean concrete is laid and then external protective walls are constructed. The internal face of this wall is evenly plastered and left rough.

4.25.1. Damp Proofing treatment

(*a*) Horizontal damp proofing is carried out in the same manner as discussed above from (2) to (5).

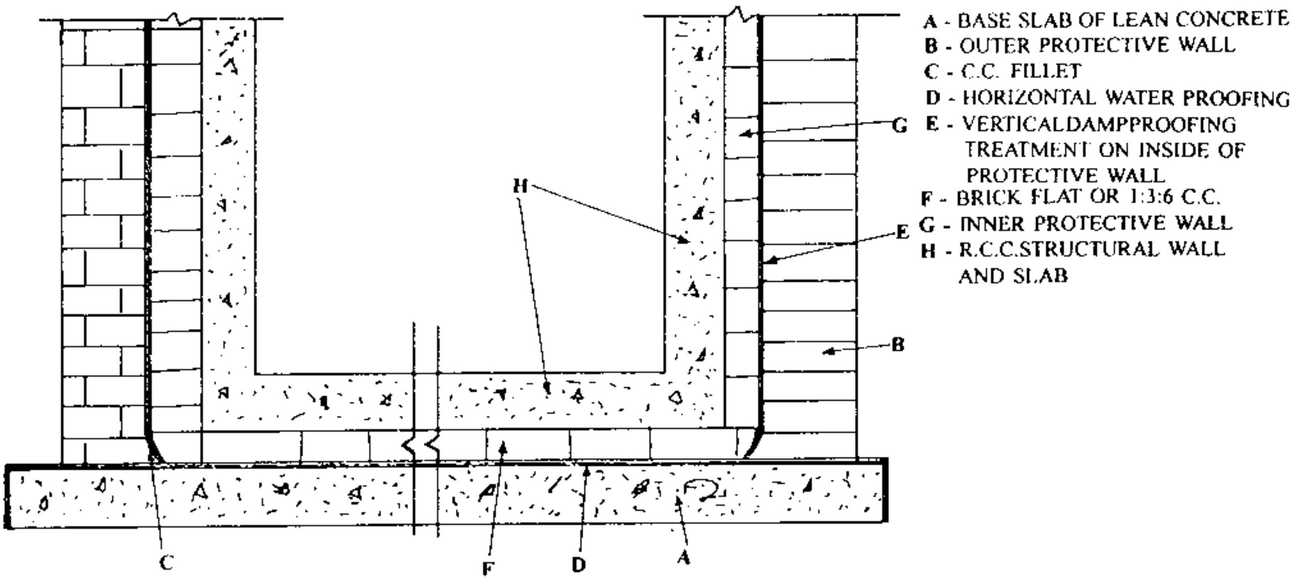


Fig. 4.8. Dam proofing of basement with limited outside space

(*b*) The vertical damp proofing treatment is applied on the inside plastered surface of the protective wall as indicated in step (7) and (8) above. The treatment should be continuous over the floor and wall. For continuation of vertical damp proofing with the horizontal, one fillet of 75 mm radius made of 1:4 cement mortar should be provided at the junction of outer protective wall and horizontal base slab. Both the horizontal and vertical membranes should be suitably protected against any damage during subsequent construction operations. For this purpose flat brick soling or lean cement concrete 1:3:6 layer and or an inner protective wall may be provided as shown in Fig. 4.8.

The space of 100 mm left between the vertical damp proofing treatment and the internal protective wall should be grouted with cement sand grout after laying the damp proof membrane.

The thickness and amount of reinforcement for R.C.C. are determined according to the depth and maximum water pressure. The construction work is carried in normal way. The inner protective wall is used as the form work for the structural wall.

4.26. INTERNAL TANKING OF EXISTING BASEMENTS

In this case the surfaces of walls and floor of the existing basement are cleaned by rubbing with wire brushes and roughened to get proper bond with the water proofing membrane. The floor is properly levelled. Fillets of 75 mm radius at the junctions of vertical walls and horizontal base slab are made of1:4 cement sand mortar to provide continuity to horizontal and vertical damp proofing.

Construction. 1st a coat of bitumen primer is applied on the prepared base slab and vertical faces. Over this primer coat, water proofing bitumen membrane is fixed on the base slab and vertical faces in continuous manner over the fillets. Logitudinal overlaps of 75 mm and end laps of 100 mm must be ensured during the process of laying the membrane. The horizontal damp proofing treatment should be protected by giving a cement plaster of 1:4 cement sand mortar during construction before laying final flooring. On the vertical walls, chicken wire mesh is fixed with nails to give support to the plaster. After fixing chicken wire mesh the vertical faces are plastered. An internal protective wall of brick masonry may be built as a protective covering for the damp proofing treatment.

4.27. WATER PROOFING OF WATER RETAINING STRUCTURES (IS-6494)

1. During the construction of under ground water retaing reservoirs and concrete swimming pools, it is essential to ensure water tightness of resulting structures *i.e.* neither there should be water flow from inside to out side nor from out side to inside when the structure, is empty. Such flows must be prevented effectively.

To divert the surface run off away from such structures, the ground should be given a slope at least for a distance of 3 m from these structures. The ground surface near the side walls should be paved and proper slope should be given to drain away the rain or other water from near by of such structures.

2. Design consideration. Suitable precautions must be taken to check development of cracks resulting leakage of water during construction of the structure, due to the following factors.

(*a*) Movements due to temperature variations.

(*b*) Movement due to shrinkage and creep.

(*c*) Movement due to heat dissipation generated during hydration of cement.

(*d*) Damage due to differential settlement of foundations.

(*e*) Cracking of concrete due to rusting of reinforcement

(*f*) Hydro static uplift pressure.

Concrete mix. The concrete used for hydraulic structures should be impermeable and of sufficient. Compressive strength. The mix of concrete should be so choosen as to provide a concrete of atleast 200 kg/cm^2 strength and impermeable. A 2.0% water proofing compound should be mixed in the mix. It should be compacted well with mechanical vibrations. At the time of construction of structures all necessary precautions of production, transportation, placing and compaction should be taken carefully.

Form work. For constructing hydraulic structure's R.C.C. walls, the form work should we completely water tight to give a clear and free from honey combing surface.

Water proofing. Before applying water proofing treatment, the concrete surface of slab and walls should be thoroughly scrapped and cleaned of all loose materials. It should be completely dry and smooth before application of water proofing treatment.

Procedure. In this case also self adhesive SBS modified bitumen membrane can be used. The procedure of laying this membrane is same as discussed in section 4.15. In addition following treatment should be applied.

(*a*) 20 mm thick 1:6 cement sand plaster mixed with 2% water proofing compound should be used for the protection of the membrane.

(*b*) The base slab floor and inside of walls should be plastered with 1:3 plaster with water proofing compound. The plaster should be done in two coats. The thickness of first coat should be 12 mm and of the second 10 mm. The final finishing of walls and bottom should be done in tiles or other appropriate cladding material.

4.28. BITUMEN MASTIC FOR WATER PROOFING OF ROOFS (IS 4365-1967)

Bitumen mastic is a mixture of bitumen, mineral fillers and well graded sand or stone chips in suitable proportion to give a semi fluid consistency when heated to about 180°C. At this temperature the mastic should be easily compressible by trowel into a uniform and compact layer not less than 10 mm in thickness. The mixture settles to a coherent, void less and impermeable solid mass under normal temperature conditions. Due to absorption of solar heat this treatment is suitable for cold regions.

4.28.1. Manufacture

The filler and fine aggregate are mixed together and heated to a temperature of 170 to 180°C. At this stage coarse aggregate is added and mixed in a mechanical mixer, till the materials are mixed thoroughly. During mixing it should be ensured that at no time, temperature exceeds more than 205°C. The mixer should be such that the whole lot is discharged with in 30 minutes.

Bitumen mastic can also pre manufactured in factories and cast in blocks.

The aggregate used should be of the following grading:

1. Passing 75 micron sieve (mineral filler)	= 40 to 45% by weight
2. Retained on 75 micron sieve and passing 2 mm sieve	= 15 to 20% by weight
3.Retained on 4.75 micron sieve and passing 2 mm sieve	= 15 to 20% by weight
4. Retained on 2 mm sieve and passing 4.75 mm sieve	= 20 to 30% by weight
5. Retained on 10 mm sieve	= Nil

4.28.2. No of coats and thickness

On horizontal roofs such as terrace and balcony two coats of bitumen mastic are sufficient. The minimum thickness of first coat should be 10 mm and that of second coat 15 mm. On vertical surfaces other than timber including skirting either two coats of total thickness not less than 12 mm or three coats not less than 20 mm thickness may be applied.

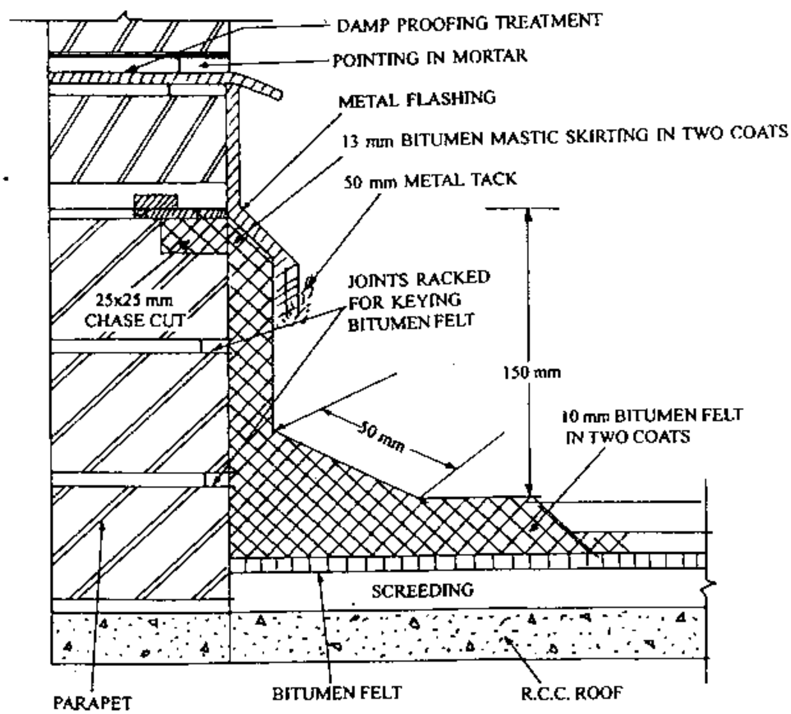


Fig. 4.9. Bitumen mastic for water proofing of roofs

4.28.3. Application

The gradients and slopes of the surface should be proper. The surface should be divided into bays of suitable size.

Spreading. In spreading the bitumen mastic following steps are involved:

(*a*) Each coat of each bay should be spread evenly and uniformly by a float to the recommended thickness on the previously prepared surface.

(*b*) Each coat should be followed by the next coat with out delay as exposure to contamination by dust or dirt may affect adhesion and may cause blistering.

(*c*) The junction between two continuous bays should not be less than 150 mm.

(*d*) When bitumen mastic is laid horizontally, timber gauges of specified thickness should be used for laying each coat.

(*e*) When bitumen mastic is to be placed on vertical surface or steeply sloping surface, the first coat should be of an adhesive laryer which acts as a base for subsequent coats.

(*f*) If any area is damaged, it should be repaired while the bitumen mastic is still warm.

4.29. DAMP PROOFING OF SLOPING ROOF

It is shown in Fig. 4.10.

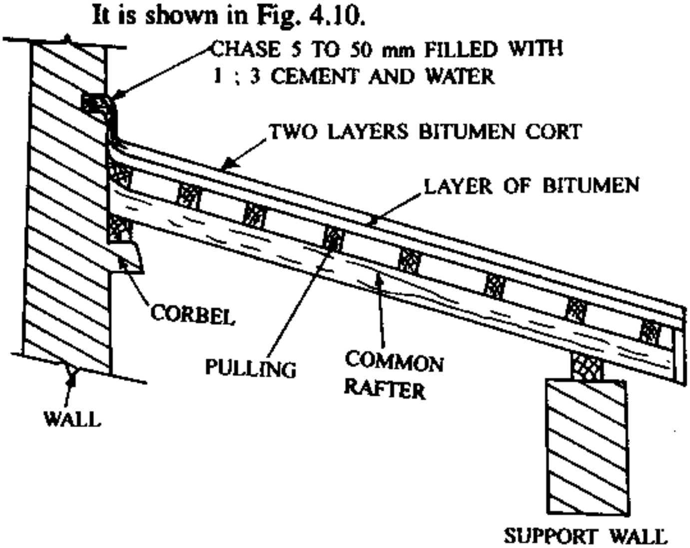


Fig. 4.10. Damp proofing of sloping roof

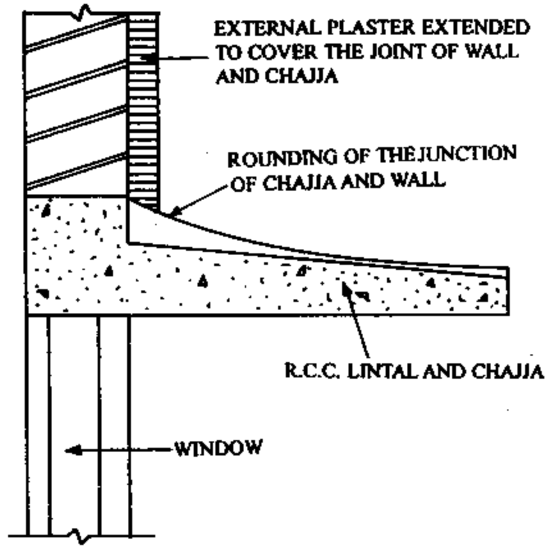


Fig. 4.11. Damp Proofing at Junction of wall and Chajja

4.30. DAMP PROOFING AT JUNCTION OF WALL AND CHAJJA

A fillet should be provided at the junction of wall and the chajja as shown in Fig. 4.11.

QUESTIONS

1. Define dampness and discuss various causes of development of dampness.
2. Discuss the remedial measures of dampness.
3. Discuss damp proof measures for floors.
4. Discuss damp proof measures for roofs in hot and arid zones.
5. Discuss the procedure of laying an bitumen membrane as damp proofing treatment.
6. Give with neat sketch the method of damp proofing of floors with parapet walls about 35 cm high.
7. Give detailed method of damp proofing of basements.
8. Identify the incorrect statement/statements
   (*a*) The damp proof course should be pervious to the moisture.
   (*b*) The damp proof course should be impervious to the moisture
   (*c*) The damp proofing property should not change with time
   (*d*) The damp proofing property should change with time
   (*e*) It should be stable in loaded and unloaded condition.
9. Causes of dampness in a building are except
   (*a*) Defective construction
   (*b*) Use of defective construction material
   (*c*) Use of damp proof compound in the plaster and mortar
   (*d*) Exposed and leaky roofs
   (*e*) Moisture rising from sub soil
10. The ill effects of dampness are
    (*a*) Efflorescence on walls (*b*) Discoloration

(*c*) Weathering of materials (*d*) Peeling off plaster
(*e*) All the above

11. The over lap of longitudinal membrane layer should not be less than
(*a*) 50 mm (*b*) 80 mm
(*c*) 25 mm (*d*) 100 mm
12. The minimum thickness of bituminous membrane should be
(*a*) 1.5 to 2.0 mm (*b*) 3 to 5 mm
(*c*) 7 to 10 mm (*d*) 12 to 15 mm
13. Usually cement concrete used as D.P.C. is of the proportion
(*a*) 1:1:2 (*b*) 1:2:4
(*c*) 1:3:6 (*d*) 1:4:8
14. Which of the following defects observed during the inspection of the building needs immediate maintenance repair.
(*a*) Pelling off plaster (*b*) Growth of vegetation
(*c*) Dampness on wall (*d*) Structural failure due to settlement
15. The water proofing menbrane should be provided
(*a*) Parallel to the slope of the tarace (*b*) At right angle to the slope of the terrace
(*c*) At 45° to the slope of the terrace (*d*) At any inclination

ANSWERS

8. (*a*), (*d*)	10. (*e*)	12. (*a*)	14. (*d*)
9. (*c*)	11. (*d*)	13. (*b*)	15. (*b*)

5

Building Maintenance, Repair Organisation and Accounts

5.1. INTRODUCTION

We all know that all materials deteriorate with age due to the action of various agencies. Deterioration is the gradual process of disintegration due to any destructive action from atmospheric agencies. To check this deterioration and keep the building in its serviceable condition is called the building maintenance. The act of maintenance may require repair or replacement, but the main objective should be as far as possible to avoid repair or replacement of any element of the building, and try to preserve it. To achieve this objective, the building should be inspected periodically, defects observed should be reported to the authorities in the performa given as appendix 5.1.

5.2. INSPECTION OF BUILDINGS

The inspection of buildings and their fittings may be carried out for a number of purposes. The purpose of inspection must be established before the commencement of the inspection. Inspection performa should be designed before the inspection to record as much information as practicable.

5.3. TYPES OF INSPECTIONS

Usually inspections may be of the following types:

1. Inspection to rectify defects. This type of inspection is carried out by the operational staff to gather the information of the defects and condition of the building. This inspection helps in solving petty items of maintenance.

2. Planned inspection. This type of inspection is carried out after defining the exact purpose of the inspection and should be done by competent inspector or surveyor and all possible points should be recorded in the standard inspection performa. Planned inspections are usually done for the following purposes:

(*a*) To prepare a complete record of the building, regarding its condition, and the condition of fittings and fixtures etc.

(*b*) To ascertain the needs of current and future maintenance for the purpose of planning, the work load and the budget.

(*c*) To investigate the cause and extent of defects occurred, necessitating the maintenance.

3. Complete building inspection. This inspection is carried out to obtain a complete and accurate record of the building, its services and fixtures to prepare a standard measurement book.

4. Control inspection. Control inspections are carried out to check whether the maintenance work has been done with standard workmanship and quality. Control inspections are carried out to evaluate the quantitative progress, quality, cost and time for the comparision with the planned standards.

5.4. POINTS TO BE SEEN AT THE TIME OF INSPECTION OF A BUILDING

At the time of inspection of a building usually following points should be noted:

1. Condition of paint of internal and external walls.
2. Condition of paint of wood work and steel work.
3. Condition of service fittings.
4. Condition of flooring.
5. Roof and other leakage.
6. Drainage from terrace and pitched roof.
7. Growth of vegetation if any,
8. Structural defects such as cracks, settlement and deflection etc.

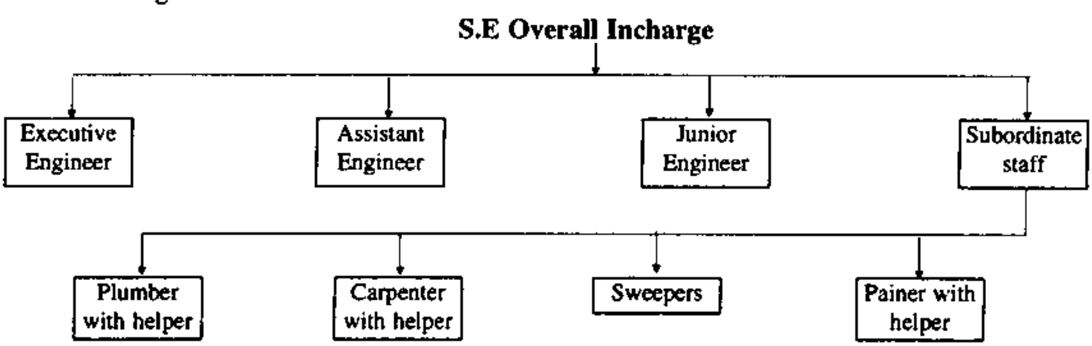
These defects are dealt in detail in respective chapters.

The inspection report should be recorded in the performa shown in appendix 1 and 2 at the end of the book.

5.5. MAINTENANCE ORGANISATION

Public works department looks after the maintenance work of all government buildings like government educational institutions, Government office buildings, Hospital and dispensaries etc. State government buildings are looked after by state public works department and central government buildings are looked after by central public works department.

Staff to the maintenance department is provided depending upon the quantum of work. Usually the maintenance organisation is as follows:



All the subordinate staff works under the charge of a junior engineer.

5.6. ESTIMATES OF REPAIRS

1. Ordinary or annual repairs. Usually the white wash and paints etc. in government buildings is done every third years *i.e.* once in three years and the amount to be spent is estimated on the percentage basis as follows:

(*a*) First class buildings ... 1.5%
(*b*) Second class buildings ... 2.0%
(*c*) Third class buildings ... 3.0%

This percentage is revised from time to time.

In case, substantial additions and alterations are to be carried out then this percentage is revised with the approval of the competent authority of the department (S.E.).

The estimate of work of repair is got prepared and sanction of carrying out repair and expenditure is obtained prior to commence the work. This sanctioned amount is for one financial year and should be consumed before 31st March of that financial year.

2. Special repairs. For special repairs, separate estimate for each building will be prepared and sanction of carrying out work and expenditure will be obtained. After the receipt of the approval of estimate and expenditure work will be started. This estimate will remain in force till the completion of the work.

3. Integral maintenance of the building. In case of integral maintenance of a building, all internal and external services and furniture as well as all appurtenant equipment as lifts, air conditioners, heating equipment, water coolers and refrigerators are included. Thus it covers all fittings, fixtures, equipments, external services like water supply, electricity, sewage disposal, drains and internal roads etc. The comfort of the occupants depend on these factors.

4. Scope of integral maintenance. Integral maintenance covers the following works.

(*a*) Petty repairs, replacement and structural repairs of building components, white and colour washing, distempering, and painting at prescribed interval.

(*b*) Repair and renewal of furniture.

(*c*) Operation, periodical maintenance, repairs, renewals of machinery and equipment for electric and water supply, air conditioning, refrigeration, vehicles and sewage installations.

(*d*) Repair of roads, culverts and berms, re surfacing of roads.

(*e*) Repair and renewals of fences, boundary walls, drains and miscellaneous items.

5. Scale of integral maintenance fund. Fixed annual grants are allotted for maintenance on the basis of a fixed percentage of the capital cost. In case of buildings, the amount is fixed by the financial authorities separately for permanent and temporary buildings at fixed rates based on plinth area of the building. The rates vary depending on the importance of the building as Hospital, offices and residential accommodation for different ranks.

For roads, the grants are worked out on the basis of terrain separately as for plains, hills and desert etc. In case of furniture the grant is based on capital cost of the item concerned. Usually the grant for machinery is based on the actual maintenance cost in the past three years. Actually it is impossible to carry out the effective maintenance with the meagre annual grants at a fixed percentage of the capital cost, when the price index is rising in leaps and bounds.

5.7. IRRITANTS TO BUILDING USERS

Usually following defects have been found as irritants to the users in order of priority:

1. Interruption in power supply and defects in electric fittings.
2. Leakage of taps and defective flushing cisterns.
3. Blockage of sewer line and drains
4. Leaking roofs
5. Broken glass panes, non closing doors and windows properly.
6. Defective joinery and repairs of floors etc.

5.8. MANAGEMENT TOOLS FOR EFFECTIVE MAINTENANCE

The principle of management objectives must be followed by the maintenance engineer. He should organise the maintenance work in such a way that all users generally fell satisfied. The tools at his disposal are as follows:

(*i*) **Data.** The Engineer incharge of maintenance should have all data of various fixtures and fittings with him. It will be helpful to plan management of resources and anticipate trouble spots.

5.9. MATERIAL MANAGEMENT

Material management is very vital. All plans and standing orders, organisation of labour etc. will prove futile, if materials are not readily available for work. With out the inventory control on materials it will not be possible to ensure smooth maintenance. Non availability of very inexpensive item as tap washer may cause delay and annoyance to users.

In addition to above, proper and modern tools in adequate number must be available for proper maintenance work. If they are not available, the management of labour and materials can not yield desired results. There must be proper and quick mobility equipment and machinery for efficient and quick results.

5.10. LABOUR MANAGEMENT

It is a very difficult and delicate task. For this purpose functional management may be adopted. In this system a nucleus of labour gang may be appointed permanently. This group may include plumbers electricians carpenters etc. Rest of the labour may be engaged through labour contractor or directly. There should be good human relation between the engineer and the workers. The workers should have a feeling that the maintenance engineer trust them. The engineer incharge should evolve a mechanism for obtaining regular information regarding the maintenance of different categories of amenities, as services, fittings etc.

5.11. CASES OF SPECIAL REPAIR IN BUILDINGS

Following types of works in a building some times have to be carried out which are classified as special type of works:

1. Opening in existing wall is to be made. The opening should be carried in the following steps:

(*a*) **Installation of dead shore.** All floors and openings near and above the opening to be made should be properly supported and strutted by dead shore system. The load on the wall to be opened should be reduced to a minimum. The arch floor should be propped independently.

Make hole in the wall to insert needle beam at such a height so that sufficient space may be available to insert precast concrete or stone or steel lintel in the wall over the opening. Spacing of holes may vary from 60 cms to 150 cms depending upon the type of masonry.

(*b*) Insert the needle beams in the holes and support them by vertical props on either side of the wall. Props should be placed sufficiently away from the wall to allow sufficient working space. For tightening the props, wedges should be used. For support wall bracing may also be used as shown in Fig. 5.1.

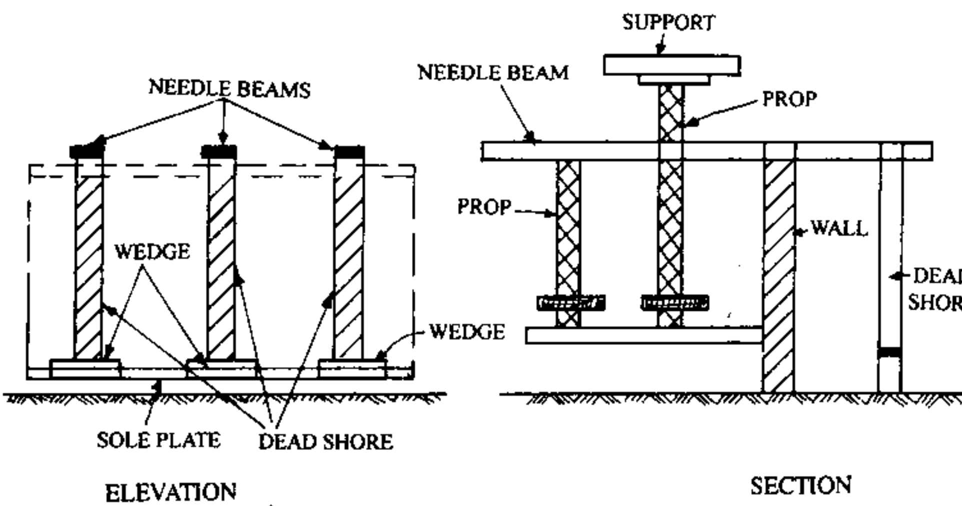


Fig. 5.1

(*c*) Now make the necessary opening for the door. This opening should be about 30 to 40 cms more than the actual size of the door to accommodate new jambs and their finish etc.

(*d*) Now desired lintel of pre cast reinforced cement concrete or stone or structural I section should be inserted into the place. It should be supported on props till the jambs develop necessary strength to support it.

Thus the work must be completed with care, taking all necessary safety precautions to avoid any injury to workers and damage to the building.

5.12. REPAIR OF SAGGED MANGALORE TILED ROOF

The sagging of pitched roof may occur either due to sagging of battens or common rafters. In case of batten sagging, the tiles should be removed and affected battens replaced. In case of sagging of common rafter due to their warping following steps may be taken.

1. Battens are released from common rafters.
2. Loads of the battens may be transferred on temporary common rafter either on one side or on both sides of the damaged common rafter.
3. To correct the sagging of the common rafter, necessary packing between the battens and common rafter may be inserted.

5.13. REPLACEMENT OF BROKEN SEWERAGE WATER PIPE

To replace the broken sewage water pipe, following procedure may be adopted:

1. To open out the sewerage water line, the earth is excavated upto the required depth.
2. Cut the broken pipe at collar and take out the broken pipe out. Now cut the collar into two halves.
3. Take the new pipe of the required length and cut its collar into two halves.
4. Insert the spigot end into the collar of the down grade pipe and place half the collar on spigot end of the up grade pipe.
5. Now rotate the pipe through 180° to bring the collar at the bed surface.
6. Necessary joining is done of the half cut collar over the spigot end if the up grade pipe is replaced and proper joint is secured.

5.14. REPLACEMENT OF WATER CLOSET SEAT

Some times the water closet seat gets damaged due to any reason, then it has to be replaced. To replace the W.C. seat, the floor finish and other floor material has to be removed. Before starting removing of this material, the W.C. seat should be properly packed with gunny bag to avoid the entry of debris and gritty mater in the sewer line. The damaged W.C. seat is taken out. While taking out the W.C. seat it must be ensured that no damage has occurred to the trap and other fittings. Now the new W.C. seat is replaced in the position of old W.C. seat and fitted properly. The floor near the new W.C. seat is finished properly.

5.15. REPLACEMENT OF BROKEN GULLY TRAP

The function of traps in drainage system is to check the entry of foul gases or air through it and at the same time to flow the sewage through it. Thus the installation of trap avoids the nuisance that will be created due to the entry of foul gases or air into the house. The trap should contain water seal of 38 to 40 mm at all times.

The malfunctioning of traps may be due to the following causes:

1. Design defects. It may be due to improper type of trap, due to loose cover or due to construction of partition. The proper shape of a trap is of U shape, but it consumes more material of construction and decreases depth of water seal. Thus it is neither self cleansing nor satisfies the requirements of no cavities and projections in the trap. It creates new pockets or voids in the trap.

The top cover of trap is to be screwed or made an integral part of the trap. Loose covers on the traps have been found to get deposited un desirable materials in side the trap. Traps have wider mouth more than 10 cm at inlet, they should be reduced to 7.5 cm at outlet. This additional piece of pipe between the main and trap needs to be cleaned frequently. Screwing of top to a trap has been found more useful than fixing it as it avoids entering undesirable material inside the trap.

Inadequate water seal. As stated above minimum seal depth should be 38 to 40 mm, but to reduce the cost of trap, the depth of water seal is reduced, which may result self syphonage. Inadequate seal creates leakage problems.

Defective installation. This is main cause of leakage. Defective floor installations may be as follows:

(*a*) Installation where trap is seated too deep from the floor level.

(*b*) Installation where one or more pipe enter into the floor trap.

(*c*) Installation where trap is over flooded.

The level of trap should be determined by the level of connection of the horizontal piping. The present practice is to locate the trap below the floor and seat it into a mass of concrete to stop leakage. But it has been observed that seating trap on concrete alone will not stop leakage and a water tight lead joint has to be provided upto the floor level in cast iron trap.

The installation of trap should be avoided in locations where one or more pipe enter the trap and where trap is likely to be over flooded, Over flooding may be avoided by the use of proper size of inlet and outlet.

On breaking the trap, water no more remains in the trap due to leakage of water and allows the entry of foul gases inside the house. Thus to prevent the entry of foul gases into the house the damaged trap is to be replaced by a new one. The portion near the damaged trap is excavated and the new trap is replaced in proper position.

5.16. CLEANING A CHOCKED RESIDENTIAL SEWER LINE WITH OUT STANDARD EQUIPMENT

This can be cleaned by one of the following methods:

(*a*) By inserting some elastic wire or brush.

(*b*) Inserting hose pipe with water jet.

(*c*) By sudden release of substantial amount of water in the sewer line.

(*d*) By plugging the upstream manhole and sudden release of stored water by removing the plug of the upstream manhole.

5.17. REPLACEMENT OF JOIST

Decayed and worn out joist due to corrosion, should be replaced. Before replacement of joist the props should be designed to support the load of the joist and fixed them on either side. The props should be properly braced to act as one unit and not individually. Top and bottom plates should be fixed with wedges.

After ensuring the transfer of the load the two ends of the joists are loosened by cutting brick work and the joists are removed. Before placing the new joists either of timber or precast R.C.C. or R.S.J., bed blocks of cement concrete of minimum thickness of 15 cm and wider than the width of joist should be placed on the wall with mortar. The new joist/joists should be placed over the bed blocks. The ends of the joist's should be painted with corrosive resistant paints before closing them. After placing the ends properly and packing concrete around them and curing it the props are released to transfer the load to the permanent system. The new joists are cleaned and painted for protection from rust etc.

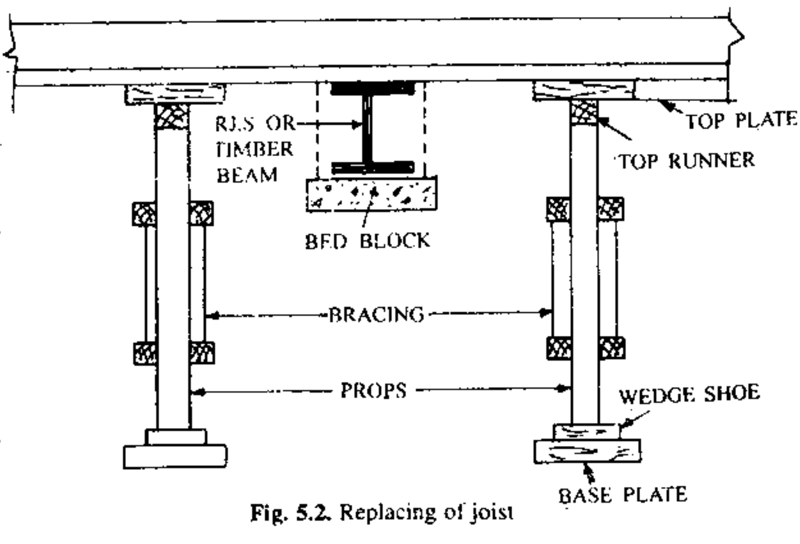


Fig. 5.2. Replacing of joist

5.18. REPAIR OF LARGE MASONRY SEWER BY GUNITING

Guniting is a process by which cement sand mortar is applied on a surface under compressed air pressure by the guniting equipment. This method is used for canal lining, to seal sewer line joints and seal the fine cracks effectively. This method also has been used effectively for tunnel lining and for strengthening existing structures. The procedure for repairing a large masonry sewer by this method is as follows:

(*a*) For proper or strong bond between cement mortar and the surface of sewer line, the surface of sewer is made rough by raking the joints.

(*b*) The joints are cleaned fully.

(*c*) The surface is saturated with water.

(*d*) Guniting is applied.

Procedure of guniting is discussed fully in chapter 23.

5.19. MAINTENANCE OF HOUSE DRAINAGE SYSTEM

To maintain the house drainage effectively, it should be inspected regularly and repaired as and when required. Proper maintenance can be carried out as follows:

1. **Inspection.** Different sections of drainage system should be inspected at regular intervals and any defect observed should be removed immediately.
2. **Flushing.** All drains should be flushed properly.
3. **Entry of undesirable material.** Materials like ash, grit, hairs, vegetable waste, rags etc. should not be allowed to enter into the drains as these will block the drains reducing their efficiency.
4. **Use of disinfectant.** To maintain better hygienic conditions, W.C.S. urinals and bath room etc. should be disinfected periodically.
5. **Workmanship.** Authorised plumbers only be allowed to carry out plumbing work.

5.20. MAINTENANCE OF HOUSE PIPE LINES

To maintain the efficiency of house pipe line system, it should be inspected periodically and suitable action should be taken as follows:

1. The elbows, sockets, valves, taps etc. should be checked periodically and tightened if found loose. Minor leakage found at joints will stop it self. If even after a week or so, it does not come down, it should be repaired properly.
2. Washers and seal pads found damaged should be replaced.
3. Pipe found cracked should be replaced immediately.

5.21. EXECUTION OF REPAIR WORK

Before executing any work in the public works department estimate of expenditure has to be prepared and administrative and expenditure sanctions from the respective competent authorities have to be obtained.

5.21.1. Estimate

It is an document containing report of the work to be done, specifications of work and detailed statement of measurements, quantities and rates of the item. This also includes the abstract of the total estimated cost for each item. In short an estimate is the probable cost of the work determined before the commencement of the work.

5.21.2. Types of estimates

An estimate may be divided into the following types:

1. **Preliminary or rough estimate.** It is a brief estimate indicating the cost of works approximately.

It is prepared on the basis of preliminary drawings of the works.

2. **Detailed estimate.** It is a precise estimate prepared on the basis of detailed drawings. The quantities of various sub heads of the work are calculated on the basis of detailed measurements. Their costs are estimated or worked out on the basis of approved scheduled of rates. For no schedule items, analysis of rates is prepared. Actually no detailed estimate is prepared until funds for the work are actually allotted or promised by the government.
3. **Revised estimate.** If during the execution of an work, the amount of the sanctioned estimate is likely to exceed by more than 5% due to rise in the cost of material or labour charges or due to any genuine reason, then the revised estimate of the work is to be submitted. With the revised estimate a comparative statement showing items of original and revised estimate and the reason for difference is also to be attached.
4. **Supplementary estimate.** When the work is in progress and it is felt that some additional item is needed which is not contingent on the proper execution of the work as initially sanctioned, it becomes necessary to obtain the sanction from the competent authority by submitting a supplementary estimate. This estimate should be accompanied with a full report of circumstances leading to the addition of the item. The abstract of the supplementary estimate should show the amount of original estimate and the total amount of the sanction required, including the supplementary amount.
5. **Screening or order of magnitude estimate.** This estimate is prepared at the very early stage when the scope is clearly defined and the essential features of the facility are identified.

5.22. FORMALITIES TO BE OBSERVED BEFORE THE START OF THE WORK

Following formalities are observed before the start of the work:

1. To obtain the administrative approval for the execution of the work from the competent authority.
2. To obtain the expenditure sanction from the competent authority.
3. After the receipt of administrative approval and expenditure sanction, a detailed estimate is got prepared by the D.E.N. and technical sanction accorded, if with in his competence. If it is not in his competence, then he will forward it to the competent authority to accord technical sanction. In short after the receipt of administrative approval and expenditure sanction, technical sanction is to be obtained.
4. Allotment of funds. In between the above period the allotment of funds should be arranged. The actual execution of the work should start after the completion of all the formalities.

5.23. WORKS ACCOUNTS

The main object of keeping works accounts is to exhibit accurately the expenditure incurred on various items of the work.

General principles of account. The accounts of works are based on the following two records:

1. Muster roll
2. Measurement book (M.B.)

5.23.1. Muster roll

It is a record in which the names of daily labourers, their particulars and attendance, amount payable to them, and the work done by them is recorded. The advance for payment to labourers is issued on the basis of the muster roll. After the disbursement of wages, the necessary certificate is recorded on the muster roll and it is kept as a voucher. Muster rolls are prepared on form 21 of the department. Muster roll form consists of three parts. Part I is for nominal roll meant for recording the attendance, absence of labourers and fine imposed on them if any. This part facililates the calculations of net wages payable to labourers and classification of cost of labour on the basis of work and sub heads where necessary.

In part II of muster roll the details of un paid items are recorded. The unpaid wages of the previous muster roll are also carried over. Payments made out of the arrears are also recorded in this part. Particulars of all wages remained un paid for a period of three months should be brought to the notice of Executive Engineer, whose orders are necessary before they can be paid off.

The part III of the muster roll is used for recording the work done by labourers employed as per the nominal roll of part I in cases where the work is susceptible to measurement. In case the work is not susceptible to measurement, it is certified that the work is not susceptible to measurement. To reproduce the details of measurement in part III are not necessary.

5.23.2. Measurement book (M.B.)

A measurement book is the initial record of all kinds of works susceptible to measurement. Thus the measurement books are the basis for all accounts of quantities of work done by contract labour employed departmentally and the materials purchased for specific works. They should be kept and maintained in such a way that the transactions are readily traceable in the accounts of the department. Measurement books are very important record for P.W.D. They should be kept in safe custody. They must be maintained accurately and kept carefully so that they may be produced in a court of law as evidence if required.

All measurement books belonging to a division should be numbered serially and a register should be maintained in the divisional office showing the serial number of each measurement book, the name of sub division to which issued, date of issue and date of its return. A similar register should also be maintained in the sub division showing the name of sub divisional officer and sectional officers to whom measurement books have been issued. Books not in use must be withdrawn, even though they may not have been completely used up.

5.24. GENERAL INSTRUCTIONS ABOUT RECORDING DETAILED MEASUREMENTS

While recording the detailed measurements, following points should be followed:

1. In the measurement book, the detailed measurements should be recorded only by the person who is incharge of the work, to when the M.B. has been issued for this purpose as divisional, sub divisional or sectional officer.
2. All measurements should be entered in M.B. neatly issued for this purpose and no where else.
3. Each set of measurements should begin with the name of work or name of supplier.

5.25. KINDS OF MEASUREMENT BOOKS

Measurement books are of the following types:

1. Ordinary measurement book
2. Standard measurement book
3. Check measurement book

5.25.1. Ordinary measurement book

As stated above, it is an initial record of all kinds of works which are susceptible to measurement. In this book entries of work done and supplies made are recorded for payment to the contractors/suppliers. The specimen form of this book is shown below. Following items are written on the top of this form:

(*a*) Name of work
(*b*) Location of the work site
(*c*) Name of agency executing the work
(*d*) Date of written orders for the commencement of work
(*e*) Date of completion of work
(*f*) Date of measurement of work
(*g*) Date of agreement and its no-----
(*h*) Name of subordinate officer in charge of labour.

(*i*) Reference of previous measurements.

Specimen of measurement book form

S. No.	*Description or particulars*	*No.*	*Length L*	*Breadth B*	*Height or depth D*	*Contents or Area*

5.25.2. Standard measurement book

The measurement book in which the standard measurements are recorded is known as *standard measurement book*. If in the department there are some buildings which are repaired periodically and the quantities of various items of works remain unchanged from year to year. In such cases of repair work to save trouble of measuring them every time it is convenient to maintain standard measurement book for such buildings.

5.25.3. Advantages of standard M.B.

Followings are the advantages of the standard measurement book

(*a*) It facilitates the preparation of estimates for repair work from time to time.

(*b*) It simplifies the preparation of contractor's bill as it is not necessary to take detailed measurements every time.

5.25.4. Precautions to be observed while using standard M.B.

Following precautions should be observed while using standard M.B.:

1. To distinguish standard measurement books from ordinary measurement books, the standard measurement books should be numbered in alphabetiç series while ordinary measurement books are numbered serially.
2. The entries in standard measurement book should be recorded legibly in ink and be certified as correct by a responsible officer.
3. A certification be obtained periodically from the divisional engineer that:
   (*a*) All the standard measurement books of the division have been inspected by him.
   (*b*) No entry has been tempered with.
   (*c*) All corrections due to additions and alterations in the building have been recorded in the book.
4. When the payments are based on standard measurements, the gazetted officer or the subordinate preparing the bill for payment has to certify that:
   (*a*) The whole of the work has been done as per standard measurements.
   (*b*) It has not been billed any where previously.

5.25.5. Check measurement book

The check measurement book is used to check the measurements made by the sectional officer. It is used by sub divisional officer. To avoid double payment, no measurement is recorded in this M.B. for the purpose of payment. It is solely used for checking purposes. At the end of the measurement in the M.B. of the sectional officer following certificate is recorded by the sub divisional officer. "check measurement was made by me in the check measurement book no..... on Page.... The sectional officer concerned was/ was not present at the time of check measurement."

As a general rule following percentage of check measurements should be made by the sub divisional officer:

(*a*) The sub divisional officer must carry out check tests about 50% of the measurements made by the subordinates both in respect of measurements made for payments of running bill and final bill. The percentage is judged by their money value. Following percentage of measurement must be checked under all circumstances.

(*b*) 35% of the work costing more than Rs. 5000/-.

(*c*) 25% of the work costing less than Rs. 5000/-.

The divisional engineer is expected to check about 20% of measurements made by his subordinate in respect of final bills, but not less than 5% in any case.

(*a*) The test checks should preferably be carried out before the payment is made.

(*b*) The individual item checked must be attested by dated initials of checking officer. He should also record the results of his checks.

If during the check measurements, the difference in measurements made by the sectional officer is less than 20% in case of original work, 5% in case of repairs and 10% in case of earth work, the sectional officers entries may be corrected accordingly before the payment is made and the following note may be recorded.

"Corrected in accordance with check measurement book no and page......."

In case the difference is more than the above limits, the whole work will have to be measured by the sub divisional officer and the matter has to be reported to the higher authorities for necessary action against the sectional officer.

QUESTIONS

1. What are the aims and objectives of inspection of buildings.
2. What points should be observed at the time of inspection of a building.
3. Give the general classification of maintenance. Generally what precentage of expenditure on ordinary repair of a building can be spent?
4. What are the management tools for effective maintenance.
5. Give the classification of estimates.
6. How the accounts of repair works are maintained.
7. How many measurement books you know?
8. What is a standard measurement book?
9. What is a check measurement book? How it is different from others?
10. Muster roll is a record in which are recorded.
    (*a*) The measurements of works/supplies
    (*b*) Name and practicubrs of labourers engaged on a particular work
    (*c*) Record of expenditure on the work
    (*d*) All the above are correct
11. Measurement book is a record of
    (*a*) All kinds of works susceptible to measurement
    (*b*) All kinds of works not susceptible to measurements
    (*c*) All kinds of labourers engaged on a particular work
    (*d*) All the above are correct
12. For checking the correctness of measurements taken by the J.EN check results are noted in
    (*a*) Ordinary M.B. (*b*) Standard M.B.
    (*c*) Check M.B. (*d*) Any M.B. can be used
13. Identify the correct statement/statements
    (*a*) Any number of muster rolls can be used at a time for a particular work

(*b*) Only one muster roll should be used at a time for a particular work
(*c*) Initial measurements are recorded in standard M.B.
(*d*) Initial measurements are recorded in ordinary M.B.
(*e*) Initial measurements are recorded in check M.B.

14. Identify the incorrect statement/statements
(*a*) Measurement entries can be recorded in the M.B by pencil in the first instance
(*b*) Standard M.B is used for recording the check results of measurements made by the sectional officer
(*c*) Entries in M.B can be erased when found wrong
(*d*) Muster roll may be used to record measurements if M.B is not available
(*e*) All are correct
(*f*) All are false

ANSWERS

10. (*b*) 11. (*a*) 12. (*c*) 13. (*b, d*) 14. (*f*)

6

Cracks in Masonry Structures and their prevention

6.1. INTRODUCTION

Development of cracks in masonry structures is a common occurrence. Crack is a line along which a material is broken into parts. It is important to understand the causes of developing cracks and measures to be taken to remove or prevent them. Most of the building materials such as bricks, mortar and concrete contain sufficient quantity of water at the time of construction. These materials shrink on drying and expand when wetted. Due to restraint to contraction, tensile stresses develop in the material causing cracks. Hence to minimize the cracking of masonry structures, materials which undergo much expansion or contraction due to moisture or thermal movements should not be used.

6.2. CLASSIFICATION OF CRACKS

Broadly cracks may be classified into two groups:

1.1. Structural cracks. These cracks develop due to the following causes:

(*a*) Incorrect design

(*b*) Faulty construction

(*c*) Over loading

(*d*) Settlement of foundation

(*e*) Effect of temperature variation

(*f*) Swelling of soil below the foundation of the structure.

The depth of these cracks is more *i.e.* through out the wall.

These cracks develop due to structural adjustment of load transfer mechanism. Thus the development of structural cracks endanger the safety of the building.

2. Non structural or surface cracks. Mostly these cracks develop due to the inducement of internal stresses in the building materials and their depth is less, only a few mm *i.e.* they exist on the surface only. Though these cracks do not endanger the safety of the building, but look unslightly and create impression of faulty work. In some situations the ingress of moisture through these cracks may spoil, the internal finish of the building. This moisture in case of R.C.C. work may corrode the reinforcement, affecting the stability of the structure.

3. Classification of cracks may also be done according to the width of the crack. According to American Concrete Institute, cracks are classified as

(*a*) Less than1 mm in width—thin

(*b*) 1 to 2 mm in width—medium

(c) More than 2 mm in width-wide

6.3. NATURE OF CRACKS

According to nature of cracks they can be classified as follows:

1. **Active cracks.** A crack which is still in progress *i.e.* the crack is still developing is called as Active crack.
2. **Dormant cracks.** If the development of an crack is not observed during a considerable period of time, then this crack is known as *dormant crack.*

6.4. CAUSES OF CRACKS IN MASONRY STRUCTURES

Followings are the main causes of development of cracks in masonry structures:

1. Over loading
2. Foundation movement and settlement of soil
3. Effect of environmental agencies as water, gases, and temperature etc.
4. Growth of vegetation
5. Vibrations
6. Chemical reaction.

1. Over Loading. The over loading of the structure may result from excessive wind pressure or snow load. These sources are classified as external source of loading, over loading may also be developed by installing excessive heavy machines, for which the foundations have not been designed. Thus the over loading due to any cause will develop defects in building as deflection of floors causing cracks on the under side of the building.

2. Foundation movement and settlement of the soil. The differential movement of foundation causes vertical or diagonal cracks near the corner of the junction of two elements of the structure. The uniform settlement of the whole structure seldom takes place. These cracks are wider at top and decrease towards the tail. The differential settlement may be due to any one of the followings.

1. Un equal bearing pressure under different parts of the structure.
2. Bearing pressure may be in excess of the bearing capacity of the soil.
3. Low factor of safety in the design of foundation.
4. Local variation in the supporting soil.

3. Effect of environmental agencies.

(*a*) **Water.** The presence of moisture causes corrosion of steel. The chemical reactions of salts present in soil as sulphates, alkalis etc. also take place in the presence of moisture. These reactions cause development of cracks.

(*b*) **Gases.** Carbon dioxide CO_2 gas only leads to cracking of elements mainly built of cement concrete. Co_2 causes carbonation of porous cement products leading to shrinkage and development of cracks.

(*c*) **Temperature.** Every building material under goes physical changes due to variation of temperature according to their coefficient of thermal expansion. Small buildings are not much affected by the variation of temperature, but long buildings under go large changes in sizes causing cracking of the structure. The expansion of flat roofs more commonly causes cracking in the brick work immediately below the roof structure than it self.

4. Growth of vegetation. The growth of vegetation takes place at the joins of masonry or cracks developed due to expansion of undernealh soil etc. It grows in favourable conditions of moisture and temperature. The growing roots of the vegetation absorb moisture from building elements, and soil causing dehydration to them and exert much pressure on the brick work resulting in split of the structure and showing of cracks.

The roots of the trees usually spread in all directions to the extent of height of the tree above the ground. They cause cracks in walls due to expansion of roots growing under foundation.

6.4.1. Remedial measures

1. Trees should not be allowed to grow near the building compound walls, etc. If any saplings of trees are found growing near the building, they should be removed at the earliest.
2. In case of new constructions, vegetation including trees should be removed and in case the soil is shrinkable, or clayey, the construction should not be started until soil has undergone expansion and stabilized at least for one rainy season.

6.5. STAINS

When salts present in the construction materials such as brick and stone. Come in contact with atmospheric agencies in due course of time, as the age of the structure advances get oxidized forming stains on the surface. They make the surface ugly. Hence they should be removed.

6.5.1. Remedial measures

Different methods used for different kind of stains are as follows:

1. **Use of soap solution.** Some kind of stains are removed by washing with soap solution. Two or three wash are sufficient.
2. **Use of acids.** For some kind of stains inorganic acid as dilute hydro chloric acid (HCL) *i.e.* (1 part of acid and 10 parts of water) is used. Tarmarind water contains tartaric acid which is very mild acid having good cleansing quality. The surface is thoroughly washed with clean water after application of acid.
3. **Sand blasting.** This method is suitable for cleansing porous materials as sand stone and certain types of bricks. This method can be used to clean and to remove stains, dirt, scales, old paints from concrete, steel and masonry specially with carving, rough textured and decorations.

6.6. EFFECT OF VIBRATIONS

Vibrations also cause devastating damage to structures, vibrations may be caused to structures by the following agencies:

(*a*) Vibrations due to use of heavy machines

(*b*) Traffic

(*c*) Driving insitu piles

(*d*) Flight of supersonic air jets.

The flight of super sonic air jets have been found to damage heavily M.B.M. Engineering Collage building Jodhpur and other residential buildings made of stone. They caused heavy cracking of different elements.

6.7. INVESTIGATIONS OF CRACKS

Before deciding upon the mode and method of rectifying the cracks, detailed investigations should be carried out to obtain the following information:

1. Nature of crack	2. Direction of crack
3. Extent of crack	4. Width of crack
5. Depth of crack	5. Alignment of crack
6. Cleanliness of faces	7. Sharpness of edges.

1. Nature of crack

(*a*) As discussed above, a crack may be grouped as active or dormant. The nature of crack may be detected by using a tell tale. A tell tale is a glass or metal strip of 2 to 3 cm in width and 10 to 12 cm in length. To determine the widening of the crack, a tell tale is fixed across the crack with mortar as shown in Fig. 6.1 (*a*). If the crack widens, the tell tale will break. In case the crack closes instead of widening out, the glass strip will either crack by buckling or will get disjointed at one of the ends.

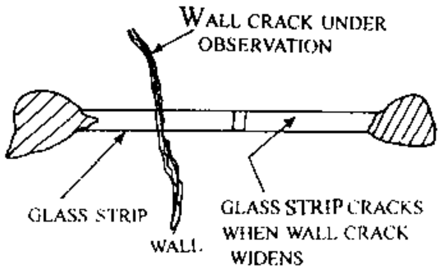


Fig. 6.1 (*a*)

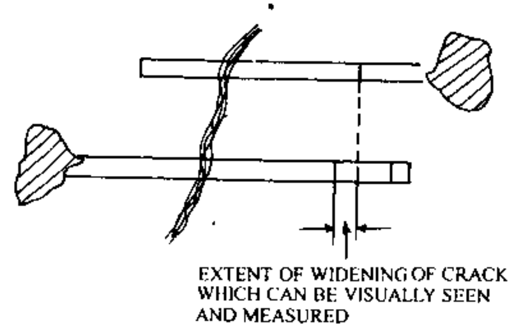


Fig. 6.1 (*b*)

(*b*) In case, it is desired to observe the rate and extent of widening of the crack, then two glass strips are used side by side instead of one strip as shown in Fig. 6.1 (*b*). After fixing the strips, a line is drawn across them. When ever widening or narrowing of the crack takes place, lines on the two plates move relative to one another. The distance between them can be measured at any time. This distance will indicate the extent of movement at the time of measurement.

2. Direction of cracks. Direction of cracks indicates the approximate causes of their formation.

(*a*) **Vertical cracks.** Vertical cracks mostly indicate over stressing of masonry due to its over loading or differential settlement of soil under foundation.

(*b*) **Horizontal cracks.** These cracks generally indicate settlement of foundation.

(*c*) **Diagonal cracks.** These cracks indicate the settlement of isolated footing or excessive shear or torsion.

(*d*) **Straight line cracks.** This type of cracks generally show shearing of bricks due to over stressing.

(*e*) **Toothed and Zig Zag cracks.** This type of cracks generally indicate the settlement of foundation. Generally such type of cracks are seen in compound walls.

(*f*) **Through cracks.** This type of cracks show shearing of wall due to imbalance of load due to change in loading pattern or bulging of wall.

(*g*) **Cracks along mortar joints.** These cracks indicate settlement at isolated places. Usually such cracks are seen in boundary and other non load bearing walls.

(*h*) **Vertical cracks wider at top.** These cracks show swelling of soil below the foundation.

3. Extent of cracks. Cracks in the vicinity of ground and passing through D.P.C. upto opening indicate settlement of foundation.

4. Width of cracks. Tapered cracks indicate the exertion of force at narrow end either due to swelling of soil or due to any other cause.

5. Depth of crack. It indicates the structural cracks. It should be observed carefully and may be determined by inserting a needle type wire.

6. Alignment of the cracks. Alignment of cracks indicates the nature of forces causing the cracks *i.e.* tensile pull.

7. Cleanliness. Bright and clean faces of cracks indicate recent development of cracks *i.e.* it is still active. Dirty and filled cracks show dormant or dead cracks.

8. Sharpness of edges. Sharpness of edges indicates development of crack due to shear or pull. Cracks formed due to vibration or compressive forces have generally roughened or grinded surface.

6.8. DEVELOPMENT OF CRACKS IN A STRUCTURE

In buildings cracks usually occur in the following members:

(*a*) Walls	(*b*) Rendering and plasters	(*c*) Roof terrace
(*d*) Wood work	(*e*) Glass panes	(*f*) A.C. sheets
(*g*) R.C.C. members	(*h*) Concrete and terrazzo floors.	

Item (*g*) and (*h*) shall be discussed in next chapter on R.C.C. structure.

6.9. CRACKS IN LOAD BEARING WALLS

6.9.1. Cracks in masonry walls

Generally cracks in masonry walls get localized at weak sections such as door and window openings, stair case wall etc. In external walls of a building generally shrinkage cracks run down wards from window sill to plinth level. On the upper story they run from window sill to the lintel level of a lower story.

6.9.1.1. Remedial measures

Shrinkage cracks in masonry could be minimised by adopting following measures:

(*a*) Avoiding the use of rich cement mortar of 1:3 in the masonry. Preferably weaker mix of 1:6 should be used.

(*b*) Plaster work should not be carried out till masonry has properly dried out after curing and has under gone most of its initial shrinkage.

(*c*) Masonry work should be done with weak composite cement lime and sand mortars of 1:1:6, 1:2:9 or 1:3:12 proportion. These mix being weak will have lesser tendency to crack due to shrinkage in individual masonry unit. The shrinkage to a great extent will get accommodated in the mortar it self.

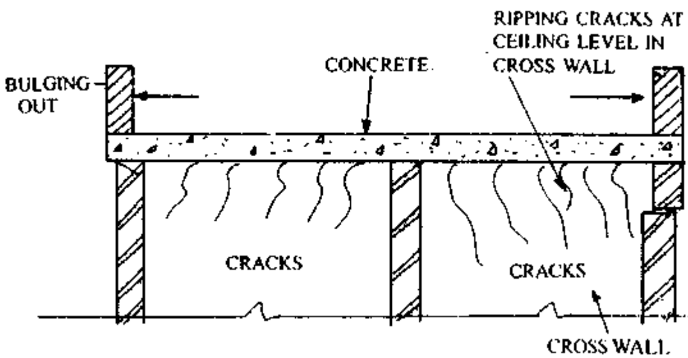


Fig. 6.2.

6.9.2. Ripping or un even cracks at the ceiling level in cross walls

In load bearing structures when the roof slab of the structure undergoes alternate expansion and contraction due to temperature variations shear cracks *i.e.* horizontal cracks develop in cross walls as shown in Fig. 6.2. These cracks develop due to inadequate thermal insulation or protective cover of the roof slab.

6.9.2.1. Remedial measures

(*a*) To reduce the heat load on the flat roof slabs, a layer of some insulating material of good heat insulation capacity with high reflective finish should be provided. For this purpose in Western India, broken China tiles are used in lime mortar over lime concrete terracing. Due to its high reflective cofficient, it reduces heat load on the roof and at the same time provides good wearing and draining surface on the terrace.

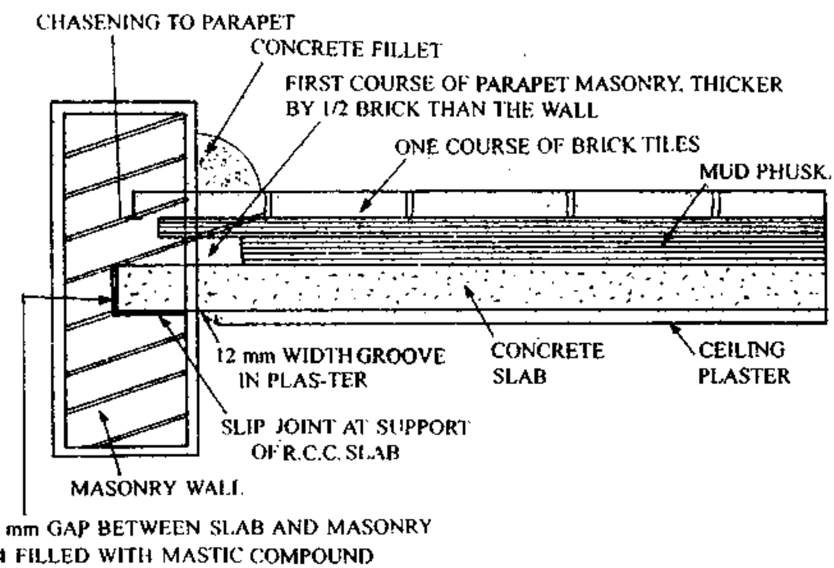


Fig. 6.3.

(*b*) Between slab and its supporting wall a slip joint may be provided as shown in Fig. 6.3. Similar joint should also be provided between roof slab and cross walls.

(*c*) The slab should have bearing on part width of the wall or project from the supporting wall for some distance as shown in Fig. 6.3 above. On the inside wall there should be a discontinuity in plaster of wall and ceiling. This discontinuity may be provided by a 10 mm wide groove as shown Fig. 6.3.

6.9.3. Formation of cracks at the base of a parapet wall

At the support of brick parapet wall or brick cum iron railing over an R.C.C. cantilever balcony, the formation of horizontal thermal cracks, is the common occurrence.

6.9.3.1. Factors responsible for such cracks

Following factors are found responsible for such cracks:

1. Difference of thermal coefficient of expansion of brick work and R.C.C. The thermal coefficient of expansion of R.C.C is twice that of brick work. Thus different expansions and contractions of the two works cause horizontal shear stress at the junction of the two materials causing cracks.
2. Drying shrinkage of concrete is three to four times that of brick work.
3. Parapet or railling does not have sufficient self weight to resist the horizontal shear developed at the junction due to differential drying shrinkage and differential thermal movement at the junction. hence the development of cracks.
4. Generally parapets are built over the concrete slab before it has undergone drying shrinkage fully.

6.9.3.2. Remedial measures

Following measures may be adopted to rectify the above defects:

1. Concrete used for slab should have low w/c ratio *i.e.* low slump. Its shrinkage also should be low.
2. The construction of brick work over R.C.C. should be done at least one month after the completion of R.C.C work, so that concrete may undergo some of its drying shrinkage.
3. Mortar to be used in parapet should be mixed type *i.e.* 1:1:6 proportion (1 cent 1 lime and 6 sand) and proper bond between concrete and brick work must be ensured.

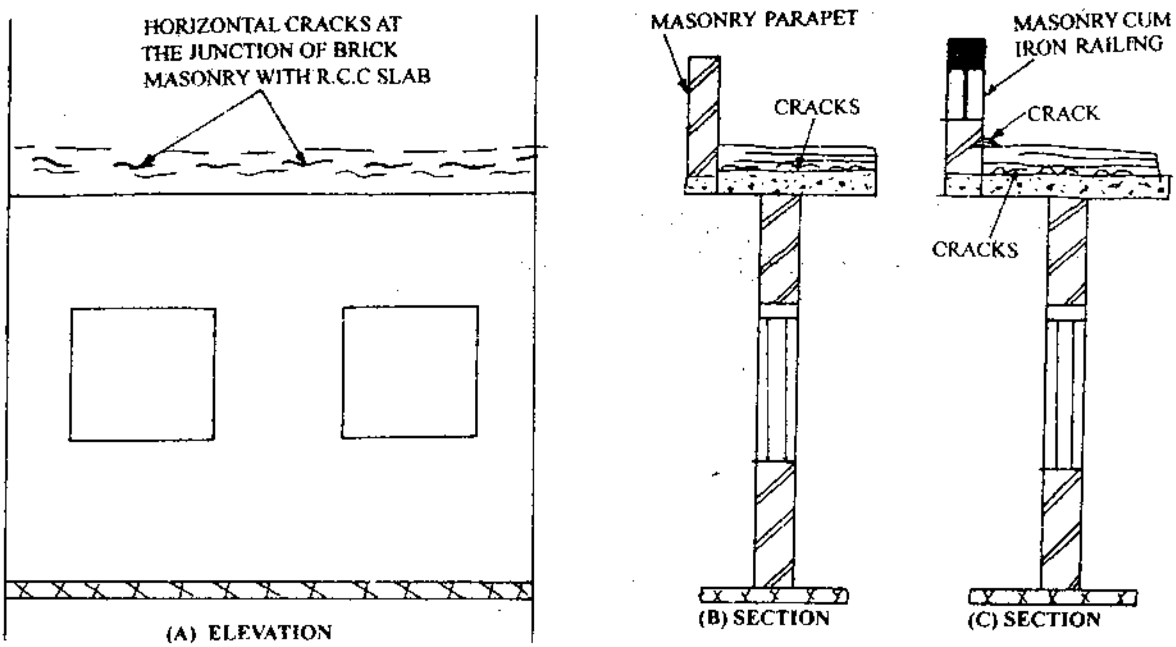


Fig. 6.4. Horizontal cracks at the base of brick masonry parapet etc.

4. Plastering on masonry and R.C.C. should be done after one month. Continuity of plaster at the junction should be broken by providing groove in the plaster.
5. In case of brick cum iron railing, the brick work should be replaced with low R.C.C. wall supporting the railing Fig. 6.4 (*c*).

6.9.4. Horizontal cracks in the top most story below slab level

These cracks develop due to the combined effect of the following factors:

(*a*) Deflection of slab (*b*) Lifting up of edges of the slab

(*c*) Horizontal movement of slab due to shrinkage

These cracks are shown in Fig. 6.5.

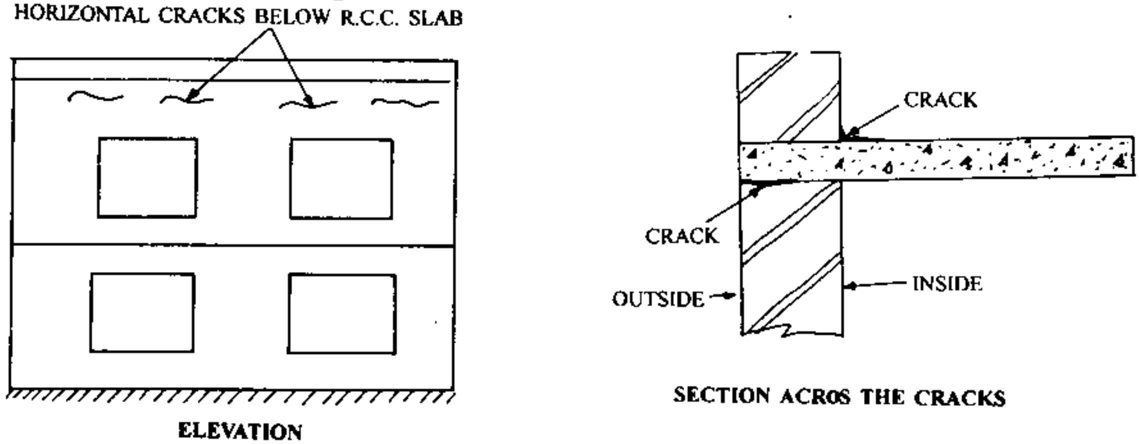


Fig. 6.5. Horizontal cracks in top most story below slab due to deflection

(*a*) These cracks appear after few months of construction and are more prominent if the span is large. Mostly these cracks are confined to the top most story due to light vertical load on the wall due to which ends of slab lift forming cracks. On the lower storys, corners are loaded with the vertical loads of the upper storys which prevent the corners to left up.

(*b*) Some times horizontal cracks develop in the top story of a building at the corners as shown in Fig. 6.6 due to lifting of the slab at corners on account of deflection of slab in both directions.

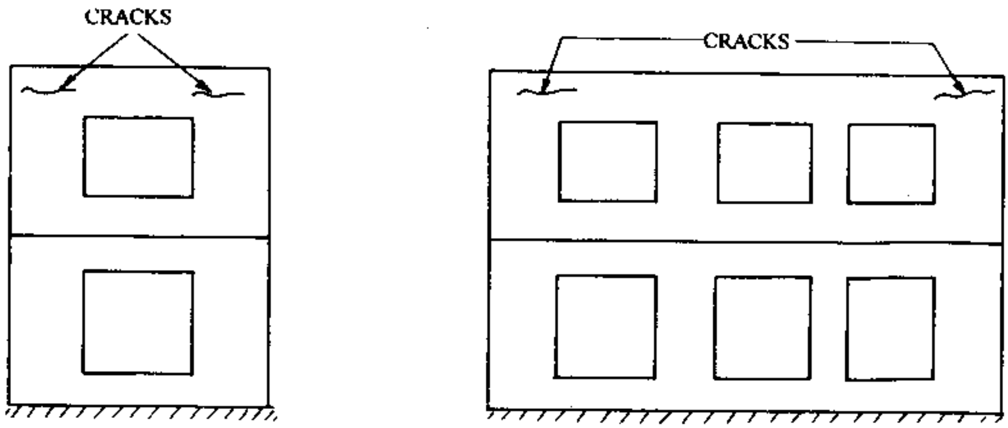


Fig. 6.6. Horizontal cracks in top story below slab due to lifting of corners

6.9.4.1. Remedial measures

These cracks can be avoided by the following measures:

(*a*) By providing adequate reinforcement at the corners of the slab.

(*b*) The deflection of beams or slabs in case of large spans can be reduced by increasing, the depth of beams and slabs to increase their stiffness.

(*c*) Adoption of part bearing or projecting the slab beyond the supporting wall as shown in Fig. 6.3.

(*d*) By providing of a groove in the plaster at the junction of wall and ceiling. Fig. 6.3.

6.9.5. Diagonal cracks in cross walls of a multi story load bearing building

These cracks develop due to differential strain in the internal and external load bearing walls to which the cross wall is attached. Excessive shear stress is developed when walls are un evenly loaded developing varying stresses in different parts of the building. The development of excessive shear stress causes cracking of walls.

Fig. 6.7 shows a multi story structure having brick walls and R.C.C. roof and floors. When greater load is placed on central wall A than external walls B-B, it is stressed more than external walls B-B. The central wall gets more stressed when either it is not correctly proportioned or is of the same thickness as that of external wall B. This develops shear stress in the cross walls bonded with these load bearing walls B-B. resulting diagonal cracking as shown in Fig. 6.7. Thus to avoid the cracking of the cross walls, the design of load bearing walls should be such that development of stresses in them is more or less is uniform.

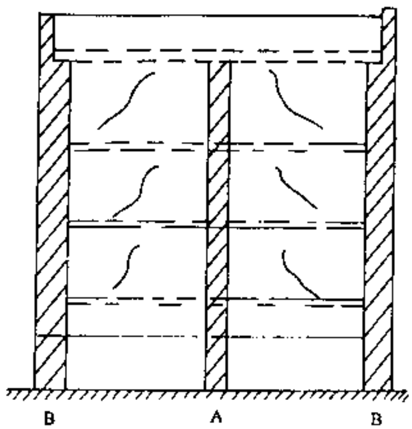


Fig. 6.7. Diagonal cracks in cross walls

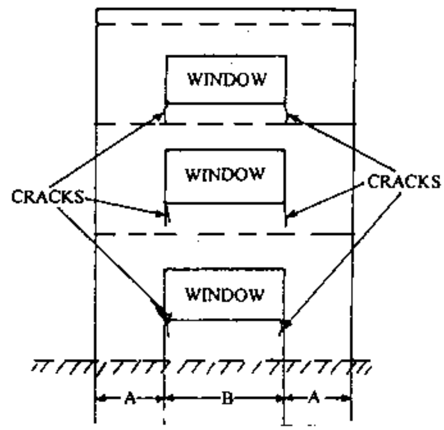


Fig. 6.8. Vertical cracks in window openings

6.9.6. Vertical cracks below openings in line with window Jambs

The elevation of a load bearing multi story building work having large window openings in the external walls is shown in Fig. 6.8. The portions marked A act as pillars and are stressed much more than the portion below window marked as B. Thus vertical shear cracks develop in the wall as shown in Fig. 6.8 due to the development of different stresses.

6.9.6.1. Remedial measures

1. Development of different stresses in different walls or part of a wall should be avoided.
2. Lintels over openings and masonry should have good shear strength.

6.9.7. Cracks in free standing walls

Walls such as compound walls, parapet walls, or garden walls are called free standing walls. In these walls generally vertical and diagonal cracks are observed.

6.9.7.1. Vertical cracks

Vertical cracks developed at regular interval of 5 to 8 m and at change of direction may be due to the combined effect of thermal contraction and drying shrinkage. In hot weather due to expansion of wall, these cracks tend to close.

6.9.7.2. Remedial measures

Cracks 5 mm wide or more should be repaired as follows:

1. The crack is enlarged in V shape and filled with weak mortar of 1:2:9 proportion. (1 cement, 2 lime and 9 sand).
2. Provide expansion joints if not already provided. For expansion joints some of the existing joints may be converted as expansion joint.

6.9.7.3. Diagonal cracks

1. If the diagonal cracks are tapering and wider at top, they have developed due to foundation settlement. If cracks are wide enough to endanger the stability of the wall, then the wall should be dismantled and rebuilt with adequate foundation.
2. In case the tapering cracks are wider at the bottom, they may be due to upward thrust due to expansion of soil or growing of vegetation near the wall. The remedial measures are discussed under effect of vegetation latter. Fig. 6.9.

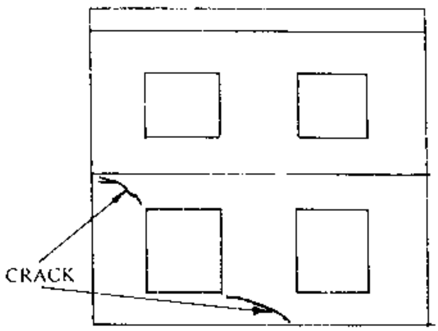


Fig. 6.9. Cracks at the corner due to foundation settlement

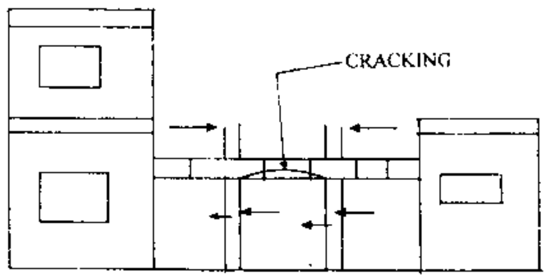


Fig. 6.10. Arching and cracking of coping stone

6.9.8. Arching

Arching up and cracking of the coping stone of a parapet or compound wall occurs if the wall is built in between two heavy structures which act as a rigid restraints and no expension joints have been provided in the coping stones Fig. 6.10. This defect can be removed by relaying the defective portion.

6.9.9. Horizontal cracks

If the horizontal cracks in bed joint occur after 2 or 3 years and the wall is subjected to periodic wetting and drying, then these cracks are due to sulphate action. For this defect there is no treatment. It has to be replaced.

6.9.10. Cracks due to foundation movement

Cracks developed due to foundation movement of a corner on an end of a building may be diagonal or vertical. These cracks are wide at top and narrow at tail. Thus they can be distinguished from other cracks. These cracks can be rectified by strengthening the foundation by under pinning and strengthening or repairing the damaged wall portion by inserting concrete stiching blocks as shown in Fig. 6.16.

6.10. R.C.C. FRAMED STRUCTURES

R.C.C. Framed structures. Cracking in brick panel walls.

The external non load bearing walls in a framed structure is known as panel walls.

6.10.1. Horizontal cracks

These cracks are developed when due to shortening of columns caused by elastic deformations, creep and drying shrinkage or greater deflection of upper beam under heavy loads, walls are subjected to large compressive force, resulting in buckling of walls and development of horizontal cracks as shown in Fig. 6.11.

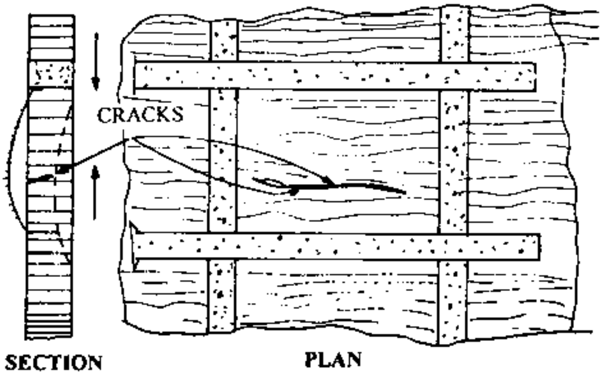


Fig. 6.11. Horizontal cracks in brick panels of a framed structure

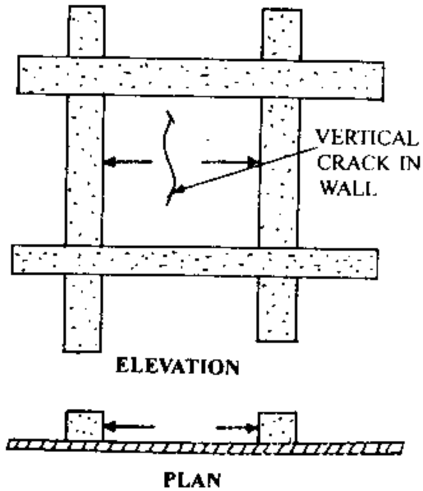


Fig. 6.12. Vertical crack in brick pannel of a framed structure

6.10.2. Vertical cracks

Vertical cracks develop if the long wall is built tightly between R.C.C. columns. Brick work may get compressed due to thermal and moisture effect developing vertical cracks. Fig. 6.12.

6.10.3. Remedial measures

This defect can be removed by opening out the joint between the top of the wall and the sofit of the beam. Thus the force in the panel is released. The joint may be refilled with suitable joint filling compound.

6.11. CRACKS IN MASONRY PARTITION WALLS

In a framed structure the internal non load bearing wall is known as partition wall. The masonry partition walls may crack due to excessive deflection of supports. The location and pattern of cracks depend upon the length to height ratio of the partition and position of door opening in the partition.

6.11.1. The length and height ratio of the partition is large, but no door opening

In this case the middle portion loses support due to the deflection in floor. Due to the greater length to height ratio, the load of the middle portion gets transferred to the ends of the supports mainly by beam

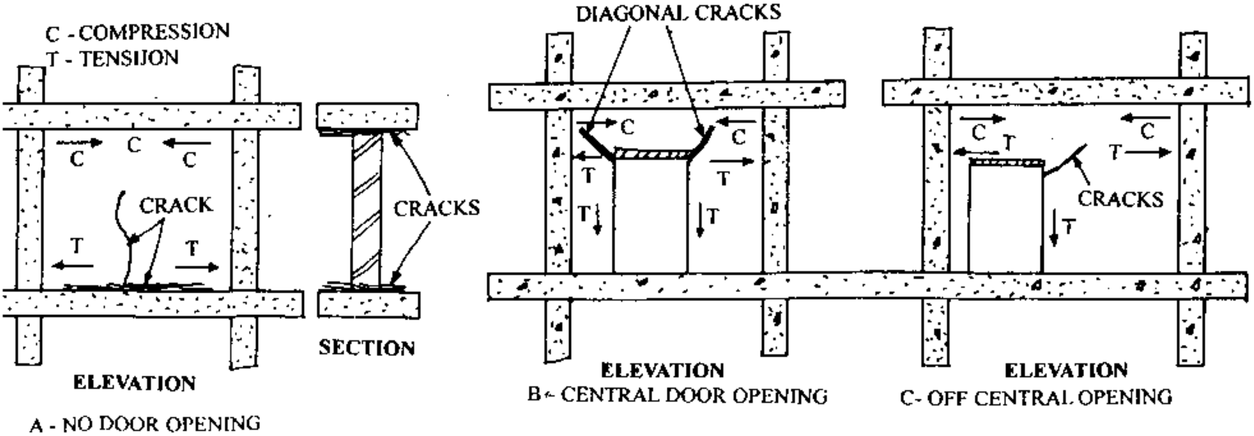


Fig. 6.13. Cracking in partition wall

action. Thus due to this thrust, horizontal cracks develop in the masonry at support or one or two courses above the support as shown in Fig. 6.13.

Vertical cracks also develop near the bottom in the middle of the partion due to tensile stresses caused by bending. These vertical cracks may be quite significant if the partion is taken upto the soffit of the upper floor slab or beam and some load is transferred to the partition due to deflection of the beam or slab. Shortening of the columns supporting the floor due to crack, shrinkage or elastic strain etc. often aggravates the cracking of the panel or partition wall.

6.11.2. Length to height ratio large but there is a central opening

In this case diagonal cracks occur on the sides of the opening as shown in Fig. 6.13 (*b*) due to the combined effect of flexural tension in the masonry portion above the opening and the self weight of supporting masonry. These cracks start from lintels where they are widest and decrease as they travel upwards. Fig. 6.13 (*b*)

6.11.3. Length of height ratio large, but opening is off the centre

In this case diagonal cracks occurs due to the combined effect of flexural tension in the masonry portion above the opening and horizontal tension in the unsupported portion of the masonry on the side of opening due to loss of support in the middle. It is important to note that a partion with the off centre of the opening is more prone to cracking than the one with central opening. Fig. 6.13 (*c*)

6.12. LENGTH TO HEIGHT RATIO IS SMALL

6.12.1. There is no opening in the partition

In this case the self load of the partition is transferred to the ends of the support mainly by arch action. The horizontal cracks develop at some height from the support as tension developed due to self weight of unsupported portion of the partition in the central region. In this case there is no beam action in the partition due to small length to height ratio. Fig. 6.14 (*a*)

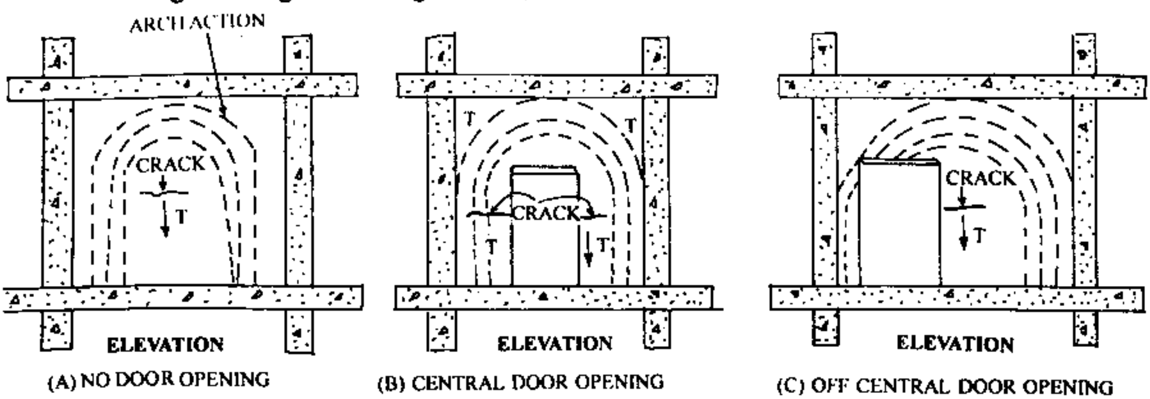


Fig. 6.14. Cracking in partition wall supported on RCC slab beam

6.12.2. Length to height ratio small, but there is a central door opening

In this case horizontal cracks develop in the lower portion of the partition mainly due to tension developed on account of self weight of unsupported masonry on the sides of the opening. Fig. 6.14 (*b*)

6.12.3. The length to height ratio small, but there is opening off the centre

In this case there is no beam action. and horizontal crack develop on the off partition mainly due to tension caused by the self load of unsupported masonry on one side of the opening as shown in Fig. 6.14 (*c*)

6.12.4. Remedial and Preventive measures

Though it is impossible to eliminate these cracks altogether, but following measures may minimise these cracks considerably.

1. When brick masonry work is to be built abutting an R.C.C. column, brick work may be deferred as much as possible to reduce shrinkage effects.
2. Brick masonry work should not be started on R.C.C. slabs and beams till atleast two weeks have elapsed after removing the centering.
3. As far as possible full frame work of R.C.C. must complete before starting the masonry work cladding and partition. This work (masonry work) should start from top story down wards.
4. Horizontal movement joint between top of brick panel and soffit of beam should be provided.
5. Up ward camber in floor slab and beam should be provided to counteract the deflection.
6. Central door opening should be provided in preferance of off centre opening.
7. Masonry partitions having length to height ratio more than 2, should be provided with horizontal reinforecement. In case of panels longer the 5 to 8 m should be provided a groove in plaster at the junction of R.C.C. column and brick panel or fix a 10 mm wide strip of metal mesh over the junction before plastering.

6.13. TELESCOPIC ANCHORAGE FOR PANEL WALLS

Between partition walls or top panel, horizontal expansion joint about 10 mm wide should be provided. The gap should be filled up with a mastic compound finished with some sealant weak mortar upto a depth of 3 cms on the external face and left open on the internal face. When structurally required lateral restraint to the wall at the top should be provided by using telescopic ancharage as shown in Fig. 6.15.

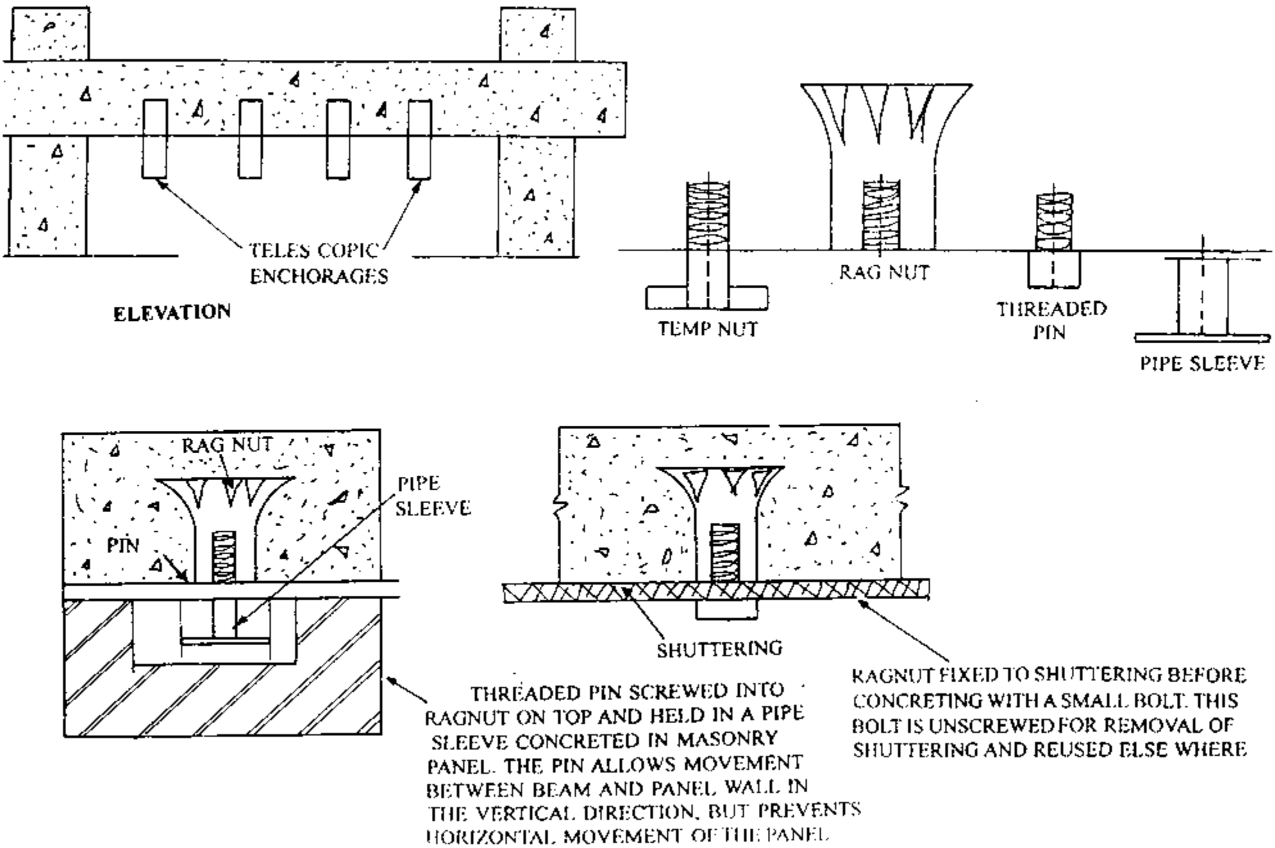


Fig. 6.15.

6.14. GENERAL MEASURES OF REPAIRING MASONRY WALL CRACKS

Repair of cracks in walls is carried out for the following reasons:

1. To restore normal aesthetic look or appearance.
2. To minimise the possibility of further damage to the building due to cracks.
3. To ensure that building is serviceable and safe.

Before carrying out any repairs to cracks it should be ensured that cracks have stabilized and not widening any more. Walls which have not bulged more than 10 mm or which are not more than 25 mm out of plumb, need no repair on structural grounds. How ever cracks due to thermal movement recur when repaired with mortar. Hence such cracks should be treated with some mastic compound. A mastic compound is a weather proofing compound usually with a putty base which remains plastic and flexible. This compound is used for bedding metal windows into masonry or concrete to seal the gap between the joints. It is comprised of 80 to 85% of whiting by weight and 15 to 20% of oil by weight (85% raw linseed oil and 15% castor oil) It is expected to take paint with out cracking, lifting or bleeding.

6.14.1. Cracks upto 1.5 mm in width

Generally such cracks do not need any repair if absorbing type bricks are used *i.e.* as normally bricks are used in India. In case of non absorbent bricks, there is possibility of penetrating rain water through these cracks. Hence even fine cracks require repair. The cracked joints are racked out and refilled with 1:1:6 cement, lime, sand mortar.

6.14.2. Cracks wider than 1.5 mm

(*a*) Generally such cracks need repair. The method of repair depends on the type of mortar used in the masonry work. In case weak mortar has been used, then the crack is enlarged and racked out upto a depth of about 25 mm and refilled with a 1:2:9 cement, lime, sand mortar and replastered with the same mortar on a 10 cms wide strip around the crack.

(*b*) In case the affected wall is built in strong mortar, in that case bricks adjoining the cracks should be cut and replaced with new bricks using 1:1:6 cement, lime, sand) mortar.

(*c*) If bricks crack, then the affected bricks should be raked or cut out and replaced with new bricks with 1:1:6 cement, lime, sand mortar.

6.14.3. Cracks due to settlement of foundation

Generally these cracks are wide enough. These cracks may be vertical or diagonal. If there is a

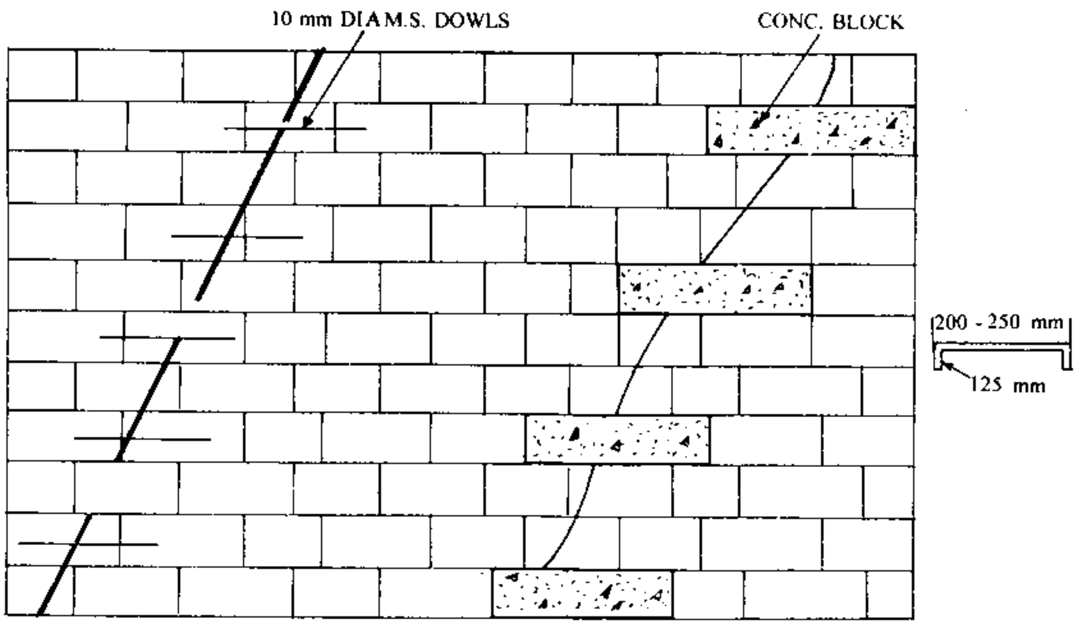


Fig. 6.16. Tretment of cracks

possibility of further movements, the cracks should be repaired by removing the damaged bricks and replacing all damaged bricks. R.C.C. blocks should be used in the affected area. Some authors have suggested the use of R.C.C blocks in alternate layers while some others have suggested the use of R.C.C blocks in every fifth or sixth layer *i.e.* at a interval of 0.5 m in vertical direction. The width of such blocks should be equal to the thickness of wall, length equal to 1½ to 2 bricks and thickness equal to 1 or 2 bricks. For such repairs mortar should not be used stronger than 1:1:6 (cement, lime, sand, mortar). These cracks may be stitched also. Fig. 6.16.

6.15. CRACKS IN PLASTERING AND RENDERING

6.15.1. Causes of cracks

Before any treatment of cracks, it is necessary to ensure whether the cracks are limited to plaster only or extend to the background also. This can be done as discussed in 6-5 using tell tale method.

6.16. SURFACE CRACKS

Surface cracks any develop due to the following causes:

(*a*) Shrinkage cracks due to use of rich cement mortar in plaster.

(*b*) In adequate curing of the plaster.

(*c*) Insufficient bond with the background due to insufficient depth of joint raking.

(*d*) Due to sulphate reaction.

6.16.1. Shrinkage cracks

These cracks develop during the first dry spell after the construction. The coat of plaster on the masonry is restrained from shrinking to some extent due to its adhesion with the back ground. Thus to limit the cracking of plaster, it is necessary that the adhesion between the plaster and back ground should be good and uniform, so that shrinkage is well distributed in the thin cracks. Before plastering the joints, they should be raked while the mortar is still green, and the plaster should be done after proper curing and drying of masonry. Initial shrinkage of masonry should have undergone before starting plastering of the wall.

6.16.2. Factors affecting the shrinkage cracks

It is a common knowledge that more the cement content in the plaster mix, greater is the shrinkage. The extent of shrinkage depends on the following factors.

(*a*) Characteristics of the surface to which plaster is applied.

(*b*) Extent of adhesion between plaster and back ground.

Thus as a general rule richer the mortar mix of plaster, stronger should be the back ground material and there should be good key in the back ground.

(*a*) In case two coasts are to be applied, then the second coat should be applied when the first coat has fully dried.

(*b*) Any discontinuity in the back ground is prone to cracking of plaster. A change from wall to ceiling may be taken as discontinuity. To keep the wall and ceiling plaster separate from each other, a cut not deeper than 6 mm may be provided at the junction while the plaster is green.

6.16.3. Remedial measures

To prevent the surface cracks at the junction between column/beam and wall, 150 mm wide chicken wire mesh should be fixed with u shaped nails at 150 mm centre to centre at the junction before the start of the plaster. The plastering of wall and column/beam in the vertical plane should be carried out in one go.

The shrinkage cracks usually are thin and should not be treated till the renewal of finishing coat of paint is applied. The surface is rubbed well with emery paper no. 60 or 80 and then two coats of paint are applied to fill the shrinkage cracks.

6.16.4. Cracks due to lack of bond with the back ground

The formation of such cracks may be established by tapping the affected area. The emition of dull or hollow sound will indicate lack of bond between plaster and back ground.

6.16.4.1. Remedial measures

The plaster from the affected area is removed, the joints in the masonry are raked upto a depth of at least 10 mm and replastered taking all precautions as a new plaster job.

6.16.5. Cracks due to sulphate effect

These cracks develop after two to three year of the construction of the structure if the affected portion remained damp for a long time due to rain or leakage of water from other sources. These cracks start as horizontal cracks in the mortar joints and extend slowly in size and length. In such situations the strength of mortar is reduced.

6.16.5.1. Remedial measures

Following remedial measures may be adopted:

(*a*) Plugging of all sources of dampness.

(*b*) The plaster of affected portion is removed if found unserviceable.

This portion is replastered using sulphate resistant cement and raking joints in the masonry upto a depth at least upto 10 mm.

6.16.6. External rendering

(*a*) If due to any consideration the external rendering is made of rich mix, then the finish should be divided into small panels varying from 0.5 to 1.0 m by providing grooves of 8 to 10 mm width in both directions.

(*b*) In case plaster is applied in two coats, then the thickness of under layer should be 12 mm of cement sand mix of 1:4 proportion.

(*c*) Top layer of 15 mm of cement sand mix of 1:1/2:2 cement coarse sand and stone chips less than 10 mm normal size. The top layer should be laid in pannels of specified pattern. Usually grooves 15 mm deep and 15 to 20 mm wide are provided. The top coat should be applied after 1 or 2 days of under coat. The surface of under coat is cleaned and a cement slurry at a rate of 2 kg of cement/m^2 of surface area should be applied. To expose the surface of stone pieces, the top layer is scrubbed and washed with brushes and water.

6.17. CRACKS IN BUILDINGS DUE TO SWELLING OF SOIL

Expansive soils swell by coming in contact with water (moisture) and exert great pressure on walls and floor of the building causing cracks in them. Fig. 6.17 shows cracks in wall due to swelling of soil under central portion of the building and Fig. 6.18 shows cracks due to heave of soil as a result of swelling of the soil under neath the building.

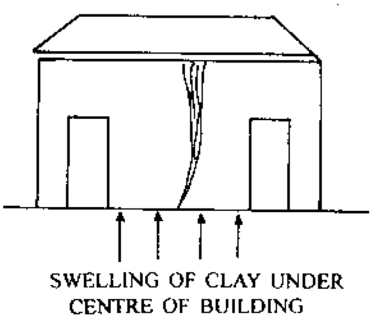


Fig. 6.17.

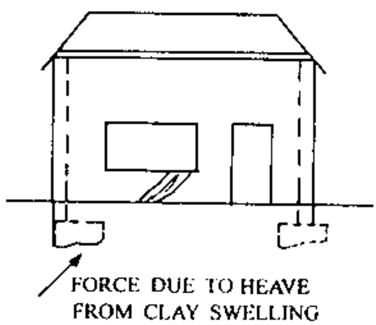


Fig. 6.18.

6.18. CORNER CRACKS

Such cracks develop in panels of concrete flooring due to curling (slipping) up of corners due to differential shrinkage between top and bottom of the slab. When load comes on the floor, curled up corners give way and develops cracks due to tension on the top. Differential shrinkage develops due to excessive use of water or excessive trowelling. There is no effective remedy for such cracks. The affected portion has to be replaced.

Cracking of floor in deep filling

In deep filling if the fill is not properly compacted it may settle due to vibration or moisture from any near by source of water. Thus in deep filling the soil should be free from organic matter, brick bats and debris and filling should be done in layers not more than 25 cm. in thickness. Each layer should be well watered and rammed.

Floors for grain godowns, ware houses, and industrial houses, etc. the filling should be carried out in layers of 25 to 30 cm thickness at optimum moisture contact. Each layer should be compacted to 95% proctor density by any suitable equipment as road roller.

6.19. HORIZONTAL EXTENSION OF FRAMED STRUCTURE

In such cases it is necessary to provide twin columns at the junction with a combined footing for the foundation of the two columns as shown in Fig. 6.19.

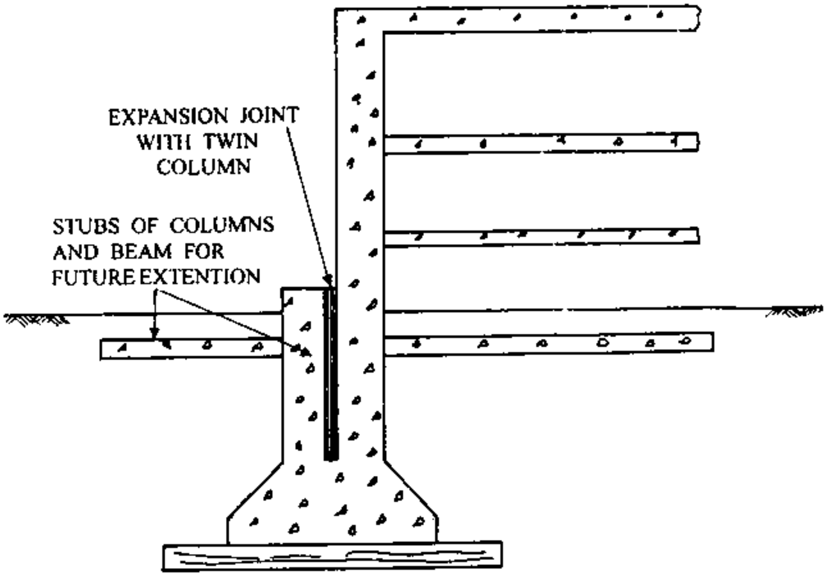


Fig. 6.19. Future extension of framed structure

QUESTIONS

1. Define cracks and give their classification.
2. Differentiate between (*i*) structural and surface cracks, (*ii*) Active and dormant cracks.
3. Discuss the causes of development of structural cracks in buildings.
4. How cracks can be rectified? Explain in brief.
5. What information should be collected before taking corrective measures of cracks?
6. Give location of cracks in load bearing walls and suggest their remedial measures.
7. State the factors responsible to cause cracks at the junction of parapet wall and roof. Suggest remedial measures of these cracks.
8. Give the remedial measures of cracks with sketch due to settlement of foundation.
9. Give the procedure of repair of cracks wider than 1.5 mm.
10. Surface cracks develop except:
    (*a*) Due to use of rich mortar in plastering
    (*b*) Due to inadequate curing of plaster
    (*c*) Due to through cracks in walls
    (*d*) Due to insufficient bond between plaster and back ground
    (*e*) Due to sulfate reaction.
11. The extent of shrinkage cracks depend upon except.
    (*a*) characteristics of the surface to which plaster is applied
    (*b*) Extent of adhesion between plaster and back ground
    (*c*) Nature of plaster
    (*d*) w/c ratio of plaster

12. Identify the incorrect statement/statements
    a) Surface cracks at the junction of the wall and ceiling can be prevented by providing a 12 mm wide groove at the junction
    (b) Surface cracks can be prevented by fixing 150 mm wide wire chicken mesh at the junction and plastering it
    (c) Surface cracks can be prevented by plastering the junction joint with 1:3 cement sand plaster
    (d) Surface cracks should be painted with 1 or 2 coats after rubbing the surface with emery paper.
13. Identify the correct statement/statements
    (a) Cracks developed due to sulphate action are horizontal
    (b) Cracks due to sulphate action develop due to moisture in the mortar joints
    (c) Sulphate effect can be removed or checked by plugging of all sources of moisture ingress
    (d) By replastering the joints with sulphate resistant cement plaster after raking the joints at least upto 10 mm depth.
    (e) All are correct
14. Tell tale method is used to ensure
    (a) Dampness (b) Live cracks
    (c) Efflorescence (d) Dead crack
15. Sand blasting is the process of
    (a) Rubbing sand on masonry (b) Rubbing sand stone on masonry
    (c) Applying sand on wet plaster (d) Forcing sand under pressure on the surface to be cleaned
16. A 20 mm wide crack is observed in a 25 cm thick external wall. Suggest remedial measures for it with sketch.

ANSWERS

10. (c)	12. (c)	14. (b)
11. (d)	13. (e)	15. (d)

7

Cracks in R.C.C. Structures and their Prevention

7.1. INTRODUCTION

In the present era, the use of concrete as structural material is increasing in leaps and bounds. In many countries concrete has replaced steel as structural material. Concrete is used in different structures as plain concrete, reinforced concrete and pre stressed concrete. Generally it is believed that well designed and well constructed concrete structures need no maintenance or very little maintenance. It has been observed that plain concrete structures are less susceptible to durability problem than that R.C.C. structures. Concrete structures have been built in highly polluted urban and industrial areas, harmful soil water in coastal areas and other hostile conditions where other construction materials have not been found suitable.

Thus concrete undergoes deformations due to applied stresses and volume changes due to shrinkage and temperature variations. These volume changes affect the long term strength and durability of concrete. The restraint caused to the volume changes induce tensile stresses in the concrete causing cracks in concrete as it is very weak in tension. Shrinkage is one of the most important factors which contributes to the development of cracks in the floor and pavements.

7.2. DAMAGES SUFFERED BY CONCRETE

Though concrete relatively is a durable building material, yet it develops many damages during its life due to many reasons. The period of damage development may be divided into two groups as

1. Damages during its production
2. Damages during its service time

7.3. CAUSES OF DAMAGES

These causes may be classified as follows:

(*a*) Applied and environmental loads exceeding the designed loads
(*b*) Accidents and subsidence
(*c*) Poor construction practices
(*d*) Faulty design
(*e*) Insufficient detailing
(*f*) Shrinkage
(*g*) Thermal stress
(*h*) Chemical reaction
(*i*) Weathering
(*j*) Reinforcement corrosion etc.

The damages in plastic stage or production stage may develop due to plastic shrinkage and settlement of concrete causing cracks. Some times at the time of removing shuttering, defects like bolt holes, honey combing, bulging, blow holes etc. are seen on the surface of the concrete.

7.4. CONTROLLING MEASURES FOR PRODUCTION STAGE DEFECTS

1. **Repair of bolt holes, honey combing etc.** These defects can be avoided by using water tight and rigid form work in such away that from work may be removed with out the use of crow bars and tools.
2. **Blow holes.** These holes are developed during concreting operation due to improper design of form work. These holes are developed in the surface of concrete by water bubbles and entrapped air against the face of form work. These holes can be reduced by adopting slightly absorbent form work and giving adequate compaction to the concrete.
3. **Un even surface.** In case the blow holes are large or surface is un even then the un even surface or holes may be filled with 1:1 or 1:2 cement sand mortar and finished. To get smooth surface crushed lime stone dust should be used in place of sand. The mortar should be rubbed over the affected surface area with a rubber face float and finally it should be rubbed with a smooth stone to get smooth finish.
4. **Honey combing.** It is developed due to inadequate compaction of concrete or loss of matrix through joints of form work or between previously cast surface and form work.
5. **Projections and bulges.** These can be repaired by chipping off the concrete from the surface and then the surface is rubbed with a grinding stone.

7.4.1. Remedial measure

In such cases the affected area is cut by saw to a depth of 5 cm and unsound material is chipped out upto the solid surface. The surface is cleaned, washed and dried. After preparing the surface a bonding coat of neat cement slurry is applied to the all exposed surface and new concrete filled and compacted.

7.4.2.

The summary of defects developed during construction is shown in Table 7.1 below.

Table 7.1. Summary of defects developed during construction of concrete structure

S. No.	*Symptoms*	*Cause*	*Preventive measures*	*Remark*
1.	Voids in concrete	Honey combing: Inadequate compaction, Loss of cement grout	(*a*) Improve compaction (*b*) Reduce max size of aggregate (*c*) Prevent leakage of mortar paste	(*a*) Inject good resin mix (*b*) Cut and repair
2.	Blow holes in form faces of concrete	(*a*) Inadequate compaction (*b*) Unsuitable mix design (*c*) Use of undesirable release agents (*d*) Air or water entrapped against form work	(*a*) Improve compaction (*b*) Change mix design (*c*) Use of absorbent form work (*d*) Use of appropriate release agent	Fill with modified polymer fine mortar
3.	Cracks in hoizontal surface as concrete stiffens or soon after that	(*a*) Plastic shrinkage (*b*) Rapid drying surface	(*a*) Use of air entrainment (*b*) Provide shelter during placement of concrete	(*a*) Seal or paint with brush by cement or low viscosity polymer
4.	Cracks in deep lifts or layers	(*a*) Plastic settlement	(*a*) Use air entrainment	(*a*) Recompact the concrete of upper layer while still plastic

S. No.	Symptoms	Cause	Preventive measures	Remark
	(*a*) Above reinforcement	(*b*) Continued settlement of concrete after starting to stiffen	(*b*) Change mix design	(*b*) Seal cracks after concrete has hardened
5.	Cracks in thick sections develop as concrete cools	(*a*) Thermal contraction	(*a*) Restraints to contraction should be minimised (*b*) Delay cooling till concrete has gained strength	(*a*) Seal cracks
6.	Erosion of vertical surfaces	(*a*) Scouring due to water movement up wards against form face	(*a*) Reduce water content (*b*) Make mix more cohesive	(*a*) Apply polymer modified mortar
7.	Colour variation	(*a*) Variation in mix proportions (*b*) Curing condtions (*c*) Material characteristics of form face (*d*) Vibration (*e*) Leakage of water from form work	(*a*) Prevent leakage from form work (*b*) Ensure uniformity of all relevent factors	Adopt surface coating
8.	Surface formed powdry	Surface retardation caused by sugar present in certain timbers	(*a*) Change form material (*b*) Seal surface of form work (*c*) Apply lime wash to form surface before applying other material	Generally no treatment required
9.	Rust strains	(*a*) Pyrites in aggregates (*b*) Rain streaking from un protective steel (*c*) Rubbish in form work (*d*) Ends of wire ties turned out	(*a*) Avoid contaminated aggregate (*b*) Protect exposed steel (*c*) Clean form work thoroughly (*d*) Turn ends of ties inwards	(*a*) Clean with dilute acid or (*b*) Clean with sodium citrate (*c*) Coat surface with sodium
10.	Plucked surface	(*a*) Careless removal of form work (*b*) Insufficient relese agent	(*a*) Apply more care in removing the form work (*b*) More care in applying release agents	(*a*) Rub fine mortar (*b*) Patch as spalled concrete
11.	Lack of cover to reinforcement	(*a*) Displacement of reinforcement during placement of concrete (*b*) Reinforcement fixed incorrectly (*c*) Inadequate tolerance in detailing	(*a*) Provide better support to reinforcement (*b*) More accurate steel fixing (*c*) Greater tolerance in detailing	(*a*) Apply protective coat to reinforcement (*b*) Apply polymer modified cement and sand rendering

7.5. CRACKING INDEPENDENT OF LOAD

As stated above, volume changes due to shrinkage, temperature variations also induce stress and cause cracks. Presence of cracks in concrete is one of the most objectionable defects. Shrinkage is the most important factor responsible to develop cracks in concrete floors and pavements.

7.5.1. CAUSES AND LOCATION OF CRACKING INDEPENDENT OF LOAD

These cracks are also known as intrinsic concrete cracks. These cracks are grouped as follows:

(*a*) Plastic cracks (*b*) Plastic settlement cracks

(*c*) Dry shrinkage cracks

The detailed discussion shall be made in subsequent sections. The cause and location of different types of cracks are shown in Table 7.2.

Table 7.2. Location and causes of intrinsic cracks

Type of crack	*Location*		*Cause*		*Remedy Assuming Redesign is not possible. In all cases, reduce restraints*
	Most common	*Sub division*	*Primary*	*Secondry*	
Plastic settlement	(*a*) Deep section (*b*) Top of columns (*c*) Through and waffle slabs (Decorated slab)	Over reinforcement Arching Change of depth	Excess bleeding	Rapid early drying conditions	Reduce bleeding by (*a*) air entrainment (*b*) By revibration
Plastic shrinkage	(*a*) Thick walls (*b*) R.C.C. slabs (*c*) R.C.C. slabs	Diagonal Random Over reinforcement	Rapid early drying – do–	Low rate of bleeding	Improve early curing
Early Thermal contraction	(*a*) Thick walls (*b*) Thick slabs	External restraint Internal restraint	Excess heat generation Excess temp gradient	Rapid cooling	Reduce heat or insulate
Long term drying shrinkage	Thin slab and walls	—	Inefficient joints	Excess shrinkage, inefficient curing	Reduce water content and improve curing
Crazing	(*a*) Air faced concrete (*b*) Slabs	Against form work Floated concrete	Impermeable form work Over trowelling	Rich mixes and poor curing	Improve curing and finishing
Corrosion of reinforcement	Columns and beams	Natural	Lack of cover	Poor quality of concrete	Causes listed should be removed
Alkali aggregate reaction	Damp locations	—	Reactive aggregate and high alkaline cement	—	Causes listed shall be removed

7.6. DEFINITION OF SHRINKAGE

It can be defined as the volume change in concrete due to loss of moisture due to evaporation or by hydration of cement or by carbonation. Reduction in volume is three times the linear contraction. Its units are mm per metre length.

7.7. CLASSIFICATIONS OF SHRINKAGE

Shrinkage can be classified in the following four categories:

1. Plastic shrinkage
2. Drying shrinkage
3. Autogeneous shrinkage
4. Carbonation shrinkage

7.7.1. Plastic shrinkage

Plastic shrinkage takes place, soon after the concrete is placed in the form work, while concrete is still in plastic stage. At this stage the paste undergoes volumetric contraction. The magnitude of this volumetric contraction is of the order of 1% of the absolute volume of dry cement. This type of shrinkage is developed due to loss of water either by evaporation or absorption by form work or by dry concrete below. Plastic shrinkage is directly proportional to the loss of water. To avoid cracks due to plastic shrinkage, the rate of evaporation should not be greater than 0.5 kg/m^2 surface area per hour.

7.7.2. Drying shrinkage

Withdrawal of water from hardened concrete stored in unsaturated air causes drying shrinkage developing cracks in the concrete.

The rate of shrinkage decreases with time. It has been observed that 14 to 34% shrinkage of 20 years takes place in two weeks time, 40 to 70% in three months and 66 to 80% in one year.

7.7.3. Autogeneous shrinkage

If no movement of moisture to or from the set paste of concrete is allowed to take place, then the shrinkage is known as autogeneous shrinkage. This shrinkage is caused by the loss of water consumed in the process of hydration of cement. The magnitude of this shrinkage is very small. Hence it is not much of significance.

7.7.4. Carbonation shrinkage

The mechanism of carbonation shrinkage is different from that of drying shrinkage. Carbonation is the reaction of carbon dioxide Co_2 present in the atmosphere with the hydrated cement minerals in the presence of moisture. Carbonation takes place even in small concentration of carbon dioxide of the order of 0.05% by volume. The rate of carbonation increases with the increase in concentration of Co_2 especially at high w/c ratio.

In the presence of moisture, Co_2 forms carbonic acid which reacts with calcium hydroxide $Ca(OH)_2$ to form calcium carbonate $CaCo_3$. Other cement compounds are also decomposed forming hydrated silica, alumina and ferric oxide. The complete decomposition of calcium compounds in hydrated cement is chemically possible even at low pressure of Co_2 in normal atmosphere, but carbonation penetrates beyond the exposed surface of concrete extremely slowly. It causes contraction in concrete, which is known as carbonation shrinkage.

7.8. FACTORS AFFECTING THE RATE OF CARBONATION

Following factors influence the rate of carbonation:

1. **Relative humidity.** Higher the relative humidity, higher the rate of carbonate. Higher rate of carbonation taken place at a relative humidity of 50 to 70%. At 100% humidity pores are saturated. with water, which reduces the diffusion of CO_2 into the paste to a great extent. On the other hand at 25% humidity there is insufficient water in pores to react with CO_2 to form carbonic acid.
2. **Time of exposure.** The rate of carbonation depth is approximately proportional to the square root of time. It doubles between 1 and 4 years and then again doubles between 4 to 10 years. However

periodic wetting of concrete by rains slows down the progress of carbonation significantly. Some authors have suggested the following relation between depth of carbonation and time.

depth of carbonation $C = \sqrt{K \cdot T}$

where

C = Depth of carbonation in mm

T = Time in years

K = A coefficient depending on environmental and physical conditions of concrete. It varies from 0.5 to 10.

3. W/c ratio. The depth of carbonation is directly proportional to w/c ratio *i.e.* higher the water/cement ratio, greater the depth of carbonation. It has been observed that depth of carbonation at w/c 0.4 is half that of at w/c ratio of 0.6.

4 Effect of cement content. Higher the cement content, lesser the depth of carbonation.

7.9. EFFECT OF CARBONATION

Following effects of carbonation have been observed:

1. It increases the weight of concrete.
2. The compressibility of cement paste is increased by carbonation.
3. It results in higher strength of concrete.
4. It results in reduction of permeability of concrete.
5. It neutralizes the alkaline nature of hydrated cement paste. It is the most important effect of carbonation.

7.10. ASSESSMENT OF CRACKS

For the assessment of cracks following information will be useful

1. Pattern of cracks
2. Type of cracks whether active or dormant
3. Old or new cracks
4. Whether it appears on the other surface of the member
5. Type of foundation used, soil condition, sign of movement of ground, if any
6. Observations on the similar structures in the vicinity.
7. Study of the method of construction, test results of the site, specifications of work etc.
8. Weather in which the structure has been constructed.

Thus cracking is a complex phenomenon and before taking any repair work in hand, the cause of damage must be identified clearly after careful investigations.

7.11. TYPE OF CRACKING

The cracking of concrete may be divided into the following categories:

1. Cracking of plastic concrete
2. Cracking of hardened concrete
3. Thermal cracking
4. Cracking due to chemical reactions
5. Cracking due to weathering
6. Cracking due to corrosion of reinforcement
7. Cracking due to poor construction practices
8. Cracking due to construction over loads
9. Cracking due to error in design and detailing
10. Cracks due to externally applied loads

7.11.1. Cracking of plastic concrete

Cracking of plastic concrete takes place when the exposed surfaces of the freshly placed concrete are subjected to very rapid loss of moisture due to low humidity, high temperature and high wind velocity. Due to the rapid loss of moisture, the surface of the concrete shrinks, developing tensile stresses in the concrete. Tensile stresses develop in the weak, stiffening plastic concrete due to the restraint developed by the surface below the drying layer of concrete. These tensile stresses develop shallow, short and discontinuous cracks running in all directions. Some times these cracks extend upto the free edges. In plain concrete slabs they are seen developing diagonally. The presence of reinforcement may change the direction of cracks as shown in Fig. 7.1.

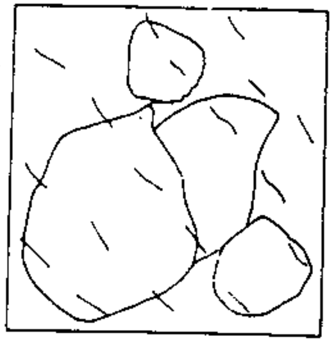


Fig. 7.1. Plastic shrinkage over

The plastic shrinkage generally takes place before the final finishing, prior the curing starts. These cracks often are wide enough on the surface. On large surface areas and horizontal surfaces as slabs or floors, they extend from few centimeters to many metres. Plastic shrinkage cracks may extend the full depth of elevated thin structural elements.

7.11.1.1. Remedial measures

The plastic shrinkage cracks can be controlled by reducing the relative volume change between the fresh concrete surface and surface below it by preventing the rapid loss of moisture due to dry winds, high temperature etc. The rapid loss of moisture can be controlled by saturating the air above the fresh concrete surface. This can be done by fog nozzles and covering the concrete surface with plastic sheets at the time of placing and finishing the concrete surface. The surface temperature may also be reduced by using sun shades. Wind velocity can be reduced by providing wind breakers. Further the concrete work may be done at night or in the afternoon period. Further horizontal work may be done after the completion of the vertical components as walls. After the formation of the cracks the best remedial measure is to seal them by brushing cement paste or low viscous polymer. This will prevent the entry of moisture or water into them.

7.11.2. Settlement cracks

These cracks develop due to the settlement of concrete after placement, compaction and finishing. Green concrete has a tendency to settle, especially in deep sections after it has started stiffening. If during this period the fresh concrete is restrained by previously laid concrete, or form work or reinforcement etc., these restraints may cause cracks, or voids near the restraining element as shown in Fig. 7.2.

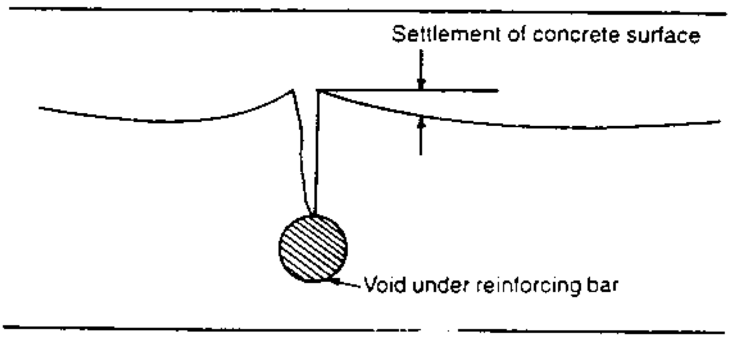


Fig. 7.2. Typical plastic settlement crack over reinforcement

7.11.2.1. Factors affecting the settlement cracks

Settlement cracks are affected by the following factors:

1. **Presence of reinforcement.** Greater the size of reinforcing bar, higher the cracking.
2. **Slump of concrete.** Greater the slump, higher the cracking.
3. **Cover thickness to reinforcement.** Lesser the cover thickness, greater the cracks.
4. **Compaction of concrete.** Insufficient compaction increases settlement cracking many folds.
5. **Flexible form work.** Highly flexible form work increases settlement cracking.

7.11.2.2. Remedial measures of settlement cracks

Settlement cracks may be checked by the following measures:

1. **Adopting small lifts.** Concrete should be poured in small thickness and each layer is compacted well before laying the next layer.
2. **Use of minimum w/c ratio.** Water cement ratio should be used minimum *i.e.* slump of concrete should be as low as practically possible.
3. **Cover to reinforcement.** The thickness of cover to reinforcement should be adequate.
4. **Time interval between placement and finishing.** Time interval between placement and finishing operation should be sufficient or adequate.

7.12. CRACKING OF HARDENED CONCRETE

Due to moisture movement, volume change is the inherent characteristic of the concrete. Upto 1.0% shrinkage of volume of cement paste has been observed due to loss of moisture from it. How ever the internal restraint provided by the aggregate reduces the magnitude of volume change upto about 0.05%. On the other hand an increase in moisture content tends to increase its volume change. If these volume changes are restrained by sub grade or by any part of the structure, then tensile stresses are developed.

When the tensile stresses exceed the concrete tensile strength, concrete cracks. The cracks may propagate at much lower stresses than are required to cause crack initiation.

On walls and slab surfaces cracking occurs due to drying shrinkage when there is higher water content in concrete of surface layers than the interior concrete. The surface cracking appears in the form of a series of shallow closely spaced fine cracks. The extent of drying shrinkage is mainly influenced by the type and amount of coarse aggregate and the amount of water content in the concrete. The shrinkage is found to decrease with the increase in the amount of coarse aggregate and reduction in water content. Further it has been observed that higher the stiffness of the aggregate, lower the shrinkage. Thus the concrete made with granite or basalt aggregate showed 50% less shrinkage than that of the concrete made with sand stone. Thus drying shrinkage can be reduced by using maximum practical amount of aggregate and an lower amount of usable water in the concrete.

In case of massive concrete elements, the tensile stresses are developed due to the differential shrinkage between the surface and interior of the concrete. Due to the quick evaporation of moisture from the outer surfaces of the concrete, the surface shrinkage is more than the interior surface and causes cracks development. In due course of time these cracks penetrate into the interior concrete.

7.12.1. Factors affecting the extent of cracking

The extent of shrinkage cracking depends upon the following factors:

1. Degree of restraint
2. Modulus of elasticity of concrete
3. Amount of shrinkage
4. Amount of creep

7.12.2. Remedial measures of shrinkage cracking

The shrinkage cracking can be controlled by the following measures:

1. By providing properly spaced construction joints.
2. By providing proper steel detailing
3. By the use of shrinkage compensating cement

7.13. CRACKING DUE TO CHEMICAL REACTION

Cement is one of the most important constituent of concrete. Usually cement is alkaline. On addition of water to the mix, the mix becomes strongly caustic solution due to the solubility of alkalis from cement. This caustic liquid attacks reactive silica to form alkali silica gel of un limited swelling type. This silica gel grows in size and its continuous growth exerts excessive pressure and causes cracking. In case of hardened concrete the alkalis of cement react with acidic compounds in the presence of moisture. The concrete matrix becomes weak due to these reactions and its constituents leach out. In case of hardened concrete silica contained in aggregate and alkalis from cement react to form a swelling silica gel and draws water from other portions of the concrete. This causes local expansion accompanied by tensile stress. If these tensile stresses are large, they damage the whole structure.

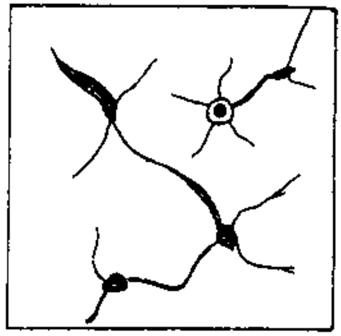


Fig. 7.3. Alkali aggregate reaction cracks

7.13.1. Symptoms of alkali silica reaction

Generally following two symptoms have been observed

(*a*) Development of map cracking as shown in Fig. 7.3.

(*b*) Leaching out of gel from cracks.

7.13.2. Remedial measures of silica-alkali reaction

Following measures may be adopted to control the silica-alkali reaction.

(*a*) Use of low alkali cement

(*b*) Proper selection of aggregate having low quantity of silica

(*c*) Use of pozzolona

7.14. ALKALI-CARBONATE REACTION

This reaction takes place between certain lime stone aggregate and cement as lime stone contains more silica. This reaction forms silica-alkali gel. The layers of gel occur between the aggregate particles and the surrounding of the cement paste. As discussed above, this gel forms map cracking.

7.14.1. Remedial measures

This problem may be minimized by adopting the following precautions:

(*a*) Avoiding the use of reactive aggregate

(*b*) Adopting use of low alkai cement

(*c*) Use of smaller size aggregate

7.15. SULPHATE EFFECT

When sulphate bearing water comes in contact with the concrete, the sulphate penetrates into the hydrated paste of cement and reacts with the hydrated calcium aluminate of cement and forms calcium sulphominate, which subsequently increases to a very large volume. The increase in volume causes high local tensile stresses resulting in deterioration of the concrete as shown in Fig. 7.4.

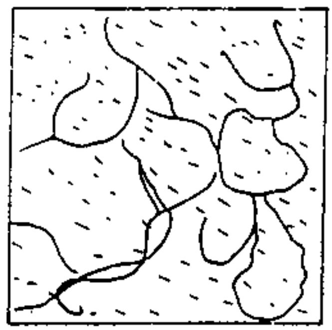


Fig. 7.4. Sulphate attack cracks

Remedial measures. The use of pozzolona cement resists the sulphate attack better.

7.16. EFFECT OF CARBON DIOXIDE

Already discussed under 7.7.4.

7.17. CRACKING DUE TO WEATHENING

Following environmental factors cause cracking of concrete.

1. Freezing and thawing 2. Wetting and drying 3. Heating and cooling

7.17.1. Freezing and thawing

The greatest damage to concrete is caused by freezing and thawing in all parts of the world except tropical. It is the most common weather related physical deterioration.

There are various explanations of hardened concrete damage due to freezing as follows:

(*a*) The voids available in hardened concrete are not sufficient to accommodate the additional solids produced due to the freezing of free water held in concrete. The ice formed due to freezing of free water exerts pressure on concrete, resulting in cracking of concrete. The damage is related to the degree of saturation.

(*b*) During depressing point of freezing, capillary water from the concrete comes out on the surface forming ice lenses parallel to the surface of concrete. This ice lenses forming exerts pressure on concrete resulting in its cracking.

(*c*) Moisture present in the capillaries of the concrete, develops water pressure in concrete on freezing, resulting in cracking of concrete. Similarly if the aggregate used is saturated above the critical degree of saturation, the expansion of absorbed water during freezing may cause cracking of the concrete.

7.17.1. Remedial measures

Following remedial measures may be taken against freezing damage

(*a*) Use of lowest practical water-cement ratio and total water content.

(*b*) Adequate use of air entrainment has been found effective to control the freezing damage.

(*c*) use of durable aggregate also proved useful to check the freezing effect.

(*d*) Adequate curing of concrete prior to exposure to freezing is important.

7.18. EFFECT OF WETTING AND DRYING, HEATING AND COOLING ETC.

When volume changes due to these effects are excessive, crack may develop resulting in the disintegration of the concrete. The fire and frost action also damage the concrete. The damage due to fire and frost appears in the form of general spalling and flacking of concrete from the surface. With the increase in temp above 300°C concrete gradually loses strength. If the aggregate used in concrete has high thermal coefficient of expansion, the damage will be greater. [For details refer page 473]

7.19. CRACKING DUE TO CORROSION OF REINFORCEMENT

The most common and frequent cause for the deterioration of concrete structures is due to cracking of concrete due to corrosion of reinforcement. Corrosion of steel takes place mainly in the presence of moisture and reaction with chloride ions. The depth of moisture penetration in off shore concrete structures can be assumed as given by the following relation.

$$d = \sqrt{2\,K\,h\,t}$$

where d = depth of moisture penetration in mm

K = Coefficient of permeability of concrete

h = Head of water in metres

t = time in year.

When reinforcing steel comes in contact with moisture, the steel reacts with the oxygen of the moisture forming iron oxide and hydroxide. The volume of these oxides is much greater than the volume of the original metallic ions. Similarly chlorine ions form HCl when react with steel in the presence of moisture. The effect of both the reactions is in the increase of volume, which causes high radial brusting stresses around the reinforcing steel bars, resulting in local radial cracks. These splitting cracks may propagate along the bars resulting in the formation of longitudinal cracks parallel to the reinforcing bars or spalling of concrete as shown in Fig. 7.5. These cracks provide easy passage to moisture, air or oxygen, fumes containing chlorides etc., helping to corrosion to continue

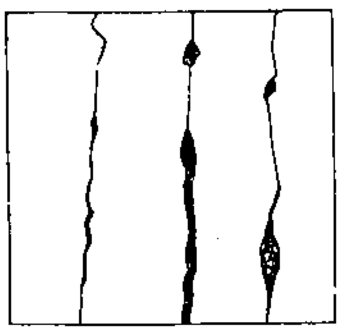


Fig. 7.5. Reinforcement corrosion crack

and causing further cracking of concrete. It has been observed that more than 40%. Concrete structures fail only due to the corrosion of reinforcing steel. Thus for the durability of concrete structures chloride effect on concrete is very important.

7.19.1. Protective measures

Reinforcement corrosion can be checked by adopting following measures:

1. The best control measure of corrosion and splitting of concrete is to keep the permeability of concrete as low as possible.
2. To keep the protective cover to reinforcement of sufficient thickness as suggested by IS 456-2000. The cover thickness is given in the following table for different conditions of exposure.

Table 7.3. Nominal cover to meet the durability requirements as per IS 456-2000

S. No.	*Exposure condition*	*Naminal cover to reinforcement in mm not less than*
1.	Mild	20
2.	Moderate	30
3.	Severe	45
4.	Very sever	50
5.	Extreme	75

3. In very sever exposure conditions, protective coating to reinforcement may be applied. A simple cement slurry coating of reinforcement is a cheap method for temporary protection of steel against rusting.

(*b*) The reinforcement bars may be dipped in molten zinc.

In this process a thin coating of zinc takes place around the steel bars. This zinc surface reacts with the calcium hydroxide present in the concrete to form a protective layer and prevents the corrosion of steel.

7.20. CRACKING DUE TO FAULTY CONSTRUCTION PRACTICES

Cracking in concrete structures also develops due to faulty practices adopted during the construction period such as follows:

1. **Adding more water than specified.** During construction to improve the workability and ease in compaction, generally some more water is added which not only reduces the compressive strength of concrete but also increases drying shrinkage and settlement.
2. **Early stopping of curing.** It will result in low strength development, higher shrinkage, incomplete hydration of cement. Thus it affect long term strength of concrete and durability of structure.
3. **Inadequate compaction or lack of form support.** 1.0% reduction in compaction will result 5% less compressive strength. These factors will also result in settlement cracks before it has developed sufficient strength to support its own weight.
4. **Improper location of construction joints.** Improper location of construction joints will result in cracking at the place of weakness.

7.21. CRACKING DUE TO OVER LOADING DURING CONSTRUCTION

The loads induced in the structure during construction may be far more serve than those experienced in service. These conditions may occur at the early ages, when the concrete is most susceptible to damage and often results in permanent cracks. Usually following errors are observed.

(*i*) Precast members are not properly supported during transportation and erection.

(*ii*) Use of arbitrary lifting points.

(*iii*) A heavy element is lowered too fast and then suddenly stopped will cause an impact on the element which may be many times more than the dead weight of the element.

(*iv*) Placing of equipment and storage of material during construction may result more severe loading conditions than for which the structure has been designed.

7.22. CRACKING DUE TO ERROR IN DESIGN AND DETAILING

The design and detailing errors that may cause unacceptable cracking are as follows:

1. Improper selection and/or detailing of reinforcement.
2. Use of poorly detailed re-entrant corners in walls, slabs and precast members.
3. Restraint of members subjected to volume charges due to variations in temperature and moisture
4. Lack of adequate contraction joints.
5. Improper design of foundation results in differential settlement of the structure.
6. Re-entrant corners. These corners provide a location for stress concentration and thus are the main locations for initial cracks, as in the case of window and door openings in concrete walls and beams.
7. Tieing a non structural member with light reinforcement with the rest of the structure to carry a major portion of the load.

7.22.1. Remedial measures

Following measures may be helpful to check these defects:

1. Provision of additional properly anchored diagonal reinforcement.
2. Provision for sufficient expansion and contraction.
3. Continuous inspection in all stages and remedial measures adopted for the removal of defects such as cracks.

7.23. THERMAL CRACKING

Thermal changes due to heat of hydration is important only for few days in case of normal structures such as buildings, but in case of mass concrete such as dams, bridges, etc. it may last for long. The temperature differentials associated with the heat of hydration affect only mass concrete such as dams, piers, large columns etc. where as temperature differentials due to changes in ambient temperature can affect any structure such as bridge decks, air field pavements, roads etc. and develop cracks.

7.23.1. Micro cracks

Very fine cracks are known as micro cracks. These cracks remain stable upto about 30% or more of the ultimate load and then start to increase in width, length and number. They are not a potential danger to the structure.

7.23.2. Crack width

It has been observed that crack width at surface of the concrete plays an important role in the durability of concrete structures. IS 456-2000 has specified crack width as follows:

1. In general, the width of surface crack should not exceed 0.3 mm in members, where cracking is not harmful and does not have any serious adverse effect upon the preservation of reinforcing steel nor upon the durability of concrete.
2. Cracking in tensile zones of members is harm full either due to exposure to the effect of weather or continuously exposed to moisture or in contact with soil or ground water. In such situations the maximum upper limit of crack width is suggested as 0.2 mm.
3. For aggressive environment such as severe category of exposed conditions, the surface width of cracks should not in general exceed 0.1 mm.

Some specifications limit the crack widths at points near the main reinforcement, instead of the surface. International prestressing Federation has recommended the maximum crack with at the main reinforcement to be 0.004 times the normal cover thickness. If the thickness of normal cover is taken as 50 mm, then the crack width near the main reinforcement comes to be $0.004 \times 50 = 0.2$ mm.

7.24. EVALUATION OF CRACKS

Before starting repair of cracked structures, the knowledge of location and extent of cracking is essential for the effective and proper repair. The objectives of repair are restoration, enhancement of durability, structural strength, functional requirements and aesthetics. Following are the purposes of the crack evaluation.

1. To identify the cause of cracking.
2. To assess the safety and serviceability of the structure.
3. To establish the extent of cracking.
4. To establish the likely extent of future deterioration.
5. To study the feasibility of various remedial measures.
6. To make the final assessment of serviceability after repairs.

7.24.1. Identification of weak spots

Apart from visual inspection, hammering the surface with light hammer and listening the sound from the area is one of the simplest method of identifying the weak spot as dull sound indicates hollowness of the surface. The suspected areas are then opened up by chipping the weak concrete for further assessment.

The comparative strength of concrete in the structure can be assessed by non destructive tests and tests on cores taken from the concrete structure to a reasonable accuracy. Commonly used non destructive tests are rebound hammer test and ultra sonic pulse velocity test.

7.24.2. Visual examination

The possible causes and nature of cracks can be ascertained by visual examination. The appearance of the concrete surface may suggest the possibility of chemical attack by the general softening and leaching of matrix. In case of sulphate attack the surface of concrete becomes white. The rust stains are the indication of corrosion of reinforcement or contamination of aggregate with iron pyrites. The discoloration or presence of dirt on the broken surface of the cracked concrete gives an indication that the crack is quite old. The general flaking of the exposed surface of the concrete suggests frost damage. The colour of concrete damaged in fire hazard indicates the maximum temperature reached.

The crack pattern is also useful in evaluating the cracks . A mesh pattern suggests the drying shrinkage cracking. The surface crazing indicates either frost attack or alkali-aggregate reaction cracking. Generally it is frost cracking. The cracks caused by unidirectional bending will be widest in the zone of maximum tensile stress and will taper along the length. The cracks caused by direct tension roughly will be of uniform width.

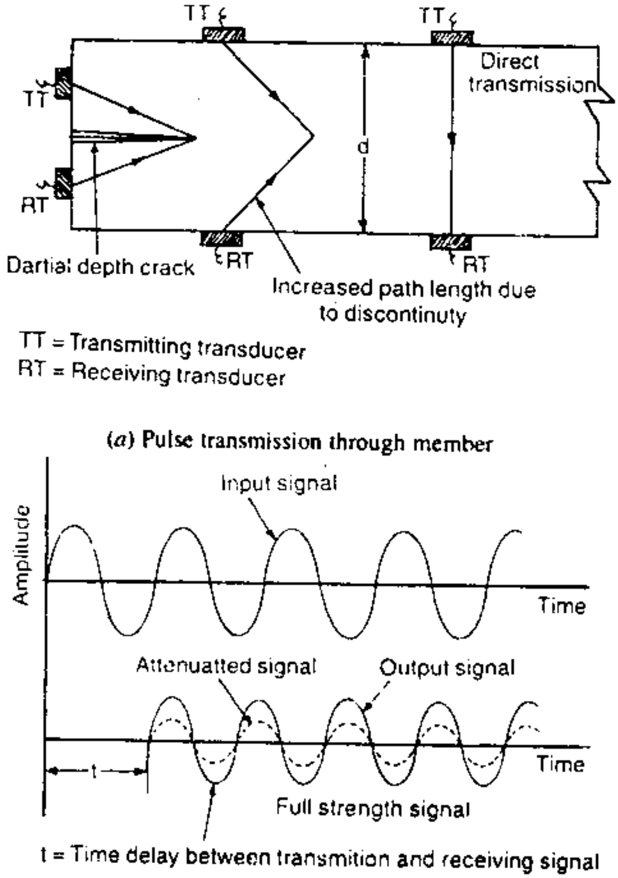
The width and location of cracks should be noted on the sketch of the structure. The width may be measured with the help of an hand held microscope with an accuracy of 0.025 mm. Location of spalling, exposed reinforcement, rust staining and surface deterioration etc. should be noted on the sketch.

7.25. Non destructive testing

For determining the accurate and reliable information about the presence of internal cracks and voids, depth of penetration of cracks which are visible on the surface, non destructive test may be used.

The most common technique to detect the crack, using ultrasonic non destructive test equipment is through transmission testing using *Soniscope*. The method consists of transmitting a mechanical pulse to one face of the concrete member and receiving it at the opposite face and calculating the pulse velocity from the time taken by the pulse to pass through the member and the distance between the transmitting and receiving transducers. If there is internal crack, the pulse will travel at the edge of the crack, increasing the path length of the pulse. The increase in path length of the signal, as it passes around the end of the crack there will be a significant change in the pulse velocity. Generally higher the pulse velocity, better the quality and durability of the concrete.

If the signal is displayed on the oscilloscope, the internal discontinuities can also be detected by weakening or reducing the strength of the signal. If no signal arrives at the receiving transducers, it indicates an significant internal discontinuity such as void or crack. The extent of discontinuity can be assessed by taking reading at a series of positions on the member. The result of ultrasonic testing should be interpreted continuously. Generally with fully saturated cracks the ultrasonic testing will be in effective. The arrangement of the test is shown in Fig. 7.6.



(b) Oscilloscopic signal

Fig. 7.6.

7.25.1. Surface hardness test

It is an other important test to determine the strength of concrete. The equipment used for this test is called schmit rebound hammer. It is a light weight and easy to operate equipment. The weight of the hammer is about 2 kg and its impact energy 2.2 N-m (Newton matre).

The equipment is shown in Fig. 7.7. All parts of the equipment are shown in the figure.

It consists of a spring controlled hammer mass that slides on a plunger with in a tubular casing as shown in the Fig.

Working. When the plunger is pressed against the surface of the concrete, the mass rebounds from the plunger. it retracts against the force of the spring. The spring is released automatically when fully tensioned, causing the hammer mass to impact against the concrete through the plunger. When the spring controlled mass rebounds, it takes a rider with it, which slides along a graduated scale and can be seen through a small window in the side of the casing. The rider can be held in any position on the scale by depressing the locking button to record the reading. The distance travelled by the mass is called rebound number. It is indicated by the rider moving along a graduated scale.

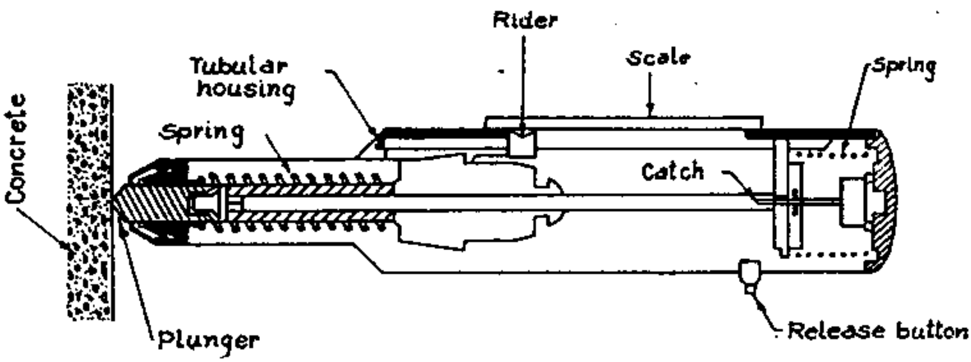


Fig. 7.7. Schmidt hardness tester hammer

The plunger is pressed hard and steadily against the surface of concrete to be tested at right angles till

(a) Instrument ready for test

(b) Body pushed towards test object

(c) Hammer is released

(d) Hammer rebounds

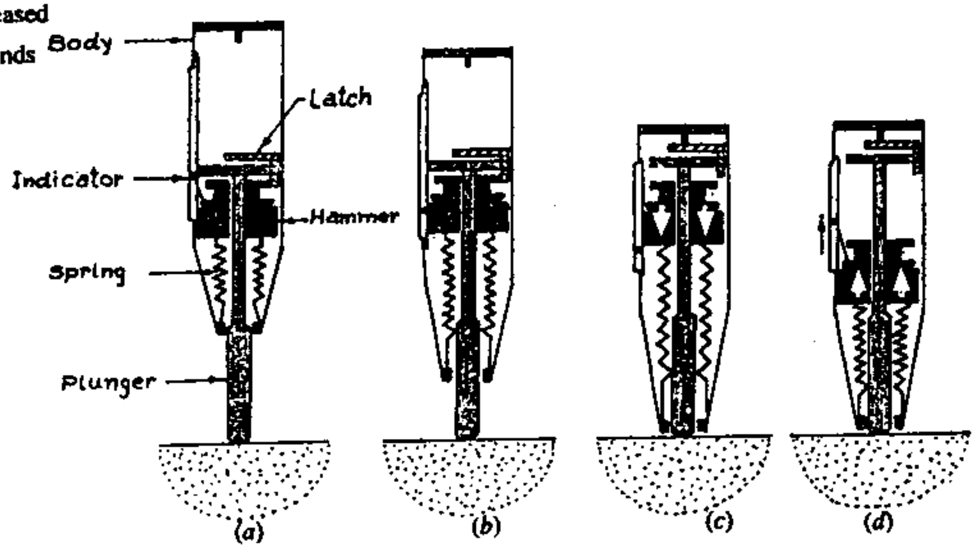


Fig. 7.8. Cross section of rebound hammer showing operating principle

the spring loaded mass is triggered off from its locked position. After the impact, the scale index is read, while the hammer is still in test position. This hammer can be operated vertically or horizontally. Fig. 7.8 shows operating principle.

7.26. SELECTION OF REPAIR PROCEDURE

The repair of concrete structures may vary to a great extent, from giving it a just superficial treatment to the total replacement. By proper investigations a number of structures have been renovated economically, though they were damaged beyond repairs. An appropriate repair method can be selected depending upon the cause, extent of damage, importance of the structural member and its location. The success of the repair will depend upon the proper choice of the method. The procedure should be selected to accomplish one or more of the following objectives.

(*a*) To improve its durability

(*b*) To improve the appearance of concrete surface

(*c*) To increase its functional performance

(*d*) To increase the stiffness of the member

(*e*) To increase the load carrying capacity of the structure

(*f*) To increase the water tightness of the structure

(*g*) To protect the reinforcement from corrosive materials etc.

Depending upon the extent and nature of the damage one or more methods may be adopted. For example to increase the tensile strength of the cracked member, epoxy grout may be used alongwith additional reinforcement. If further cracking is not anticipated, then epoxy injection can be used to restore flexural stiffness of the member. In water retaining structures cracks likely to cause leakage should be repaired, unless the leakage is insignificant. When the appearance of the cracks becomes un acceptable, they should be repaired.

The long term success of the repair procedure mainly depends upon the nature of cracks as well as their cause. If the cracks are developed due to continuing settlement of the foundation, in that case repair will not be effective till the settlement problem is tackled.

7.27. TREATMENT OF CRACKS

The treatment of cracks of concrete structures is carried out in the following two stages:

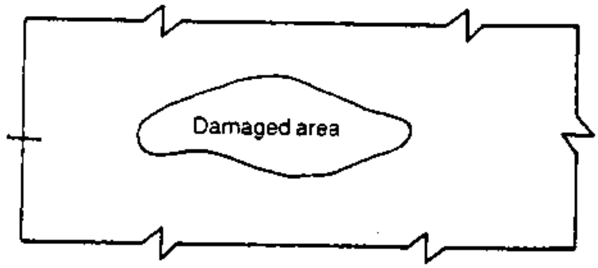
1. Preparation of surface for repair
2. Application of repair material

1. Preparation of surface. Before the execution of any repair, one of the essential requirements common to all repair techniques is to remove the damaged concrete with the help of proper tools and equipments. While removing the damaged portion, care should be taken that no damage is caused to the un affected portion. For preparing the surface for repair following steps are adopted.

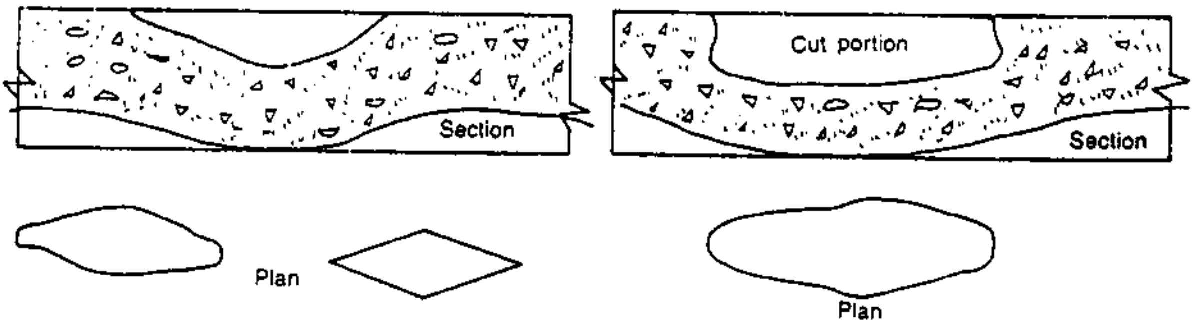
(*a*) Complete removal of damaged portion.

(*b*) Under cutting along with the formation of smooth edges.

(*c*) Removal of cracks from the surface.



(*a*) Plan of damaged area



(*b*) Incorrect method of cutting damaged part (*c*) Correct method of cutting

Fig. 7.9. Preparation of surfaces by cutting out the damaged portion

(*d*) Formation of well defined cavity with rounded inside corners. The incorrect and correct cavity of the damaged area is shown in Fig. 7.9 (*b*) and (*c*) respectively. The plan of damaged area is shown in Fig. 7.9 (*a*)

(*e*) Providing rough and uniform surface for repair.

The surface so prepared should be clean, dry, strong and free from laitance

(*a*) Clean surface. Means that there should be no foreign matter such as loose particles, dirt, grease, oil, paint, resins etc. on it.

(*b*) Dry surface. Means that no free water should be there on the surface.

(*c*) Free of laitance. Laitance is a very thin layer of high water cement ratio gel, which appears on the surface during concrete compaction. The laitance is quite weak and has poor adhesion with the parent concrete. Thus it should be removed before laying the repair material on the surface. Strong concrete below the surface refers to the ability of concrete to resist fractures due to the stresses developed on it due to repair materials etc.

Dust and other foreign matter present on the surface of the concrete usually can be removed by wire brushing. If this method is not found satisfactory, then grinding or sand blasting/steel shot blasting and scarifying may be adopted. These are the common methods of dust removing.

For cleaning a concrete surface, the sand or steel shot blasting is the most effective method. In some cases low pressure water jet blasting has been found most effective. The presence of oil substances on the concrete surface can be detected by sprinkling water on the surface. If the water stands in droplets with out spreading out immediately, it indicates the presence of oily substances on the surface which will interfere with the bonding of repair materials.

The grease, oil and animal fats etc. can be removed by scrubbing the surface with caustic soda solution, detergents or trisodium phosphate. The process is known as chemical cleaning. During the washing procedure, a vigorous scrubbing action should be carried out with stiff broom. To remove all traces of loosened oil as well as cleaning solution, the surface should be washed off thoroughly with a pressure hose.

If on scrapping the surface with a knife blade, a fine powdery substance is observed on the surface, it indicates the presence of laitance on the surface, which may be removed by acid itching. In case acid itching method is adopted, then the surface should be pre cleaned by removing any built-up of oil, grease, and dirt etc. In case the presence of chlorides in concrete is not objectionable, a 10% solution of hydrochloric acid (HCl) in water should be applied in the ratio of 1:15 litre/m^2 of the surface. A stiff broom or brush should be used to spread and vigorously scrub the acid solution uniformly on the surface. After the subsidence of foaming action, the surface should be washed off thoroughly with water and still scrubbing it with stiff broom. This is necessary to remove the salts which might have been formed due to the reaction of the acid with the concrete. The presence of acid after washing should be checked with the litmus paper. In case, the presence of chloride is objectionable a 15% solution of phosphoric acid can be used. The presence of acids from other sources may also be ascertained by placing litmus paper in a thin film of water on the surface of concrete. A pH value blow 4 indicates the high value of acidity of the concrete for the successful application of repair.

7.28. REPAIR PROCEDURES

The repair of cracked/damaged structures can be classified into two categories as follows:

1. Ordinary procedures 2. Special procedures

7.28.1. Ordinary procedures

The fine or superficial cracks can be rectified by treating the surface with soft distempers, white wash or silicate cement paints etc. The methods and materials for the repair of patches of damaged concrete in the structure are discussed below.

The repair can be carried out in four steps as follows:

(*a*) **Preparation of surface.** The cracked and damaged areas are cut out from the solid concrete. The area to be cut out should be marked with a saw cut to a depth of about 5 mm to show neat edges. The edges should be cut as straight as possible and at right angled to the surface with corners rounded with in holes. The edges should be slightly under cut to provide keys at the edges of the patch. To prevent the edges from breaking under load, the thickness of the edges should not be less than 25 mm. All the loose and unsound concrete should be removed. All the loose material should be cleaned and the surface washed off before starting the actual patching work. Excess water from the cavity should be removed. To obtain a good bond, the surface of the concrete should be coated with a thin layer of neat cement slurry before placing patching concrete.

If the reinforcement has been corroded, then the concrete should be removed from the considerable area to ensure that all corroded area is exposed for cleaning with ease. Carbonated or chloride contaminated concrete in contact with reinforcement should be removed and in its place fresh concrete or impermeable resin compound is placed. After cleaning the reinforcement, corrosion controlling chemicals such as phosphates may be applied on the exposed surface of the reinforcement. In case of cement based repairs a slurry coating of polymer latex and cement can be used. Resin based coatings are suitable for both cement based and resin based repair materials.

(*b*) **Selection of materials.** The repair materials should be selected in such a way that the mechanical properties of the repair materials should be similar to those of structure being repaired. The cement based repairs can provide fire resistance, while resin soften at relatively low temperature. For conventional repairs, the cement based materials to be used for patch work may either be mortar or concrete depending upon the extent of repair.

7.29. APPLICATION OF MATERIALS

For filling or applying the materials generally following methods may be adopted:

1. Dry packing
2. Concrete replacement
3. Mortar replacement
4. Grouting
5. Large volume prepacking of concrete
6. Shot creting or Guniting

After preparing the surface, a bonding coat should be applied to all the cleaned exposed surfaces. It should be done with a minimum delay. The bonding coat may be of cement slurry or a paste of equal amount of cement and sand mixed with water to a fluid consistency. Adequate preparation of surface and good workmanship are the ingredients of efficient and economical repairs.

1. Dry packing. In this method low water content mortar is placed on the prepared surface. To produce an intimate contact between the mortar and the existing surface, the mortar is well rammed. Due to the low w/c ratio of the paste, the shrinkage of the mortar is less and it provides a durable, strong and water tight patch.

For repair work usually cement and sand mortar in the proportion of about 1:2.5 to 1:3 is used. Usually sand passing 1.18 mm I.S. sieve is used. However coarse concreting sand may also be used, but for a smooth finish of the surface, for the final layer, fine sand should be used. The first layer of repair material should be applied immediately after the application of bonding coat while bonding coat is still wet. Provision of some mechanical anchorage for the patch work should be provided. It may be done by providing dowels drilled and grouted into the surrounding concrete. The w/c ratio of the mix should be chosen carefully as excess water will increase the shrinkage which may loosen the replaced material, whereas less water will not make a solid, sound and strong pack. The w/c ratio of the mix should be such that the mortar could be moulded into a ball by hand and at the same time it does not exclude water, but leave the hand damp only.

To minimise the shrinkage in place, the mortar should be left for 30 minutes after adding water and then remixed before it is used. The repair material should be filled in place properly and well compacted. The thickness of the compacted layer should be about 10 mm. The next layer normally should be applied after the preceding layer has developed sufficient strength to support the next layer. In order to obtain a good bond, the preceding layer should be scratched before placing the next layer. Each layer is compacted well over the entire surface with the help of 200 to 300 mm long hard wood stick and upto 25 mm diameter hammer. The last layer should be struck flush with the surface. There should be no time lag between the layers. In case there is a delay in between the layers, a fresh bonding coat should be applied when the work resumed. The mortar may be finished by placing a flat hard wood against the mortar and strike it several times with a hammer. The patch work is cured by covering it with a absorbent material that keeps it damp, then it may be covered with polythene sheets sealed at edges. Shading from sun should be done. After the completion of the whole patch work, curing membrane may be sprayed.

For the repair of in active or dormant cracks, the portion of the crack adjacent to the surface is widened to form a slot of 25 mm wide and 25 mm deep with a power driven saw tooth bit. The base of the slot should be slightly greater than the surface width. Now the slot is thoroughly cleaned and dried. After the slot is dry, the bonding coat is applied prior to placing the repair material. After finishing the surface it should be moist cured by tying wet burlaps along the length of the crack.

2. Concrete replacement. Generally this method is used for large and deep patches as encountered in the repair of old and deteriorated portions of concrete structures, where concrete is to be replaced to a minimum depth of 15 cms. Usually this method is adopted for the repair of walls, piers, kerbs, parapets and for refacing of walls and relining of channels etc. This method particularly has been found suitable for situations where the hole extends through out the concrete section or where the surface area of the hole is at least 0.09 m^2 with a minimum depth of 10 cms for plain concrete. For R.C.C. the minimum area of the hole should be 0.045 m^2 and the depth little more than the diameter of reinforcing bars.

Procedure. The defective concrete is removed upto the sound surface and reinforcement is cleaned. In case it is not possible to place the repair material immediately after cleaning the reinforcement, then a protective coating to reinforcement must be given to protect it form corrosion.

In case of plain concrete, the defective area is prepared as discussed above in sec. 7.28. In case of R.C.C. a minimum clearance of about 25 mm around the each exposed reinforcing bar should be provided. In case of wall repairs, the top of the hole should be cut to a fairly horizontal line with a 1 in 3 upward slope from back towards of the face to prevent formation of air pockets at the top during vibrations. The bottom and sides of the hole should be cut sharp and approximately square as shown in Fig. 7.10. All interior corners should be rounded off to a minimum radius of 25 mm. For repairing the wall more than 0.5 m, the back formwork is built in one piece and the front formwork is made in horizontal sections to place concrete conveniently in about 30 cms deep layers or lifts. All joints of formwork should be mortar tight. Before placing the front sections of the form work for each lift, the surface of the old concrete should be coated with cement grout of the same w/c ratio as that for the mortar in the replacement concrete. To reduce the shrinkage there should be a minimum time interval of 30 minutes between the placement of two lifts. The mix proportion and w/c ratio of the replacement concrete should be the same as used in the structure. The water content should be used as low as possible. If possible, the compaction of the repaired material should be done by internal vibration. In case external vibrations are used, then care should be taken that the seals between the form work and the existing concrete are not damaged. The stripping period of the form work may vary from 20 to 48 hours depending upon the location and extent of repair.

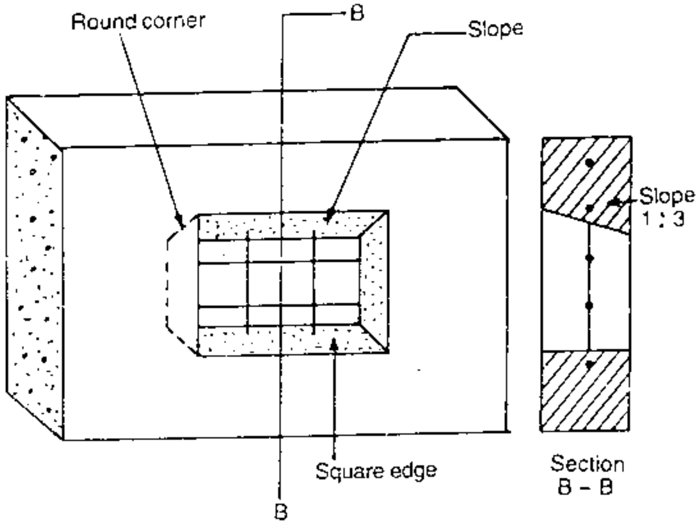


Fig. 7.10. Repair by concrete replacement method

3. Mortar replacement. This methods is useful for cavities too wide for dry pack and too shallow for the concrete replacement. Generally this method is used for shallow depressions not deeper than the thickness of side concrete to the nearest reinforcement bars near the surface. For replacement of deteriorated concrete this method is useful only for small patches. The mortar replacement can be done by hand or by using a small pressure gun.

It is preferable to pre shrink the repair mortar by mixing it to a plastic consistency as long in advance as cement permits. The pre shrinking time ranges from 60 to 120 minutes. For hand placing the mortar should be of the same proportion as that of mix of the structure. In case of pressure gun, the mortar should be of cement sand proportion of 1:4.

In case, the hole to be repaired is deeper than 25 mm then the mortar should be laid in layers not exceeding 15 mm in thickness to avoid sagging and loss in the bond. The subsequent layers may be applied at an interval of 30 minutes or more. The final layer should be placed slightly overflowing the hole and struck off level with the surface.

4. Grouting. The deep and wide cracks may be repaired by filing them with either neat cement grout or cement sand grout depending upon the width of the crack. The cement sand ratio may be kept as 1:4. The w/c ratio should be kept as low as practicable to maximise the strength and minimise the shrinkage. Water reducing agent may also be added to improve the properties of the grout.

Procedure. The surface along the crack is cleaned first and then built up grout ports in the form of nipples or seals are provided at intereals. Afterwards the crack is sealed between the ports with a cement paint etc. Before applying the grout, the seal is tested. After testing the seal, the whole area is filled with grout mortar. After the crack is filled, the pressure should be maintained for several minutes to ensure good penetration. This method particularly is useful for the wide cracks in concrete walls and gravity dams etc. For narrow cracks in concrete, chemical grouts consisting of solutions of two or more chemicals that can combine to form gel and solid precipitate can be used advantageously. The chemical grouts are also useful in moist conditions and provide wide limits of control of gel time.

5. Large volume pre packed concrete. This method of repair is used for the repair of old works and usually is adopted in situations where placing of concrete by conventional methods is difficult. This method is used advantageously for the repair of larger jobs, under water placement, repair of tunnel lining, resurfacing of dams, spillways, retaining walls, piers etc.

Procedure. A well designed and constructed form work is placed around the surface to be repaired. This form work is filled with clean and well graded coarse aggregate. The aggregate is well compacted in the form work and wetted after compaction. Now the grout of designed proportion of cement, fine sand and some pozzolonic material is pumped into the voids of the compacted mass of aggregates. The water content of the grout should be as low as practicable for the desired fluidity. Some admixtures to the mixing water may be added to increase the fluidity of the grout and to control early stiffening of the grout and mixing water. The form work must be closed type, open only at the top to avoid trapping of air pockets. The form work may be of conventional rigid type that either encloses the member to be repaired or sealed to it at its edges. To monitor the progress of aggregate grouting, some times transparent panels are provided. The grout lines are attached to inlets or injection points fixed to the form. The pumping of the grout should be started from the lowest point as shown in Fig. 7.11 and proceed upward in order to prevent the formation of the air pockets. In case complete filling from bottom requires very high injection pressure, more than one injection point, may be built into the form work at different levels. The spacing between grout lines should not be more than 1.5 m centre to centre and the grout level in the mass of aggregate should increase uniformly as determined by the observations of grout levels in the grout pipes. In the grout pipes above the level of the out lets, a positive head of at least 1 to 2 m should be maintained. The injection of the grout should be smooth, and un interrupted operation. After the forms have been filled, positive head should be maintained till the grout has set.

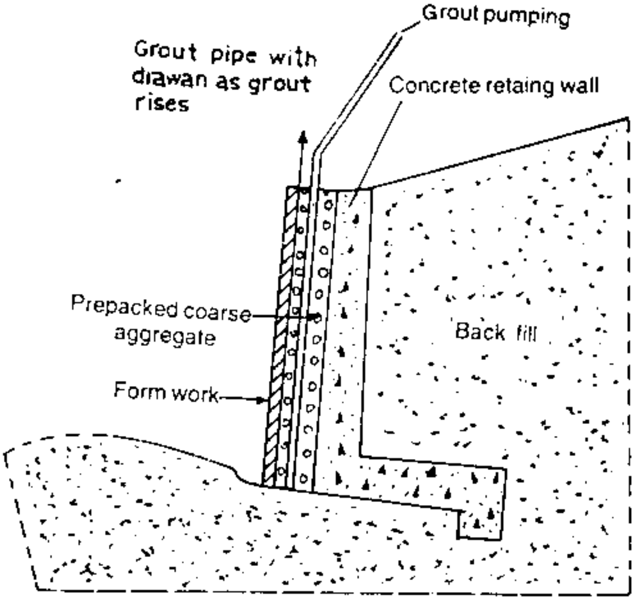


Fig. 7.11. Pre packed concrete repair of a retaining wall

6. Sprayed Concrete or Shot creting. Shot creting is a process of conveying concrete or mortar through pressure hose and applied pneumatically at high velocity on the surface. The application of shot crete has been found useful in several major repair works due to ease with which it can be applied on vertical, horizontal or overhead surfaces. Mostly it is used for tunnel lining and for protective covering of soft rocks, for laying new canal lining or its repair, reservoir lining, for stabilizing rock slopes and repair of old and damaged concrete works.

The objective of this type of repair is to replace the lost or removed concrete and to increase the effective cover to the steel reinforcement or to protect against future damage by adding additional concrete.

Preparation of surface

All the affected or damaged concrete should be removed upto the sound and strong surface. The un damaged surface also must be prepared thoroughly roughening it to remove all original cement laitence, surface deposits and impurities. For the development of good bond, the prepared surface must be rough, sound and homogeneous.

When a large portion of the structure is defective, the whole of the accessible external surface should be encased with a specified minimum thickness of sprayed concrete, which should be brought out to uniform profile any eyeable lines by additional infilling of the area from where damaged concrete has been removed. This can be achieved by applying sprayed concrete over the areas of un damaged concrete also. The surface should be prepared as discussed above.

In case the sprayed concrete is with out polymer admixtures, then generally a welded steel fabric or steel fibres are incorporated in it to minimise the risk of development of cracks of sufficient size, which may allow penetration of air and water. The incorporation of steel fabric encourages the development of a large number of very fine and insignificant cracks. A typical fabric may be in the form of a mesh made of 3 to 4 mm diameter high tensile bars welded at a spacing of 75 to 100 mm. With the use of such a fabric the minimum thickness of sprayed concrete should be 50 mm, which will provide adequate cover to the fabric it self. The fabric reinforcement should be securely fixed by nails driven into the plugs set in parent concrete and bent over to grip the reinforcement. The spacers should be fixed to hold the reinforcement at 12 mm from the surface. The fixing points should be close enough, so that the mesh does not bulge out during the concrete spraying. The thickness of sprayed concrete may be reduced if non corroding steel fabric is used. The minimum thickness of sprayed concrete may vary from 30 mm to 50 mm.

Holes of at least 20 mm wide and 20 mm deep should be cut at the perimeter of the area to be sprayed with the help of pneumatic tools. The edges of the steel fabric will stuck in these holes to provide sound finish at these points. To check the correct thickness, light timber profiles should be fixed securely at correct positions.

Specifications. The maximum size of aggregate to be used in sprayed concrete should be 10 mm. It should be clean and well graded from 10 mm to 1.18 mm, but there should be no excess of fine particles. It should be free from dust, silt and clay. The typical cement aggregate ratio may vary from 1:3.5 to 1:4. The strength of concrete at 28 days should be about 30 MPa. Where ever possible the construction joints should be formed at a slope, not at right angle as in the case of cast concrete. Normally the face of the sprayed concrete is carried forward at a slope to form the construction joint sloping. To get a good bond at the joint the interface of the joint must be cleaned of rebound, overshoots and laitance etc.

In case defects are in isolated areas, patch repair may be adopted, but the repair should extend at least upto 300 mm on the sound concrete at the perimeter of the defective areas and should terminate in chases or holes. Rectangular patches are preferable to irregular shaped patches.

The spraying should be carried out with the nozzle held at right angle to the interface and at such a distance that concrete compacts effectively. Usually 1 m distance from the face is sufficient. To form an even layer on the surface, the nozzle should be fanned from side to side and up and down. If there is any unevenness in the spray of the material, the nozzle should be turned away from the work till the spray becomes even again. The thickness of layer at a time should not be more than about 50 mm on vertical surfaces and 25 mm on overhead surfaces. The surface of each layer may be slightly trimmed with the edge of steel float and must be wetted again once set before applying the next layer.

Curing. The curing of sprayed concrete is more important even than that of conventional cast concrete as water loss in thinner sections may take place easily and cause more serious adverse effects on its properties. The curing may be done by fine water spray, by tieing wetted hessian etc. Curing compounds may also be used.

Curing of repair work. Curing of patch material needs much more care than that of a complete structure due to the tendency of old concrete to absorb moisture from the replaced material. Same curing methods may be adopted as used for curing of conventional concrete.

7.30. SPECIAL PROCEDURES

The polymers are of recent origion. They have been introduced recently in concrete technology for multipurpose application in the repair and maintenance of concrete buildings and other structures. For concrete repairs mainly following two different types of polymers are used. Polymers may be natural or artificial compounds made from large sized molecules.

(*a*) Polymers used as modifiers for cementitious systems.

(*b*) Reactive thermosetting resins.

For the repair of active as well as dormant cracks, epoxy, (a resin) mortars consisting of an epoxy, hardener, and sand have been found effective to seal the cracks. The epoxy resins and polymers possess excellent adhesive and sealing properties, but the cost of this type of repair is very high.

7.30.1. Polymer modified cementitious system

Normally polymers used as admixtures for cementitious systems are latex (a milky white disperson in water). These polymers are used to gauge the cementitious mortar as a whole or as a partial replacement of mixing water. The polymer latex forms a net work of polymer strands inter penetrating the cement matrix and improves the structural properties and reduces permeability of the mortar. Such mortars provide the same alkaline passivation protection to steel as conventional materials do. These mortars can be placed in a single layer of 12 to 16 mm thickness and provide adequate protective cover.

7.30.1.1. Functions of Polymer latex

The functions of the polymer latex are as follows:

1. It acts as a water reducing plasticizer.
2. It provides a good bond between repair mortar and concrete surface to be repaired.
3. It improves the tensile and flexural strength of the mortar.
4. It reduces the permeability of the repair mortar against water.

7.30.1.2. Modifiers for Cementitious systems

Following types of polymer latexes have been used as modifiers for cementitious systems:

1. Polyvinyl acetate (PVAC)
2. Styrene butadiene rubber (SBR)
3. Polyvinyl dichloride (PVPC)
4. Acrylics and modified acrylics

Generally styrene acrylics, polyvinyl dichloride are not recommended for repair mortars for reinforced concrete works. Polyvinyl acetate (PVAC) latexes are widely used as general purpose bonding aids and admixtures for building industry for interior applications. In concrete repair mortars styrene butadiene rubber (SBR) acrylic and modified acrylic latexes most commonly are used as admixtures.

7.30.2. Resin based materials

The resin mortars are used for repair in locations where the area to be repaired comparatively is small and the cover is less than 12 mm. In case of resin mortars the protection of reinforcement depends upon the total permeability of the cover. In this case the surface of the reinforcement should be prepared to a very high standard. The resin mortars are made with reactive resins and carefully graded aggregates.

Usually in concrete repair works, epoxy resin mortars are used. The polymer and acrylic resin based mortars are used for small area repairs where very rapid development of strength is required. In most of the repair situations the polymer based repair material is bonded directly to the concrete or other cementitious materials. Thus it is important that the mechanical and physical properties of polymer repair mortar and concrete should be similar. The polymer bonding aids may assist in achieving a reliable bond between green un cured concrete and cured concrete.

7.31. POLYMER BASED REPAIRS

The polymer concrete includes composites prepared by one of the following methods:

1. Polymer impregnated concrete (PIC)
2. Polymer cement concrete (PCC)
3. Polymer concrete

7.31.1. Repair by polymer impregnated concrete

In this system of repair, the damaged concrete surface is cleaned thoroughly and dried. After cleaning and drying the cracked surface, it is flooded with a monomer, which is then polymerized in place filling and structurally repairing the crack.

A monomer system is a liquid consisting of small organic molecules capable of combining to form a solid plastic. The monomer system used for impregnation or injecting into the concrete contains a catalyst or initiator and the basic monomer. They also contain a cross linking agent. On heating the monomers, they join to getter. The process of joining together is known as *polymerization.* After polymerization the product on cooling becomes tough, strong, durable plastic that greatly enhances a number of properties of the concrete.

Monomers do not mix with water. They have a varying degree of toxicity, flammability and volatility. These are low viscosity fluids which are soaked into dry concrete, filling the cracks in the same way as water. However if the cracks contain moisture, the monomer will not be soaked into the concrete at each crack face, resulting in unsatisfactory repair. Further if a volatile monomer evaporates before the polymerization, the repair will be ineffective.

(*a*) Repair of fractured elements

For repairing fractured elements, polymer impregnation method may be used. In this case the fracture is dried first, then it is temporarily encased in a water tight sheet metal. Now the fracture is soaked with monomer and polymerized. On polymerization of the monomer the fractured element becomes a solid mass with enhanced strength and properties. large voids in compression zones may be filled with fine and coarse aggregates before flooding them with monomers, providing a polymer concrete repair.

(*b*) Treatment of concrete surfaces with large number of cracks

In this case vacuum impregnation may be applied:

Process. The part of the structure to be repaired is enclosed with in an air tight plastic cover and then air from all the cracks with in the cover is sucked by applying vacuum. After removing air from all the cracks, the monomer or resin grout is forced under one atmospheric pressure (1 kg/cm^2) in cracks and pores of the concrete surface. On completion of impregnation, the cover is removed before the impregnation hardens. The selection of appropriate impregnent and degree of vacuum depends on experience. This process is extensively used to reduce the permeability of weak concrete masonry. This process may also be used to improve the abrasive resistance of industrial concrete floor slabs. However polymer impregnation has not been found successful for the repair of fine cracks.

7.32. RESIN BASED REPAIRS

In reinforced concrete, cracks wider than approximately 0.3 mm require sealing to check the entry of moisture, oxygen and other harmful gases etc. The choice of the method and materials will depend upon the cause of cracking, and whether there is need of permanent structural filling of cracks to carry out any other required strengthening. For restoring the structure to its original strength, the use of law viscosity epoxy resin has been found very effective. With epoxy resin system it is possible to fill completely cracks finer than 5 mm by using pressure injection technique. However work should be carried out skillfully to avoid the blowing off the surface seals due to back pressure that may develop in case of very fine cracks. To fill the fine cracks fully sustained pressure for several minutes may be required.

Generally the resin and hardener are in liquid form and each by itself is stable for an in definite period. On mixing these substances together a chemical reaction takes place and their liquid system is converted into a tough plastic solid at ambient temperature. They develop excellent strength and adhesive properties. They are resistant to many chemicals. They have been found to possess good chemical and physical stability. They harden rapidly and resist water penetration. Thus they provide durability and resistance to cracking. Resin mortars may be obtained by adding coarse sand as filler.

The epoxy based compounds are invariably formulated with plasticizers, extenders, dilutents, and fillers to produce a large number of products having a wide range of properties. The excellent adhesion characteristics fast setting properties, high strength, and chemical stability has led their extensive use in the concrete construction.

7.32.1. General use of Epoxies

In concrete construction, epoxies have been used for the following purposes:

(*a*) For providing skid resistant over lays and wearing surfaces on concrete floors.

(*b*) As water proof membrane.

(*c*) Most extensively used in the repair of pot holes.

(*d*) To seal cracks in structural members.

The clean and dry surface is painted with epoxy compounds before placing the repair material. The cracks may be sealed with epoxy compounds, epoxy mortar or portland cement mortar after priming the surface with epoxy compound. For early and quick use, polymer or resin overlays may be constructed. They can be put to early use due to faster curing. As they are joint less they are more hygienic and chemical resistant.

7.32.2. Materials

Epoxy, polyester and acrylic resins as a class are known as thermosetting materials due to the fact that on curing their molecular chains are locked together permanently. These materials do not melt on heating like thermoplastic materials. These materials loose strength with the increase in the temperature. Generally they are supplied as two or three component system as resin, hardener and filler.

7.32.3. Classification of resins

Broadly resins are classified as follows:

(*a*) Epoxy resins

(*b*) Unsaturated reactive polymers resins

(*c*) Unsaturated acrylic resins

Acrylic resin system forms high strength materials. They are based on monomers of very low viscosity or blend of monomers and methyl methacrylate monomers.

Polyester and acrylic resins contain volatile constituents which are inflamable. Most acrylic resins are highly inflamable with a flash below 10°C. Their vapours also cause toxic reaction.

7.32.4. Properties of Commonly used resins

(*a*) **Epoxy resins.** Epoxy resins have the following properties:

(*i*) Their strength is very high

(*ii*) Their bonding characteristics are good

(*iii*) They have high impact resistance

(*iv*) They have high chemical resistance

(*b*) **Polymer resins.** These resins have a better resistance to heat and thus can be laid over wider temperature range. They are mixed with cement and fine hard aggregate and can be laid in thickness upto 15 mm.

(*c*) **Polyvinyl acetate (PVAC).** When the over lays of this material are laid over the existing concrete, they are used as bonding aid. The liquid can be applied directly on a clean sound surface and allowed to dry. The slight re-emulsification of the film on being rewetted by the application of fresh mortar topping provides a good bond.

(*d*) **Natural rubber latex.** The admixture has excellent adhesive properties, but difficult to mix with ordinary portland cement. Generally it is used with less alkaline high alumina cement for patch work or laying floors over which vinyl tiles are to be laid.

(*e*) **Styrene-butadiene rubber (SBR).** It is an effective and good alternative to polyvinyl acetate (PVAC). It is highly water resistant. However the dried film does not develop good bond on rewetting. Thus it will act as debonding layer if allowed to dry out. Hence the mortar mix should be applied while the tack coat of S.B.R is still wet.

(*f*) **Acrylic resins.** These admixtures when mixed with monomers develop excellent water resistance and improved bond strength. By this type of resins seam less, and non dusting thin floor over lays can be readily produced.

(*g*) **Styrene acrylic resins.** A mixture of tough styrene with acrylic resin using 1:3 cement sand mortar can be used to produce hard wearing floor overlays at a moderate cost.

7.32.5. Repair Procedure

7.32.5.1. Use of resin mortars

The surface preparation requirements are same as those for cement based repairs. The constituents of resin based material must be mixed together thoroughly in mechanical mixers. Most of the failures of the resin based repairs have been repeated due to either inadequate mixing or improper proportioning. For smaller repair works to get proper proportioning the constituents normally are available in pre batched packs.

After the preparation of the surface, a tack coat or primer of un filled resin is applied to the freshly exposed surface of cement concrete and reinforcement. In general, one coat is sufficient, but if the sub strata is porous, two coats will be needed. In case two coats are applied, the second coat should be applied while the first coast still is tacky.

The patching material should be applied while the primer is still tacking and each successive layer should be applied before the previous layer have cured too much. The resin based materials cure (harden) by chemical reaction, which starts as soon as constituent materials are mixed. Thus they have little pot life *i.e.* mixing period is very short. Hence the quantity of materials to be mixed in any one batch should be precalculated, so that it could be used before it becomes too stiff to use. The resin based patch works should be well compacted so that they become impermeable.

While using resins and hardners, normal safety measures must be observed *i.e.* gloves should be worn and splashes should be washed off from the skin, but solvents should not be used for this purpose. Adequate ventilation should be provided and smoking, eating and drinking should not be allowed during the application of resin based materials.

7.32.5.2. Resin injections

The polymer injunction under pressure will ensure that the sealing material or sealent penetrates to the full depth of crack.

Procedure. The injection holes are drilled at close intervals along the length of the crack and the epoxy is injected under pressure in each hole in turn till the injection material starts to flow out at the next hole. At this stage the hole which is injected is sealed off and the next hole is treated.

Preparations. Before injecting the epoxy, it should be ensured that the crack at the surface is sealed between the holes with rapid curing resins.

7.32.5.3. Repairs of cracks in massive structures

In this case a series of holes usually 20 mm in diameter and 20 mm deep spaced at 150 mm to 200 mm interval intercepting the crack at a number of points are drilled and epoxy injection is injected in these holes to seal the crack. The method has been used successfully in the repair of cracks in dams, piers, buildings and other such structures. However unless cause of cracks is removed, cracks may reoccur again some where in the structure. This method has not been found effective, if the cracks are constantly leaking and can not be dried out. Epoxy injecting is a highly specialized job, which requires a high degree of skill for satisfactory execution of work.

7.33. STEPS INVOLVED IN EPOXY INJECTION

Following steps are involved in the epoxy injection:

(*a*) Preparation of surface

The cracks are cleaned by removing all dirt, oil, grease, fine particles of concrete etc. These elements may prevent the penetration of epoxy and development of bond between the filling material and the surface of the cracks. The contaminants should preferably be removed by flushing the surface with water or solvent. The solvent is then blown out using compressed air or by air drying.

To check the leacking out of epoxy before it has gelled or cured (hardened), the surface cracks should be sealed. The surface can be sealed by brushing an epoxy along the surface of the cracks and allowing it to harden. If extremely high pressure is needed for injecting the epoxy, then epoxy injection should be sent through a V shaped groove of 12 mm depth and 20 mm width. After filling the epoxy in the groove, it should be struck off flush with the surface.

(*b*) Installation of entry ports

The entry port or nipple is an opening to allow the injection of a adhesive directly into the crack with out leaking. The spacing of injection ports depends upon many factors such as depth and width of cracks, the variation in the crack width with its depth, viscosity of epoxy and injection pressure etc. The choice of spacing actually depends on experience.

In case of V shaped groove of the crack, a hole of 20 mm diameter upto a depth of 12 to 25 mm below the top of the V grooved section should be drilled into the crack and A tire valve stern is bonded with an epoxy adhesive in the hole. In case of other shaped crack than V shaped groove, the entry port is provided by bonding a fitting, having a hat shaped cross-section with an opening at top to fill the adhesive. This fitting is kept flush with the concrete face over the crack.

(*c*) Mixing of epoxy

The mixing can be done either by batch or continuous method. In batch mixing the adhesive components are premixed in specified proportions with mechanical stirrer in quantities which can be used prior to commencement of curing or hardening of the material. With the hardening of the material the pressure injection becomes more difficult. In the continuous mixing system the two liquid adhesive components pass through metering and driving pumps prior to passing through an automatic mixing head. The continuous mixing system allows the use of fast setting adhesives that have short working life.

(*d*) Injection of epoxy

In its simplest form, the injection equipment is consisted of a reservoir attached to a long flexible tube. This system provides a gravity head to the flowing material. For small quantities of repair materials, usually the small hand held guns are the most economical. A steady pressure can be maintained by these small guns which reduces the chances of damage to the surface seal.

For big jobs often power driven pumps are used for injection. Pressure to be applied for injecting the material should be selected carefully. The use of excessive pressure may multiply the cracks, causing additional damage. As stated earlier also the injection pressure is governed by the depth and width of cracks, the viscosity of resions seldom exceeds 0.1 MPa. Fine cracks preferably be injected under low pressure in order to allow the material to be drawn into the concrete by capillary action. To increase the injection pressure during the course of work, the common practice is to over come the increased resistance against flow as crack is filled with material. For relatively larger cracks, gravity head of few centimeters may be enough.

In case of vertical and inclined surfaces, the injection process should start by injecting epoxy into the entry ports at the lowest level until the epoxy level reaches the entry port above it. Then the injection tube is removed and the lower port is capped. For forcing the epoxy into fine hair line cracks, a pressure upto 0.7 MPa can be applied on the port from which the injection tube has been removed for a period of 1 to 10 minutes using inert gas. The process is repeated at the successively higher ports until the cracks have been fully filled and all ports capped.

For horizontal cracks the injection should start from one end of the crack to the other in the same manner. If the pressure maintained remains constant, then it indicates that the crack is full. In case pressure does not remain constant, it indicates that the epoxy is still flowing into unfilled portion or leaking out of the crack.

(*e*) Removal of surface seal

After hardening of the injected epoxy, the surface seal may be removed either by grinding or by other suitable means. Fittings and holes at the entry ports should be painted with an epoxy patching compound.

7.34. HEALTH AND SAFETY PRECAUTIONS

The epoxy materials are toxic and skin irritants. Hence their skin contact, inhalation of their vapours and ingestion must always be avoided. For this purpose fallowing precautions should be observed.

(*i*) During all mixing and blending operations full face should be covered and goggles worn.
(*ii*) Rubber gloves and protective all over should be used.
(*iii*) Skin cream may be used for the protection of skin.
(*iv*) Adequate fire protection should be provided.

QUESTIONS

1. State the defects developed in concrete during its construction period.
2. How the assessment of cracks is made?
3. Define cracks in concrete and give their classification. Discuss plastic cracks.
4. Discuss cracks due to chemical reactions. Also suggest their remedial measures.
5. On what factors the method of repair of cracks depends.
6. Write a note on the preparation of surface for the repair of cracked concrete surface.
7. Discuss the following methods of crack repair.
   (*a*) Concrete replacement
   (*b*) Mortar replacement
   (*c*) Resin based repairs

OBJECTIVE TYPE QUESTIONS

1. The distress in concrete structures may develop due to
   (*a*) Errors in design and detailing (*b*) Poor construction practice
   (*c*) Thermal and shrinkage stresses (*d*) Corrosion of reinforcement
   (*e*) All the above
2. In concrete structure the most common defect is
   (*a*) Surface crazing (*b*) Cracking of concrete
   (*c*) Scalling of concrete (*d*) Spalling of concrete
3. Cracking of plastic concrete can be checked by
   (*a*) Using concrete of lowest possible slump
   (*b*) Giving adequate vibrations and by proper form design

(*c*) Providing sufficient time interval between placement of different element of the structure
(*d*) Covering the surface by plastic sheets during the final finishing
(*e*) All the above

4. Cracking due to corrosion of reinforcement is characterized by
(*a*) By exposed reinforcement
(*b*) By rust staining
(*c*) By longitudinal cracks parallel to reinforcement bars or spalling of concrete
(*d*) Spalling and splitting of concrete in a definite pattern
(*e*) All the above
5. The weak spots in a concrete member can be identified by
(*a*) Tapping the surface and listening its sound
(*b*) By opening up the suspected weak portion
(*c*) By observing the exposed reinforcement, rust stains, surface deterioration etc.
(*d*) By non destructive tests
(*e*) By all the above
6. The selection of repair technique is based on the following objective/objectives
(*a*) To restore load carrying capacity
(*b*) To improve its durability
(*c*) To improve the functional requirements
(*d*) To check the access of corrosive agents to reinforcement
(*e*) All the above
7. The best way of removing laitance from the concrete surface is
(*a*) By sand blasting (*b*) Grinding, scarifying and sand blasting
(*c*) Acid itching (*d*) Cleaning with caustic soda solution or detergents
8. Deep and wide cracks in concrete members can be repaired by
(*a*) Shot creting or guniting (*b*) Grouting
(*c*) Epoxy injection (*d*) Mortar replacement method
9. For the repair of large and deep patches, the most suitable method is by
(*a*) Dry packing (*b*) Mortar replacement method
(*c*) Pre packed concrete method (*d*) Concrete replacement method
(*e*) Grouting
10. Epoxy injection technique is used for
(*a*) Sealing narrow cracks (*b*) Sealing active leaking cracks
(*c*) Repairing hydraulic structures (*d*) Any of the above
11. Jacketing is the process of strengthing of
(*a*) Run ways (*b*) High ways
(*c*) Roofs and floors of buildings (*d*) Bridge piers and building columns
12. Stiching of cracks is adopted for except
(*a*) To re-establish the tensile strength across major cracks
(*b*) To stiffen the structure
(*c*) To strengthen the cracks which have a tendency to close as well as to open
(*d*) To check the crack from further opening
13. Polymer concrete usually is prepared by the use of
(*a*) Methyl methacrylate (*b*) Latex of styrene butadiene acrylic
(*c*) 99.5% pure sulpher (*d*) None of the above
14. Sulpher concrete can be used for
(*a*) Repairing fractured concrete members
(*b*) For repairing slabs and decks having fine dormant cracks
(*c*) As a practical substitute of polymer modified cement concrete overlays
(*d*) As a practical and economical substitute of polymer impregnated concrete
15. The preparation of surface for repair consists of
(*a*) Complete removal of unsound material

(*b*) Removal of cracks from the surface
(*c*) Under cutting with formation of smooth edges
(*d*) Providing rough tough surface
(*e*) All the above

16. For sealing cracks in concrete structures by epoxy, the minimum width of routing should be
(*a*) 15 m (*b*) 12 mm
(*c*) 9 mm (*d*) 20 mm
(*e*) 3 mm (*f*) 6 mm

17. Identify the correct statement/statements
(*a*) Shrinkage is directly proportional to loss of water
(*b*) If no movement of moisture is allowed from the set paste of concrete the shrinkage is known as autogeneous shrinkage
(*c*) The reduction in volume is three to four times of linear contraction in shrinkage
(*d*) Carbonation shrinkage causes contraction in concrete
(*e*) The most important effect of carbonation is to neutralize the alkaline nature of cement paste.
(*f*) All are correct
(*g*) None is correct

ANSWERS

1. (*e*)	5. (*e*)	9. (*d*)	13. (*a*)
2. (*b*)	6. (*e*)	10. (*a*)	14. (*d*)
3. (*e*)	7. (*a*)	11. (*d*)	15. (*e*)
4. (*e*)	8. (*b*)	12. (*b*)	16. (*f*)

8

Joints, Repairs and Maintenance of Concrete Elements

8.1. INTRODUCTION

It is seldom possible to cast all concrete needed in a structure with out interruption. From safety and durability considerations masonry and concrete structures should not be raised more than 1.5 m at a time. Hence some kind of joint has to be provided. This kind of joint is called construction joint. Construction joints are a source of weakness in the structure. Hence efforts should be made to obtain good bond at these joints. To avoid trouble arising from bad construction joints, it is essential to have knowledge how and where to construct a construction joint.

Further due to the variation in environmental conditions, the properties of concrete are affected to a great extent. The rise and fall in temperature causes expansion and contraction in concrete respectively. To safeguard against all the ill effects, there is need for the provision of joints in the concrete. The drying shrinkage causes cracks in concrete. The ingress of moisture, water vapours and atmospheric gases such as carbon dioxide, oxygen, sulphour dioxide etc. cause deterioration of concrete structures which need repair and periodic maintenance.

Maintenance is French word, which means to preserve a structure or equipment to an acceptable standard of serviceability. Thus the process or act of preserving and keeping the concrete surface in good condition of serviceability is called as repair and maintenance of concrete.

8.2. TYPE OF JOINTS

Broadly joints may be classified into four categories:

1. Construction joints
2. Expansion joints
3. Contraction or dummy or control joints
4. Isolated joints

8.2.1. Construction joints

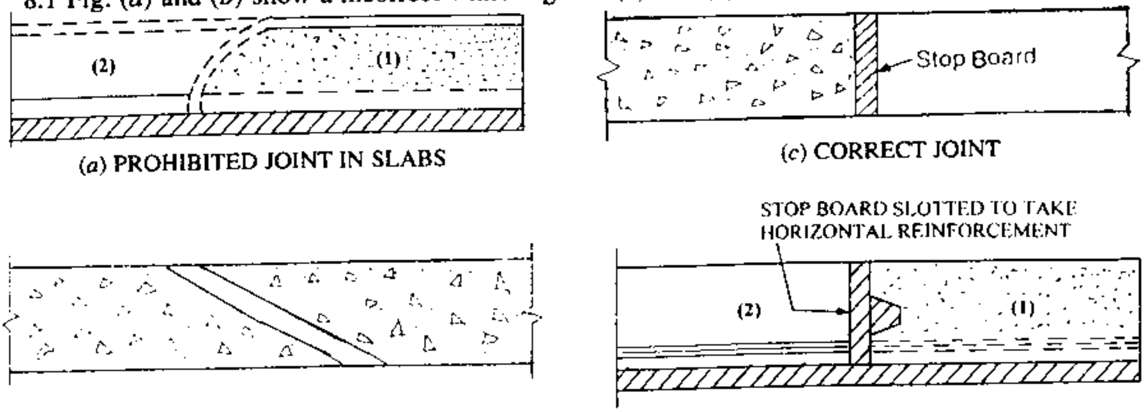
These are temporary joints left between subsequent operations. The position of construction joints should be preplaned before starting the concreting. Till such locations the concrete must be placed in one operation. The joint should be located at such places where the concrete is least vulnerable to maximum bending moment and maximum shear force.

All care exercised in producing and compacting concrete to ensure good quality concrete is wasted if construction joints are not provided properly. The extent of trouble likely to arise from the bad construction joints depends to a great extent on the type of structure. A water retaining structure may be more seriously damaged by leakage of water through joints than earth retaining structures. The leakage of water leaches out material at the joint, resulting in widening the joint. It becomes serious as the structure becomes older. The leaching salts are deposited on the joint surface making it unsightly.

8.2.1.1. Causes of development of defects

The defects in construction joints may be due to the following probable reasons.

1. The joint is not made either vertical or horizontal, but made inclined which is very weak and generally flakes off. In a vertical joint proper stop end board must be used. if no stop board is used the concrete near the joint will be honey combed and form a plane of weakness as shown in Fig. 8.1 Fig. (*a*) and (*b*) show a incorrect while Fig. 8.1 (*c*) and (*d*) show correct position of joint.



(*a*) PROHIBITED JOINT IN SLABS

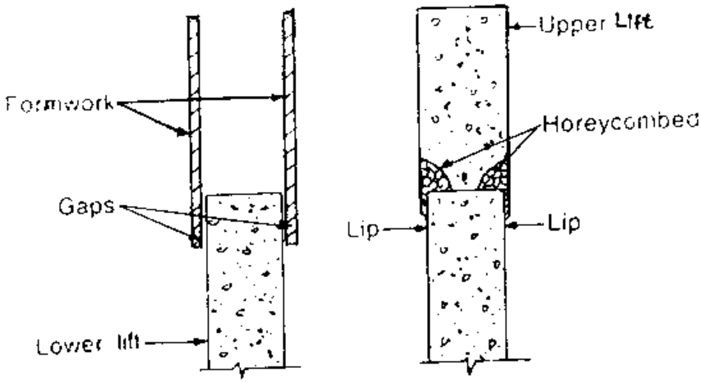
(*c*) CORRECT JOINT

(*b*) INCORRECT JOINT

(*d*) CORRECT JOINT

Fig. 8.1. Correct and incorrect position of joint

2. The concrete may not have been properly spread and compacted to form a smooth horizontal surface.
3. Due to badly fixed shuttering causing a lip to form on the surface. This may happen, if the shuttering is not properly clamped to the lower portion in case of a vertical structure as wall or column. The loss of mortar also causes honey combing near the joint as shown in Fig. 8.2.



Form work in position for upper lift CORRECT

Upper lift placed and form work removed INCORRECT

Fig. 8.2. Fixing of shuttering

8.2.2. Correct position of joints

In order to avoid defects in construction joints, the general principle is that the position of construction joints should be decided in advance, so that they occur at suitable place of minimum shear force and should not be left to chance. For proper transmission of stresses across the joint, it is necessary to extend the reinforcement of the old concrete into the new concrete. Shear keys should also be provided as shown in Fig. 8.3. At the joints before adding new concrete, the surface of the old concrete should be treated as follows:

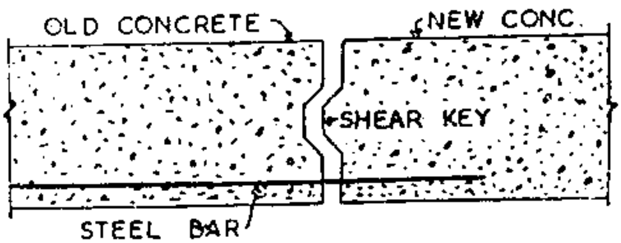


Fig. 8.3. Provision of shear key

(*a*) If the second layer is to be added with in 4 hours after laying the first layer, the laitance on the surface of the old concrete should be rubbed with a wire brush and cleaned with water before the new concrete is poured, but no water should be allowed to stand over the surface.

(*b*) If the second layer is to be added with in 48 hours after the first layer, then the surface is rubbed with a wire brush and cleaned with water as above and a 1.5 cms layer of cement mortar of the same composition as that of concrete should be applied over the cleaned surface before the new concrete layer is placed.

(*c*) If the second layer is added after 48 hours of the first layer laid or on old concrete, then the laitance on the surface of the old concrete should be removed either by sand blasting or by chiseling and the surface is cleaned with water. Then a slurry of neat cement should be applied on the cleaned surface and worked into interstices with broom. After which a 1.5 cms thick layer of sand and cement mortar of the same composition as that of old concrete should be applied before the slurry dries out and then concrete is placed immediately. Apart from appearance consideration of the work, the place of joint should be such that it may not weaken the structure.

8.2.3. Vertical joints

Vertical joints reduce the shear strength of R.C.C. beams and slabs considerably, but practically have no effect on the bending strength, if made properly. This has been illustrated with the help of Fig. 8.4. Fig. 8.4 shows a beam loaded with a uniformly distributed load of 2 tonnes. The up ward reaction at each support is of one tonne as each support shares the half of the total load. Due to this upward force, there is a tendency of the beam to break due to vertical shearing force as shown in Fig. 8.5. Thus if a vertical joint is placed near the supports, the beam is likely to fail as shown in Fig. 8.5. However at the centre of the beam there is no such tendency of shearing. This has been shown in Fig. 8.6. Which is a diagram of the half bean with the same distributed load of 2 tonnes/m run.

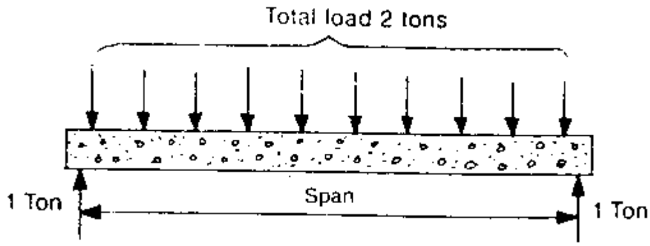


Fig. 8.4.

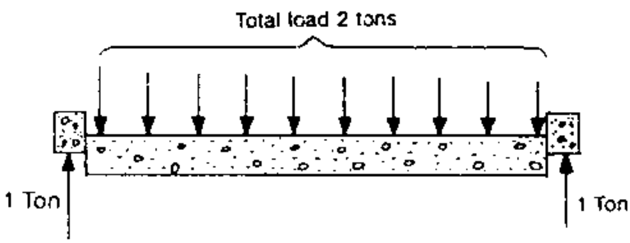


Fig. 8.5.

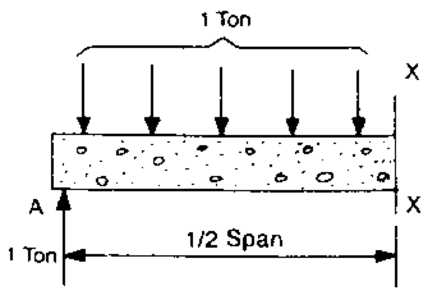


Fig. 8.6.

In this case the upward force at A is fully balanced by the down ward weight acting over half span of the beam. Thus there is no tendency for the beam to slide up or down on the section XX.

8.2.4. Bending strength

Bending is a condition set up in a beam by the loading and its effect is measured by the magnitude of its bending moment of a section of the beam. In Fig. 8.6 the force of one tonne at A exerts a clockwire B.M. on the section XX. In this case the lever arm is equal to half the span. The distributed load on the beam also exerts a turning effect on the section XX, but of opposite nature. In this case the B.M. is anti clockwise and half in magnitude of the first. The lever arm in this case being 1/4 of the span. The net B.M. tries to rotate the section XX in clock wise direction, but the reinforcement and concrete are able to resist this rotation. The stresses developed in concrete beam section under such conditions are shown in Fig. 8.7. From Fig. 8.7, it will be seen that compression and tension stresses developed in the beam act at right angle to the cross-section of the beam and if a vertical plane of weakness such as construction joint exists there, it will not affect the bending strength of the section appreciably.

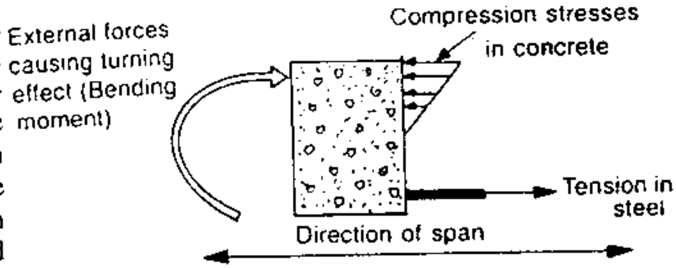


Fig. 8.7. Stress development in beams

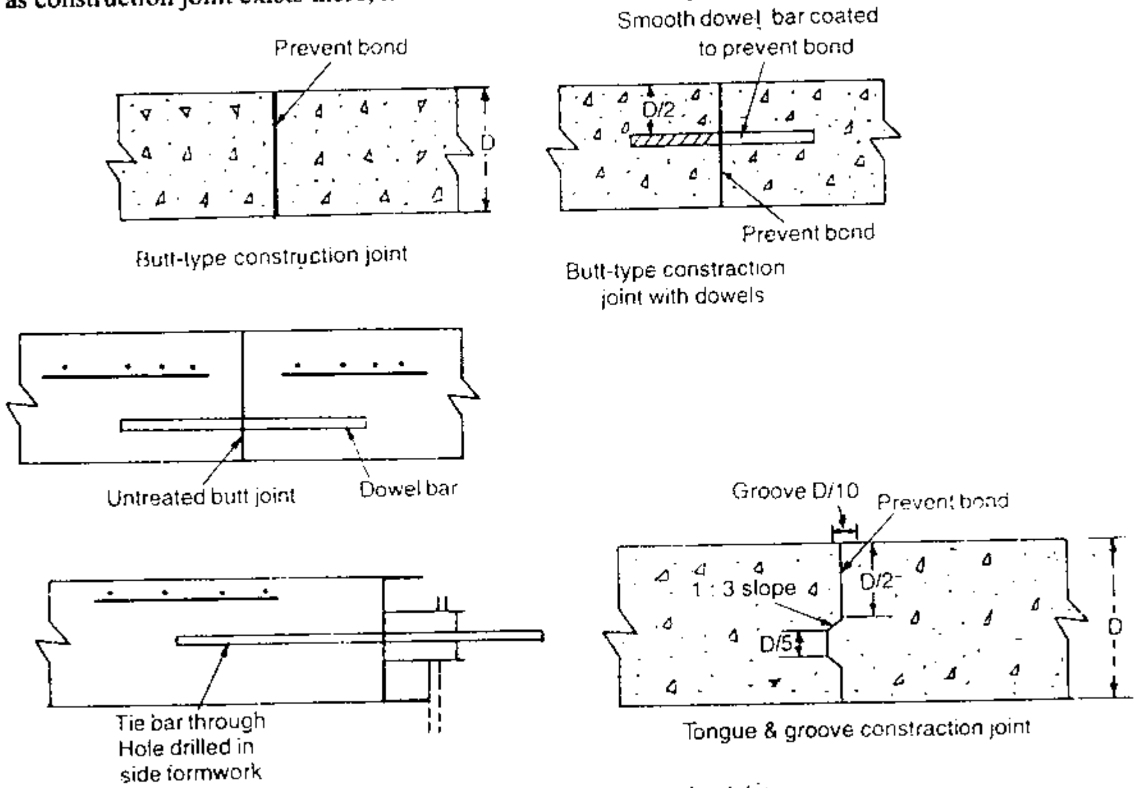


Fig. 8.8. Different types of construction joints

8.2.5. Location of Construction joints

1. Walls and Columns. In case of walls and columns the construction joints should be horizontal. They should be provided at floor level, sofit level of lintels and sill level of windows. They should not be provided at the corners, as it would be difficult to tie the corners. In columns the concrete should be filled to the level, preferably upto few cms below the junction of beams.

Beams and slabs. In case of a beam, the bending stresses act at right angle to the section, *i.e.* they act in the direction of the span and do not affect the bending strength of the section appreciably. The vertical joints reduce the shear strength of R.C.C. beam or slab. Thus the best location for the construction joint in beams and slabs is where the shear stresses are least. In most cases of beams and slabs this condition will be satisfied if the joint is provided at the extreme position of the middle third of the span. In case of short span slabs the joint may be provided at the centre of the span.

2. If it is un avoidable to provide a construction joint at the junction of a beam and a slab, then special arrangement should be made using shear reinforcement or providing a suitable key to increase the shear strength of the joint.

3. The construction joint should be located where it is supported by other members. The construction joint should be properly covered while finishing the structure. Some construction joints are shown in Fig. 8.8.

8.2.6. Concreting in high and long walls

When concrete is to be poured in long and high walls, provision of suitable joints is essential. If the wall is not required to be water proof, then ordinary horizontal and vertical joints may be provided. In case walls are to be made water proof, then special care has to be taken. For vertical joins it is essential to provide a proper stop end board with a water stop as shown in Fig. 8.9 Fig. 8.9 (*a*) shows concreting in first portion with vertical stop board while Fig. 8.9 (*b*) shows concreting in second portion after the stop board has been removed and water seal stretched.

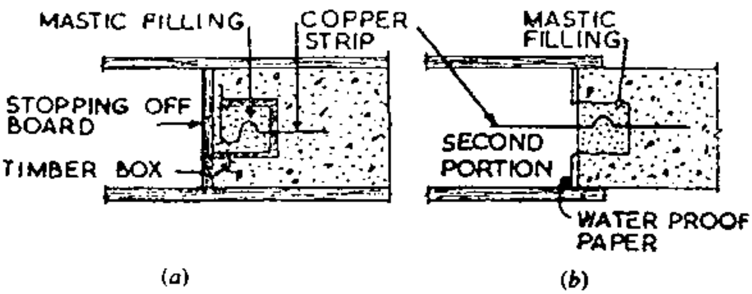


Fig. 8.9. Water seal arrangement

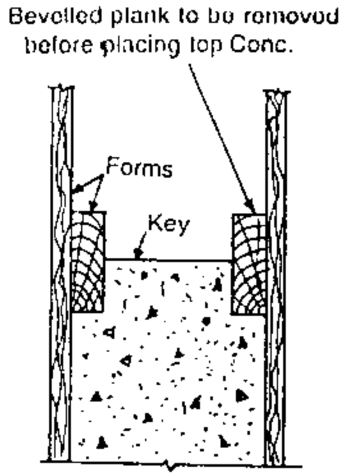


Fig. 8.10. Keys for horizontal joints

8.2.7. Horizontal joint

In case of horizontal joints, keys should be provided as shown in Fig. 8.10. In this case the wooden pieces are inserted in the first layer of concrete as shown in Fig. 8.10. They are removed before the new concrete is poured.

8.2.8. Joining columns in multi storyed buildings

In this case dowels must be left in the lower columns which connect them with the upper columns. The floor slab in such cases is concreted over the lower columns at least 48 hours after placing the concrete in the column. If this time interval is not given, the column concrete may shrink leaving a gap between the floor concrete and itself (column concrete).

8.2.9. Joints in water reservoirs and tank walls

These structures require special care and treatment as these are subjected to large heads of water causing seepage. These joints should be made water proof. To make them water proof, a copper strip is inserted across the joint as shown in Fig. 8.9. The strip is kept loose by providing a loop at its centre and thus it can provide space for the movement of the wall. The loop is enclosed in

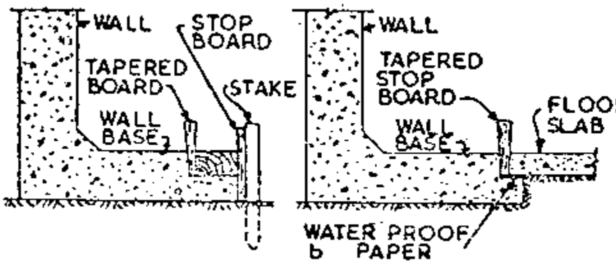
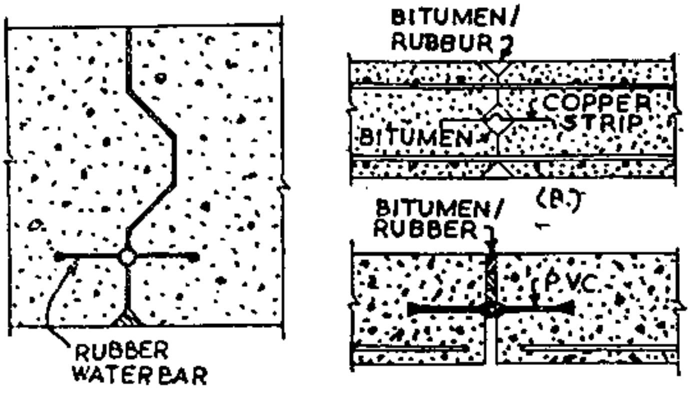


Fig. 8.11. Joints in water retaining structures

a soft mastic around it, so as to enable it to move freely. The loop is kept towards the water surface of the wall. It is un usual to make the walls of the tank monolithic and in one operation with the wall base. The floor slab is laid separately and a proper joint is provided in between the base slab and the wall base as shown in Fig. 8.11.

While laying wall base, a step is made to receive the floor base. After the concrete of wall base has hardened, the floor slab is laid and a water proof paper is put on the step before concreting. The tapered stop boards as shown in Fig. 8.11 should not be taken out till the concrete in the floor slab has hardened. Now the joint is filled with a plastic material which may remain plastic at all temperatures and whether dry or wet. Fig. 8.12 shows different types of water stops.



(a) (c)

Fig. 8.12. (*a*) Joint for mass concrete water, retaining structure, (*b*) Joint for R.C.C. water retaining structure

8.2.10. Joints in concrete floors and pavements

Generally the concrete pavements and industrial floors are constructed in alternate bays to minimise the early shrinkage of concrete. To allow maximum possible shrinkage in the concrete, the alternate bays should be concreted after the maximum possible time interval.

In case of dimensional roof slabs and in other special conditions expansion joints should be provided to take care of the expansion and contraction of the concrete. In pavements proper joints are provided to take care of cracks developed due to thermal expansion and contraction, due to variation in temperature and long term dry shrinkage.

8.2.11. Joints in Road surfaces

In case of concrete roads, the area is divided into panels and each panel is cast separately from each other. In the joints between these panels some plastic material as felt, bitumen or cork is filled. This material allows free movement of each panel and saves it from cracking. The edges of each panel are

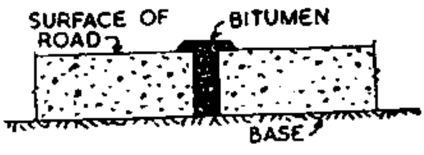


Fig. 8.13. Joint in road surfaces

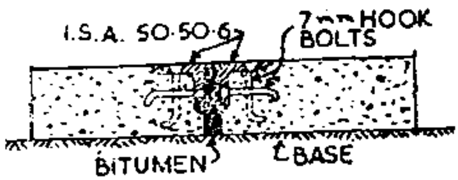


Fig. 8.14.

prevented from damages by filling enough bitumen in the joints as shown in Fig. 8.13. In case of roads having heavy traffic, the edges are further reinforced by providing iron angles built in the slabs during concreting as shown in Fig. 8.14. The angles are fixed into the concrete by means of 7 mm hook bolts.

8.2.12. Joint in Buildings

In buildings, vertical and horizontal joints in walls can be provided more conveniently at off sets, recesses, floor

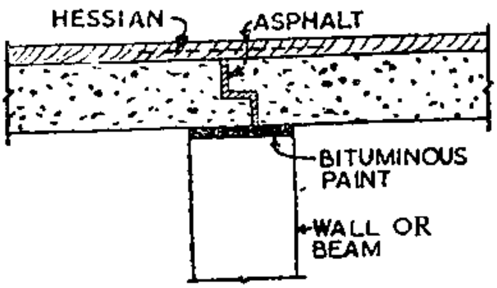


Fig. 8.15. Joint in slab over beam

lines etc. The expansion joint in a roof slab must be water tight and as well capable to allow free movement to the roof. It is always given over a wall or beam as shown in Fig. 8.15. A bitumen paint layer is essential between the slab and the wall or beam under it to ensure free movement of the slab. The joint can either be vertical or made in the form of a step to eliminate further the possibility of water leaking through it. Asphalt is filled in the joint. In order to prevent cracking of asphalt over the joint a piece of hessian is placed over

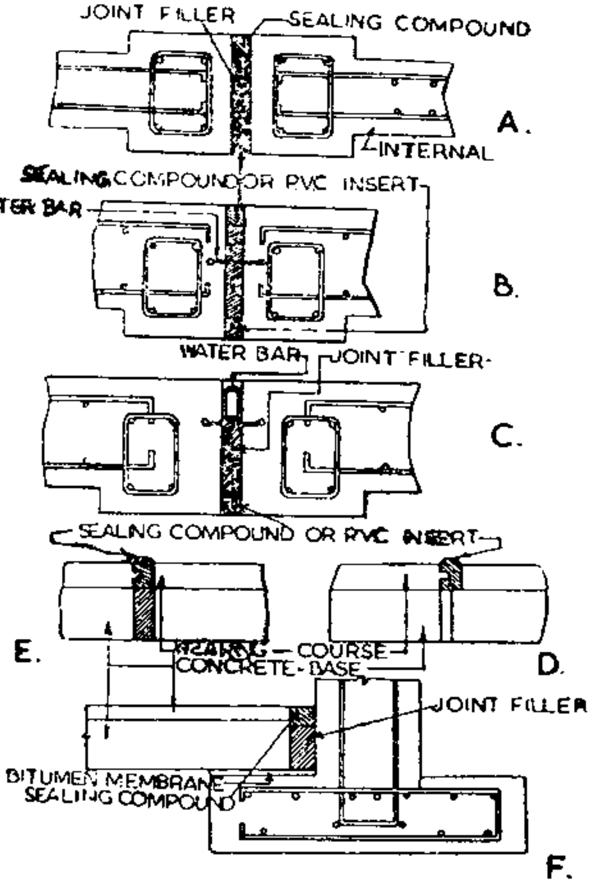


Fig. 8.16. Typical joints design for reinforced concrete over wall

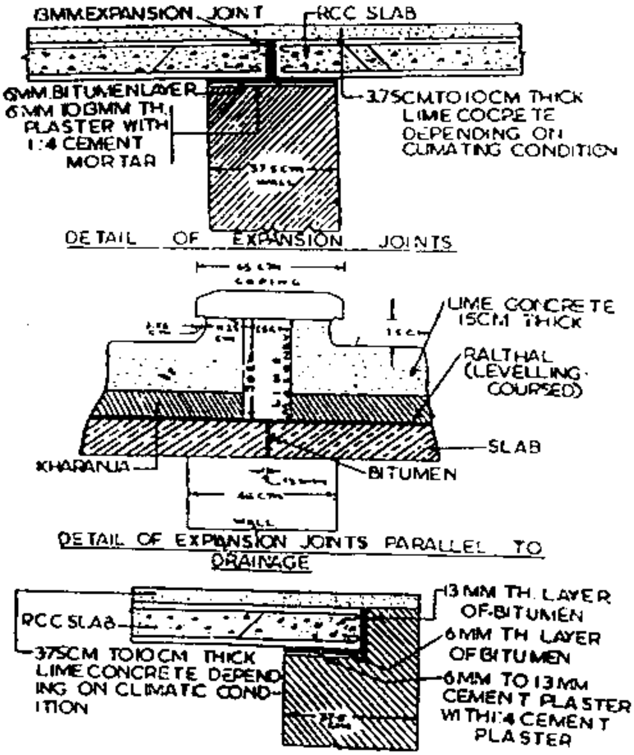


Fig. 8.17. Detail of bearing of RCC slab over wall

the joint and covered with asphalt as shown in Fig. 8.15. This reinforces the asphalt and keeps it separate from the slab by which the flexibility is increased. Fig. 8.16 and 8.17 show details of joints over walls and beams.

8.3. EXPANSION JOINTS

In concrete, volume change takes place due to many reasons. Thus to safeguard against this volume change, certain provision such as provision of joints must be made to relieve the stresses produced in the concrete. Expansion is a function of length. Concrete is very sensitive to change of temperature and expands if the temperature rises, and contracts if it falls. The expansion of concrete causes compressive stresses and contraction causes tensile stresses in the concrete. Some movements are also caused by the deflection of supports as well as shrinkage of concrete. If the concrete members are not allowed free movement then internal stress will be developed in the structure and may prove disastrous to the safety of the structure. Thus it is essential that there should be some provision for the free movement of the structure.

A long building experiences large expansions. It is estimated that a 60 m long building with a variation

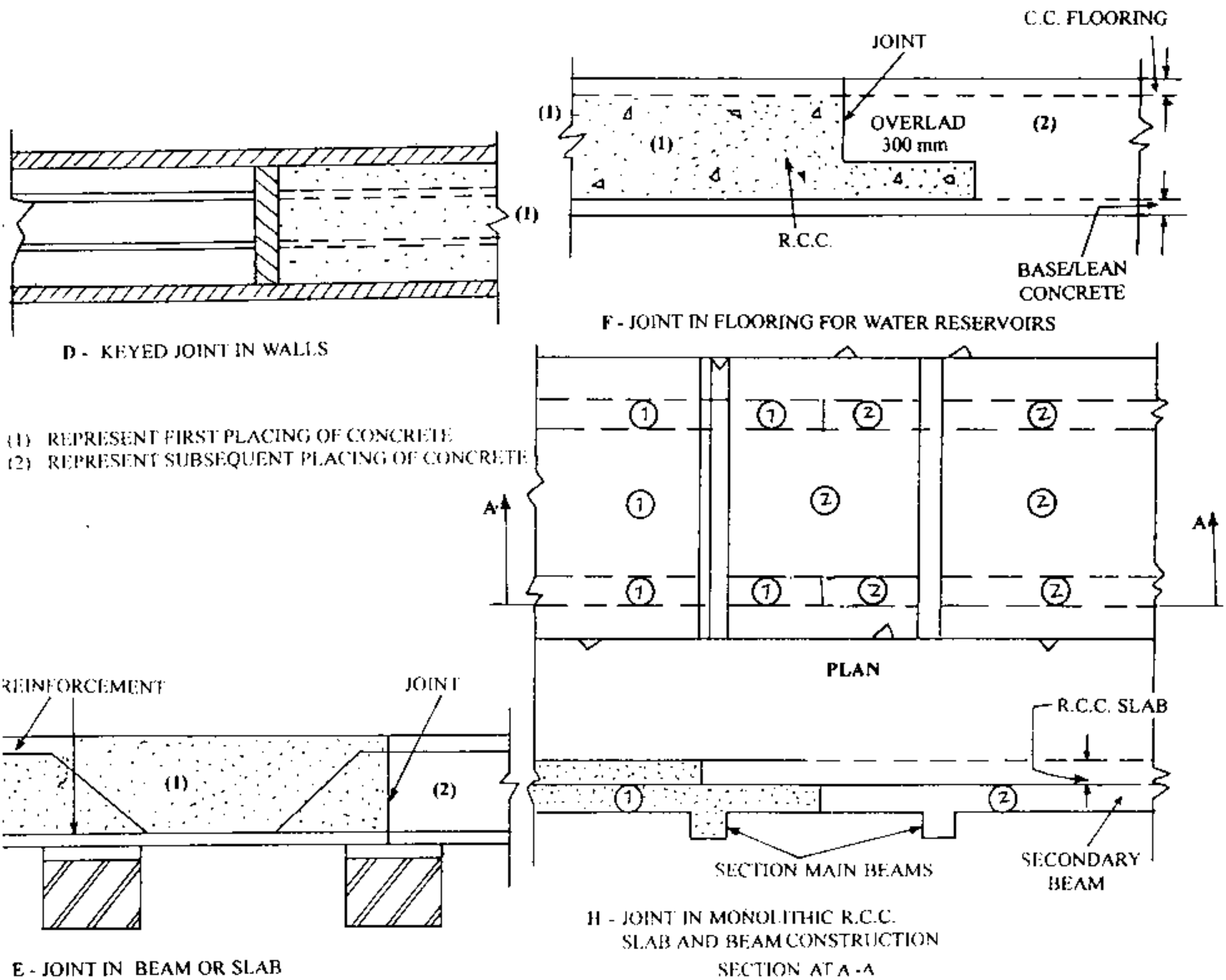


Fig. 8.18. Some building joints

of temperature of 50°F or 10°C may undergo an expansion of 2.5 cms. Thus buildings more than 45 m long should be provided one or two expansion joints Fig. 8.19.

Roof is one of the building elements which is subjected to maximum temperature variations. The roof is subjected to expansion during the day and contraction during the night or from season to season. This expansion and contraction causes pushing or pulling to the supporting load bearing walls. Thus serious cracks develop in the masonry walls supporting the slab. Thus to prevent the pushing and pulling of the wall, the slab should be made to slide over the wall. The expansion of concrete has been found

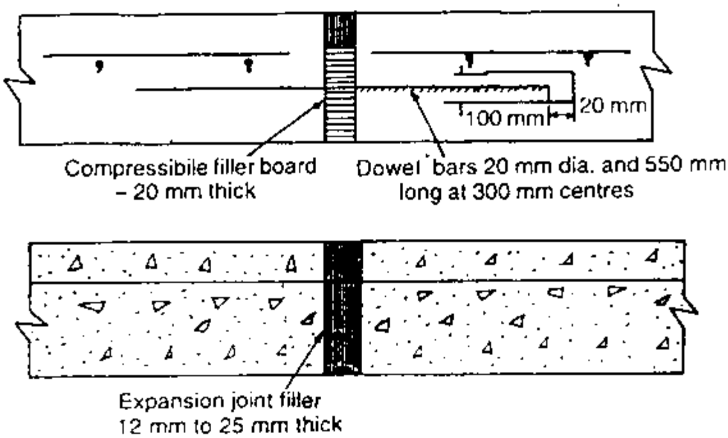


Fig. 8.19. Expansion joints

to depend on w/c ratio of the concrete. For a 30 m long 1:2:4 cement concrete structure the expansion for different w/c ratios is found as shown in Table 8.1.

Table 8.1. Showing concrete expansion with w/c ratio

W/c ratio	*Amount of expansion in cms*
0.3	0.4
0.6	1.25
0.7	2.4

8.3.1. Spacing of expansion joints

The spacing of expansion joints is kept according to the amount of expansion. For a 60 m long concrete structure for a variation of 50°F in temperature, the expansion will be about 2.5 cms with the value of coefficient of thermal expansion as 6.0×10^{-6} for plain concrete and 6.5×10^{-6} for reinforced concrete.

The width of joint should not be more than 1.25 cms. On this basis the spacing of the expansion joints may be kept about 35 m apart. As per IS 456-1978 any structure more than 45 m in length should be provided one or two joints. From practical considerations the spacing between expansion joints may be kept between 18 to 20 m. However recent studies suggest longer spacing than derived from theoretical calculations as frictional resistance affects the concrete expansion.

Further expansion joint spacing is also affected by the season of construction. For structures constructed in summer season, expansion joint spacing may be kept more than for structures constructed in winter. The joint spacing should be such that total expansion for summer constructed structures should not be greater than 1.25 cm and 2.5 cm for winter constructed structures. Apart from above intervals, expansion

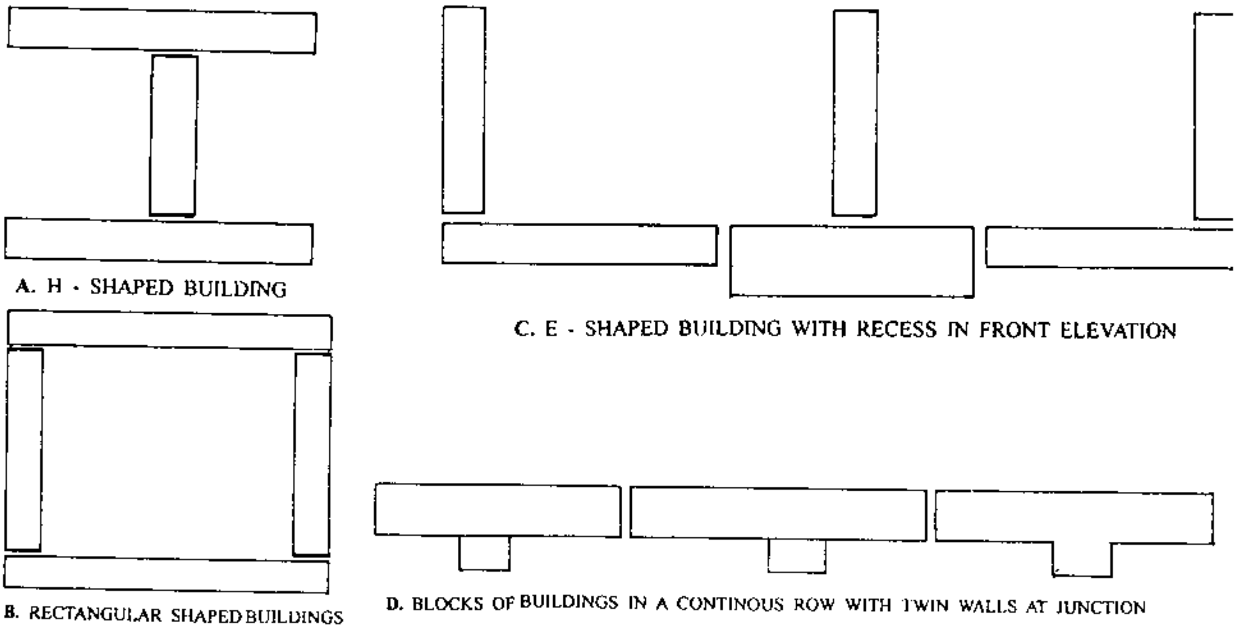


Fig. 8.20. Location of expansion joints at change of direction

joints should also be provided at locations where the structure changes its direction *i.e.* L, T and U positions of the structures. Fig. 8.20 shows location of expansion joint.

8.3.2. Points to be observed to make expansion joints effective

To make the expansion joints more effective, following points should be kept in mind:

1. Adjacent to the expansion joint, the structure preferably should be supported on separate walls or columns, but not necessarily on separate foundations.
2. Reinforcement should not extend across the expansion joint.
3. The break between the sections should be complete.

IS-456-2000 has suggested the following recommendations on the construction of expansion joints.

As the location, spacing and nature of expansion joints depend on many factors, hence the decision on the above factors should be left to the discretion of the designer of the R.C.C. structure. However for general guidance, it has been recommended that structures longer than 45 m in length should be provided one or more expansion joints.

Fig. 8.21 shows typical details of expension joint in walls. Fig. 8.22 shows typical details of expansion

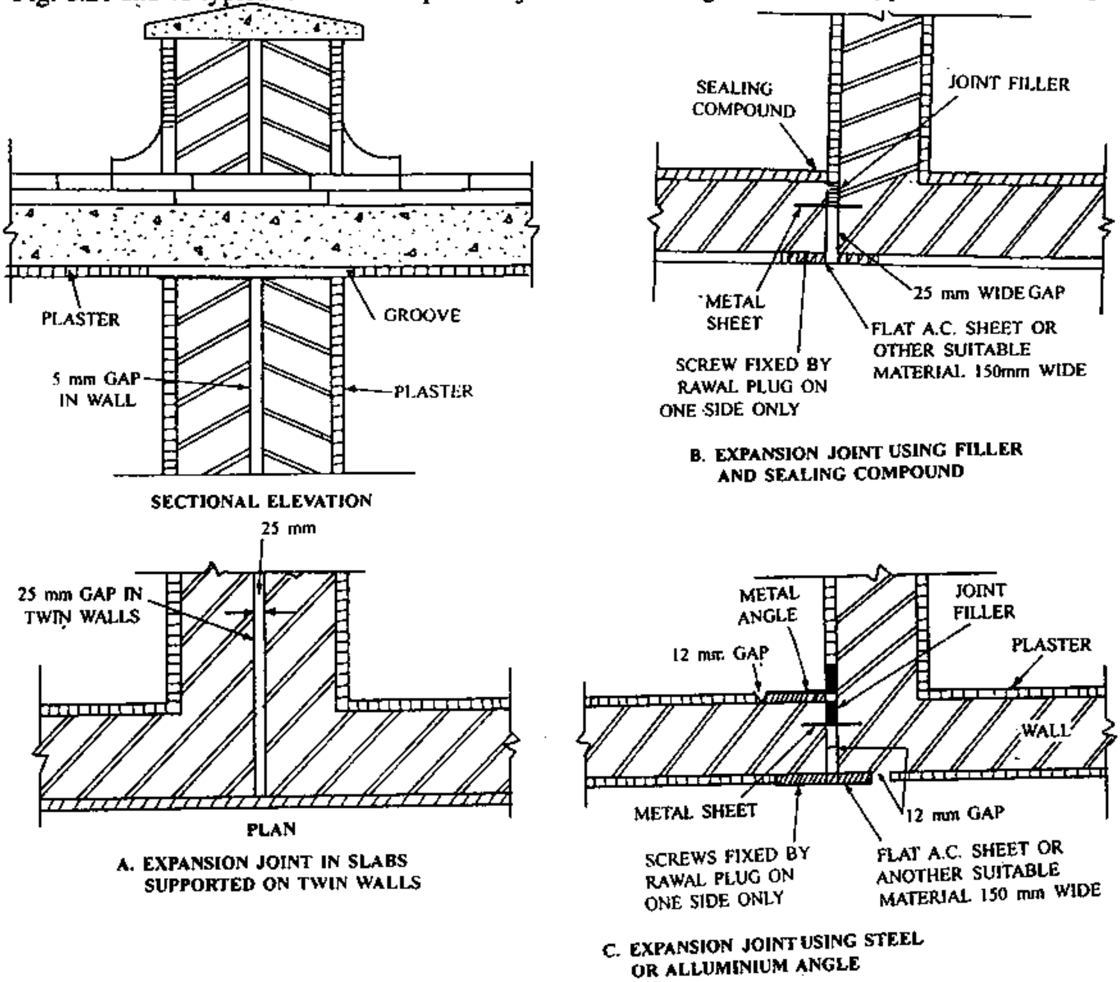


Fig. 8.21. Typical details of expansion joints in walls

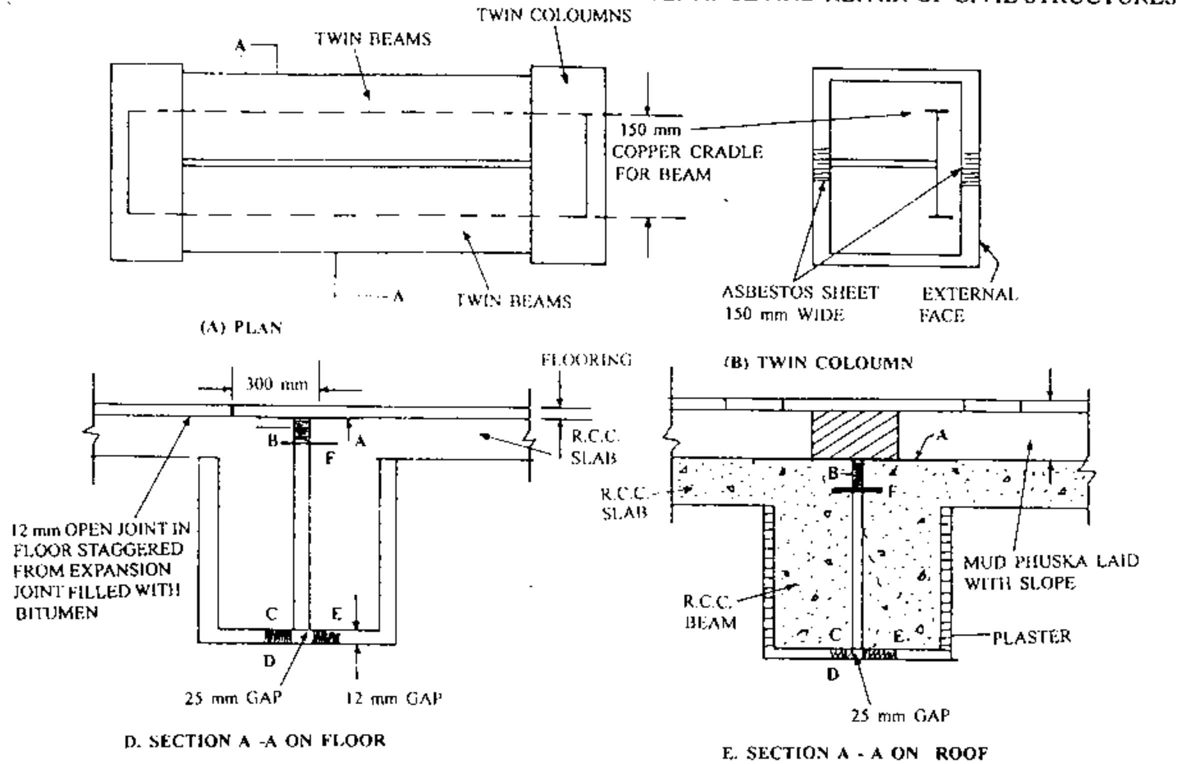
joint of twin beams with twin colums. Fig. 8.23 gives details of expansion joint on outer face of column while Fig. 8.24 gives details of expansion joint at corner column.

Fig. 8.25 gives details of raised type expansion joint at roof.

Fig. 8.26 gives details of expansion joint at wall and beam junction.

Fig. 8.27 gives details of expansion joint at roof and floor junction.

Fig. 8.28 gives details of slip or sliding joints at floor/roof.



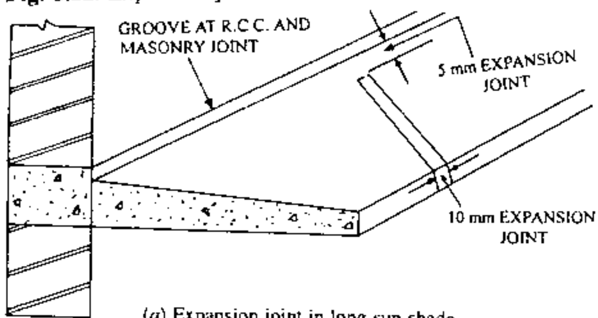
A - HOT BITUMEN PAINTING @ 1.7Kg/ M^2
B - BITUMEN FILLER
C - RAWL PLUG & 50 mm SCREW @ 300 mm C/C (XX)
D - ASBESTOS SHEETS 150 mm WIDE OR PVC SHEETS
E - RAWL PLUGS & SCREWS WITH OVAL SHAPED SLOTS & WASHERS @ 300 C/C
F - COPPER CRADLE

Fig. 8.22. Expansion joint twin beams with twin columns

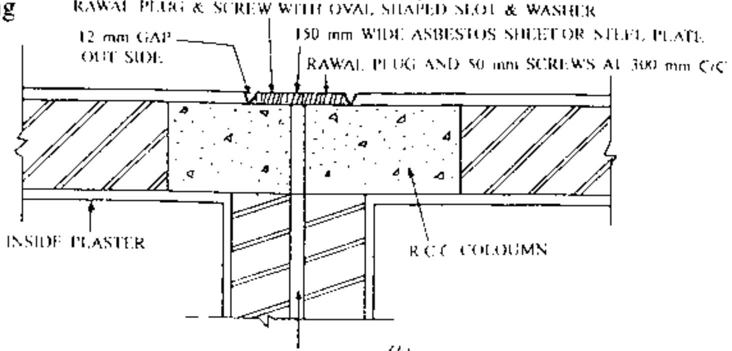
Slip joints provide sliding movement of one component over an other with mininum of restraint at the interface of the two components as a joint between R.C.C. slab and top of supporting wall below.

Contraction joints

Concrete shrinks or contracts due to plastic and drying shrinkage. Stresses in concrete are developed when shrinkage is restrained, resulting in cracking of concrete. To avoid these cracks contraction joints are provided. Contraction joints are also called as dummy or control joints. Contraction joints may be avoided by providing sufficient reinforcement in the structural element to take up the shrinkage stresses. Contraction joints are generally provided in un reinforced concrete pavements and floors.



(*a*) Expansion joint in long sun shade



(*b*)

Fig. 8.23. Details of expansion joint at outer face of column

The spacing between con-raction joints may vary from 5 o 10 metres.

Contraction joints are nade at the time of placing oncrete by embedding a tim-er batton or plate of sufficient lepth and thickness. This imber is removed when the oncrete has hardened. Some mes steel plates of sufficient epth and thickness may be mbedded into the concrete nstead of timber and removed vhen concrete has hardened.

The recent practice of roviding contraction joints is) cut a groove in the concrete f stipulated depth and width vith the help of sawing nachine. Normally sawing is one with in about 24 hours of nishing the surface. If the saw ut is done after seven days or nore, the depth of cut should e kept as 1/3rd of the iickness of the slab. The inimum width of 3 to 4 mm sufficient. Wider widths of its are unnecessary and un conomical as their cutting and ealing cost will be higher. The

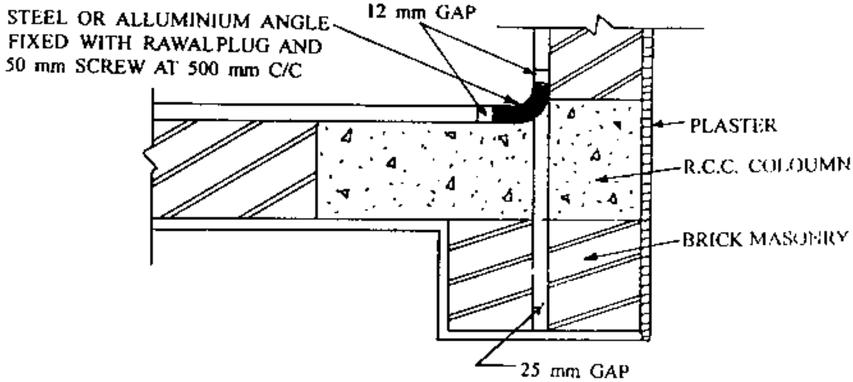


Fig. 3.24. Details of expansion joint at corner face of column

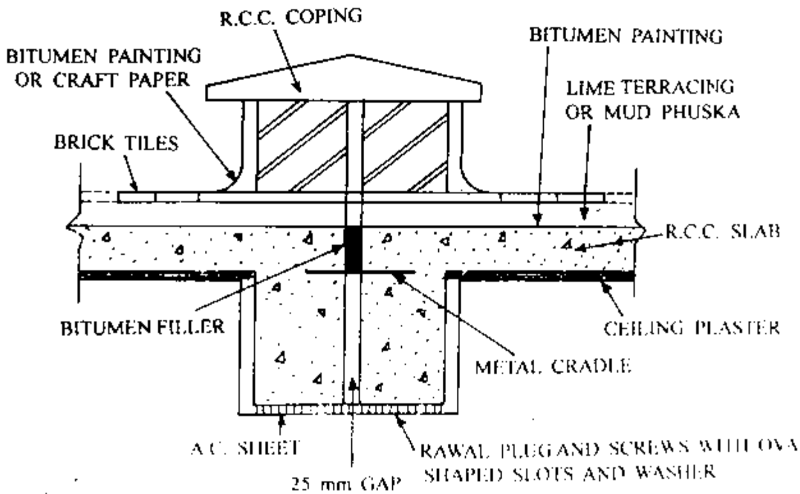


Fig. 8.25. Details of raised type expansion joint at roof

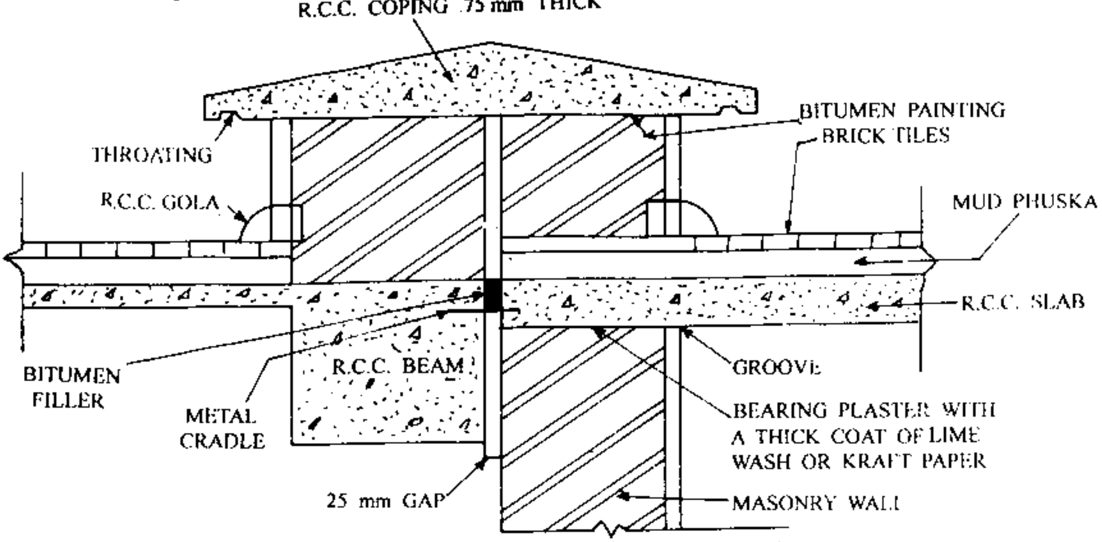


Fig. 8.26. Details of expansion joint of wall,beam junction

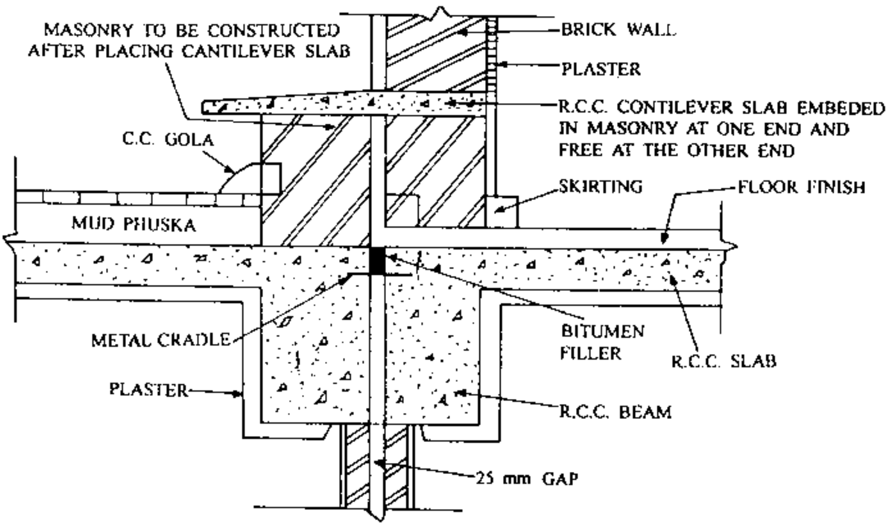


Fig. 8.27. Details of expansion joint at Roof and floor junction

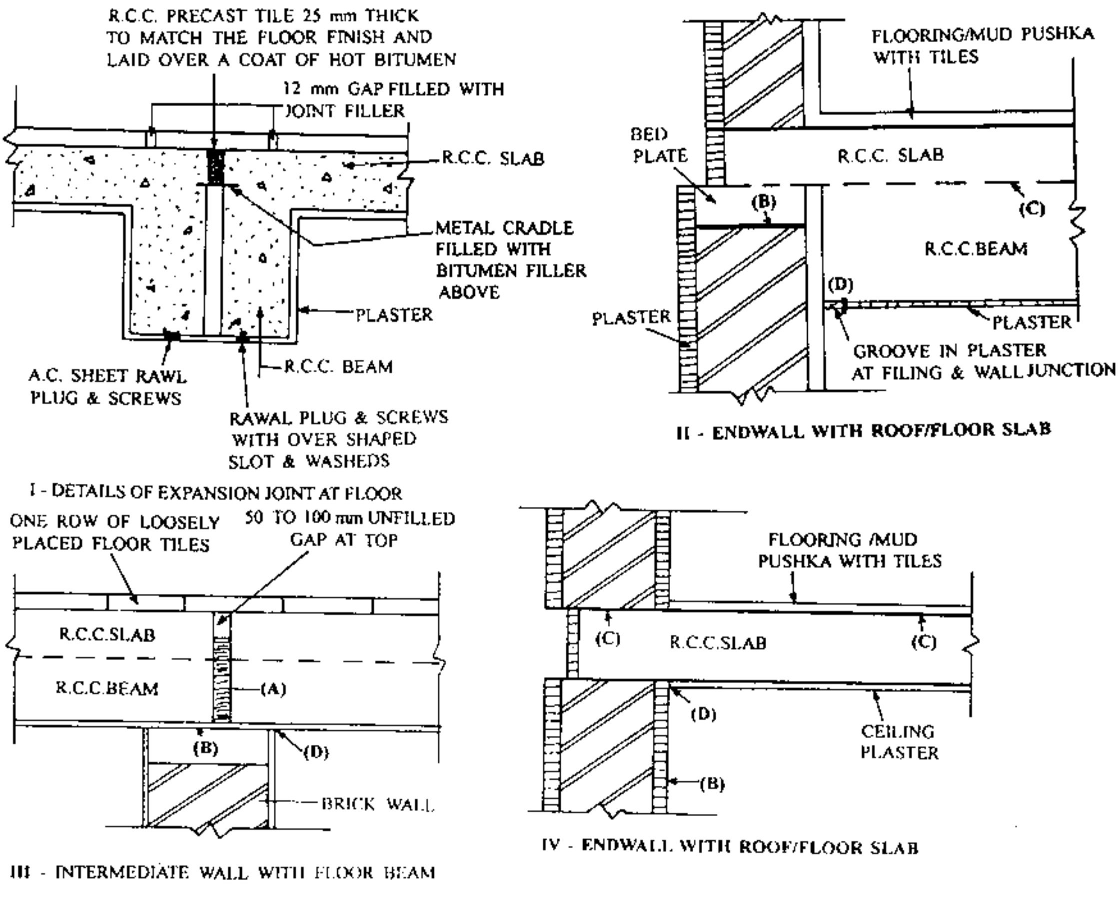
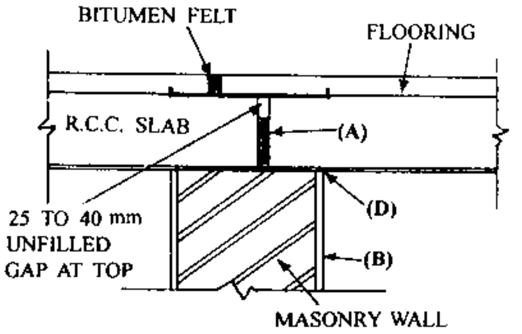


Fig. 8.28. Details of slip joint at floor/and roof



V - INTERMEDIATE WALL WITH FLOOR SLAB

Fig. 8.28.

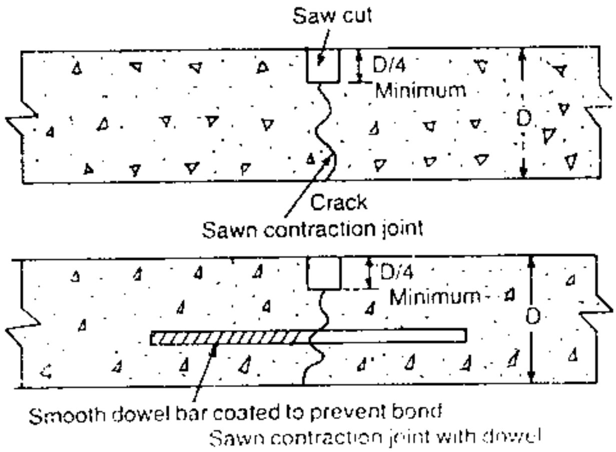


Fig. 8.29. Contraction joints

roove should be filled with suitable joint sealing compound to improve the riding quality of the pavement. t will also protect the edges of the concrete and prevent water from seeping into the base. The depth of oint should be about 0.25 times the hickness of slab as shown in Fig. .29.

In residential building floorings he conventional contraction joints re avoided by casting the slab in lternate bays to allow for the total lastic shrinkage and for maximum xtent of drying shrinkage. To reate discontinuity between the adjacent ays and to prevent the development of ontinuous cracks, usually glass or luminium strip is placed in between the ays. A contraction or dummy joint in avement slab is shown in Fig. 8.30.

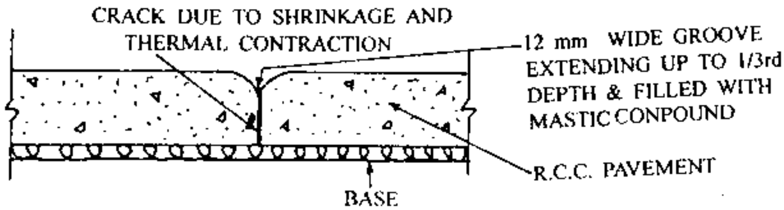


Fig. 8.30. Dummy joint in slab

.5. ISOLATION JOINTS

As the name suggests, this type of oint is provided where the concrete floor neets the permanent structural elements uch as walls, columns, foundations etc. The depth of the isolated joint is kept qual to the full depth of the concrete loor and its width of 10 to 12 mm is sufficient.

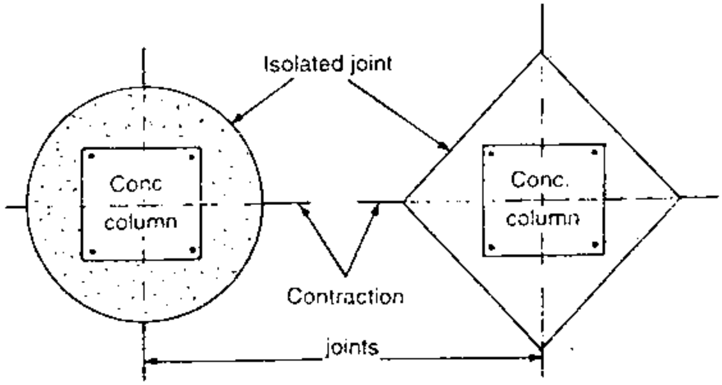


Fig. 8.31. Isolated Joints around column

To avoid ingress of moisture or other undesirable elements, these joints should be filled with resilient naterials and topped with joint filling compounds as shown in Fig. 8.31. A typical layout on ground of oints for concrete floor is shown in Fig. 8.32.

.6. REPAIR AND MAINTENANCE OF CONCRETE

Concrete works may fail due to any of the following reasons:

1. Faulty mix design 2. Faulty workman ship 3. Unfavorable weather conditions
4. Development of cracks due to variation in temperature or otherwise.

Methods of repair of new and old concrete works

For repairing concrete works following methods may be adopted:

1. By the use of expanding cement
2. By dry pack method
3. By replacement of concrete
4. By replacement of mortar
5. By pre packed concrete

8.7.1. By the use of expanding cement

This method specially is useful for hydraulic structures. If small cracks have developed in the structure, the crack is cleaned and either the concrete made of expanding cement or cement sand mortar is filled in the prepared place This cement expands upto 1% of its volume and fills space tight against the old surface, forming water tight joint or repaired surface. It takes about 15 days for full expansion. Further development of shrinkage cracks in concrete can be eliminated by using a small quantity of expanding cement.

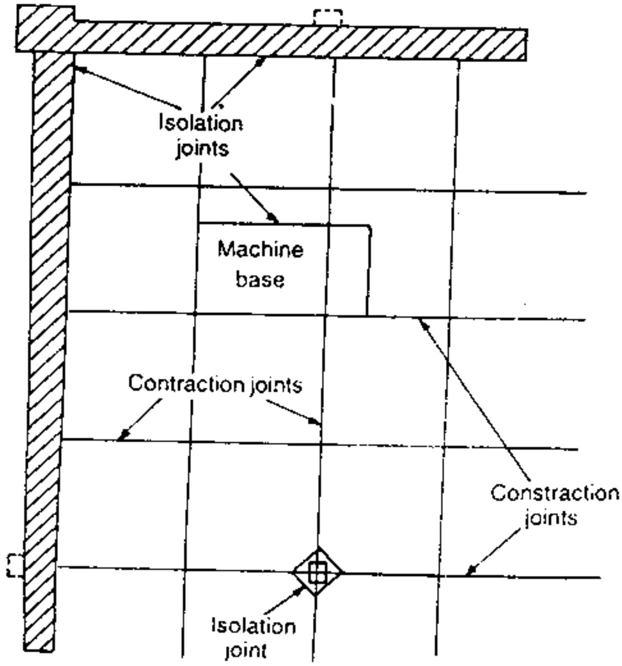


Fig. 8.32. Typical joint layout for concrete floor on ground

8.7.2. By dry pack method

This method is suitable for very small cracks or holes usually not deeper than 2.5 cms. The holes are made sharp and square on the surface and the interior portion is roughened and cleaned thoroughly and the dry pack material paste is filled. Step wise procedure is as follows:

(*a*) The hole is prepared well by roughening the interior of the hole and cleaning it by blowing compressed air or by any suitable means.

(*b*) The hole is washed by a water jet.

(*c*) The hole is allowed to dry. Over this dry surface a thin layer of cement sand mixture in the proportion of 1:1 is spread.

(*d*) Before the cement grout layer dries out, the dry packed material is put in the hole. The dry pack material is consisted of 1 part of cement and 2½ part of sand. Water should be added in a very small quantity to avoid shrinkage.

(*e*) Now the dry packed material is well compacted. The thickness of compacted layer should not exceed 1 cms in any case.

(*f*) To make the good bond with succeeding layer, the upper surface of the layer should be made rough.

(*g*) Till the hole is fully filled, the procedure is repeated and the last layer is finished to mach the surrounding surface.

8.7.3. Replacement Concrete and Mortar Methods

They have been discussed in chapter 7, Page 96 and 97.

8.7.4. Prepacked Concrete

This method is specially useful for the repair of tunnel lining, dams and bridges, under water construction of bridge piers, dry docks etc. In this method the aggregate coarser than 6 mm is filled in form placed around the structure to be repaired, and a grout mix consisting of 1 part of cement, 1/2 part of finely divided active siliceous material and 1/2 part of fine sand is pumped into the aggregate to fill the voids of aggregate and form a compact mass. The resulting concrete is strong practicallv having no shrinkage as the coarse aggregate particles are in direct contact with each other. Due to this fact this system has proved to be an ideal one for patch work in hardened concrete. The water in the grout should be as minimum as possible.

8.8. TYPICAL REPAIRS OF CONCRETE STRUCTURES

Beams, columns and slabs are the most important components of the concrete structures. Due to the large number of cracks or damages observed in these components of the structure, the repair and rehabilitation of such members assumes greater importance. Techniques of repairs of these components have been discussed in the following sections:

8.9. REPAIR OF CONCRETE FLOOR AND SLAB SYSTEM

For change of occupancy *i.e.* use of the structure to increase life span of concrete slab system, generally their repair or renovation and upgradation is needed. Provision of services below the floor surface may also require the replacements of floor surface. These may require complete structural up gradation or the repair of visual damages only or provision of a thin surface topping to the existing concrete to produce a wearing surface having a good resistance to abrasion and wear.

Before carrying out the repair of concrete floor and slabs, the causes of damage must be investigated and specifications of repair are drawn keeping in view the future use of the floor. The floor should be surveyed for the defects and the existing levels of the floor should be recorded with respect to a known datum. The existing services in the floors should also be plotted and tested for their satisfactory condition. In many cases only the bonding coat may be sufficient, while in other cases the topping over the whole area may be required. Before carrying out the repair operation, the damaged area and the joints should be repaired, otherwise these defects may reflect up through the new topping.

Under certain circumstances, the slabs in concrete structures may deteriorate in selective locations exposing the reinforcement. Scaling may occur due to an inadequate internal air void system in the concrete. Considerable scaling may also occur in the presence of moisture and also due to freezing and thawing in cold regions. The surface delamination of concrete in the slab may also occur due to the corrosion of reinforcement. The delamination of concrete above and around the reinforcement indicates deterioration which is dangerous for the long term structural integrity. To reduce the further corrosion of the embedded reinforcement, repair should be done to prevent the moisture infiltration into the concrete.

For a large extensively damaged slab system, the use of a thin over lay of methyl methacrylate polymer concrete has been found very useful, as usually polymer concrete does not absorb moisture.

8.9.1. Preparation of surface

Each repair area should be marked by a saw cut 3 mm wide and 6 mm deep groove around its perimeter upto at least 100 mm out side of the damaged area as shown in Fig. 8.33. The entire area in between this boundary should be scarified by a suitable machine or by hand to remove the concrete upto a level below the damage to get a sound and clean concrete suitable for repair. After the scarification of the damaged area, the delaminated surface should be located by using a small chipping gun.

The reinforcement in the delamination area should bee exposed and chipping continued till all concrete with in 12 mm of the entire exposed portion of reinforcing bars in removed. To ensure that all delaminated unsound concrete has been removed, the prepared surface should be resounded again. To remove all corrosion byproducts from the reinforcement, it should be sand blasted. Finally the entire repair area should be blown off with the compressed air to remove any loose corrosion particles, concrete, blasting sand and dust etc.

In case of cement sand mortar repair, the prepared surface of reinforcement is coated with a cement paste layer. This cement paste layer will provide additional protection to the reinforcement. After the coated surface has dried, the area to be repaired is kept thoroughly wet for 24 hours, if possible. Before filling the cementitious material consisting of 1:3 cement sand mortar of suitable workability by hand, all water from the surface should be wiped off. For small repair works, the proprietary materials may be used, which are carefully batched and quality properly controlled. Due to higher workability of the repair mix. they should be only hand tempted.

For other cement sand mixes vibrating hammer with square bottom plate are often used, but for a large area, a short beam fitted with form vibrator may be used for compaction. The repairs finished off by hand trowel. It should be allowed to cure for 7 days by covering it with polythene sheets.

For high quality local repairs dry cementitious mortar materials along with a polymer as styrene butadiene, rubber latex etc. can be used.

8.9.2. Procedure

The exposed surface of concrete and reinforcement are coated with a primer compatible with the repair system. The primer can be applied by rolling it on the surface with a paint roller and allowed to harden. The primer coat on the reinforcement provides it an additional protection against corrosion. After the primed surface has hardened adequately, it becomes impervious to moisture and could remain protected from environmental effects.

In case of deep sections, an initial bedding layer of polymer concrete is placed around the exposed reinforcement to ensure that the exposed reinforcement is fully surrounded by the polymer concrete. In deeply removed areas the polymer concrete is spaded beneath the reinforcement to remove the air pockets. After this, the chipped areas are back filled with sand loaded polymer concrete. Over the exposed reinforcement a thin coat of neat polymer concrete followed by a 6 mm layer of polymer concrete is applied.

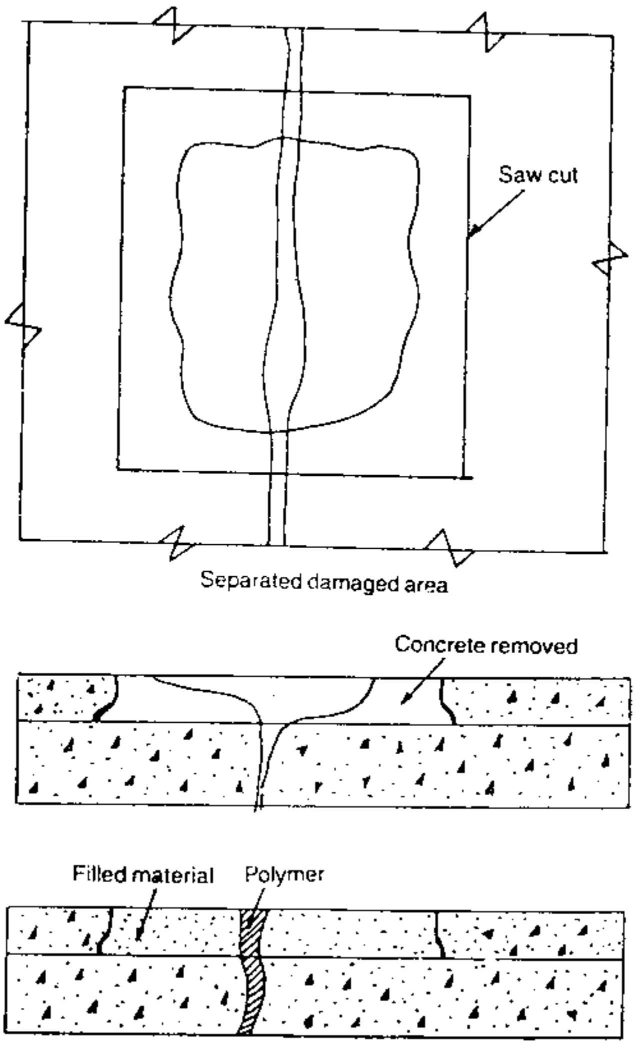


Fig. 8.33. Repair of damaged area of a concrete slab

Before applying the second layer of polymer concrete to build up the cover thickness in the area over the reinforcement, the first applied material should be allowed to be hardened. To provide a minimum thickness of 6 mm polymer concrete over the entire repaired area, a final layer of polymer concrete is applied. Over the exposed reinforcement a minimum 12 mm polymer cover is desirable.

After hardening the final layer of polymer concrete, the joint between the repair material and the repaired concrete should be sealed with the same primer as placed on original prepared surface.

In deeper patches, to control the shrinkage, the material should be applied in layers. At higher temperatures above 21°C, the rapid evaporation of polymer liquid reduces the working time available before the material gains the initial set. Thus placing, screeding and trowling must be done quickly. In such situations working at night or early in the morning gives better control for reducing ambient temperature.

8.10. ORERLAYS AND SURFACE TREATMENTS

For active or dormant cracks in structural and pavement slabs, both can be repaired by laying bonded topping or overlay. Mostly cracks developed due to variation in loading, moisture and temperature are subjected to movement. These cracks will reflect through any bonded overlays and the crack repair will be in effective. However drying shrinkage cracks can be repaired effectively by the use of overlays.

Fine dormant cracks of bridge decks and slabs can be repaired by the use of overlays of polymer modified Portland cement concrete or mortar. In highway bridge a minimum thickness of 40 mm of the overlay should be used. For such repairs polymers such as latexes of styrene, butadiene acrylic, non re-emulsifiable polyvinyl acetate and certain water compatible epoxy resin system can be used. The minimum quantity of resin solids should be 15% by mass of the portland cement.

8.10.1. Procedure

Before applying an topping or overlay, the old floor slab should be shot blasted to make it rough to develop good bond between the old surface and the topping. After shot blasting, the surface should be well cleaned and saturated with clear water. The localized depressions or damages should be repaired before applying cementitious topping. Usually two types of toppings may be used, namely bonded or un bonded toppings. The thickness of the topping is governed by the strength and thickness of the old floor slab.

8.10.2. Bonded toppings

These toppings require bonding aids, such as resins, polymers and cementitious grout. A cementicious grout of creamy consistency can be applied by brush on the floor slab immediately before placing the topping mix. The proportion of mix of 1:1:2 by mass of cement, sand and 10 mm size coarse aggregate has been found quite satisfactory for the topping. The sand to be used should be of medium grade (zone II) and the coarse aggregate should be hard and clean. Generally granite aggregate is used. In addition to granite, flint or quartzite, gravel, ballast and hard lime stone can also be used. The quantity of water to be added should be minimum to attain full compaction. The topping mix should be laid in 20 to 40 mm thick layers in bays such that the construction joints of old floor must reflect up through topping.

The mix should be competed on the old floor and troweled level at intervals while topping is hardening. After final troweling the topping should be left for curing by covering it with polythene sheet for at least 7 days.

In case of polymer modified portland cement topping, a bond coat consisting of bromide latex mortar or an epoxy adhesive should be applied immediately before placing the topping. The polymer modified topping should be mixed, placed and finished rapidly with in 15 minutes in warm weather. 24 hours curing of such toppings is sufficient.

8.10.3. Unbounded toppings

This is an additional slab laid over the old floor slab, hence no surface is required. However the construction joints in the old floor must be reflected through the new slab. As a damp proof membrane properly lapped polythene sheets are laid over the base slab. Concrete of compressive strength of 300 kg/cm^2, having cement 350 kg/m^3 of concrete should be placed and compacted. The concrete should be laid in bays of sizes upto 15 m^2. The thickness of concrete may be 100 mm. Before hardening of this concrete a high strength topping of 10 to 15 mm thickness should be placed over it and compacted well over the surface. The mix of the topping may be as 1:1:2 cement sand and 10 mm coarse aggregate as above.

8.10.4. Reconstruction of slab

In case of broken slabs, it is preferable to construct it afresh. In case of ground floor slabs, the sub grade should be inspected, compacted and brought to correct level by using lean concrete about 150 mm thick or well graded crushed rock material is laid. A polythene sheet should be placed over the top of the sub base to act as a damp proof layer before concreting. The concrete is fully compacted with any suitable method, finished and cured at least for 7 days by covering it with polythene sheet. It should not be loaded for 28 days.

8.11. REPAIR OF BEAMS

In case of extensively damaged beams, additional reinforcement at the bottom of the beam together with the new stirrups should be provided. The stirrups either can be anchored by expanding bolts set in side of the beam below the slab sofit or may be taken right round the beam through holes drilled in the slab. To provide a good bond between the old and new concrete, the old surface should be roughened. The new concrete may be placed by guniting. If required shear connectors may also be provided by expanding bolts etc.

8.12. SURFACE COATINGS

A layer of material which adheres to the surface and forms a continuous membrane or film is known as coating. Generally coatings adhere to the concrete and form membrane after their application. Concrete basically is a permeable or porous material. The porosity of concrete is developed due to the evaporation of about 60% water added to it for workability. After placing the concrete, it retains about 25% water as water of crystallization and 15% water as gel water during its curing period. The evaporation of water forms capillary pores which allow ingress or diffusion of carbon dioxide and other gases into the concrete. These gases and carbon dioxide dissolve in the pore water to form acidic solution, which further reacts with the ingredients of concrete and damage it. The porosity of concrete also allows ingress of water containing harmful reagents in solution, which are a potential source of damage to the concrete.

Concrete is strongly alkaline and is susceptible to attack from acidic reagents. Thus for the protection of the structural concrete, coatings of suitable materials should be applied. Different types of coatings are discussed below.

8.12.1. Types of Coatings

1. Anti-carbonation coatings. The coatings applied to the concrete surface to check the process of carbonation are called anti-carbonation coatings. The carbonation is the process in which carbon dioxide reacts with pore water forming carbonic acid, which reacts with calcium hydroxide and forms calcium carbonate ($CaCO_3$). In the process other cement compounds are also decomposed damaging the concrete. The anti carbonation coatings are based on chlorinated rubber, polyurethane resin or acrylic emulsions. These coatings may be effectively used to resist carbonation and general atmospheric deterioration of reinforced concrete. In situations where the spalling and corrosion are more wide spread, the use of anti carbonation coatings has not been found satisfactory.

2. Coatings to resist acidic effects. In industrial areas, the concrete structures occasionally are subjected to abnormally acidic environment due to the release of sulpher dioxide from steel plants, oil refineries, and power stations etc. into the atmosphere. These gases readily dissolve in atmospheric moisture and rain water, forming sulfurous acids. Concrete in constant contact with such waters disintegrates easily. Thus to protect the concrete from such environment, coatings of highly chemical resistant materials should be provided. Under most circumstances two coats of polyurethane coating has been found most suitable.

3. Coating to protect cracked concrete. The very fine cracks not considered structurally significant may be protected by applying coatings over the cracks locally. These are known as conventional coatings. The coatings should have flexibility and ability to bridge the cracks.

Epoxy polyurethane and high build polyurethane formations have been found very successful to protect the cracked concrete.

8.13. LEAK SEALING

Leakage of water in concrete structures is a inevitable source of damage to reinforcement. The construction joints, shrinkage and restraint cracks form the leak paths. The amount of leaking water vary from damp patches to running leak. In case of damp patches the water evaporates from the patches so formed and in case of running leaks, pool of water is formed on the un drained surfaces. Honeycombed concrete, expansion and contraction joints are also the common route for heavy leakage. Damp patches may also be formed due to the passage of water through voids formed due to plastic settlement along the reinforcement bars.

In case of water retaining structures, the extent of leakage may be determined by monitoring the loss of water from the structure. According to B.S. 5377, the structure may be assumed as water tight if total drop in surface level does not exceed about 1.5 mm in 24 hours.

For effective leak sealing, it is essential to identify the sources and routes of leakage. Due consideration must be given to the likely cause of leakage and behaviour of structure during the service period.

8.13.1. Techniques of Leak Sealing

Leak sealing is very expensive. It should be taken up when it is necessary. Leak sealing methods may be classified as follows:

1. Conventional leak sealing methods
2. Leak sealing by injection method

8.13.1.1. Conventional methods

Minor sources of leakage may dry up by autogeneous healing, which is the accumulation of calcium salts along the path of the leak. The accumulation of salts will obstruct the passage of water and reduce the leakage to negligible proportion. After identifying the leak spots, the remedial measures may involve the local or total surface seal in the form of a coating system. Following sequence of action may be adopted:

1. Surface preparation.
2. Filling depressions or dents etc. This process is known as imperfections of surface with resin based grouts.
3. Application of primer.
4. Finally application of two coats of high build paint.

Procedure. The suspected joints and random shrinkage cracks are filled with the injection of a low viscosity resin. Short patches of honey combed concrete should be filled with a resin based mortar or putty. Laitance and surface contaminants should be removed by sand blasting and power wire brush. Thus the preparatory work is quite extensive.

The movement joints as expansion and contraction joints may be sealed by filling a resin into them. On hardening, this resin will form a flexible sealant. The concrete joints must be thoroughly prepared and cleaned before the application of the sealant. If required an appropriate primer or bonding coat should be applied.

8.13.1.2. Injection sealing

From pressure and liquid flow considerations, the simplest and most cost effective way is to seal the leakage from the water retaining side of the structures. In case, it is not possible to reach the wet side, the leakage can be tackled from the dry side, which is considerably more difficult than wet side. To seal the leakage successfully, the water passage must be filled with sealant *i.e.* grout completely. As the working time of the typical repair material is very short, the velocity of flow of material should be kept very high to fill the water passage fully.

To seal the leakage, the first basic requirement is to confine the water flow to a tube, through which the sealant may be introduced. Once the flow of water has been controlled, the connection between the tube and concrete must be made strong enough to withstand the injection pressure. During injection process, the concrete may be over stressed. Hence it is preferable to maintain low pressure.

8.13.2. Methods of grout injection

The grout may be injected by the following methods:

1. **Direct method.** In this method the grout is injected against the pressure gradient from the down stream side. The direct method is very slow, as the grout is pumped very slowly through very

narrow passage against pressure and the pressure can not be maintained for a long time to achieve the complete penetration. In many cases water may find another finer path way leaking from the same source.

2. **Indirect method.** In this method, the grout is introduced on the pressure side so that the path ways are filled under the acting hydrostatic head. By this method the work of sealing the leakage can be completed quickly as surface seals are not required and mechanical anchorages may be used.

8.14. UNDER WATER REPAIRS

For under water repairs same methods may be adopted as for above the water surface *i.e.* dry repair with modifications as per need. However materials used in above water repairs are found unsuitable for under water repairs, laboratory trials should be carried out. The laboratory trials are also necessary to identify the possible problem areas and to ensure the smooth site operations. As usual, before under taking the repair work, the damaged area should be cleaned of marine contaminants. This will help in detailed inspection for assessing the extent of damage. In case of smaller areas cleaning can be done by using mechanical wire brushes, needle guns or scabbing tools etc. In case of larger areas, a high pressure air jet may be used. After cleaning the surface, the extent of cracked and spalling concrete should be ascertained either with the help of divers or remote operated vehicles to photograph the area.

8.14.1. Special features of under water repair

Following are the special features of under water repairs:

1. The under water repairs are more complex and highly costly. Hence the repair operations should be as simple as possible. The choice of technique depends on the available mode of access to the damaged area.
2. For the adequate preparation of the damaged area, special techniques may be necessary.
3. The repair material must be compatible with under water use both during placing and curing. Cementitious materials have been found more suitable for under water repairs.
4. Form work and placement method adopted should be such that mixing of repair material with the water should be minimum.
5. The supervision of under water repair is costly and difficult.

8.14.2. Steps involved in under water repair

In under water repair, following steps are involved:

1. Preparation of damaged area. The preparation of damaged surface consists of removal of cracked or badly damaged concrete and cutting of distorted reinforcement. The damaged concrete may be removed by any of the following methods:

(*a*) **By the use of high pressure water jetting.** In this method, water jet with a pressure between 200 to 1000 atmospheric pressure is directed on the concrete surface to remove the hardened cement paste mortar from the spaces between the aggregates. In this process the reinforcement is itself cleaned and can be used in repair. If the reinforcement is also to be cut, then the abrasive slurry is injected into the cutting jet.

(*b*) **By the use of splitting technique.** In this process the damaged concrete can be cut by inserting the hydraulic expanding cylinders into predrilled holes, and then increasing the pressure in these cylinders till the splitting of the concrete takes place.

(*c*) **By the use of expanding cement.** In this case the expansive cement is mixed with water to form a cement paste. The cement paste is filled into plastic bags and these plastic bags are deposited in the pre drilled holes in the structure. The expansion of the cement during the next 12 hours to 24 hours generates stresses of the order of approximately 3000 kg/cm^2, which is quite sufficient to split the concrete.

(*d*) **By the use of soft explosion.** In this case, the pressurized carbon dioxide cartridges are placed in pre drilled holes. The cutting dust and earth is filled in the holes and rammed with wooden tools to make it water tight. The pressure is then released by electrically detonating a small initiating charge in each cartrige producing comparatively a gentle explosion, which results in controlled splitting of concrete by cracks formed between the prepared holes.

(*e*) **By the use of diamond tipped saw.** This method is useful for miner works only as for core cutting. In this case a hydraulically powered diamond tipped saw and drill is used for cutting the concrete under water. The reaction force to the tools can be provided by strut or strap arrangement bolted to the structure.

(*f*) **Cutting of steel.** For cutting of steel under water, usually following methods are adopted:

(*i*) Oxygen fuel gas cutting
(*ii*) Oxy arc cutting
(*iii*) Mechanical cutting

After the removal of damaged concrete, all broken or distorted steel has to be removed and replaced before restoring the cover. The reinforcing bars are replaced with new lengths, joined either by couplers or lapped with the existing bars. Immediately before replacing the damaged concrete, the surface must be flushed with clean water to remove any microbiological growth which may reduce the bond significantly between the repair material and the surface.

8.14.3. Application of Materials

1. Placement of mortar. For the prevention of future deterioration or in case of miner damages cementitious or resin based materials may be filled into the cracks. This patch work is suitable only for small volumes. To reduce wash out of cement from conventional cementitious grouts and mortars, adhesive admixtures should be used. The high performance mortars mixed above water can be poured by free fall through water to fill the form work. Normally the mixes are formulated to be self levelling to ensure good compaction with out vibration. These mixes can be laid in thickness varying from 20 mm to 150 mm. To safe guard against wave action damage on vertical faces, the repair may be carried out using either form work and free flowing grout or a hard epoxy putty.

The normal epoxy or polyester resin mortars are totally unsuitable for under water use. For under water use special formulations have been developed. Normally these are free flowing, hence they can be poured through water into the form work. For vertical face work, special types of under water grade epoxy putty has been developed.

2. Grout injection into the crack. The general principles for injecting grouts into the cracks are the same as that for above water injecting; but due to the risk of washout of cementitious material, generally non conventional epoxy resin injections are preferred. As shown in Fig. 8.34 epoxy putty is used to seal the cracks between the injection points. The epoxy resin must be of low viscosity solvent free under water grade, so that water in cracks may be replaced by a structural material. For small repair work, the hand held

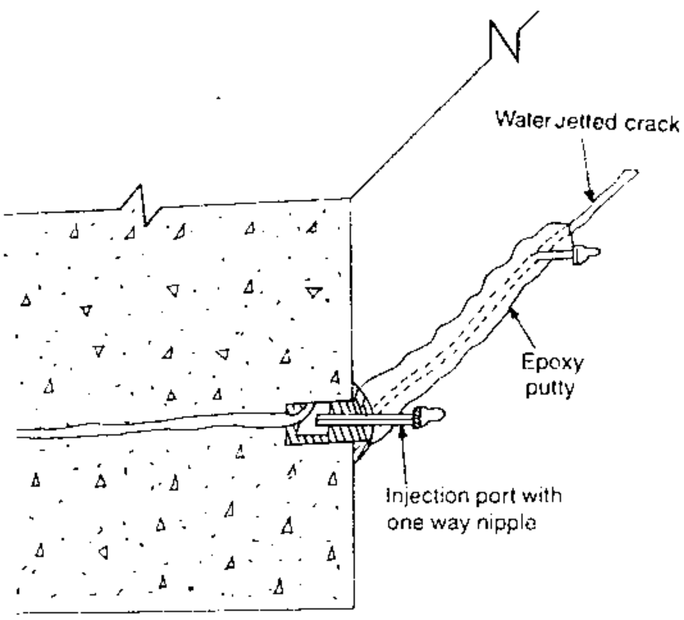


Fig. 8.34. Under water crack injection arrangement

cartridge injection gun may be used satisfactorily.

3. Large scale repair. For placement of bulk repair material under water, following requisites are necessary.

(*a*) The form work complete with inlet pipes and external vibrators should be easy to erect.

(*b*) The existing structure should be able to withstand or bear the vibrations.

(*c*) To ensure an leak proof joint, flexible seals should be used.

(*d*) For vertical repairs, to secure the form work with the concrete a positive attachment of steel straps or rock bolts fixed into the hole drilled in the concrete as shown in Fig. 8.35 should be used.

(*e*) In between the concrete face and form work a thick layer of compressible gasket as neoprene rubber should be used to form an final seal.

(*f*) Finally the gaps due to un expected variations in levels should be sealed.

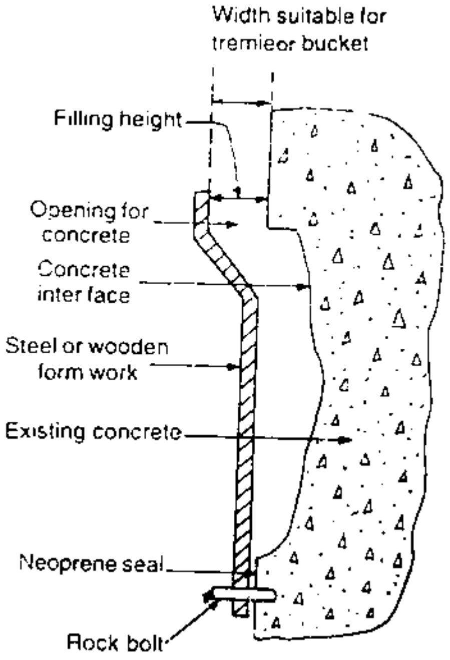


Fig. 8.35. Form work details for under water repair

8.14.4. Mix design

For under water repair certain modifications in the mix design may be done depending upon the nature of work. On the basis of experience, the concrete mix proportion should be selected to give the desired strength having slightly more sand in the mix, *i.e.* the mix should have some more fine aggregate. To have a provision for wash out of cement, the cement content is increased by 25% of the designed quantity of the cement. Lean mixes having cement less than 350 kg/m^3 have not been found suitable for under water repair works.

Round river gravels and well washed marine drudged aggregates have been found quite suitable for tremie pipe and pump placing methods of concrete.

For heavily reinforced concrete for small repairs to obtain necessary flow characteristics super plasticizing admixtures should be used in the mix.

8.14.5. Placement methods

For under water repairs, the method of placement of concrete should be selected in such a way that the contact area between the concrete and water is minimum to prevent turbulence. The concrete may be placed by any of the following methods:

1. By tremie pipe method
2. By skip (Bottom open bucket)
3. By pumping
4. By pre packed aggregate method

The pre packed aggregate concrete method of placement has been found ideally suitable for under water or tidal works where access conditions are limited or conventional concrete may be washed out by fast flowing water.

QUESTIONS

1. Discuss different types of Joints.
2. Discuss the procedures of concreting in long and high walls with emphasis on the provision of joints.
3. Discuss the correct location of construction joint.
4. Explain expansion joints with reference to their spacing and effectiveness.

5. What are contraction joints? How are they provided?
6. Discuss the under water repairs of concrete in detail with the help of suitable sketch where ever possible.
7. How leaks from under water structures can be checked?
8. Discuss the repair of floor slab system with suitable sketches.
9. Name different methods of repairing new and old concrete works and discuss dry pack method fully.
10. In concrete structures joints may be provided of the type.
    (*a*) Construction joint (*b*) Contraction joint
    (*c*) Expansion joint (*d*) Isolation joint
    (*e*) All the above
11. The delibrably provided joints in concrete area called
    (*a*) Construction joint (*b*) Expansion joint
    (*c*) Isolation joint (*d*) Leakage joint
12. The construction joint should be provided where
    (*a*) Shear force is maximum (*b*) Bond strength is maximum
    (*c*) Shear force is minimum (*d*) Any where in the section
13. Identify the incorrect statement/statements
    (*a*) Vertical joints reduce the shear strength of concrete considerably
    (*b*) The best location of providing construction joint in concrete slab and beams is the middle third portion of the span.
    (*c*) The construction joint should be provided at the support of the beam and slab
    (*d*) In water retaining structures a copper strip should be provided across the joint with a loop at is centre
    (*e*) The loop should be free to move and provided towards the water surface of the wall
    (*f*) The floor slab of water retaining structure should be mondithic with its walls
14. Identify the incorrect statement/statements
    (*a*) Concrete expansion is a function of its w/c ratio
    (*b*) Higher the w/c ratio, higher the expansion of concrete
    (*c*) Higher the w/c ratio, lower the expansion of the concrete
    (*d*) Spacing of expansion joint should be about 20 m
15. Identify the incorrect statement/statements
    (*a*) Contraction joint is provided to avoid the development of shrinkage cracks
    (*b*) Contraction joints are also known as dummy or control joints
    (*c*) Contraction joints are usually provided in the R.C.C. floors and pavements
    (*d*) Spacing of contraction joints may vary from 5 to 10 m
    (*e*) Contraction joints may be provided after the setting of concrete
16. The technique of epoxy injection is used for
    (*a*) Sealing actively leaking cracks (*b*) Repairing of hydraulic structures
    (*c*) Sealing narrow cracks in structural members (*d*) All the above
17. For sealing cracks in concrete structures by epoxy injection, the minimum width of routing should be
    (*a*) 20 mm (*b*) 15 mm
    (*c*) 9 mm (*d*) 6 mm
    (*e*) 3 mm
18. The minimum thickness of bonded over lays of polymer modified cement concrete or mortar should be
    (*a*) 100 mm (*b*) 75 mm
    (*c*) 50 mm (*d*) 25 mm
19. The polymer impregnation of concrete to check the leakage is effective
    (*a*) When the cracks are dry (*b*) When the cracks contain moisture
    (*c*) When cracks are fine (*d*) When volatile monomer evaporates

ANSWERS

10. (*e*)	12. (*c*)	14. (*c*)	16. (*c*)	18. (*a*)
11. (*b*)	13. (*c*)	15. (*a*, *e*)	17. (*d*)	19. (*a*)

9
Maintenance and Repair of Finishes

9.1. INTRODUCTION

Building finishes are provided to give a aesthetic and elegant look to the building and at the same time to protect the exposed surfaces from atmospheric and other agencies. Generally the selection of finishing materials is done on the basis of the appearance they provide, economy, thermal insulation and location and maintenance. Main elements for application of finishes are walls (internal, external), floors, ceilings, doors windows, columns etc. In this chapter finishes of walls and floors will be discussed.

9.2 DEFINITIONS

1. Plastering. It is the term used to describe the process of spreading material over irregular and coarse textural walls, columns, ceilings etc. to provide a smooth, hard, and level finish, which can be painted for the sake of appearance.

Plaster. The layers of mixture of materials as cement-sand, lime-sand and cement, lime sand is known as plaster. These materials are mixed in pre predetermined ratio and spread over the surface to be plastered.

Rendering. Generally the term rendering denotes external plaster and allied finishes applied for protection and decoration of the surface. It can be designed for performance to suit different back grounds and conditions of exposures or weather as heavy rains, dusty winds, large variation in temperature or corrosive atmosphere.

Cladding. The protective layer of wall tiles or stone veneers applied on the external face of the wall is called cladding. These are provided on important buildings to provide an alternative exterior finish. Their maintenance is less.

9.3 APPLICATION OF PLASTER (IS 1661-1972)

9.3.1. Suction effect of the back ground

Generally the surface, over which the plaster is to be applied is prone to suck out moisture from the plaster mix. This tendency of sucking moisture can be checked either by wetting the back ground suitably, if it is dry or sprinkling with cement slurry. If the back ground is too much moistened, plaster would creep and fall down due to its own weight. On the other hand if the surface is too dry, it will suck excessive moisture from the plaster mix, rendering it weak, porous and friable. Too much water makes it impossible to keep the mortar in position till it sets.

9.3.2. Initial set

Cement and cement lime mortars should be applied before the setting process starts. The initial setting of cement starts after 30 minutes of adding water. In the case of cement plaster, the commencement of initial set is fairly noticeable, but in case of cement lime mortar it is not. Thus such mortars should be used with in two hours of adding water to the mix. retempering of plaster mixes after initial set has commenced, will result in loss of strength and efficiency

9.3.3. Dubbing out

Where some part of the surface is uneven, the hollows should be filled with under coat of the plaster upto the general level of the wall face or surface. This operation is called dubbing out. After dubbing, required finish is carried out. Dubbing out operation should not be carried out in one operation for a depth more than 10 to 5 mm. The second and subsequent coats should be applied after a gap of 10-12 hours.

9.3.4. Mortar mix

Mixes for plastering, usually adopted are as 1:3, 1:4, 1:6 cement sand and 1:1:6, 1:2:9 cement, lime, sand mixes. Infact cement-lime-sand mixes are preferred due to their better workability, ease of spreading on the surface, and less proneness to cracks due to shrinkage. The cement-plaster is more laborious to spread and level than lime or cement lime plaster. Besides cement plaster shrinks on drying and develops cracks.

9.3.5. Suitability of cement lime mixes

These mixes have the following advantages:

1. Cement lime mixes have high workability and marked ease of application.
2. These mixes have reasonably long working time about 2 hours.
3. These mixes have fairly slow rate of strength development and adequate early strength to with stand building conditions.

These properties become less pronounced as the proportion of cement is increased in the mix. More cement proportioned mixes need moisture to complete the setting process and thus rapid drying in the early stages should be avoided.

9.3.6. Number of coats

Where ever possible, the ideal number of coats is two, namely the under coat and finishing coat. In the past, single finishing coat plaster had been carried out successfully on reasonably plane back grounds of brick, concrete and similar materials. For very rough surfaces as rough stone masonry, or expanded metal lathing fixed over timber joints etc. two or three coats of plastering is necessary.

The finished surface of the plaster should be flat and fine textured (smooth). Thus to get such surface usually Gypsum layer is used. Over the base course of plaster a thin layer of Gypsum of about 3 mm thickness is applied and troweled it level and smooth. As the irregularities in the surface of even most accurately laid brick work or blocks work are generally of more than 3 mm. Hence to achieve a satisfactory finish, two layers of plaster should be applied, one as base course or under coat and the second as finishing course.

Instead of applying a fine grained plaster in two coats to irregular surfaces, generally it is the practice to spread coarse grained material which is easily spread as base coat and the surface is rendered level with a wooden straight edge. The surface is left rough and furrowed 2 mm deep with a scratching tool diagonally in both direction to form keys for the finishing coat. The finishing coat of 6 mm thickness of fine grained material is applied after the under coat has hardened sufficiently, but not dried. In any case, finishing coat should be laid with in 48 hours of laying the under coat. The finishing coat should be finished with trowel to produce smooth finish.

9.3.7. Thickness of plaster

In a single coat plaster 12 to 15 mm thickness is adopted. 15 mm thickness is adopted on rough side of single brick or half brick wall, where as in two coat plaster generally the total thickness should not exceed 20 mm and 15 mm in case of concrete soffits. The base coat generally is of 12 mm thickness varying from 10 to 12 mm and the finishing coat 6 mm thick (3 to 8 mm). The thickness in case of three coat plaster normally should not exceed 25 mm. The thickness of base coat may be 10 to 15 mm, and that of second coat 3 to 8 mm and finishing coat 3 to 5 mm.

9.3.8. Sand for plaster

Sand grading for internal, external and ceiling plaster should as shown in the following Table 9.1

Table 9.1. Sand grading as per IS-383-1970 and (IS-1542-1977)

IS Sieve designation	*Percentage Passing*			
	Grade zone-1	*Grade zone-2*	*Grade zone-3*	*Grade zone-4*
10.0 mm	100	100	100	100
4.75 mm	90 – 100	90 – 100	90 – 100	95 – 100
2.36 mm	60 – 95	75 – 100	85 – 100	95 – 100
1.18 mm	30 – 70	55 – 90	75 – 100	90 – 100
600 micron	15 – 34	35 – 59	60 – 79	80 – 100
300 micron	5 – 20	8 – 30	12 – 40	35 – 50
150 micron	0 – 10	0 – 10	0 – 10	0 – 15

Note. The grading of 600 micron sieve should not fall out the limits as shown in the table out side more than 5%.

Table 9.2. Grading of sand for masonry mortar (IS-2116-1980)

Masonry Mortars (IS 2116-1980)		*Plaster (IS 1542-1977)*	
IS Designation	*Percentage passing by weight*	*IS Designation*	*Percentage passing by weight*
4.75 mm	100	4.75 mm	95 – 100
2.36 mm	90 – 100	2.36 mm	95 – 100
1.18 mm	70 – 100	1.18 mm	90 – 100
600 micron	40 – 100	600 micron	80 – 100
300 micron	5 – 70	300 micron	20 – 65
150 micron	0 – 15	150 micron	0 – 50

9.3.9. Fineness Modulus of sand for plaster

Fineness modulus of sand to be used in plaster should not be less then 1.4 in case of crushed sand and not less than 1.5 for naturally occurring sand.

When plaster to be sued in two or three coats, the sand to be used in the under coat should be of zone II of the table 9.1, having fineness modulus not less than 2.0.

Lime putty. The mix proportion of lime unless otherwise stated, generally refers to the volume of putty. Lime putty will be obtained by slaking lime of class B and C with fresh water. The putty at a time should not be prepared more than what may be consumed in seven days. It should be kept moist during this period.

Lime putty weighs about 1200 kg/m^3 and one cubicmetre dry hydrated lime normally gives 0.8 to 0.9 m^3 of lime putty. But for all practical purposes volume of lime putty is taken to be the same as that of dry hydrated lime.

Note. One quintal (100 kg) of quick lime will form 175 m^3 of dry hydrated lime.

9.4. SEQUENCE OF PLASTERING

External plastering may be started from top floor and carried out down wards.

Internal plastering. It may be started where ever building frame and cladding work are ready and the temporary supports for the ceiling resting on walls or floor have been removed.

The ceiling plaster should be completed before commencement of wall plaster. In case of high ceiling, same scaffolding may be used for plastering the top portion of the walls. In case of ceiling of roof slab, plaster shall not be started until the terrace work has been completed as the ceiling plaster is likely to be disturbed by the vibrations caused in terracing operations. The rounding of corners should be completed alongwith finishing coat to prevent any joint marks showing out later. Plastering of cornices, decorative features etc. should normally be completed before the finishing coat is applied. The time interval between the under coat or base coat and second/finishing coat should not be more than 5 days.

9.4.1. Preparation of surface

For proper bonding between the back ground and under coat the surface should be well prepared.

1. Brick wall surface. Along with the roughness of brick surface, the joints should be raked upto a depth of 10 to 12 mm for providing key to the plaster. The loose mortar should be brushed. Efflorescence if any should be removed by brushing and scrapping. The surface should be thoroughly washed with water, cleaned and kept wet before plaster is started.

Concrete surface. Concrete surface may be roughened as follows:

(*a*) Concrete surface may be roughened by sand blasting.

(*b*) By Pock Marking with a pointed tool. The pock is a depression. The depth of pock should not be less than 3 mm and spaced not more than 5 cms centres. All the resulting dust should be cleaned and a coat of 1:1 cement sand slurry on the surface is spread.

(*c*) Alternatinely to get rough surface a mortar of 1:2 cement sand by volume is prepared of wet consistency and dashed forcefully on the surface. It is left to harden with out troweling smooth. The surface is roughened and moistened sufficiently before the application of plaster. This process is known as *spatter desh.*

(*d*) Any unevenness in the back ground must be levelled before the application of plaster by dubbing already discussed and any serious projections should be cut.

(*e*) When plaster is applied to provide an unbroken surface over a board or similar back ground, plaster may be reinforced at the joint by suitable wire mesh to avoid higher stresses and movements in the plaster.

9.4.2. Mixing of plaster mix

1. Hand mixing. It can be done on clean and water tight platform. The mortar is mixed back and forth for 10 to 15 times after adding water.

2. Machine mixing. In mixers it should be mixed at least for 5 minutes after putting the ingredients in the drum. Mechine mixing is preferable than hand mixing for all types of mortars.

Cement lime plaster. 1st cement and sand are mixed dry in the required proportion till a uniform colour is obtained. Lime putty is mixed in required water. This lime water is added to the cement sand mixture and mixed for some time to get the required consistency of the plaster. This should be used with in 30 minutes after adding water before initial setting starts. Partially set mortar should be rejected.

Water requirement. For 1:3 proportion cement plaster, quantity of water required is 70% by weight of cement. This percentage may vary depending on richness of mix, nature and condition of fine aggregate, temperature and humidity at the time of working.

9.5. APPLICATION OF PLASTER

1. For brick work, suitable scaffoding is required

2. Gauges. To ensure even thickness and a true surface, plaster about 15 × 15 cms should be applied first at not more than 2 m intervals over the entire surface. This 15 × 15 cm plaster is known as Gauge. This surface will be truly in the plane of the finished plaster surface. After this, the mortar should be laid in between these gauges slightly more than the specified thickness with trowel. This mortar is brought to true surface by working with a wooden straight edge by horizontal and vertical movement of the wooden edge.

Finally the surface should be finished off true with trowel or float depending upon the required texture. Trowel finish will be smooth and that of float sandy granular texture. Over working with trowel or float should be avoided. All corners, edges, angles and junctions should be truly vertical and horizontal.

While suspending the work at the end of the day, the plaster should be left, cut clean to lines both horizontally and vertically. At the time of restarting the plastering, the edges of the old plaster should be scrapped, cleaned and wetted with cement slurry before applying the plaster to the adjacent areas to ensure the proper bond between the two surfaces.

The plastering should be closed at the end of the day on the body of the wall and not nearer than 15 cm to any corner or curved surfaces, or edges formed by the junction of two planes. It should also not be left on features as plaster bands, cornices, and corners. Horizontal joints should not occur on the top of parapet and copings as these shall lead to leakage. No portion of the surface should be left out initially to be patched up later on.

The plaster should be finished to a true and plumb surface and proper degree of smoothness as required. The work should be tested with a true straight edge not less than 2.5 m long and with plumb bob. Horizontal lines and surfaces should be tested with level and all jambs and corners with a plumb bob.

Curing

Curing should start after 24 hours after finishing the plaster and it should be kept wet or cured for a period of 7 days.

9.6. REQUIREMENT OF CEMENT FOR PLASTERING

First the quantity of mortar is estimated depending on the thickness. This amount is increased by 20% for wastage and filling depressions etc. The amount of cement required for different thickness of plaster is reproduced in the following Table 9.3.

Table 9.3

Thickness of plaster in mm	*Mortar quantity in m^3*	*Cement sand (1:3)*		*Cement sand (1:4)*		*Cement sand (1:6)*	
		Cement in bags	*Sand m^3*	*Cement in bags*	*Sand m^3*	*Cement in bags*	*Sand m^3*
6	0.072	0.73	0.077	0.55	0.077	0.37	0.077
10	0.12	1.22	0.128	0.91	0.128	0.61	0.128
12	0.144	1.47	0.154	1.10	0.154	0.73	0.154
15	0.172	1.75	0.184	1.31	0.184	0.88	0.184
18	0.216	2.20	0.231	1.65	0.231	1.1	0.231
20	0.224	2.29	0.240	1.71	0.240	1.14	0.240

9.6.1. Cement plaster with a floating coat of neat cement

The cement plaster of 1:3 cement sand proportion should be done as discussed above. When the cement plaster has been smoothened with a wooden straight edge, a uniform layer of neat cement paste has to be applied on the entire surface of the plaster and rubbed smooth. The cement to be used for this neat paste should be 1 kg/m^2 surface. Smooth finish should be completed with trowel immediately and in no case later than 30 minutes after adding water to the plaster mix. The application of neat cement coat is called *floating coat.*

9.6.2. Cement plaster for slab bearings

The roof slab should be free to move at the bearings on the walls, and sliding joints should be provided at the bearings. Thus the slab should be rested over a smooth surface obtained by a plaster finish over the bed blocks or bearing surface of the wall. The plaster surface should be given a white wash finish, which will give the surface a smoother surface.

The 1:3 cement sand plaster of 6 mm thickness with a floating coat of neat cement should be provided at the bearings. Over this plaster a thick coat of white wash or lime wash should also be provided to provide a free movement to the slab over the bearings. The white wash should be provided after curing plaster for 3 days. While plastering, all precautions should be taken as those for usual plastering.

9.7. GYPSUM PLASTER

Gypsum is a chalk like material. It is a crystalline combination of calcium sulphate and water ($CaSo_4.2H_2O$). It is available as natural gypsum and as a synthetic byproduct of major industries as fossil fuelled power stations. Natural gypsum is mined all over the world.

9.7.1. Advantages of gypsum plaster

1. It expands very slightly on setting and this is not likely to cause cracks on the surface on setting.
2. On drying out, it forms a sufficient dense surface to resist normal knocks.
3. It is comparatively easy to spread and level.
4. It has no appreciable chemical action on paints.
5. It does not cause alkali attack like lime or cement plasters.
6. As the gypsum plaster gives a smooth surface, it is used as a finish coat to cement sand plaster under coat.
7. Gypsum mixed with water can be spread in a thin layer of 2 to 3 mm thickness.
8. It sets in about 1 to 2 hours.

9.7.2. Disadvantages

1. Gypsum plaster is not suitable for exterior finish as it absorbs moisture.
2. It also can not be used in damp situations.
3. Cement should not be mixed with gypsum plasters.

Uses. Gypsum is used for the manufacture of many building products as tiles, boards, blocks, plaster. Gypsum products are light weight and high fire resistant. Gypsum used for plaster work is of about 70% purity. Gypsum of this purity is mined extensively in India.

9.7.3. Plaster of Paris (POP)

Plaster of paris is a Gypsum product. When powdered gypsum is heated to about 170°C, it drives out or loses about 75% of its combined water and hemi hydrate ($CaSO_4.1/2\ H_2O$) gypsum is produced. Finely ground hemi hydrate gypsum when mixed with water sets and hardens very quickly in about 10 minutes, making it unsuitable for wall or ceiling plaster. It is ideal for making medical casts and other decorative plaster works for buildings. Wet plaster of paris is brushed into moulds to provide cornices and other decorative plaster works.

9.7.4. Gypsum plaster used as finish coat (IS 2547 part-1 1976)

The gypsum, which is used as finishing coat to cement sand under coat is retarted hemi hydrate gypsum. A retarting agent is added to plaster of pairs to delay the setting time to 1 to 3 hours to allow time for spreading and leveling the material as a finish coat. Classification and setting time of gypsum is given in the following Table 9.4.

If the cement plastered surface is finished with a wooden float, it will give a sandy granular texture. To provide a smooth and true finish coat to the plaster for wall and ceiling surfaces, gypsum plaster generally is preferred in high class construction. It is also used for construction with various forms of moldings etc. The surface is made with retarted gypsum plaster. If the cement plaster is finished with steel trowel then gypsum plaster is not necessary.

Table 9.4. Type and setting time of gypsum

S. No.	*Type of gypsum plaster*	*Setting time in minutes*	
		Neat plaster	*Sand mixed plaster*
1.	Plaster of Paris	20 – 40	120 – 900
2.	Retarted hemi hydrate gypsum plaster	60 – 180	120 – 900
	(*a*) Type A–Undercoat-Browning plaster or metal lathing plaster		
	(*b*) Type B–Final coat plaster, Finish plaster or Board finish plaster		
3.	Anhydrous gypsum plaster for finishing only	20 – 360	—
4.	Keene's plaster for finishing only	20 – 360	—

Application. The gypsum is mixed with water to a workable consistency and applied over the cement plastered surface and finished with steel trowel to a smooth surface. No undulation should be left. The finished surface should be smooth, true to plane, slope or curves. After drying the surface is sand papered to produce smooth and even surface.

Dry out. Gypsum plaster should not be allowed to dry out quickly before it hydrates fully. It needs time for combining the all water needed for setting and hardening. Dry out may be caused by the application of plaster on highly absorbent under coat. The dry out condition makes the plaster friable *i.e.* easily breakable or crumbling.

An impervious backing to a thin plaster finishing coat may be as dangerous as a too absorbent surface as it does not hold sufficient water and the finish dries out too quickly.

9.8. EXTERNAL RENDING (IS 2402-1963)

General. The common brick walls or R.C.C. frame structures due to their colour and texture do not provide attractive external finish to the buildings. Thus the external faces of walls are rendered with one or two coats of cement sand or lime sand mixture. This finish may be smooth or textured. This external rendering generally improves the resistance of wall to rain penetration. The extent of weather protection depends on the bond of the rendering with the backing, surface finish and mix materials.

9.8.1. Types of finishes

Following finishing generally are adopted for external rendering:

1. Trowelled or floated plain finish
2. Scrapped finish
3. Textured finish
4. Rough cast plaster
5. Pebble desh finish
6. Machine applied finish
7. Exposed aggregate or Grit wash finish
8. Stone veneering finish.

9.8.1.1. Trowelled or floated plain finish

For external rendering steel trowelled finishes are not recommended as steel trowel brings out water and fine particles of cement or lime of plaster mortar to the surface, which on drying, shrink and causes surface cracks. The wooden float leaves the surface coarse textured which is less liable to surface cracks.

In case of large continuous surfaces, it is recommended that either groove or bands may be formed in the plastered surface. In this case if any cracks develop, they will be localized in these grooves or bands. Such treatments also enhance the aesthetic look of the exterior. It is particularly important where the back ground changes, such as the junctions between the roof slab and the parapet.

The floated finishes require high standards of workman ship to minimise the risk of cracking, crazing and irregular discoloration in service usage.

9.8.1.2. Scrapped finish

In this case, the top 1.5 mm layer of the final coat after being levelled and allowed to stiffen for a few hours is scrapped with a saw blade or steel straight edge forming combing surface.

9.8.1.3. Textured finish

Textured rendering usually is applied in two coats. The first coat is applied in between the gauge spaces as discussed above, and allowed to dry at least for 24-48 hours before applying the second or the finish coat. After drying the under coat or first coat of plaster, the second coat is spread by trowel and finished off level. When the second coat has become sufficient hard, but still wet, the surface is textured with wooden combs, brushes, wire mesh or old saw blades or rubbing with sack etc. By varying the ways of texturing a variety of effects can be produced on the surface. By the above methods of texturing following patterns may be obtained.

(*a*) Horizontal or vertical ribbed texture (*b*) Fan texture

(*c*) Torn texture etc.

The brand name or proprietary textured finishes generally consist of granules or flacks and a binding agent (acrylic polymer). The granules or flakes are applied over a smooth level under coat of cement plaster and finished with trowel. The finishing treatment is applied in a single coat with a trowel with out keying on the plastered surface. The average dry film thickness varies from 1.0 to 1.5 mm. These can be applied to curved surfaces as pillars, domes, arches etc.

The scrapped or textured finishes generally are less liable to crack and crazing than plain finishes as they tend to discolor evenly during the life of the building. Also the distribution of flow of rain water over the surfaces reduces the risk of penetration through tendering. How ever such finish attract dust, and dirt due to their rough texture.

9.8.1.4. Rough cast plaster

1. This plaster is applied in two coats. The first or under coat consists of 12 mm thick 1:4 cement coarse sand layer and the final or top layer of 10 mm 1:3 cement fine sand mixed with 10% finally ground hydrated lime by volume of cement. A mixture of sand and gravel or crushed stone from 6 mm to 10 mm normal size is dashed over the top layer when it is still plastic.

2. Preparation of surface. As discussed above on page 135.

3. Mortar. For under coat mortar mix should consist of 1:4 (1 part cement and 4 part coarse sand) by volume. The fineness modulus of sand should not be less than 2.5.

(*b*) **Top layer.** The top layer should be 1:3 cement and fine sand mix. To improve its plasticity about 10% finely ground hydrated lime by volume of cement should be added to it while mixing the mortar.

4. Application of mortar. The under coat is applied in the same manner as already discussed in between the 15 × 15 cms gauges and finished with a wooden float. The top layer is applied after 24 to 48 hours after the under coat layer has taken initial set, but not allowed to dry before the top layer is laid. The mortar for the top layer should be sufficiently plastic, so that mix of sand and gravel may get pitched (fixed) with the plaster surface.

Finish. Before applying the finish (mixture of sand and gravel) it should be ensured that the surface on which finish is going to be applied is in plastic state. The rough cast mixture (sand and gravel or sand and crushed stone of uniform colour of 6 mm to 10 mm normal size) should be mixed in specified proportion to produce desired effect.

The wetted mixture of sand and gravel should be dashed on the top layer while it is still in plastic state by hand scoop so that the mix gets well pitched into the plastic base. The mixture is dashed again over the vacant space if any, so that the surface become homogenous with sand and gravel mixture. To ensure satisfactory bond between the dashed material and top layer, the aggregate may be lightly tapped into the mortar with a wooden float or flat or a trowel. Other precautions shall be the same as discussed under topic plaster application.

9.8.1.5. Pebble dash finish

This finish is obtained by throwing dry pebbles, shingle or crushed stone on the freshly applied finish coat of rendering, and slightly pressed into so that the pebbles adhere to the rendering. The pebbles are left exposed as pebble surface. The size of the pebbles or stones may vary from 6.3 mm to 12.5 mm and may be adopted as pr desired look. The under coat and finish coat are of mix, suitable to the back ground. It is trowelled and finished level.

The pebble and rough cast finishes have the advantages of scrapped or textured finishes. Any hair cracks that may develop due to dry shrinkage of rendering are concealed by the surface texture. These finishes are more satisfactory under sever conditions of exposure from the point of view of durability, resistance to cracking and crazing and weather proofness etc.

9.8.1.6. Machine applied finishes

There are many finishes comprising brand materials and patented processes. These finishes are applied by specialists. The final coat is applied by hand operated or power operated machines, which throw the material on the wall. Following types are common finishes.

(*a*) **Material is thrown at random.** These finishes have an open porous surface and behaves as hand applied scrapped finish and are equal in water proofness, durability and resistance to cracking and crazing. This process gives low density finishes.

(*b*) **Finishes applied by machines.** The roughness of the finished surface varies with the material used and the type of machine. These finishes can be applied to curved surfaces such as arches, pillars, and domes. Machine applied finishes are relatively more durable.

9.8.1.7. Exposed aggregate finish

· This type of finish is produced by exposing a specially selected aggregate. The selected aggregate is applied over the prepared surface of the wall or members. The method of exposing the aggregate adopted is to wash the cement of the green concrete by brush. The brush is dipped in water and cement is washed from the concrete surface. The proportioning and placing of the mix determines the pattern and disposition of the aggregate exposed.

9.8.1.8. Stone venering

Various types of stone facing is a popular finish. Stone veneering and exposed aggregate finish have relatively long life and do not need maintenance during service usage. All other finishes have varying life and need periodic repair and maintenance.

9.9. FUNCTIONAL REQUIREMENTS OF EXTERNAL RENDERING

The functional requirements of external rendering are as follows:

(*a*) To increase the durability of the structure and to reduce its maintenance cost.
(*b*) To check penetration of moisture into the structure.
(*c*) To cover the unsightly surface.
(*d*) To provide a particular decorative surface to the structure.

9.9.1. Factors which influence the selection of rending

Following factors influence the selection of a particular rendering:

(*a*) Durability
(*b*) Adhesion between rendering and the background
(*c*) Resistance to cracking and crazing.

9.9.2. Resistance to water penetration

Water may penetrate through the pores of a rendering or through cracks or both. Rain water falling upon a relatively smooth and little or non absorbent surface does not distribute itself evenly on the surface, but tends to run down the surface in dry and thin lines *i.e.* in streaks. On the other hand a rough surface will break the flow and thus avoid the concentration of water at any one point.

Where cracks occur, particularly in dense and impermeable rendering, water may find its way between the rendering and back ground, resulting in loss of adhesion, further cracking and disintegration of rendering. Water may soak through the wall and may cause dampness and discoloration of finishes inside.

9.9.3. Durability

Cement and cement lime renderings with properly graded fine aggregate have sufficient durability and need no protective coating.

Soluble salts, particularly sulphates present in the clay bricks produce harmful effect leading to cracking and loss of adhesion. The problem aggravates due to cracks and presence of dampness in the back ground. The chemical reaction between the sulphates and constituents of cement takes place in the presence of moisture and damp conditions and diffuse to the surface only in solution.

Out of the two methods of applying rendering, namely laying with a trowel or float and throwing on by hand or by machine, throwing on is likely to produce more durable rendering due to better adhesion.

9.10. EXPOSED STONE GRIT PLASTER (GRIT-WASH)

General. This is a decorative permanent finish for exterior walls and is more popular these days. It is also known as "washed stone grit plaster".

It consists of two layers (1) 12 mm thick 1:4 cement and coarse sand mix layer known as under coat, (2) Top layer 15 mm thick of 1:½:2 (cement coarse sand and 10 mm normal size stone chipping. The top layer is laid in panels with grooves all-round as per specified pattern. The top layer is scrubbed and washed with brushes and water to expose the stone chipping. The depth of grooves usually is 15 mm and width 15 mm to 20 mm.

9.10.1. Materials

10 mm normal sized stone chipping, obtained by crushing hard stone. The chippings should be free from harmful or deleterious materials. The grading of the chips should be such that they should pass 100% through 12.5 mm sieve and 100% or fully retained on 6.3 mm sieve. Before use, the stone chippings should be sieved and thoroughly washed.

For the under coat, the mix should contain coarse sand conforming to grading for zone II of Table 9.1 and having fineness modulus not less than 2.0.

For finishing coat the fine aggregate should conform to grading of zone IV of the same table. Cement used is ordinary portland cement.

In case of exposed marble chip plaster, mortar consisting of white cement, marble powder, and marble chips in the proportion of 2.5:1:6 *i.e.* (2.5 part white cement, 1 part marble powder and 6 part marble chips) should be used.

9.10.2. Preparation of surface

Same as for ordinary plaster *i.e.* raking of joints and roughening the surface.

9.10.3. Application of under coat

The 12 mm thick layer of 1:4 proportion cement and coarse sand should be applied on the prepared surface and levelled and finished with wooden floats only. The surface should be roughened by furrowing with a scratching tool. The furrowing of about 2 mm depth should be done diagonally both ways to provide key for the top layer. The distance between scratched lines should not be more than 10 cms. The surface is to be kept wet till the top layer is applied.

9.10.4. Application of top layer or coat

The top layer should consist of cement mortar and stone chippings in the proportion of 1:1/2:2 (1 cement, 1/2 coarse sand and 2 stone chipping of 10 mm normal size).

15 × 15 mm sized grooves should be provided on the surface and tapered wooden battens matching the size and shape of grooves should be fixed on the under coat with nails before the application of the top layer.

The top layer is applied after 24 to 48 hours of laying of the under coat when the initial set of under coat has taken place. Before applying top coat, the under coat should be cleaned and a coat of neat cement slurry at the rate of 2 kg/m^2 area should be applied in panels in uniform thickness. The top layer should be pressed into the under coat to provide proper bonding between under coat and top coat. Vacant space left if any should be filled with specified mix.

9.10.5. Finish

The top surface of the plaster should be finished to a true and plumb surface. The surface should be frequently tested with a true straight edge not less than 2.5 m long and plumb bob. All horizontal lines and surfaces should be tested with level and all corners and jambs with a plumb bob. All corners, angles, and junctions should be trully horizontal or vertical as the case may be. All rounding of corners junction should be true to templates. Wooden battens are removed care fully so that the edges of the panels of top coat are not damaged. Damage if any should be rectified. The finished surface of the top coat should be scrubbed and washed with nylon brushes and plain water after the mix has taken initial set *i.e.* after 1 to 2 hours of applying the top layer. Scrubbing and washing should continue till the stone chippings are sufficiently exposed. Thus the name exposed stone grit plaster. Any chips dislodged during scrubbing the space should be filled with specified mix.

Curing. After finishing the top surface, it should be cured for 7 days.

9.11. TILING ON EXTERNAL FACE OF WALLS (IS-4101 Part III 1969)

Wall tiles provide a wide range of architectural treatment for external facing, while finishes with natural stones are restricted by the availability of suitable stones and possible dressing for the facing. Wall tiles can be made in a wide range of patterns, shapes, and colours. However, it may not be enough to make these tiles in the same manner as for interior work, since when exposed to weather, dimensional changes are much more.

9.11.1 Functional requirement

The functional requirements of the external wall tiles are as follows:

(*a*) To achieve a particular degree of effect or to obtain an over all architectural expression.

(*b*) To cover an unsightly surface.

(*c*) To increase the durability and reduce the maintenance cost of the structure.

(*d*) To assist in protecting the structure against rain penetration and other weather conditions.

9.11.2. Choice of tiles and other mosaics

The type of the tile to be used and the method of fixing should be decided clearly. Following factors govern the choice of materials:

(*a*) The appearance or effect desired.

(*b*) Exposure conditions and the degree of protection required.

(*c*) Nature of the back ground on which tiles are to be fixed.

The methods discussed here for wall tiles fixing are generally applicable to the unit of an area not exceeding 900 cm^2. The type of tiles used are terrazzo tiles, or ceramic glazed tiles or unglazed clay facing brick tiles or mosaic tiles of various shapes and sizes.

9.11.3. Durability

Excessive temperature variations of the environment will cause cracks and bulging of tiles. Dark coloured tiles absorb heat readily. Hence in such environmental conditions joints of sufficient width around the tiles should be provided to accommodate the thermal movements.

For durability, resistance to penetration of water is very important. Water may seep into the facing mainly through the joints, tiles and mosaics themselves unless they are glazed and impervious. The seepage through broken glaze and pervious body of the tile and mosaics is possible. To prevent the seepage, the joint filling should be impermeable, complete and with out cracks. Once water has entered into the facing, it may affect the fixing and cause loss of adhesion and also cause frost action to develop. It may also cause chemical action in the back ground and dampness, damaging the interior finish. Hence proper water proofing of joints consistent with exposure conditions should be provided. It may further be supplemented by providing protection projection features.

9.11.4. Surface preparation

The joints should be properly raked, dust and loose mortar brushed. Efflorescence if any, should be removed by brushing and scrapping. Then surface should be thoroughly washed with water, cleaned and kept wet before floating or 1st coat is applied.

In case of concrete surface, if a chemical retarder has been applied to the form work, the surface should be roughened with wire brush and the resulting dust and loose particles cleaned off. Care should be taken that no retarder is left on the surface.

9.11.5. Application of floating coat

The floating coat should be applied after the back ground has under gone completely initial drying and shrinkage. The thickness of this coat is kept 13 mm. The float coat or rendering is applied to form a suitable surface for the application of tiles, in case the back ground is not suitable for direct fixing of tiles. The mix generally consists of 1:3 cement and coarse sand mortar. To improve the workability and ease in application and finishing lime 1/4 part of cement by volume may be added. Water proofing agent may also be added. The final floated coat should be true to plumb.

In case the thickness of the floating coat is needed more than 13 mm, then it should be applied in two coats and each coat should not be more than 10 mm thick. In such situation each coat should be considered as the back ground for the following coat. Each coat should be allowed to dry out before the application of the next coat to avoid cumulative stresses to be set up. A strong coat should not be applied on a weaker coat, which would not be able to restrain its movements.

9.11.6. Bedding mortar for tiles and mosaics

The mix for bedding mortar should be 1:3 or 1:4 cement sand by volume. Before the commencement of tiling, it should be ensured that there is proper adhesion or bond between the floating coat and back ground and no part of the rendering should emit hollow sound. The floating coat should be completed at least one weak before fixing of tiles begins and should be free from visible moisture.

The tiles of non porous bodies should not be soaked with water where as tiles with porous bodies should be completely immersed in clean water for at least one hour before use. After soaking, the tiles should be stacked tightly on a clean surface to drain away the water. The tiles should be fixed as soon as the surface water has drained away.

9.11.7. Wetting of floating coat

If necessary the floated coat should be wetted just sufficient to prevent it from absorbing water from the bedding mix. The wetting of floated coat should be carried out before applying bedding mix on it to start tiling.

9.11.8. Fixing of tiles

The tiles are placed evenly and tapped firmly into position to ensure that the tile is fully embedded in the bed material *i.e.* bed mix is fully coated on the back and corners of the tile. The resultant thickness of bed mix behind the tile generally should be 6 mm, but not more than 12 mm in any case.

Uniform spaces between tiles may be obtained by using insertable spacer pegs, which should be inserted as the work progresses. The spacer should not be more than 2 mm thick. Any adjustment to the tile should be done with in about 10 minutes of its fixing. The flatness and trueness of the surface is ensured with a straight edge. Cleaning off the surface should be commenced after 1/2 to 2 hours after fixing the tiles.

9.12. GROUTING OR POINTING OF TILES

This should be done at least one day after fixing the tiles. The general properties of an ideal grouting and pointing mix should as follows:

(*a*) It should have low shrinkage
(*b*) Low compressive strength
(*c*) Good adhesion
(*d*) Good impermeability
(*e*) Easy cleaning

Mix. 1 cement and 2 stone dust mixed with clean water to the required consistency. A water proofing agent may also be added.

Grouting joints upto 5 mm wide. The grouting mix may be applied to as large area as possible, before commencement of hardening of the mix. Hardening will depend on climatic conditions. The grout should be applied with a sequence working back and forth over the entire area untill all the joints are completely filled. After this all surplus grout should be removed from tiles with a damp cloth and subsequently tiles polished with dry cloth.

Pointing, joints 5 mm wide or more. In case of pointing a small proportion of fine sand should be used in the mix. All voids between the tiles and bed should be filled completely with the pointing material with the help of a suitable pointing tool. After wards all surplus material should be cleaned off.

9.13. DEFECTS IN PLASTERING

The defects in plastering and their causes are given in tabular form below

Table 9.5.

S. No.	*Name of defect*	*Cause of occurance*
1.	Blistering (Swelling)	This occurs due to high local relative expansion of the finishing coat. To prevent this lime should be properly slaked before use.
2.	Bond failure OR Loss of adhesion	The bond failure results in hollow patches, flaking of top coats and bulging or peeling off substantial areas. Hence joints should be properly raked.
3.	Cracking	Cracking develops due to structural movement or due to shrinkage or exposure to direct sun
4.	Crazing	This results due to the development of tensile stresses due to shrinkage. It can be eliminated by controlling the shrinkage and there by limiting the tensile streses with in safe limits.
5.	Irregularity of surface	This is caused by faulty workmanship.
6.	Blowing or popping	This defect develops in the plaster when some ingredient of the mix keeps on expanding even after the plaster coat has set. The use of unslaked lime in plaster is a common example of such a ingredient.
7.	Efflorescence	Efflorescence takes place due to the presence of salts in the masonry. These salts get dissolved in moisture absorbed by the masonry either due to dampness of leaking water or ingress of moisture. When the solution of the salts comes on the surface, the moisture evaporates leaving white patches on the surface called efflorescence.
8.	Recurrent surface dampness	This happens due to the presence of salts in the plaster which melt and become liquid causing dampness. Such salts are known as delinquescent salts.

Some of the defects in plastering develop due to not observing proper precautions at the time of plastering such as

(*a*) Mixing of material not properly done

(*b*) Proper application of plaster coats not undertaken

(*c*) Use of very rich mortar in plaster work

(*d*) Pure cement coat is used in top layer

9.13.1. Other minor causes are as follows

(*a*) Poor bond with base material

(*b*) Weak rendering under coat

(*c*) Entrapped moisture in between two coats

(*d*) Use of unsuitable material

(*e*) Weak substrata backing structure

(*f*) Impact due to accident etc.

9.13.2. Remedial measures

Most of the defects are visible on the surface, but there are some other defects which occur due to other than materials and techniques of plastering etc. The causes of these defects should be investigated before taking remedial measures. The area giving dull sound on light hammering indicates separation of plaster from the masonry. Such areas should be cut and removed. The defective areas should be cut in regular shape and replastered. Successful repair needs skilled workmanship. In case of cracking or crazing sufficient area should be cut and suitable base should be provided for plastering.

If necessary the mortar joints should be raked upto a depth of about 1½ cms with a pointed tool, cleaned of all dust and washed with water before plastering. The loose and old porous plaster must be sealed with cement or other suitable material such as paint to prevent moisture absorption. In the repair of corners expanded metal or wire mesh should be used as reinforcement. For this repair the plaster should be cut on both sides of corner upto a length of 10 to 15 cms. The wire mesh is fixed at the edge of the corner upto the full height of the repair and non shrinkable plaster mortar mixed with bonding agent is applied and finished.

9.14. POINTING

It is another method of rendering brick surface. In olden period pointing as rendering was mostly adopted for exterior surface of the building. Pointing can be adopted as rendering only when the bricks used are of good quality and less water absorbent. Due to non availability of good bricks and continuous rainfall, pointing gradually is being replaced by plastering. How ever pointing still is in prevalence.

9.14.1. Operations in pointing

In pointing following operations are involved:

(*a*) Raking up the mortar joints upto a depth mostly upto 15 mm with a pointed tool. This depth may be upto 20 mm.

(*b*) Cleaning loose mortar and dust from the joints by hard wire brush.

(*c*) Washing the surface with water and keeping the same wet for several hours before the application of the pointing.

(*d*) Pressing the mortar into the prepared joint with trowel and forming the desired shape with the special tool.

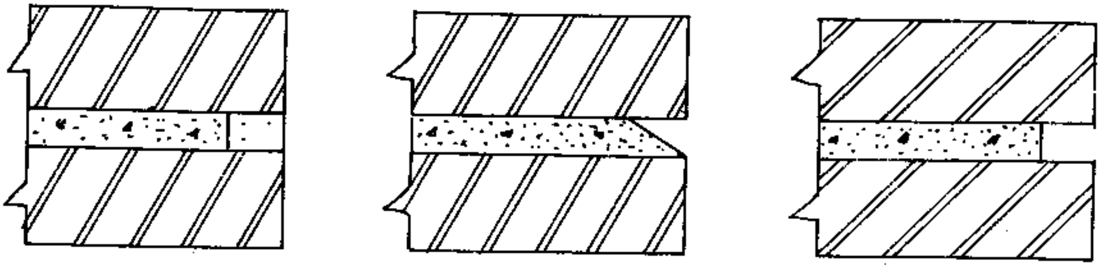
(*e*) Removing the surplus mortar and cleaning the surface.

(*f*) Curing the finished surface from 10 to 14 days by sprinkling water on it.

9.14.2. Types of pointing

Pointings may be of the following types:

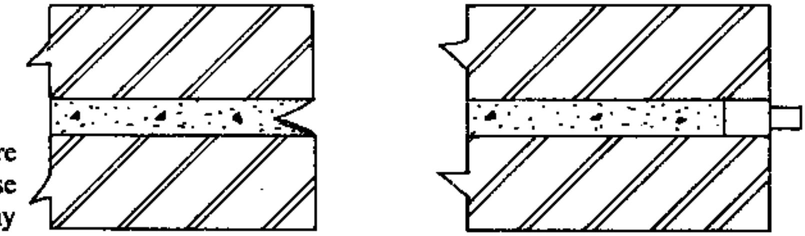
(*a*) Flush pointing (*b*) Struck pointing



FLUSH POINTING WEATHERED POINTING RACKED OR/RECEED POINTING

(*c*) Tuck pointing

(*d*) Recessed pointing.



V POINTING RAISED & CUT/OR TRUCK POINTING

Fig. 9.1.

9.15. MAINTENANCE OF MUD PLASTER

In rural areas usually there are mud wall houses. The plaster of these walls get eroded every year in rainy season. To provide durability to such plasters Central Building Research Institute carried out experiments to enhance the stability of mud plaster. On the basis of experimental results, they recommended the following treatments to plaster.

1. Use of bitumen cut back. Bitumen cut back is prepared by adding 2 kg of Kerosene per 100 kg of bitumen. This cut back is mixed in mud of plaster at the time of plaster at the rate of 70 kg of cut back per cubic metre of mud mortar. This mortar is applied on the walls in the thickness of 10 to 15 mm. This provides a durable water proof mud plaster.
2. The spray of bitumen cut back also has proved useful.
3. Painting the wall plaster with liquid formed by heating 2 part of bitumen and 1 part of bitumen pitch in a vessel has also proved effective to safe guard mud plaster.

These treatments though economical, but provide black surface, which is not pleasing. Hence to get a pleasing look following treatment may be given.

1. Painting wall plaster with shellac and Neptha solution gives a good water repellent surface.
2. Providing a coat of sodium silicate or its spray provides a good water repellent surface.

9.16. PAINTING

Objective of painting. Paint protects, preserves and decorates surfaces and enables them to be cleaned easily. Paint forms a protective layer over the surface on which it is applied and helps them looking beautiful. Paints do not allow the surfaces to get weathered or affected by other external factors. Each surface has its own characteristics. Thus each surface needs a different kind of paint. There are several kinds of paints for walls, metal surfaces and wood surfaces. Here only paints for walls have been discussed.

9.16.1. Functional requirements of paints

A paint must possess the following properties:

1. **Consistency.** A paint should be workable and have a good flow. A too thick paint will drag or streak while too thin a paint will tear. To ensure correct working with brush, paste paint and thinner may be mixed in suitable proportion by volume (usually equally) to get a suitable consistency.
2. **Spreading power.** The covering capacity measured in square metres of the surface that can be

covered by one litre of paint is called the *spreading power of the paint.* It varies with the kind of paint material, surface to be painted and whether it is first coat or second coat.

3. **Drying.** Under normal conditions a paint should dry enough in six to nine hours, so that dust should not stick to it. It should become dry and hard in twenty hours to take another coat.
4. **Durability.** The resistance to disintegration of the paint by oxidation is called its *durability.* It is judged by the duration of time during which the paint coating maintains its decorative and protective value.

9.16.2. Types of paints

There are following types of paints:

1. **Oil paints.** These are the traditional paints having a linseed oil medium. Their finishes vary from flat to oil glossy. Oil paints dry by evaporation of their solvents and by oxidation. Now these paints have been replaced by synthetic paints.
2. **Synthetic paints.** The medium for these paints is a chemical compound. One type of synthetic paints is oil modified alkyd resin. These paints set more quickly and offer greater durability than oil paints, where corrosion is the main concern. These paints have better flow and easier to apply than oil paints.
3. **Water paints.** These paints are commonly known as distempers. They are mainly used on internal walls and ceilings and mostly give a flat finish. They have a drying oil or varnish medium emulsified in water. They are prepared at the site by adding water to make a paste.
4. **Cement paints.** It is a water paint. Snowcem and its varieties are a popular brand of cement paints. Often they are used externally. They contain white or coloured portland cement with a water proofing agent, accelerator and extender.
5. **Emulsion paints.** Mostly these paints are used on wall surfaces. It is a oil bound distemper. A emulsion paint has the pigment and medium dispersed as very tiny balls in water. Oil, synthetic resins and bitumen are common mediums. Different emulsion paints are alkyd, bitumen, polyvinyl acetate and styrene emulsion paints etc. Their finish obtained varies from flat to egg shell gloss.
6. **Cellulose paints.** These paints dry very quickly by evaporation of solvent. These paints usually are used as spray paints in automobile industry. They are not suitable for general building work, but can be used for furniture and fittings etc.
7. **Special paints.** Aluminium paints, bituminous paints, rubber paints, fire resistant paints, heat resistant paints, fungicidal paints, texture paints etc. are some of the special paints. These are used for special applications.
8. **Varnishes.** Varnishes are of two kinds (*i*) oil varnish, (*ii*) spirit varnish:
   (*i*) They are sued to give a transparent film to the surface. The relative proportion of the oil and the resin control the usage. If oil is predominant ingredient, then a more elastic varnish is obtained for external works. In case the solvent is predominant ingredient then a high glossy surface is obtained which dries very rapidly. It is useful for internal work.
   (*ii*) *Spirit varnishes.* These are the solution of shellac dissolved in methylated spirit. They are suitable for internal surfaces only like furniture etc.

9.16.3. Applications of paint

The paint film consists of a number of coats as priming coat, under coats and finishing coats. The performance of the paint depends upon the selection of primer and filler etc. and preparation of the substrata surface, which is very laborious and costly.

9.16.3.1. Preparation of surface

For the success of the paint work, the preparation of the surface to be painted is most important. The surface should be smooth, clean, dry and free from corrosion or other paint defects. Each coat of paint should be dry, hard and rubbed down with fine abrasive paper before applying the next coat. Painting should be done in a well ventilated and dust free place.

9.16.3.2. Priming coat

The first layer of paint, generally applied for better adhesion to the sub strata is known as priming coat. It should suit the back ground and adhere to it. It must be compatible with subsequent layers. A priming coat must also satisfy the following requirements.

(*a*) For getting good finish from the subsequent coats of the paint, the priming coat should penetrate the porous surfaces to seal their pours.

(*b*) It should check the corrosion of the metal surfaces.

(*c*) It should be able to seal the chemically active surfaces as new lime plaster surface, concrete surface etc.

9.16.3.3. Under coats

These coats cover the priming coat and bond the subsequent coats and build up adequately thick paint film. They should have a suitable shade to match the final coat.

9.16.3.4. Finishing coat

This is the last coat to give desired colour and finish to the surface. Finishes vary from flat to egg shell gloss to enamel (High gloss) Gloss paints are more durable for exterior use than flat paints. Some times a flat paint is adopted for walls as it does not enhances the irregularities of wall surfaces.

9.17. SCHEDULE OF PAINTING OF NEW SURFACES

It is shown in Table 9.6 below.

Table 9.6.

S. No.	*Type of finish*	*Prining coat or primer*	*Under coat*	*Finishing coats*
1.	White wash	1 coat of white wash (add some binding material)	—	2 coats
2.	Colour wash	1 coat of colour wash	—	2 coats
3.	Dry distemper	A seal coat (Glue with whiting). A thin coat of distemper with water	Filler is to be used to fill holes if needed	2 coats
4.	Oil bound distemper	One coat of alkali resistant cement primer (Glue-alum)	— do —	2 coats
5.	Emulsion paint	A thin coat of emulsion paint	— do —	2 coats
6.	Flat or semi gloss paint	1 coat of alkali resistant cement primer	— do —	2 coats
7.	Acrylic emulsion paint (Exterior use)	— do —	— do —	2 coats
8.	Cement paint	A thin coat of cement paint	— do —	2 coats

9.18. COMMON DEFECTS NOTICED IN PAINTING WORKS

In painting work, usually following defects are observed:

1. Surface not properly prepared before painting. This is the general defect noticed.
2. Nail and other small holes left unfilled in plaster and wood work.
3. Variation in the shade of the paint when large areas are painted especially in external surfaces.
4. Brush marks are clearly seen on the surface. This indicates that the painter is not skilled.
5. Poor paint adhesion with the back ground leading to flaking.

6. Use of sub standard paint.
7. Use of improper primer, especially when painting steel and wood work.
8. Painting left out in:
   (*a*) Sides, top and bottom edges of door and window shutters.
   (*b*) Rebates in joinery and unexposed surfaces of beads in glazing.
   (*c*) Fan hooks.

9.19. REMEDIAL MEASURES OF PAINT DEFECTS

The remedial measures or precautions in paint work are shown in the following Table 9.7.

Table 9.7.

S. No.	*Defects*	*Remedial measures or precautions taken*
1.	Un even finish or patchiness	This can be removed by applying extra coat of primer
2.	Cracking or chipping of paint film	Avoid use of excess putty and thick coat of paint
3.	Flaking off paint film	Before applying paint, putty should be covered completely with priming coat and no gaps should be left.
4.	Blistering or swelling of paint film	(*a*) Painting under direct sun rays should be avoided (*b*) The surface should be fully dried before applying the next coat, especially between the two coats of the paint.
5.	Efflorescence	(*a*) The plaster surface should be allowed to dry fully before applying paint to it. Usually it takes about 6 months for plaster to dry fully. (*b*) To allow inside moisture to escape, use of distempers and emulsions is recommended which forms porous film which helps moisture to escape. (*c*) Clean the surface thoroughly with soap solution and clean water.
6.	Non drying or slow drying of paint film	Protect from moist atmospheric conditions as far as possible. The oily or greasy surface should be scrubed with a rag soaked in spirit and washed with soap and water.
7.	Loss of gloss	The surface is thoroughly cleaned and ensure proper preparation of surface and its drying.
8.	Brush marks	The proper viscosity of paint should be ensured before use and good quality brush should be used for painting work.

9.20. FLOORS

The properly supported horizontal surfaces which divide the building into different levels for providing accommodation one above the other with in a limited space are called *floors*.

The floor just above the ground level is called ground floor and just below the ground level is called a basement floor. Floors constructed above the ground floor are called upper floors. Depending upon the location of the upper floors above ground level these are further classified as first floor, second floor etc.

The main function of the floor is to provide support to occupants, furniture and equipment of building.

9.20.1. Flooring

The covering or surface cover over the sub grade or base course or floor covering is called *flooring*. This is meant to provide a hard, clean, smooth, impervious, durable and attractive surface to the floor.

9.20.2. Sub grade or base course

It is the base over which flooring is laid. The purpose of base course is to provide strength and stability to support floor covering and all other super imposed loads.

9.20.3. Factors affecting the selection of flooring

Each type of flooring has its own merits and demerits. There is not even a single type of flooring which may be suitably provided under all circumstances and more so when floors have to serve different purposes as residential, Industrial, Institutional and assembly etc. Following factors affect the selection of flooring or floor covering.

(*a*) Initial cost
(*b*) Appearance
(*c*) Cleanliness
(*d*) Durability
(*e*) Damp resistance
(*f*) Sound insulation
(*g*) Thermal insulation
(*h*) Smoothness
(*i*) Hardness
(*j*) Comfort criteria
(*k*) Fire resistance
(*l*) Maintenance etc.

9.21. TYPES OF FLOORING

The floor finishes or flooring usually depend on the following factors:

(*a*) Expected load
(*b*) Desired resistance to abrasion and wear
(*c*) Speed of execution, architectural and aesthetic requirements of a building

9.21.1. Type of flooring in common use

Following types of flooring are in common use:

(*a*) Cement concrete flooring
(*b*) Granolithic concrete floor topping
(*c*) Insitu terrazo flooring
(*d*) Crazy marble flooring
(*e*) Brick on edge flooring
(*f*) Tile flooring
(*g*) Kota stone flooring
(*h*) Marble flooring
(*i*) Wooden board flooring
(*j*) Wood block flooring

9.22. STRUCTURE OF A FLOOR

The elements of floor are as follows:

(*a*) **Sub base.** For stability, adequate support should be provided below the floor. It depends on the characteristics of the soil underneath and its bearing capacity. For heavy structures, a hard core sub base in the form of dry brick or stone ballast to a depth of 100 to 150 mm is sufficient.

(*b*) **Base concrete.** It is provided to give a smooth level surface on the ground floor over which a floor finish may be applied.
For heavy duty floors the thickness of concrete shoud be 150 mm.
For light duty floor the thickness of concrete may be 75 to 100 mm.
Lime concrete (1 lime, 1 surkhi and 1 fine sand) or lean concrete of mix 1:5:10 or 1:4:8 generally is used for base concrete. The nominal size of coarse aggregate may be 40 mm.

(*c*) **Cushioning layer.** In places as verandha, kitchen, bath room etc. proper slope can not be provided due to the thickness of floor topping, hence in these places cushioning layer is provided.

9.22.1. Thickness of cushion layer

40 to 50 mm for lime concrete, with graded brick aggregate of 25 mm size. It should contain 40% mortar (1 lime, 1 surkhi and 1 fine sand) over the structural slab of upper floors. It helps in oblaining a level surface over suspended floors and in embedding service pipes and conduits.

9.22.2. Topping

It depends on the expected load, resistance to abrasion and wear, aesthetics of the surface finish and cost.

Choice of floor finish. Correct choice of floor finish can enhance the beauty (character and beauty) of a building.

Kota stone. It has good resistance to abrasion and wear. It also provides a neat sanitary surface. Hence adopted for important public places, such as air port lobby, Railway stations.

Terrazo floor. It has a pleasant surface finish and generally preferred for residential buildings and offices.

Concrete flooring. Generally it is adopted for work shops, ware houses, pavements etc.

Marble and granite. This flooring is preferred for prestigious buildings as banks. Commercial establishments, auditorium etc.

Slope in flooring. Slope should be provided depending upon the smoothness of the surface finish.

(*a*) Concrete floors. It ranges 1:48 to 1:60 depending on location.

(*b*)Brick on edge floors. It ranges from 1:36 to 1:48.

(*c*) Water closet portion it should be 1:30.

9.23. GENERAL PRECAUTIONS IN THE CONSTRUCTION OF FLOORS

To obtain the objective of the flooring, preparation of sub base is very important. In addition to sub base following measures should be adopted:

(*a*) *Cleaning the base.* The base should be cleaned of all dirt and lose particles, laitance etc.

(*b*) For proper bond or key, under layers should be left rough for proper bond with top layers.

(*c*) If the surface has hardened so that it can not be roughened by wire brush, then the surface should be roughened with chipping or hacking.

(*d*) A coat of cement slurry should be applied on the roughened surface to get good bond between base and the flooring.

(*e*) Before applying bedding plaster to the wall, joints should be raked upto 10 mm in case of skirting, dado etc.

9.24. SHRINKAGE CONTROL

Concrete undergoes considerable dry shrinkage on evaporation of water from the concrete mix. To control the shrinkage cracks, following measures should be adopted.

(*a*) Area on which flooring is to be laid, should be divided into panels of suitable size with the help of strips of glass or aluminium.

(*b*) Concrete should be laid into alternate panels.

(*c*) Concreting in alternate panels should be laid at a interval of 18 to 24 hours.

(*d*) Concrete mix for topping should be sufficiently stiff to prevent accumulation of excess water or laitance.

9.25. CEMENT CONCRETE FLOORING (IS-2571-1970)

Cement concrete of 1:2:4 is laid in a thickness of 25, 40 or 60 mm as specified over the base concrete. Concrete flooring possess good durability and resistance to abrasion, wear and impact. The concrete mix should be so chosen as to carry the expected loading.

It is suitable for houses, offices, shopes, hospitals and light industrial buildings as it can be easily cleaned and maintained.

9.25.1. Slipperiness

Trowel finish is good enough to provide non slippery surface as slipperiness depends mainly on the surface treatment.

9.25.2. Size of panels

Panels should be of uniform size and no dimension of panel should exceed 2 m for indoor and 1.25 m for court yard, terrace etc. in exposed situations. The area of panel should not exceed 2m^2. Length of a panel should not exceed 1½ times its width. The border panel should not exceed 450 mm in width and the joints in floor finish should extend through the border and the skirting.

9.25.3. Floor finish

Floor finish are of two types as follows:

1. Floor finish constructed monolithic with base concrete. In such cases the finish topping should be placed in position with in 2 to 3 hours of laying the base concrete depending on atmospheric conditions and temperature. In monolithic construction a small thickness of topping is sufficient, as strength is provided to it by the base concrete. Monolithic floor finish are fairly strong and economical and have good wearing properties.

9.25.3.1. Monolithic floor finish how ever present difficulties in construction of flooring of upper floors

(*a*) Such constructions are completed in much advance of other building works. It is likely to be damaged due to subsequent building operations.

(*b*) Time available for laying the topping monolithic with the structural slab is very much restricted.

(*c*) Repair work of monolithic floor topping is very difficult.

9.25.3.2. Bonded floor finish laid separately on a set and hardened base

Such a finish is suitable for laying in suspended floor slabs where structural concrete would have been laid much in advance of laying the flooring. In this case thickness of toping is kept thicker. This type of finish is suitable under the following conditions.

(*a*) Finish to be laid on base concrete on ground floors, which has already hardened sufficiently, so that monolithic bond with floor topping is not feasible. In such situations the floor topping should be laid with in 48 hours of laying the base concrete.

(*b*) This type of construction is also suitable for repairing old finishes.

9.25.3.3. Floor laying in two layers

In situations where a very dense and smooth surface is desired, the floor topping is laid in two layers:

(*a*) Under layer of 1:2:4 mix with stone aggregate of nominal size of 12.5 mm. The constituents are measured by volume.

(*b*) Wearing layer of very stiff and richer mix of 1 cement and 2 to 3 parts of stone aggregate of nominal 4.75 mm size.

9.25.4. Materials

Coarse aggregates. Size of coarse aggregate for different parts of cement concrete should be as follows:

(*a*) Base concrete (lean cement concrete or lime concrete)
- Graded aggregate upto 40 mm and below.

(*b*) Cement concrete topping of 40 mm thickness and above
- Graded from 20 mm and below.

(*c*) Cement concrete topping of 25 mm thickness
- Graded from 12.5 mm nominal size and below.

Table 9.8. Proportion for nominal mixes of concrete

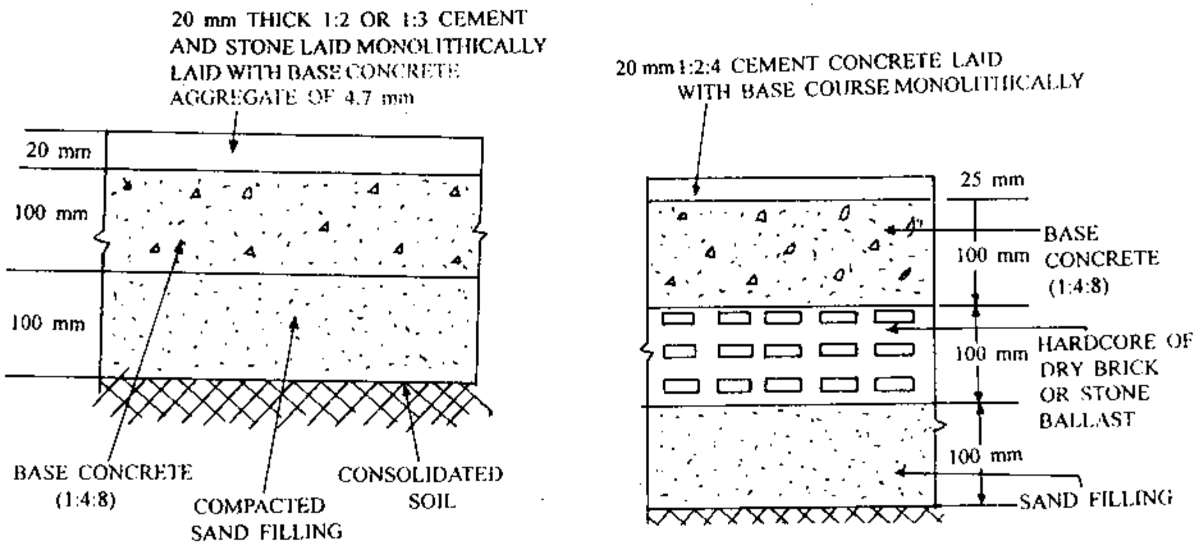
Grade of concrete	*Total quantity of dry agg by mass of 50 kg of cement mass in kg*	*Proportion of fine agg to coarse agg by (mass)*	*App. proportion of mix.*	*Max. Quantity of water per 50 kg of cement bag in liters (w/c ratio)*
M5	800	Generally 1:2 subject to an upper limit of 1:1½ and a lower limit of 1:2½	1:5:10	60 (1.2)*

Grade of concrete	Total quantity of dry agg by mass of 50 kg of cement mass in kg	Proportion of fine agg to coarse agg by (mass)	App. proportion of mix.	Max. Quantity of water per 50 kg of cement bag in liters (w/c ratio)
M 7.5	625	1:2	1:4:8	45 (0.9)*
M 10	480		1:3:6	34 (0.68)*
M 15	350		1:2:4	32 (0.64)*
M 20	250		1:1½:3	30 (0.60)*

Fig in last columns in parentheses indicate water-cement-ratio by weight.

9.26. PREPARATION OF SUB BASE

Sub base components for different conditions of sub base are shown in Fig. 9.2.



(a) Without hard core sub base (b) Compacted earth

Fig. 9.2. Insitu cement concrete flooring

The earth filling in plinth is consolidated thoroughly. There should be no loose pockets in the whole area. Well rammed earth filling is covered with clean sand upto a depth of 100 mm as shown in Fig. 9.2 (*a*).

In heavy duty flooring, sub base should consist of well compacted sand layer of 100 mm and an additional 100 mm thick well compacted hard core of dry brick or stone ballast of 40 mm size blinded with coarse sand or moorun Fig. 9.2 (*b*).

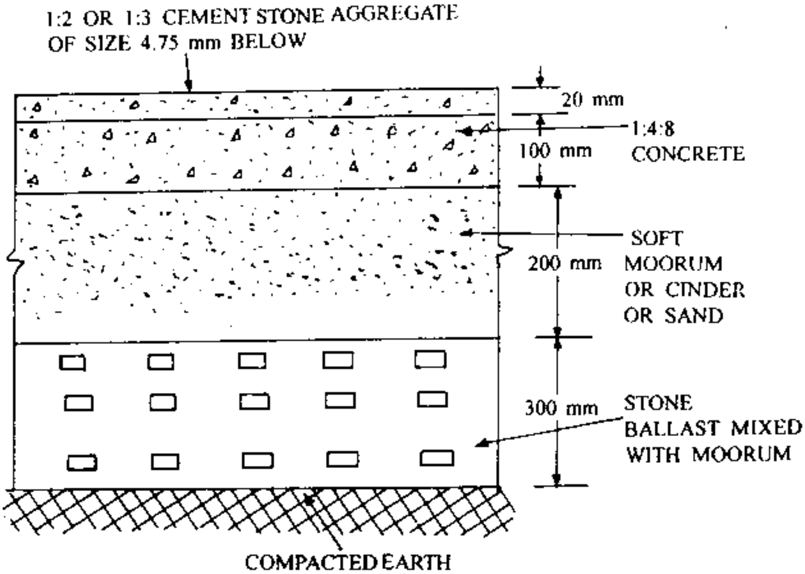


Fig. 9.2. (*c*) Sub base for expansive soil

In case of expansive soils as black cotton soil the top 60 cm soil should be rammed. Then 40 mm graded stone ballast is mixed with locally available soft moorum in the ratio of 1:1 and laid. It is well compacted to a layer of 30 cm thickness. It should be saturated with water. This surface is covered with 20 cm thick layer of soft moorum or cinder or sand and compacted well before laying the 10 cm. thick base concrete as shown in Fig. 9.2. (*c*).

9.27. SPECIFICATIONS FOR LAYING MONOLITHIC FLOOR FINISH

The topping should be laid with in 2 to 3 hours of laying the base concrete, while it is still green to have proper bond.

Base concrete. 100 mm thick 1:4:8 cement concrete. Size of aggregate 40 mm nominal size.

Strips. The depth of strips should be equal to the combined thickness of base concrete and the topping. They should be coated with thick coat of lime wash to avoid sticking of strips with the concrete of the panel. Before placing base concrete, the sub base should be well wetted.

Floor finish. Topping concrete should be laid with in 2 to 3 hours of laying base course.

Topping. Usually 1:2:4 cement concrete of 25 mm minimum thickness as shown in fig. B above. Alternatively it may of 1 part of cement and 2 to 3 parts of stone aggregate of 4.75 mm and below. Thickness of concrete may be 20 mm as shown in Fig. 9.1 (*a*) and (*c*) above.

In case of structural slab on upper floors, minimum thickness of of topping 1:2 or 1:3 cement and stone aggregate of size 4.75 mm) should be 15 mm and should be placed monolithically with the structural concrete and finished.

9.28. SPECIFICATIONS FOR CONCRETE FLOOR TOPPING (BONDED CONSTRUCTION)

Preparation of base etc. is same as in section 9.21 above.

Floor topping should be applied separately over the base concrete, 100 mm thick 1:5:10 lean concrete. Nominal aggregate size would be 40 mm.

The base concrete may be spread over the whole area at a time. Care should be taken to provide proper bond between base course and topping. Floor topping should start with in 48 hours of laying base course.

Cushioning layer of lime concrete. The cushion layer is provided over the structural slab. The lime concrete will consist of 40 parts of lime mortar and 100 parts of brick aggregate of 40 mm size. Lime mortar shall be 1 lime, 1 surkhi and 1 fine sand.

Preparation of base concrete. The surface should be cleaned of all dust, laitance etc. and made rough. After washing the surface, the topping should be laid with in 12 hours. Before placing topping a neat slurry of cement at the rate of 2 kg cement/m^2 of surface should be applied.

Fixing of glass strips. Cement concrete flooring should be laid in one operation using glass, Aluminium, PVC or brass strips. The thickness of glass strip should be 4 mm, aluminium or brass strip thickness 2 mm should be fixed in 1:4 cement mortar (cement and coarse sand). There should be a gap of 36 to 48 hours between fixing of strips and laying of concrete topping. The concrete should be filled upto the top of strips. It will ensure separation of panels, uniformity of colour of all panels, straight edges, and corners at the junctions of two panels.

Laying of floor topping with strips. The concrete mix should be stiff. If water or laitance accumulates on the surface, the concrete should be scraped and replaced by fresh mix of concrete of proper workability. No dry cement should be spread over the surface to absorb surplus water.

Finishing of surface. After full compaction, the surface should be finished with trowling or floating. The satisfactory resistance of floor to wear depends largely on care with which trowling has been done. The objective of trowling is to obtain a hard and close knit surface as possible.

The time interval between successive trowling is very important. Immediately after laying the concrete only just sufficient trowling is done to give a level surface. In early stages excessive trowling should be avoided as this tends to make a layer rich in cement to the surface. The final trowling should be done when concrete has become sufficiently hard and a considerable pressure is required to make an impression on the surface.

9.28.1. Laying of concrete with out strip

In this case the base concrete and topping should be laid in alternate panels. The intermediate panels should be filled after 24 or 48 hours depending on atmospheric and temperature conditions.

The panels should be bounded by angle iron/flat of the same thickness as that of concrete flooring. The surface of angle iron/flat should be smeared or coated with soap solution to avoid sticking of concrete to iron surface.

These angle iron/flat should be removed the next day of laying cement concrete. The ends are repaired, if found damaged with 1:2 mortar (cement and coarse sand) and allowed to set for 24 hours.

The alternate panels then should be cleaned of dust, mortar droppings, and concreted. While laying concrete, care should be taken that the edges of the previously laid panels are not damaged and fresh mortar not splashed over them. The joints between the panels should be as fine straight line.

9.28.2. Laying of topping in two layers

This method is adopted when very dense and smooth surface of flooring is desired. The thickness of under layer may be 25 mm of 1:2:4 cement concrete by volume. The miximum size of coarse aggregate should be 12.5 mm. It should be laid in panels as discussed above. It should be left rough after tamping. It should be levelled with screed board.

9.28.2.1. Topping course

The top wearing layer of 15 mm thickness of 1:2 or 1:3 proportion (1 cement and 2 to 3 parts of stone screening of 4.75 mm nominal size and below) by volume depending on the quality of finish and abrasive

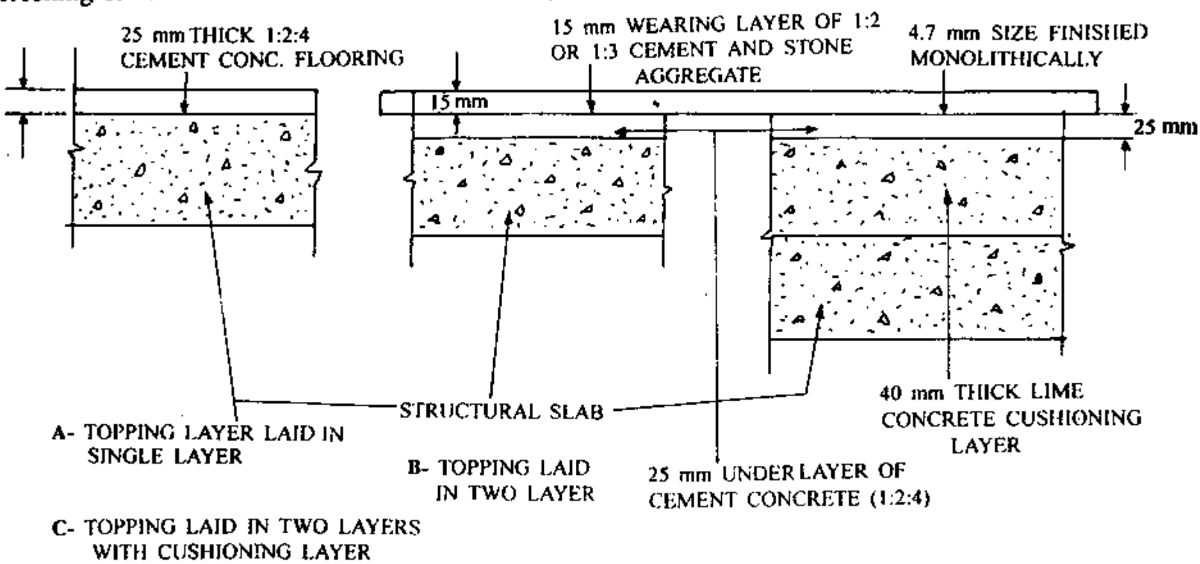


Fig. 9.3. Bonded floor finish over structural slab

resistance desired, should be laid immediately over the rough but green surface of the under layer. The consistency of this concrete should be stiffer than the under coat. It should then be thoroughly tamped, struck level and finished with wooden float as shown in Fig. 9.3 (*b*) and (*c*).

9.28.2.2. Curing

10 days curing minimum by any suitable method.

9.28.3. Precautions

As discussed under general precautions.

9.28.4. Limitations of cement concrete flooring

Many fine particles of sand and cement come to the surface with water forming a weak surface, having poor resistance to wear. In a short time the concrete surface becomes full of dust and requires frequent vigorous sweeping. It can not be washed clean.

9.29. CEMENT PLASTER IN SKIRTING, DADO AND RISERS OF STEPS

9.29.1. Skirting

A band of plaster at the bottom of the wall not exceeding 30 cms in height above the floor is known as skirting. Usually its height is kept 10 to 12.5 cms. It is either finished flush with the wall plaster or it is projecting out uniformly by 6 mm from wall plaster. If it is made flush with plaster, in that case a groove of 10 mm wide and 5 mm deep is provided in plaster at the junction of the skirting with plaster. Skirting work is carried out simultaneously with laying of floor. Its corners and junctions with floor should be rounded off neatly upto a radius of 25 mm. The mix for skirting usually is 1 cement and 3 coarse sand. The usual thickness of cement plaster is 18 mm to 21 mm, with a projection of 3 to 6 mm alround uniformly.

9.29.2. Finish over stairs

Risers should be finished with minimum thickness of usually 6 to 10 mm. Thickness over treads should not be less than 20 mm for monolithic finish and not less than 40 mm for finish laid over the hardened concrete.

Surface finish as usual with raking of joints upto 15 mm.

The quantity of cement applied for floating coat is 2 kg/m^2 of area.

9.30. GRANOLITHIC CONCRETE FLOOR TOPPING (IS 2114-1984)

Granolithic concrete floor topping is adopted for floors of heavy duty Engineering factories, work shops, garages, ware houses etc., where floor is subjected to heavy loads and severe abrasion and impact. The concrete is made with aggregates of high hardness, surface texture *i.e.* this concrete is of high abrasion resistance. A high class workman ship is essential for laying this concrete.

9.30.1. Mix proportion

For floor topping, granolithic concrete mix adopted is 1:1:2 (1 cement, 1 coarse sand and 2 coarse aggregate by volume).

The coarse aggregate should be from hard rock as Granite, Basalt, Trap and Quartzite, of 12.5 mm nominal size and below, fine aggregate may be of grading of zone 1 and 2 of standard grading. table 9.1.

9.30.2. Method of construction

There are two methods of laying this floor topping:

1. It is laid with in 3 hours of laying of the base, so that it is cast monolithically with the base concrete. The minimum thickness of the topping should not be less than 20 mm. For ground floors this method should be adopted.
2. The floor topping is laid on a hardened base concrete. In this case the thickness of topping should be 40 mm.

9.31. TARRAZO (MARBLE CHIPS) FLOORINGS LAID IN SITU (IS 2114-1984)

In situ tarrazo is a popular floor finish in residential and public buildings. It is preferred due to its decorative and wearing properties and ease in cleaning. This flooring consists of an under layer of 1:2:4 cement concrete. The maximum size of coarse aggregate should be 12.5 mm. The thickness of this under layer may vary from 34 mm to 28 and the thickness of top marble chip layer may vary from 6 to 12 mm, total thickness being 40 mm. The thickness of terrazo topping depends on the size of the marble chips. The under layer is laid over base concrete or cushioning layer. General principles of laying are the same as that of cement concrete.

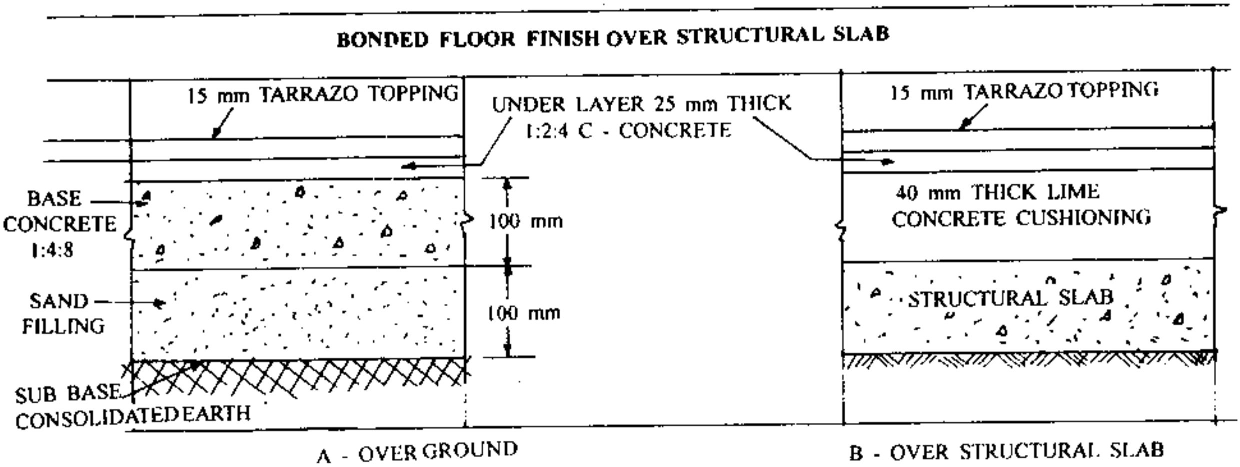


Fig. 9.4. Tarrazo floor finish

9.31.1. Base concrete

It is a lean concrete of 1:5:10 or 1:4:8 proportion. The thickness of base concrete generally is kept as 100 mm. The base concrete is laid over sub base. The sub base is prepared as discussed earlier. Fig. 9.4 (*a*)

9.31.2. Cushioning layer

The thickness of cushioning layer over structural slab concrete in case of upper floors is kept 75 mm. It is laid as discussed earlier. Fig. 9.4 (*b*)

9.31.3. Terrazo Topping

The mix consist of cement, with or with out pigment, marble powder, and marble chips and water. The size of chips used in terrazo varies from 1 to 10 mm.

9.31.4. Proportion

1 part cement, 3 parts of chips and 1 part of marble powder by weight of cement. The proportion of aggregates by volume is shown in Table 9.8 below.

Table 9.8. Grading and thickness of terrazo topping

Grade No.	*Size of marble chip in mm*	*Ratio of chips to binder (cement)*	*Min. thickness of top layer mm*
0 0	1 – 2	1.75:1	6
0	2 – 4	1.75:1	9
1	4 – 7	1.75:1	9
2	7 – 10	1.50:1	12

9.31.5. Marble chips

Chips should be hard, sound, dense and homogeneous in texture with crystalline and coarse grain. They should be of the specified colour. Common colour being white, pink, black yellow and green. The chips should be of uniform colour and free from stains, cracks and weathering. In case the chips greater than 10 mm is used, then the minimum thickness of layer should not be less than 1.7 mm times the maximum size of chip. Where large size chips as 20 or 25 mm are used, the chips should be of flat shape and bedded on the flat face, so as to minimise the thickness of wearing layer.

9.31.6. Proportion of Pigment used

It is shown in the following Table 9.9.

Rest. Procedure of laying base and under layer is same as discussed above.

Table 9.9. Cement pigment proportion for various colours of topping

Colour	*Pigment to be used*	*Proportion of pigment*	*Proportion of cement ordinary gray portland cement*	*Proportion of white cement*
Red	Red oxide of iron	1	15 to 20	NIL
Black	Carbon black	1	25 to 40	NIL
Bottle Green	Green chromium oxide	1	15 to 30	NIL
Pink	Red oxide	1	NIL	100 to 300
Cream	Yellow oxide of iron	1	NIL	100 to 400
Yellow	Yellow oxide of iron	1	NIL	25 to 75
Light Green	Green chromium oxide	1	NIL	50 to 150
Fawn	Yellow oxide of iron	1	6	4

9.31.7. Laying of terrazo topping

Terrazo topping should be laid on the under layer while it is still plastic, but sufficiently hard to check cement to rise to the top. Generally it is achieved between 18 to 24 hours of laying the under layer.

Before laying the terrazo topping, cement slurry of the same colour as the topping should be applied to the surface of the under layer immediately before laying of topping starts. As far as possible laying of entire topping should be completed in one stretch.

Water to the dry mix should be added in small quantities, preferably in a fine spray. The mix should be of stiff consistency, but workable. The prepared mix should be laid with in 30 minutes of adding water to it. The terrazo topping should be compacted fully by tamping. It should be laid in uniform thickness, slightly more than the specified thickness to allow grinding decrease in the thickness. It should be trowelled over well pressed and brought true to the required level by straight edge. It should be ensured that maximum amount of marble chips come to the surface and spread uniformly.

The time interval allowed between successive trowelling is very important. Immediately after laying the topping, that much trowelling which is just sufficient to level the surface is needed. Excessive trowlling in early stages may be avoided, as it will tend to work up cement to the surface and finish may crack. Also it will need more grinding of surface to expose marble chips. The surface should be left for 12 to 18 hours to dry, and after this, the surface should be cured by ponding not less than for 72 hours before starting 1st grinding.

9.31.8. Grinding

It may be done either by hand or by machine.

Manual grinding should not commence before at least 48 hours of laying the tarrazo topping where as machine grinding should start after 3-4 days of laying the tarrazo topping. This time interval depends on materials used, their proportion and weather conditions. The sooner the grinding is done, the easier it is. However if it is done too soon, the chips from the topping may tear off.

After the first grinding, the surface should be thoroughly washed to remove all grinding mud and it is covered with a grout of cement and pigment as that of the topping and of same mix proportion.

It should be allowed to dry for 24 hours and cured for 4 days (In 1st grinding Carborundum stone of coarse grade No. 60 is used)

Second grinding. The second grinding is done with machine fitted with grit blocks of 120 no. The surface is again washed clean and repaired as in 1st grinding and allowed to cure for 3 days.

3rd grinding. It is done with machine fitted with grade grit block no. 320 to get even, and smooth surface with out any pin holes.

In case of manual grinding. The carborundum stone of coarse grade 6, 80 and 120 should be used in 1st, 2nd and 3rd grinding respectively.

9.31.9. Finishing

After final grinding, the surface is washed clean, oxalic acid powder is dusted over the surface at the rate of 33 gm/m^2 area. Then water is sprinkled over the surface and it is rubbed hard with felt or pads of woollen rags. Next day the surface is wiped with moist rag and dried with a soft cloth and finished clean. Now the surface should be covered with oil free saw dust. The saw dust should be removed after the completion of all work as electrical fittings, plumbing etc.

Before occupying the area, it should be washed clean with dilute oxalic acid solution, dried and rubbed with clean cotton waste and if desired wex polish may be applied.

9.32. BRICK ON EDGE FLOORING (IS 5766-1970)

The usefulness of this flooring depends on the good wearing quality of bricks and case and quickness in installation. The performance depends on the quality of bricks, care in preparation of beding and laying.

Materials. Bricks class design 75 *i.e.* 1st class as per IS 1077-1966 should be used.

Mortar for joints 1:4 or 1:6 cement and fine sand by volume.

Base course lean concrete 1:4:8 or 1:5:10 proportion.

Laying. The bricks should be laid on edge on a 12 mm mortar bed in plain or diagonal herring bone pattern. Each brick should be properly bedded and set by gently tapping with trowel handle or wooden hammer. The inside face of brick should be coated with mortar before laying the next brick to provide proper bond and pressed against it. On completion of a portion of flooring, the vertical joints should be filled from top with mortar. To obtain a true plain surface it should be checked frequently during laying period. (Rest is same as for brick masonry)

9.33. KOTA STONE FLOORING

Thickness available 20, 25, 30 mm.

For residential building 20 mm thickness is sufficient

For public building minimum 25 mm thickness is sufficient

It is laid on 20 mm thick base layer of 1:4 mix (1 cement 4 coarse sand)

9.34. BITUMEN MASTIC FLOORING (I.S. 1196-1978)

Bitumen mastic is an intimate homogeneous mixture of mineral fillers and bitumen. It is quite suitable for use in the flooring of industrial buildings, ware and grain houses and surfacing of bridge decks etc. due to its resilience, imperviousness, durability, ease in maintenance and wearing qualities. The thickness of flooring depends on the traffic conditions to which the flooring is likely to be subjected. For special and light duty flooring, the thickness may vary from 15 to 25 mm. For medium duty flooring 25 to 35 mm and for heavy duty flooring thickness may vary from 30 to 50 mm. It may be laid in one or two coats.

Fine aggregate should be of crushed hard rock or natural sand. The percentage passing through 75 micron should be limited 45 to 55% weight and should not be retained on 2.36 mm, sieve. The coarse aggregate should be of hard and durable rock. For special flooring, light duty flooring and medium duty flooring the maximum size may be 4.75 mm while for heavy duty flooring it may be 9.5 mm. On the lower side it should not pass through 600 micron I.S. sieve.

9.35. MAINTENANCE AND REPAIR OF BITUMEN MASTIC SURFACES

The bitumen mastic surfaces require relatively less maintenance. Superficially dust etc. may be removed by washing with warm water and soluble detergent. In case the surface is very dirty, a small quantity of soda may be added to the warm water. After the dirt has been removed, the floor should be washed with clean water.

It is essential that oil or grease etc. should not be allowed to stay on the floor for long as the surface of bitumen mastic is liable to get softened by such substances, hence they should be removed immediately.

Repair. When a damaged section has to be removed, hot bitumen mastic should be placed around and over the affected area. After this area has softened, it should be cut away and made good with the fresh mastic.

If an attempt is made to cut the affected area with hammer and chisel or softening it with below lamp, considerable damage may occur, which can be avoided by using hot bitumen mastic.

Repair of heaved surface of floor. Actually it is very difficult to repair a heaved floor surface. The only solution is to remove the damaged portion and cut the sub base to the surrounding level. Apply the cement water slurry to the cut surface and refill the concrete of high quality with 0.45 water cement ratio and compact well. If tile of any kind is to be laid then place the tile of proper thickness and finish as for new flooring in usual way.

Repair of floors. Various types of defects may develop in floors of buildings, which require proper remedial measures for effective use of the buildings. The techniques of repair depend upon the type of defect.

9.35.1. Preparation of surface of the floor for repair

Before replacing the floor concrete toping over the existing concrete, the concrete surface must be prepared properly.

9.35.2. Steps involved in surface preparation

For proper preparation of concrete surface usually following steps are involved:

(*a*) **Removal of contamination.** Oil, grease, wax or sealers may destroy the proper bond between the top floor coat and its base material. Thus the process of complete removal of contamination and little removal of sub strata of concrete is called as surface preparation.

The presence of such contamination may be determined by dropping a small quantity of muriatic acid on the surface. No reaction indicates presence of contaminants. The presence of oil can be ascertained by heating the small area of surface by blow lamp to a temperature upto 66°C. The greasy touch of the surface indicates the presence of oil. Tri sodium phosphate is one of the typical contamination remover.

(*b*) **Removal of bulk.** Removal of laitance or a thin layer of concrete surface is called removal of bulk. Various methods of preparing hardened concrete may be employed. The most common method of preparing hard concrete surface is chipping with the help of a square tip chisel. The method selected should be effective to get the desired results and not to damage the sound concrete. Following methods may be employed for surface preparation in order of merit.

(*i*) Shot blasting (*ii*) Sand blasting
(*iii*) Water blasting (*iv*) Acid itching

(*i*) **Shot blasting method.** This method is preferred for removing thinner section of concrete. In this method small steel balls strike the concrete with high velocity to crush the laitance or upper layer. The surface should be cleared with vacuum cleaner.

(*ii*) **Sand blasting.** In this method sand (hard silica) is used in place of steel shots. Same procedure is applied as in case of shot blasting. This method requires more care during cleaning operation.

(*iii*) **High pressure water blasting.** In this case to remove upper layer of concrete a water jet with a pressure of about 0.8 kg/cm^2 is applied on the surface. To remove the wetted laitence thorough rinsing of the substance is necessary. Water pressure below 0.8 kg/cm^2 is insufficient for most of the applications. This is helpful in removing loose laitance and other surface contaminants.

Acid itching. Acid itching is the last resort of removing bulk from the concrete surface. After acid itching, the surface should be rubbed and washed thoroughly to remove residual chemicals and fine dust produced by itching which may act as bond breaker. The removal of acid may be tested with moist pH paper. The pH value should not be less than 10.

Surface cleaning. It is the last, but most important operation in the cleaning of concrete surface. All loose particles and dust must be removed before placement of patching repair material. The best method of removing loose particles and dust is pressure washing with water. For washing the surface, a pressure of the order of 0.3 kg/cm^2 has been found most effective.

The prepared surface is dried before putting the floor topping. A bonding agent must be applied on the prepared surface with the help of stiff brush or rubbed with the help of stiff and clean broom. The bonding coat should be tacky prior to the application of topping layer.

9.36. COMMON DEFECTS OF CONCRETE FLOORS

Following are the general defects of concrete floors:

1. Shrinkage cracks. Shrinkage and its effects has been discussed on page 82 in detail. However methods to minimise shrinkage cracks are discussed in brief here. Following measures may be adopted to reduce the shrinkage effect.

(*a*) Use of largest maximum size of aggregate will reduce shrinkage substantially.

(*b*) Use of minimum possible water cement ratio as practicable for the required workability.

(*c*) Curing for the longer period than recommended helps in reducing shrinkage.

(*d*) Providing spacing joints at 2.5 to 3.0 m for 100 mm thick floor slab and 3 to 4 m apart for 125 mm thick slab.

(*e*) Providing saw cut joints upto a depth of at least one fourth of the slab thickness.

(*f*) Placing joints at restraint corners.

(*g*) Isolation of slab from foundation, walls or other structural elements will reduce shrinkage effects.

2. Development of crazing cracks. These cracks are very fine large in number, but very shallow and seldom affect the durability of the surface. They develop due to the rich paste in the top layer. Crazing can be prevented by the following measures.

(*a*) Avoiding fast drying of the surface. It can be done by starting curing of surface at the earliest possible.

(*b*) W/c ratio of the mix should not be high. Normally the slump should not exceed 75 mm.

(*c*) Concrete surface should not be finished till bleeding water is present on the top of the concrete surface.

(*d*) No dry cement or sand should be sprinkled on the surface to dry the bleeding water.

(*e*) Steel trowling should be avoided as it brings more paste to the surface.

3. Settlement. Some times settlement causes cracking of the floor and creates drainage problems. Inadequate soil compaction is the most usual cause of settlement. It can be prevented by adopting following remedial measures.

(*a*) The top soil should be replaced with a coarse grained sand before placing concrete over it.

(*b*) Cohesive sub grade soil should be compacted by ramming and granular sub grade soil by vibrating.

(*c*) In poor soils, dense graded granular soil base fully compacted should be laid before placing slab.

(*d*) To avoid washing away of material, the rain run off should be kept away from the base slab.

(*e*) The back fill areas should be compacted fully in layers of 25 cm to 30 cm thickness.

4. Surface scaling. After placing concrete in place, most probabily scaling occurs after first or second winter. Scaling of concrete can be avoided by the following measures.

(*a*) Air entrained concrete should be ued as it avoids scaling.

(*b*) Proper slope should be provided, so that water may drain quickly and may not create low spots of water during finishing.

(*c*) Remove loose concrete. If necessary the floor may be treated and broom finish applied.

(*d*) Surface should not be finished having rain water or bleed water on it. Dry cement or mixture of dry cement and sand should never be sprinkled over the surface to absorb water from the surface before finishing.

(*e*) Curing of concrete surface may be continued even after 28 days curing with the help of hessian or curing compounds.

5. Popouts. These are small marks on the surface of concrete developed by the internal pressure from particles near the surface. The common causes for the development of popouts are presence of absorptive chemical reactive particles near the surface. Following measures may be adopted to minimise the effect of popouts.

(*a*) Large particle near the surface may be pushed beneath the surface before floating the surface.

(*b*) Smaller coarse sized aggregate should be used in concrete.

(*c*) To reduce the permeability of the concrete low water cement ratio should be used in the concrete. This concrete will be more resistant to the popouts.

(*d*) Non reactive aggregate should be used in the concrete.

(*e*) If only reactive aggregate is available for the production of concrete, in that case concrete should be cured with ponding method or fog spray method. After curing, concrete surface should be washed properly.

9.37. REMOVAL OF DIFFERENT TYPES OF STAINS

1. Ink stains

(*a*) Fresh ink stains. These stains can be removed by scrubbing (rubbing) and washing with rag or cotton dipped in ammonia till the stain disappears. Wash the surface with clean water.

(*b*) Old and deep stains. These stains can be removed by applying a paste of sodium carbonate mixed with marble powder called whiting. Leave this paste on the surface for 15 minutes and then clean. If the stains are not removed completely, but reduced in intensity, then repeat the procedure. Sodium carbonate can be replaced by one of the following chemicals.

(*i*) Oxalic acid
(*ii*) Ammonium oxilate
(*iii*) Citric acid
(*iv*) Sodium citrate
(*v*) Hydrogen peroxide

2. Dirt and Rust stains. These stains usually occur in bath rooms due to the use of iron buckets.

(*a*) Light and fresh stains. These stains can be removed by applying paste prepared by mixing sodium citrate and glycerine and water in the proportion of 1:6:6 and some whiting. Apply this paint on the stained surface and leave it for 15 to 20 minutes. Clean and wash the surface with clean water. If stains are not fully removed, repeat the process.

(*b*) Deep and old rust stains. These stains can be removed by applying a paste of sodium hydro sulphate and sodium citrate in equal parts. Apply this paste on the stained surface for 15 minutes only. This paste should not be left for more than one hours as it will form black spot or mark on the surface. However these black spot may be removed by applying fresh hydrogen peroxide.

3. Fresh oil stains

(*a*) For removing such stains from the floor, first, wash the stain on the surface, and then rubb them with hydraded lime. After this, they should be rubbed either with petrol or Benzene.

(*b*) Old and deep oil stains. These stains can be removed by placing a thick cloth saturated with acetone and amyl acetate over the stainted surface. To allow the process of evaporation of chemicals, place over the thick cloth some powder of marble powder (whiting). After about 30 minutes, clean the spot. In case the stains are not removed or cleaned, repeat the process. In place of acetone and amylacetate, carbon tetrachloride can be used.

4. Paint and varnish stains. These stains can be removed by ready made paint remover available in the market. The use of paint remover is the cheapest and best. Alternatively they can be removed by the use of carbon tetrachloride with amylacetate. In case of wooden surface, soften the paint with blow lamp and remove the paint softly with an iron scraper.

5. Bitumen stains. These stains can be removed by softening them with mild heat of blow lamp. The bitumen melts and starts dripping through expansion joints. The stain may also be removed by softening the stain with hot kerosene oil and scrapping it. The remaining light stains may be removed by applying carbon tetrachloride over it.

Floor stains can be removed by scrubbing it with a mixture of tri sodium phosphate, plus hydrogen paroxide plus ammonia in equal parts. Alternatively sodium hydro sulphite with whiting may be used. These substances should be applied on the stain for 20 to 30 minutes. After this period the spot is cleaned washed with water.

6. Tea and coffee stains. These stains can be removed by scrubbing with a mixture of Glycerine and water in the ratio of 1:4 and mixed with whiting. Keep this paste over the stain for 15 to 20 minutes, wash the floor with clean water.

7. Urine stains. Urine stains can be removed first applying oxalic acid on the spot and rubbing it with hard brush and then washing it with clean water.

8. Blood stains.

(*a*) Fresh blood stains can be removed by washing with cold water.

(*b*) Old and dry blood stains. These stains can be removed by scrubbing detergent on the spot and then rubbing it with brush and washing with clean cold water. If stain is not removed fully, but, has become light, then repeat the process. It will be removed in one or two wash.

9. Smoke and fire stains. These stains can be removed by rubbing the stained surface with powdered pumice. To obtain a clean surface, the process may be repeated several times.

10. Very dark and deep stains. The stains can be removed by the use of solution of 1 part of sodium citrate and 6 part of water. The solution is sprinkled over the surface. Then the surface is coated with a thin layer of sodium hydro sulphate crystals. After about 2 hours, the surface is cleaned with fresh water.

QUESTIONS

1. Explain the term floor and flooring.
2. What factors influence the choice of type of flooring?
3. Explain the process of laying concrete flooring with sketch.
4. What is terrazo flooring? Give full method of its laying.
5. What are the common defects in concrete flooring?
6. Discuss the method of removing following stains from the floor:
   (*a*) Ink stains (*b*) Tea and coffee stains
   (*c*) Dirt and rust stains (*d*) Bitumen stains
7. Identify the correct statement/statements
   (*a*) Cement lime mix for plaster has high workability and ease in application
   (*b*) It has more working time of about 2 hours
   (*c*) The rate of strength development is slow
   (*d*) All are correct
   (*e*) None of above is correct
8. Gauges in plaster work are applied at spacing of
   (*a*) 5 m (*b*) 10 m
   (*c*) 2 m (*d*) 7.5 m
9. To check bleeding from concrete surface, it should be finished with
   (*a*) Steel trowel (*b*) Wooden float
   (*c*) No need of finishing (*d*) All are correct
10. To thickness of plaster at bearings should be
    (*a*) 10 mm (*b*) 6 mm
    (*c*) 4 mm (*d*) 8 mm
11. Slope in concrete flooring usually is given in the range of
    (*a*) 1:48 to 1:60 (*b*) 1:30 to 1:40
    (*c*) 1:70 to 1:80 (*d*) 1:80 to 1:100

12. For removing damaged bitumen mastic floor should be removed by
    (*a*) By placing hot bitumen mastic around and over the damaged area
    (*b*) By chilling the whole area
    (*c*) No necessity of removing damaged area, concrete may be placed over it
    (*d*) All are correct
13. For removing of bulk contaminants from the concrete surface by high water pressures water pressure should be
    (*a*) About 0.8 kg/cm^2 (*b*) About 1.5 kg/cm^2
    (*c*) About 0.7 kg/m^2 (*d*) About 0.2 kg/cm^2
14. Identity the incorrect statement/statements
    (*a*) Pebble desh finish are more satisfactory under severe conditions of exposure from durability, resistance to cracking etc.
    (*b*) Store veneering facing has relatively long life and does not need periodic repair and maintenance
    (*c*) Gypsum plaster is most suitable for out door plaster
    (*d*) For external rendering trowelled finishes are usually recommended
    (*e*) For large continuous surfaces groove or band should be provided to localized the cracks formed.

ANSWERS

7. (*d*)	9. (*b*)	11. (*a*)	13. (*a*)
8. (*c*)	10. (*b*)	12. (*a*)	14. (*c*, *d*)

10

Water Supply System and its Maintenance

10.1. INTRODUCTION

For the existence of human, animal and plant life water is the second important requirement after air. The importance of water in human life can be judged from the fact that the development of cities in the world has practically taken place near some source of water supply. The water supply system consists of the following systems:

1. Source of water
2. Intake system
3. Conveyance system
4. Distribution system etc.

1. **Source of water.** Source of water may be river, canal, lake and under ground source.
2. **Intake.** An intake is a structure constructed across the surface of water to permit the withdrawal of water from the source. The structure may be of stone masonry, brick masonry, R.C.C. or concrete blocks. The structure should be water tight and strong enough to withstand all forces likely to attack it.
3. **Conveyance system.** This system includes all devices which lead water from intake to the consumer such as pipes, valves, treating tanks as filtrations and sediment reservoirs and distribution reservoirs and tanks.
4. **Distribution system.** This system consists of methods of distribution as gravity system, gravity and pumping system combined and methods of layout of distribution pipes. Following are the four main methods of laying distribution pipes.

10.2. ADVANTAGES AND DISADVANTAGES OF DIFFERENT TYPES OF DISTRIBUTION SYSTEMS

The advantages and disadvantages of different types of distribution systems are shown in the following Table 10.1.

Table 10.1

S. No.	*Method of distribution*	*Advantage*	*Disadvantage*
1.	Gravity system	(*a*) In this method water is conveyed through pipes by gravity only. (*b*) It is the most reliable method of distribution. (*c*) In case of fire, motor pump may be used to develop high pressure for fire fighting	It is useful only when the source of supply is situated at a higher level than the distribution area

S. No.	Method of distribution	Advantage	Disadvantage
2.	Gravity and pumping system combined. In this system the treated water is pumped and stored in elevated distribution reservoir.	Usually this method is applicable in most of the cases: (*a*) In case of fire, motor pump can be used to develop high pressure or can be taken up direct from pump house after closing the valve for elevated reservoir. (*b*) In this case pumps generally work at uniform rate, hence they suffer less wear and tear. (*c*) This method is economical (*d*) This method is fairly reliable as some water is available from elevated reservoir even during breakdown of pumps.	Its cost is higher than gravity system.
3.	Pumping system	(*a*) In this system water is directly pumped to the mains leading to the consumers. (*b*) No. of pumps will depend on the demand of water. (*c*) In case of fire high capacity pumps can be operated to develop pressure.	(*a*) In case of power failure entire system is disturbed. (*b*) It requires constant attendance as pumps are to be kept in working condition all the time.

10.3. SYSTEM OF SUPPLY OF WATER

Different methods of layout of distribution pipes and their merits and demerits are discussed below:

1. Dead end or tree system. This system consists of one main supply pipe from which sub mains are taken out. From sub mains branch lines are taken out and from branch lines service connections to the consumers are given. This system is adopted in localities which are expanding irregularly. The water pipes are laid at random with out planning for future roads. Fig. 10.1.

Advantage

(*a*) In this system discharge and pressure can be determined accurately at any point in the distribution system.

(*b*) The design calculations are simple and easy.

(*c*) Less number of valves are required for cut off supply.

(*d*) The diameters of mains are to be designed for the population to be served by them only. This fact makes the system cheep and economical.

(*e*) Laying of water pipes is simple.

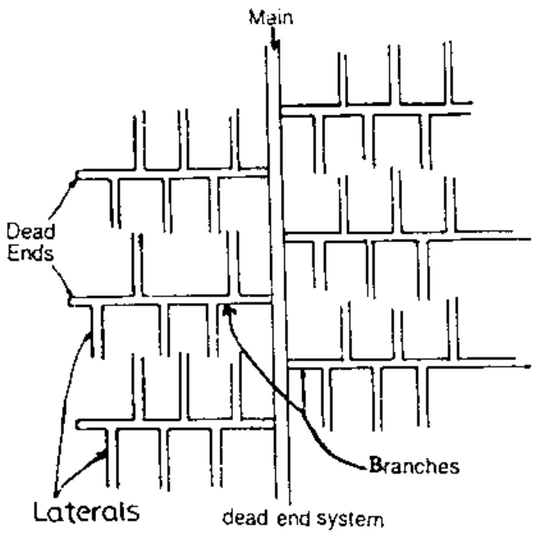


Fig. 10.1. Dead end system

Disadvantages

(*a*) During repairs large area is affected and it causes great inconvenience to the consumers of the area.

(*b*) In this system there is large number of dead ends

(c) There is no free circulation of water.

(d) Scour valves are to be provided at dead ends to remove the stagnant and polluted water from there. Thus much of the treated water is wasted. Hence it is costly.

(e) Requires careful attendance and operation of the scour valves.

(f) Water available for fire fighting is limited.

2. Grid iron method. This system is also known as reticulation or interlaced system. The mains, sub mains and branches are inter connected with each other. This system is more suitable for towns having well planned roads and streets. Fig. 10.2.

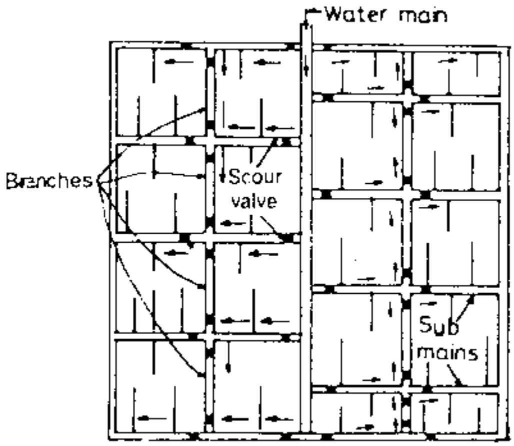


Fig. 10.2. Grid iron system

Advantage

(a) During repairs only a very small portion of the distribution area is affected.

(b) There is free circulation of water. Hence it is not likely to be polluted due to stagnation.

(c) Water is delivered at every point of distribution system with a minimum loss of head.

(d) Plenty of water is available for fire fighting.

Disadvantage

(a) The cost of laying water pipes is more.

(b) It requires more length of pipes.

(c) The procedure of calculating the size of pipes, and pressures at various points of distribution is laborious.

(d) The number of valves required is more as four valves are to be installed at each cross junction.

3. Circular method. This method is also called as ring system as a ring of main pipes is formed around the distribution area as shown in Fig. 10.3. The advantages and disadvantages of this system are same as those of grid iron system. In this system the distribution area is divided into circular or rectangular blocks and water mains are laid on the periphery of these blocks. This system is most suitable for towns having

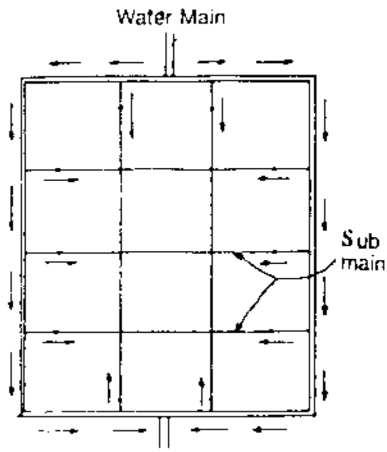


Fig. 10.3. Ring system

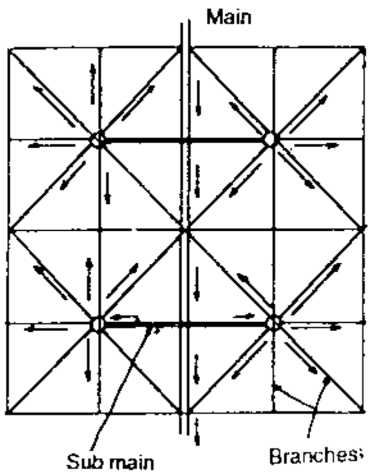


Fig. 10.4. Radial system

well planned roads and streets.

4. Radial method. This method of layout is just reverse of the ring method. In this system the water is taken from the mains and pumped into the distribution reservoirs, situated at centers of different zones as shown in Fig. 10.4. This method of layout gives quick service. The calculations for design of sizes of pipes are also simple. This method of layout is most suitable for town having road lay out radially.

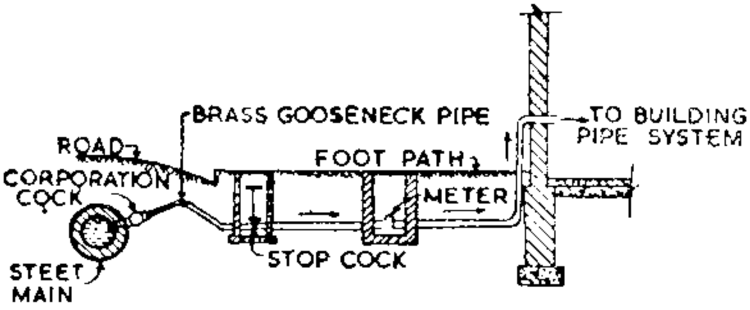


Fig. 10.5. House Connection

Fig. 10.5 shows house connection with water destribution system and Fig. 10.6 shows ferrule and its connection.

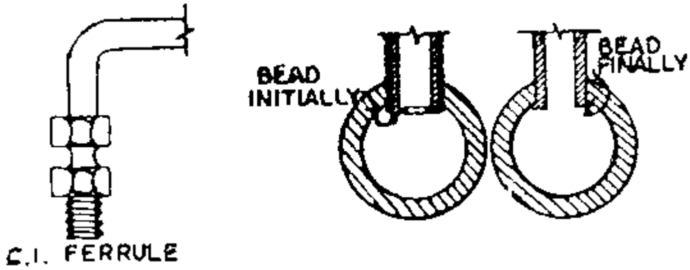


Fig. 10.6. Ferule

10.4. SYSTEM OF WATER SUPPLY BASED ON DURATION

Based on the duration of supply, there are following two systems of water supply. They are discussed in tabular form along with their advantages and disadvantages:

Table. 10.2.

S. No.	*System*	*Advantages*	*Disadvantages*
1.	**Continuous system.** In this system water is supplied to the consumer all the 24 hours	It is the most ideal system of water supply and it should be adopted as far as possible.	Its only disadvantage is high wastage of treated water.
2.	**Intermittent system.** In this system water is supplied during fixed hours of the day. The usual duration of supply is one to four hours in the morning say from 6.30 to 10.30 a.m. and from 5.30 to 8.30 p.m. in the evening. However period of supply may be kept as per convenience of public and department concerned. This system can prove useful under the following conditions:		
	(*a*) The available pressure is poor.	(*a*) The working of the system is easy and simple.	(*a*) This system needs more number of valves for its working.
	(*b*) The quantity of water available is not sufficient to meet the various demands of consumers.	(*b*) It is possible to maintain good working pressure in each zone.	(*b*) More possibility of pollution of stored water
			(*c*) Mains of large size are required.
			(*d*) Difficulty to meet fire demand during non supply period.

S. No.	System	Advantages	Disadvantages
			(e) Development of vacuum in pipes. On stopping the water supply, partial vacuum may be developed in pipe line. There is danger of leacking undesirable gases in the pipe line through leakage which may cause health hazzards to the consumers. (f) Water taps might remain open during non supply period and there may be huge wastage of treated water.

10.5. ASPECTS OF A GOOD DISTRIBUTION SYSTEM

A good distribution system should satisfy the following two aspects:

1. Adequate pressure should be available at different points of distribution system. The effective pressure in pipe (after subtracting all losses as entry, exist, bend and friction losses) should be sufficient enough to raise the water to the required height in the building and to deliver the required quantity at all times even during the period of peak demand. In the same zone of water supply, there should not be great variation in minimum and maximum effective pressure. If there is great variation in the minimum and maximum effective pressure, the area should be divided into pressure zone to isolate the regions of high and low pressure areas. The minimum pressure at the terminal end should not be less than 3 m.

10.5.1. Boosting of pressure

If adequate pressure is not available due to greater elevations or excessive loss of head due to leakage, the pressure may be boost up by the following methods:

(a) By replacing the present line by suitable bigger diameter pipe line.
(b) By providing an rider or parallel additional line.
(c) Using booster pump. They may be provided at the by pass of main line out of the three methods of boosting pressure, rider method is most economical and practicable method. Hence it is the most suitable method for pressure boosting in pipe lines.

2. Supply of desired quantity to all areas. The distribution system should be capable to supply water in adequate quantities with appropriate pressure to all parts of the distribution zone. Adequate quantity include all demands such as water supply for domestic supply and industrial use and fire fighting purposes etc. The distribution should be capable to supply good quality water. The water should not get polluted in the way.

10.6. CAUSES OF LOSS OF PRESSURE

Following causes have been found for the loss of pressure:

1. Leakage through pipes. The main source of pressure loss and wastage of water is the leakage through pipes. It may be due to poor quality pipes and fittings, improper jointing and lack of supervision.

2. Partial opening of valves. In case valves are not opened fully either due to lack of proper handling or due to lack of proper maintenance such as improper lubrication there is loss due to change in velocity, resulting loss of pressure.

3. Clogging of pipe. Some material like sand, clay or salt may enter into the distribution system either through the leaking joint or while laying or repairing and joining the pipe. This material gets deposited inside the pipe, reducing the cross sectional area of the pipe. This deposition increase the frictional resistance to the water flow resulting in the loss of pressure.

4. Corrosion and incrustation. Corrosion increases upto six times the volume of the metal on which it has developed and reduces the cross-sectional area of the pipe. Corrosion formation and its effect have been discussed in detail in next few pages.

(*b*) **Incrustation.** Dissolved impurities such as dissolved calcium and other salts get deposited in layers in side the pipe line, specially in case of pipe carrying hard water. Thus due to corrosion and incrustation the cross-sectional area decreases and the inner surface of pipe becomes rough. This roughness of surface increases the frictional loss, resulting the loss of pressure.

10.7. CAUSES OF LEAKAGE

Leakage of water through the distribution system may be due to the following causes:

1. **Cracks in pipes.** Usually pipes are subjected to various pressures caused by internal as well as external agencies. Water hammer is caused by the flowing water, if valve is closed suddenly. This pressure is sufficiently high. External pressures are caused by self weight of pipe, external loading and due to change in temperature. If the pipes are not designed properly to withstand these pressures, then cracks may develop in the body of the pipes or they may burst causing leakage of water, resulting in huge wastage of treated water.
2. **Opening of pipe joints.** The joints of pipes may open due to high pressure inside the pipe line or due to the use of weak material in joints. Air bubbles left in side during the lead caulking weaken the joint as it can not withstand high pressure. In such conditions joint opens and causes wastage of water.
3. **Leakage through valves.** This leakage is due to the use of inferior or weak packing materials, improper fittings, and movable part which are more prone to wear and tear. If defective parts are not replaced in time and proper upkeep is not maintained, leakage will be heavy.

10.8. WASTAGE OF WATER

A considerable amount of treated water is wasted mainly due to the following reasons.

1. By carelessness of consumers
2. By leakage through joints of pipes

Thus in order to ascertain the amount of wastage of water, the waste water surveys are carried out. If the wastage of water could be brought down to the minimum, it will result in increased supply of water to the consumers and it will also help in reduction of the cost of treated water. All unauthorised connections can be detected by thorough inspection of pipe line and house connections.

10.8.1. Water waste surveys

For carrying out the water waste surveys, a certain area of the locality is selected. The selected area is isolated from the rest of the locality by proper manipulation of valves. Then the flow of water through pipes is recorded and the results so obtained are suitably analysed. If the wastage of water is found to be excessive, the selected area is further reduced into smaller units and the procedure of checking is repeated and the area having water wastage more than the permissible limit is identified and measures are taken to reduce it to the permissible value.

10.8.2. Necessity of conducting water waste surveys

In any water distribution system, wastage is an important factors and should be taken into consideration at the time of estimating the total demand of the area. Though metering water supply has reduced wastage to a considerable extent, even then in a well maintained and metered system 10 to 25% wastage of water has been deducted. Hence wastage can not be left unattanded.

We know that velocity of flow is proportional to the square root of head. Hence higher the value of pressure head, higher the velocity. Thus where pressure is high and efficient methods of prevention of wastage are not adopted, wastage may go upto 50%. A consistent loss of about 3% water may result about 10% loss of revenue. Hence the necessity of waste water surveys and its prevention.

10.8.3. Permissible wastage of water

The maximum permissible limit for wastage of water through water pipes can be taken as 11.6 litres per centimetre diameter of pipe per kilometer length per hour. Thus for 30 cms diameter pipe per kilometer length, the wastage of water may be taken as 348 litres per hour.

10.9. PREVENTIVE MEASURES FOR WASTAGE OF WATER

Following preventive measures may be adopted to bring down the wastage of water and damage to property and risk of contamination of water carried through pipes.

1. Design
2. Fittings
3. Inspection
4. Meters
5. Propaganda
6. Service connections
7. System of supply
8. Tests

1. Design. The design of layout of distribution system should be such as to locate the point of leakage easily. For this condition a distribution line should serve about 2000 to 3000 persons only.

2. Fittings used. The fittings used for joining the pipes should conform to the standard requirements.

3. Inspection. To check the wastage of water, house to house inspection should be carried and heavy penalty be imposed on defaulter consumers. For this purpose, vigilance force may be appointed by the local authority. Unauthorised users should be punished heavily. Leakage can be detected by the inspection of pipe joints and fittings.

4. Installation of meters. Installation of meters help in checking the wastage in the following two ways:

(*a*) Water charges on the basis of quantity of water makes the consumer conscious about the wastage of water. They realise the importance of treated water and make economical use of water.

(*b*) If a meter is installed in the distribution line at the entry point and it indicates the flow during the period from 0 to 4 A.M. in the pipe line, it shows leakage in pipe line. During this period people remain asleep and there is no likely hood of use of water. Thus arrangements of removing the leakage should be made.

5. Propaganda. Public should be made aware of the importance and value of treated water by propaganda through media, radio, news papers and television etc.

6. Service connections. All the service connections of distribution system should be carried out under the skilled supervision of authorised plumbers only.

6. System of supply. Though intermittent method of water supply has been found to reduce the wastage of water, but it has its own draw backs as difficulty in fire fighting during non supply period, requirement of large number of valves, pollution of stored water, greater size of water mains, development of vacuum, taps may remain open etc.

8. Tests. For carrying out tests for wastage of water, a special department is to be maintained by the local authority. The tests should be carried out carefully and the results should be properly interpreted, analysed and arranged to suggest suitable remedial measures.

10.10. TESTS FOR WASTE WATER

To detect the location of leakage of water following tests may be carried out.

1. Coloured water test
2. Compressed air test
3. Filling the pipe
4. Hydraulic gradient

5. Metal rod 6. Observation 7. Steel rod

1. Coloured water. Some soluble colour is mixed with water. This coloured water is allowed to flow through the pipe. If there is any leakage at any section of the pipe line, the point of leakage can be identified easily with the help of this coloured water.

2. Compressed air. When compressed air is blown through the water pipe, the air bubbles will be seen at the point of leakage.

3. Filling the pipe. In this method a certain length of the pipe is selected and the quantity of water required to fill that length is determined from the values of diameter and length of the pipe. The actual quantity used to fill completely the selected length is noted. The difference between the theoretical amount of water and the actual quantity of water used to fill that length gives the amount of wastage of water. If the amount of wastage is excessive, suitable remedial measures should be adopted.

4. Hydraulic gradient. This method is used to determine the serious leakage in water pipes. The hydraulic gradient is plotted with accuracy on a graph paper. The sudden change in the slope of the hydraulic gradient indicates the point of leakage of water.

5. Metal rod. In this method, a metal rod is taken and it is inserted into the ground in such a way that it makes contact with the water pipe. The noise created by the excaping water from the pipe can be heard either by amplification devices or with ears directly. The magnifying devices magnify the sound to the extent of 10000 times the original sound, with the help of such magnifying sound devices, the sound of excaping water can be heard even when there is no contact of the rod with the water pipe.

6. Observation. The leakage of water can also be detected by direct observation of ground above the water pipe. The presence of luxurious green spot or a melted patch of ice, or a soft spot, on the ground indicates the leakage of water through the water pipe under the ground. At such places, ground should be excavated, inspected and pipe line repaired.

7. Steel rod. In this method a sharp edged steel rod is taken, and it is thrust into the ground along the water pipe line. The steel rod is then withdrawn. If the pointed edge of steel rod becomes wet, then it indicates the leakage of water.

8. By the use of waste water meter. Usually to detect wastage of water DEACONS waste water meter is used. This meter consists of a disc held in balance by a counter weight. When water passes over the disc it is forced down. The movements of disc are directly transferred to a pencil point by a system of levers. This pencil point moves on a graph paper mounted on a drum. The drum continuously rotates in clockwise direction and the rate of flow is automatically recorded on the graph paper.

10.11. PIPES USED IN WATER SUPPLY SYSTEM

In water supply system following types of pipes are used:

1. Asbestos cement pipes 2. Cast iron pipes
3. Cement concrete pipes 4. Copper pipes
5. Galvanised iron pipes 6. Lead pipes
7. Plastic pipes 8. Steel pipes
9. Wood pipes 10. Wrought iron pipes

The advantages, disadvantages and use of these pipes are shown in Table 10.3. below:

Table 10.3.

S. No.	*Type of pipe and their use*	*Advantages*	*Disadvantages*
1.	**Asbestos Cement pipes.** These pipes can be used for carrying water under very low pressure. Their use for carrying water is very much restricted.	(*a*) The inside surface of pipe is very smooth.	(*a*) The pipes are brittle.

S. No.	*Type of pipe and their use*	*Advantages*	*Disadvantages*
		(*b*) Joining of pipes is easy and flexible. (*c*) The pipes are anti corrosive (*d*) The pipes are cheap in cost (*e*) The pipes are light in weight. Hence they are easy to handle and transport.	(*b*) These pipes can not stand impact forces during handling and vibrations of traffic when placed under roads. (*c*) These pipes are not durable. (*d*) These pipes can not be placed in exposed places.
2.	**Cast iron pipes.** These pipes are extensively used for carrying water. These pipes are available in 120 cm diameter or more. These pipes are manufactured from pig iron. Class A pipe can with stand pressure of 60 m head class B 120m head, class C 180 m head and class D pipes can with stand 240 m head.	(*a*) The cast iron pipes are easy to join. (*b*) These pipes are not subject to corrosion. (*c*) These pipes are strong and durable. (*d*) Service connections can be made easily. (*e*) Under normal conditions their use full life is 100 years (*f*) The cost of these pipes is moderate.	(*a*) Breakage of these pipes is large. (*b*) The carrying capacity of these pipes decreases with age. The decrease in capacity may be 30 to 40%. (*c*) These pipes can not be used for pressures greater than 0.7 N/mm^2. (*d*) Pipes more than 120 cm in diameter become heavy and uneconomical.
3.	**Cement Concrete pipes.** The diameter of these pipes may vary from 50 cms to 250 cms or more. The plain cement concrete pipes can be used for low heads upto about 15 m. R.C.C. pipes can be used upto 75 m heads and for higher heads pre-stressed concrete pipes are used.	(*a*) The inside surface of these pipes can be made smooth. (*b*) The maintenance cost of these pipes is low. (*c*) The useful life of these pipes is about 75 years. (*d*) These pipes can be cast at site also, hence transport cost may be reduced. (*e*) These pipes being heavy in weight are not affected by the force of buoyancy when placed under water even when they are empty. (*f*) These pipes do not need expansion joints as these pipes have least coefficient of thermal expansion in comparison to other types of pipes.	(*a*) If no reinforcement is provided they possess no tensile strength and can not withstand high pressures. (*b*) These pipes are heavy and difficult to transport. (*c*) These pipes are likely to crack during transport and handling operations. (*d*) The repairs of these pipes are difficult. (*e*) These pipes are likely to cause leakage due to porosity. (*f*) These pipes are affected by acids, salty water and alkalies.

S. No.	*Type of pipe and their use*	*Advantages*	*Disadvantages*
		(*g*) Under normal conditions these pipes are not affected by ordinary soil or atmospheric actions. (*h*) These pipes will not fail under normal traffic loads when placed below roads. (*i*) These pipes are not corroded. Hence there is no danger of rusting and incrustation.	
4.	Copper pipes. These pipes are not affected by hot water *i.e.* they do not sag due to hot water.	(*a*) Copper pipes are used for taking hot water in buildings and steam boilers only. (*b*) They are not liable to corrosion. (*c*) They can be bent easily.	Their cost is very high. Hence they are not used for water distribution system.
5.	**Galvanised iron pipes.** Usually these pipes are used for service connections. Their diameters vary from 6 mm to 75 mm.	(*a*) These pipes are cheap, light in weight and easy to handle and transport. (*b*) These pipes are easy to join.	(*a*) These pipes are liable to incrustation. (*b*) These pipes can be easily affected by acidic or alkaline waters. (*c*) The useful life of these pipes is about 7 to 10 years.
6.	**Lead pipes.** Usually lead pipes are not adopted for carrying water *i.e.* for water conveyance.	(*a*) These pipes can be bent easily. (*b*) These pipes need less special parts. (*c*) These pipes are used for apparatus required for alum and chlorine dosages.	(*a*) The acidic water reacts with lead pipes. Hence they can not be used for carrying hot water. (*b*) Lead pipes sag or bend by heat. Hence they can not be used for carrying hot water.
7.	Steel pipes. Steel pipes are made of mild steel. Generally the diameter of steel pipes is greater than 120 cms. The inside and out side surfaces of these pipes are galvanised.	(*a*) The length of these pipes is more, hence the number of joints becomes less. (*b*) The pipes are cheap in first cost. (*c*) These pipes are durable and strong to with stand the high internal water pressure. (*d*) These pipes are flexible to some extent, hence can be laid on curves easily.	(*a*) The maintenance cost of these pipes is high. (*b*) These pipes are likely to be rusted by slightly acidic or alkaline water. Out side earth also may cause rusting of pipes. Rivets used for joints form nucleus for the process of rusting. (*c*) During break down these pipes require more time for repair. Hence not suitable for distribution system. (*d*) These pipes are likely to bend under combined action of external and internal loads.

S. No.	Type of pipe and their use	Advantages	Disadvantages
		(*e*) These pipes are light in weight. Hence they are easy to transport	
8.	Plastic pipes. Plastic pipes are of recent origin. Plastic pipes are available of the following types. (*a*) Low density polythene pipes. (LDPE). These pipes are flexible and can be used for point to point. Conveyance of water for long run.	(*a*) In closed pipes damage due to freezing and thawing is eliminated. (*b*) The cost of these pipes is less *i.e.* they are cheap. (*c*) These pipes are durable and possess enough strength to resist impact, atmospheric and sun light effects. (*d*) These pipes are flexible and possess low hydraulic resistance. (*e*) These pipes are free from corrosion. (*f*) These pipes are light in weight and easy to bend, join and install them. (*g*) These pipes are good electric insulators. (*h*) These pipes are easy to transport as they are available in coils upto certain diameters.	(*a*) It is difficult to obtain plastic pipes of uniform composition. (*b*) The coefficient of thermal expansion of plastic pipes is high. (*c*) These pipes are less resistant to heat. (*d*) Some plastic pipes impart taste to the water.
9.	Wooden pipes. These pipes are prepared from wooden planks or staves joined by steel bands. These pipes are seldom used for the conveyance of water.	(*a*) These pipes are light in weight.	(*a*) These pipes are prone to wet rot due to alternate wetness and dryness. (*b*) These pipes should remain full of water. (*c*) They can not bear high pressure.
10.	Wrought iron pipes. Generally wrought iron pipes are not used for conveyance of water	(*a*) These pipes are light in weight (*b*) They can be easily cut, threaded and worked.	These pipes are costly and less durable as compared to cast iron pipes.

10.12. CORROSION OF PIPE

The metals chiefly concerned with corrosion are iron and steel. Usually mains and distribution pipes are made of iron and steel.

The corrosion of iron and steel is an electro-chemical process, which usually takes place when two dissimilar metals are in an electrical contact in the presence of moisture and oxygen. The same process takes place in the steel alone due to the difference in electro-chemical potential on the surface which forms anodic and cathodic regions, connected by the electrolyte in the form of the moisture.

The term corrosion is used to indicate the loss of material of the body of the pipe due to the action of water. This is a process of oxidation. The metallic structure of pipe is attacked and dissolved by water forming ferric hydroxide. Pipe corrosion may be internal as well as external and leads to disintegration of metal. Internal corrosion is due to the flowing water in the pipe and the external corrosion is due to moist soil above the pipe surface.

It has been observed that in a completely dry atmosphere no corrosion can take place, most probably below 40% relative humidity. It has also been observed that 100 relative humidity also does not contribute to corrosion. 70 to 80% relative humidity is most favourable for corrosion formation.

10.13. FACTORS CONTRIBUTING TO PIPE CORROSION

Following factors have been found to influence the formation of corrosion:

1. **Acidity.** Acidity of water is the most important factor in corrosion formation. The oxygen ions of acids oxidize the metal, forming corrosion. Water having low pH value due to the presence of carbonic acid or other acids is corrosive.
2. **Chlorine ions** (Chlorination). The presence of free chlorine or chloromines makes the water corrosive and it may be responsible for making the water corrosive in nature, which if unchlorinated would have caused no corrosion.
3. **Biological action.** The growths of iron bacteria and sulpher bacteria may develop aerobic and an aerobic corrosion respectively.
4. **Alkalinity.** Water having sufficient calcium bicarbonate alkalinity is anti corrosive in nature.
5. **Electric currents.** Corrosion is likely to be developed by earthing of electrical systems to water pipes or by the union of dissimilar metals.
6. **Organic and mineral constituents.** The presence of high quantity of total solids in water accelerates the process of corrosion. Calcium and magnesium chlorides have been found particularly active in hot-water systems. Nitrates play a secondary role in corrosion process. High ammonia contents are objectionable in boiler feed waters. Organic matter plays a great role in anti corrosion treatment process.
7. **Oxygen.** Under ordinary conditions the presence of oxygen is not the primary or sole cause of pipe corrosion, though oxygen is found in both the corrosive and non corrosive waters. In fact in some cases aeration is employed for the prevention of corrosion.

10.14. TYPES OF CORROSION

Corrosion may be of two types as follows:

1. **Local.** In case of local corrosion only separate areas of pipe surface are attacked.
2. **Uniform corrosion.** In case of uniform corrosion the pipe metal is evenly attacked over the entire surface.

10.15. EFFECTS OF PIPE CORROSION

Following effects are observed of pipe corrosion:

1. Due to pipe corrosion, small projections may be formed in side the pipe surface. These projections are cone shaped. These projections decrease the cross-sectional area of the pipe. Thus the carrying capacity of the pipe is reduced.
2. Pipe corrosion leads to the disintegration of pipe line, which needs heavy repairs resulting in huge expenditure.
3. Pipe corrosion imparts colour, odour and taste to the flowing water, which may be injurious to the health of the consumers.
4. Pipe corrosion also seriously affects the pipe connections.
5. Pipe corrosion may render the flowing water unfit for human consumption.

10.16. THEORIES OF PIPE CORROSION

The phenomenon of pipe corrosion is explained with the help of the following theories:

1. Action of water motion. According to this theory, the turbulent flow in pipes produces cross currents, which develop or impart great pressure on pipe material. The repeated attack on pipe material leads to the pipe corrosion.

2. Bimetatic action. According to this theory, when two dissimilar metals are placed in water and kept in contact with each other, hydrogen ions are liberated from water and deposited on the metal having low potential to emit-ions which may be soluble in water. The positively charged ions are liberated from the metal having a higher potential to emit ions, which may be soluble in water. The sources of bimetallic action are impurities in water, copper and lead fixtures, and electric current.

3. Biological action. According to this theory, the bacteria is considered to be responsible for pipe corrosion The following two types of bacteria are considered responsible for pipe corrosion.

(*a*) **Iron consuming bacteria.** This bacteria is aerobic, *i.e.* it operates in the presence of oxygen. This bacteria consumes iron ions to support their activities. Thus iron ions are continuously eaten away by the bacteria. This type of bacteria will be predominant in water having a higher iron content.

(*b*) **Sulphate reducing bacteria.** This bacteria is anaerobic *i.e.* it thrives in the absence of oxygen. This bacteria reacts with sulphur and produces hydrogen sulphide which attacks on pipe material causing pipe corrosion.

4. Chemical reaction. According to this theory, the acidity or alkalinity of water and presence or absence of carbon dioxide are important factors. The chemical reaction takes place between the pipe material and water, resulting pipe corrosion.

5. Electrolysis. According to this theory, the flow of current is considered responsible for pipe corrosion. The passage of electric current may be due to attachment of wire of electric fan, light, telephone etc. to the pipe material. Due to electric current, bimetallic action takes place causing pipe corrosion.

10.17. PREVENTION OF PIPE CORROSION

In practice it is impossible to completely eliminate the pipe corrosion, but it can be minimized by the following measures:

1. **By selecting proper pipe material.** In case of metallic pipe material, it should be resistant to dissolving effect of water. The alloys of steel or iron with chromium, copper or nickel are found to be more resistant to corrosion.
2. **Application of preventive lining.** The surfaces of pipes should be coated with anti corrosive linings. The coatings or lining of cement mortar, bitumen, asphalt, paints, resins, zinc and tar etc. have been found effective to control pipe corrosion. The degree of effectiveness depends upon the properties of the coating material.
3. **Treatment of water.** To prevent pipe corrosion, proper treatment of water should be done. Usual treatments employed are adjustment of pH value, control of calcium carbonate, removal of dissolved oxygen and carbon dioxide, addition of sodium silicate etc.
4. **Cathodic protection.** It is found that if entire pipe length acts as cathode, the pipe corrosion may be minimised to a great extent. This can be achieved by connecting the pipe line either to a negative pole of a D.C. generator or to anodic metals such as magnesium. The emerging currents from anodic areas are neutralised and corrosion is prevented. This treatment has been found most effective, but it is very expensive and involves many practical difficulties.

10.18. PIPE JOINTS

For ease in handling, transporting, and placing in position pipes are manufactured in small lengths of 2 to 6 m metres. To make a complete continuous length of pipe line, these small pieces are joined together after placing them in position. The design of these joints depends mainly on the condition of pipe, internal water pressure and the condition of the support. Mostly following types of joints are used in water supply system.

1. Spigot and socket joint
2. Expansion joint
3. Flanged joint
4. Mechanical joint

5. Flexible joint
6. Screwed joint
7. Collar joint
8. A.C. pipe joint.
9. Cement joint

1. Spigot and socket joint. Some times this joint is also called bell and spigot joint. Spigot is the normal sized end and the socket or ball is the enlarged end. Mostly spigot and socket joint is used for cast iron pipes.

Construction. For the construction of this joint, the normal end (spigot end of one pipe is slipped into the bell or socket end of the other pipe untill contact is made at the base of the socket. After this operation hemp yarn (sutli) is wrapped around the normal or spigot end of the pipe and the joint is tightly filled by means of a caulking tool or yearning iron upto 5 cm depth. The hemp is packed tightly to maintain regular annular space and for preventing jointing material from falling inside the pipe. Fig. 10.7.

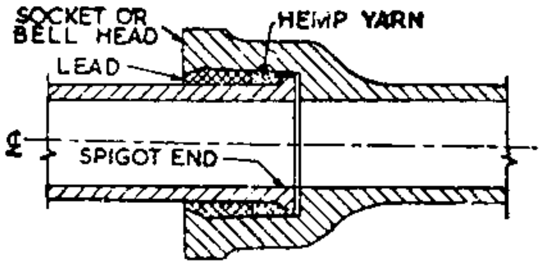


Fig. 10.7. Socket and spigot joint

After packing of hemp, a gasket or joint runner is clamped in place around the joint, so that it fits tightly against the outer edge of the bell. Some times to make the contact tight between the runner and the pipe wet clay is used, so that hot lead may not run out of the joint space. After this operation molten lead is poured into the V shaped opening left in the top by the clamped joint runner. The space between the hemp yarn and the clamp runner is filled with molten lead. The runner is removed when the lead has hardened. The lead shrinks on cooling. This lead is again tightened by means of the caulking tool and hammer.

This joint is slightly flexible and allows pipes to be laid on flat curves with out the use of pipe specials.—The quantity of lead required per joint varies from 3.5 kg to 4.0 kg for 15 cms diameter pipe to about 45 to 50 kg for 120 cms diameter pipe. Now a days to reduce the cost of lead filling, certain patented compound of sulphur and other materials are available in the market for filling in joints, but these materials do not provide flexibility to the joint equal to that of lead joint.

2. Expansion joint. This joint is used when pipes are subjected to severe temperature changes leading to the expansion and contraction of the pipe. This joint checks the setting of thermal stresses in the pipes. Fig. 10.8.

Fig. 10.8. Expansion joint

Construction. In this joint, the socket end is flanged with cast iron follower ring, which can freely slide on spigot end or plane end of the other pipe. An elastic rubber gasket is tightly pressed between the annular space of socket and spigot by means of bolts as shown in the figure.

In the beginning, while fixing the follower ring, some space is left between the socket base and the spigot end for the free movement of the pipes under variation of temperatures. When pipe expands, the socket end moves forward and when pipe contracts it moves back ward in the space provided for it. The elastic rubber gasket keeps the joint water tight in every position.

3. Flanged joints. These joints are generally used for joining temporary pipe lines as they can be dismentaled easily and assembled again at an other place. Mostly these joints are used for joining pumping stations, filter plants, hydraulic laboratories and boiler houses etc., where it may be necessary to occasionally dismantle and re assemble the pipe lines.

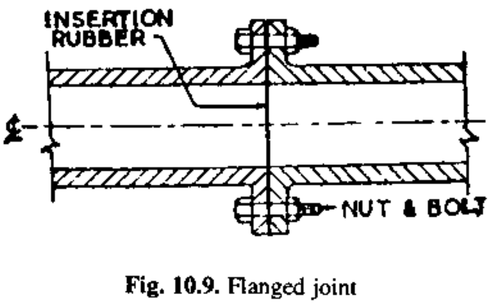


Fig. 10.9. Flanged joint

Construction. The pipes have flanges on their both ends, cast, welded or screwed with the pipe. The two ends of the pipes which are to be joined together are brought in perfect level near one another. The flanges are bolted after placing a hard rubber washer between them. For securing a perfect water joint, placing a gasket or washer of rubber, canvas, copper or lead in between the two ends of flanges is very necessary.

This joint can not be used at places where it has to withstand the vibrations or deflection of pipes etc. In case steel pipes are to be joined by these joints, in that case it is better to screw the cast flanges separately on the pipes and then they are jointed.

4. Mechanical joints. These joints are used for joining cast iron, steel or wrought iron pipes, when both ends of pipes are plain or spigot. There are two types of mechanical joints:

(*a*) **Dresser-Coupling joint.** This joint is very strong and rigid and can withstand vibrations and shocks upto a certain limit. This type of joint is most suitable for carrying water lines over bridges where it has to withstand heavy vibrations.

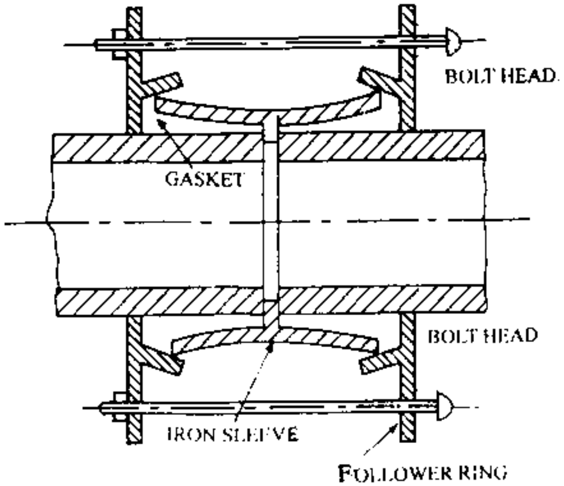


Fig. 10.10 (*a*) Dresser coupling joint

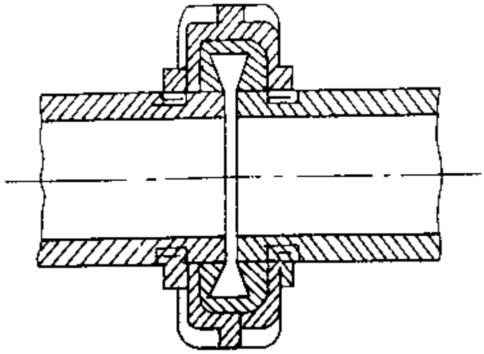


Fig. 10.10 (*b*) Victaulic joint

Construction. This joint essentially consists of one middle ring, two follower rings, and two rubber gaskets. The two follower rings are connected together by bolts. When they are tightened, they press both the gaskets tightly below the ends of middle ring making the joint water tight. Fig. 10.10 (*a*).

(*b*) **Victaulic joint.** This joint can bear shocks and vibrations etc. This joint is used for cast iron, steel or wrought iron pipe lines in exposed places.

Construction. As shown in Fig. 10.10 (*b*) in this joint a leak proof ring or gasket is slipped over both the ends of the pipes. This gasket is pressed from all sides on both the pipes by means of half iron couplings by bolts. To allow free expansion, contraction and deflection, the ends of the pipes are kept sufficiently apart from each other.

5. Flexible joint. This is a special type of

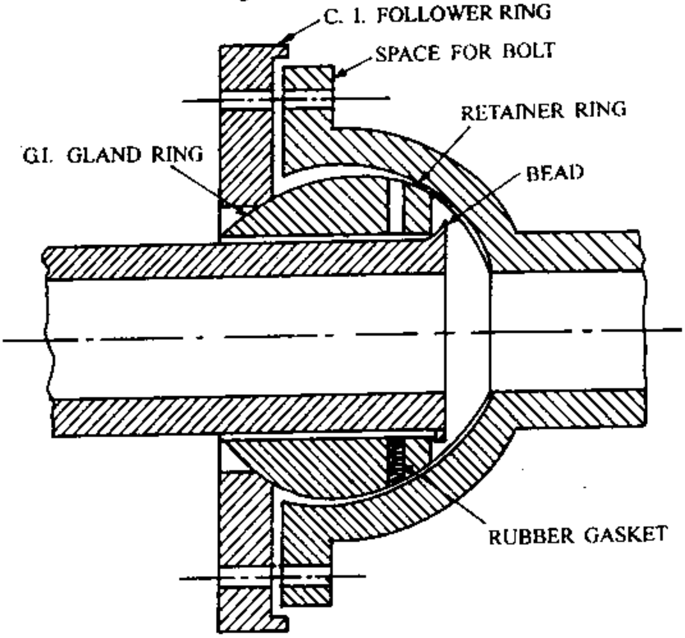


Fig. 10.11. Flexible joint

joint. Some times it is also called as universal or Bell and socket joint. It is used at such places where settlement is expected to take place after laying the pipe line. This joint can also be used for laying pipe line on curves as at joint the pipes can be laid at angles.

Construction. The socket end is cast in spherical shape as shown in Fig. 10.11. The spigot end is plain, but has a bead at the end. At the time of making this joint, the spigot end of one pipe is placed in the spherical end of the other pipe. Then a retainer ring is slipped and stretched over the bead. After this a rubber gasket is moved, which touches the strainer ring. After this operation a split cast iron gland ring having the outer surface of the same shape as inner shape of the socket end is placed. Finally over this split cast iron gland a cast iron follower ring is moved and is fixed to the socket end by means of bolts as shown in Fig. 10.11 From this fig it will be seen that if one pipe is given any deflection the ball shaped portion will move in side the socket and the joint will remain water proof in all positions.

6. Screwed joint. Mostly this joint is made for connecting small diameter 2.5 cm or 1.25 cm cast iron, wrought iron and galvanized pipes as hose pipe line. The ends of pipes have threads on out side, while socket or coupling has threads on the inner side.

Construction. To join the pipes a single socket is placed on both ends of the pipes and screwed. To make the joint water tight zinc paint or hemp yarn (sulti) is wrapped in the threads of the pipe before screwing the socket over it. Fig. 10.12 (*a*). Fig. 10.12 (*b*) shows a screwed and socket joint.

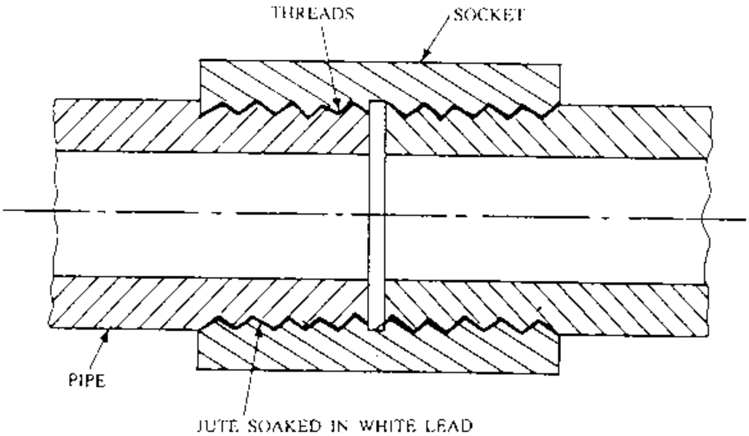


Fig. 10.12 (*a*) Screwed joint

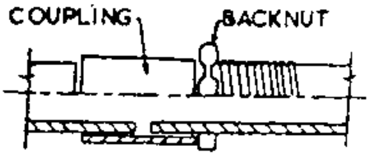


Fig. 10.12 (*b*). Screwed and Socketed joint

7. Collar joint (RIGID). This joint is used for joining the big diameter ranging from 50 cms to 250 cms or more concrete and asbestos cement pipes. A bigger diameter ring than the pipe diameter called collar is used to join the two pipes of the same diameter.

Construction. For making the joint, the collar is placed in position and the ends of the two pipes are laid on the same level against each other. The rubber gasket between steel rings or jute rope soasked in cement paste is place4d in the grove in between the pipe and collar to maintain the alignment of pipes. The collar is placed in such a way so that it may have equal lap on both pipes. Now 1:1 cement sand mortar is filled in the space between the pipes and the collar as shown in Fig. 10.13.

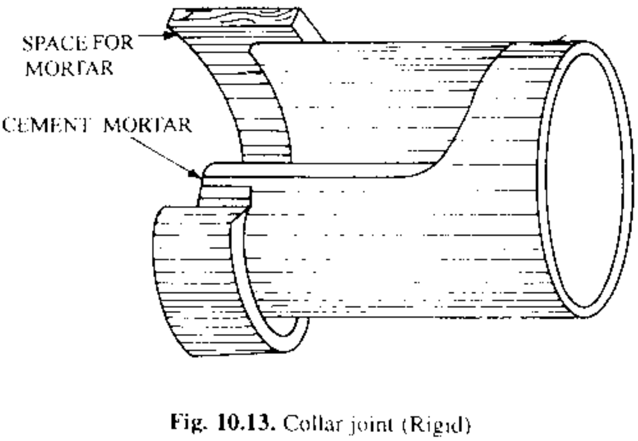


Fig. 10.13. Collar joint (Rigid)

8. Joint for A.C. pipes. For joining small diameter A.C. pipes, this joint is used.

Construction. For joining the two pipes, they are placed against each other at the same level and two rubber rings are slipped over the pipes. Then the coupling is pushed over the rubber rings as shown in Fig. 10.14. The rubber rings are used to make the joint water tight.

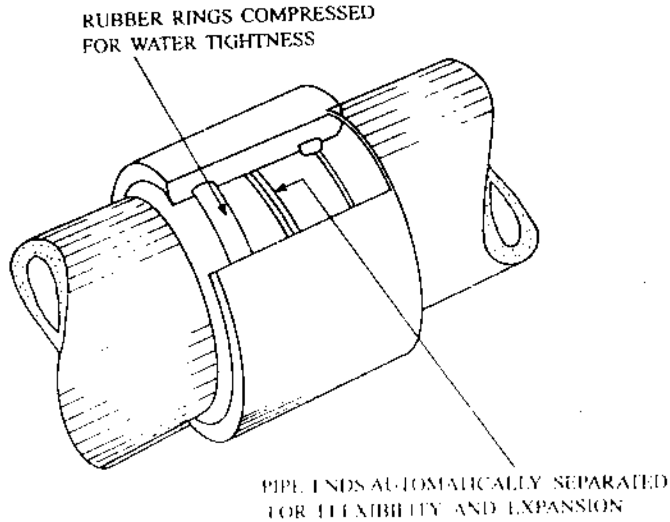


Fig. 10.14. A.C. Pipe joint

Pipes laying. Generally pipes are laid below ground level, when the pipe line passes through open areas, the pipes may be laid over the ground. The procedure is as follows:

(*a*) First of all a detailed map of the area showing all roads, streets and lanes is prepared. On this map the proposed pipe line with sizes and length of pipes is market. The position of existing pipe lines, sewer lines etc. also be marked on it. In addition to this, the position of valves, and other pipe specials, stand posts are also marked, so that at the time of laying the pipe line there should be no difficulty in the execution of the work.

(*b*) After general planning, the centre line of pipe line is transferred on the ground from the detailed plan. The centre line is marked by means of stakes driven at 30 m intervals on straight lines. On curve, this interval may be kept from 7 to 15 m. If the road or street have curbs (Kerbs) in that case the distance of centre line from curb line should be marked.

(*c*) After the transfer of centre line on the ground, the excavation of trenches is started. The width of the trench should be kept from 30 cms to 45 cms more than the external diameter of the pipe. At every location of each joint the depth of excavation should be 15 to 20 cms more for a length of one metre for ease in joining the pipes. The excavation of the trench should be done in such a way that only pipe remains supported and its joint portion remains over hanging. The pipe line should be laid more than 90 cms below the ground, so that pipe may not be damaged or break due to impact of heavy traffic moving on the road or ground. The sides of trenches should be protected by means of timber planks if deep excavation is carried out in soft soils.

(*d*) After the excavation of trenches, pipes are lowered in it. Lighter pipes are lowered manually and heavy pipes are lowered with the help of derricks. The pipe laying should be started from the lower level and proceed towards higher level with socket end towards higher end. The joining of pipes should be carried out simultaneously with the laying of pipes.

(*e*) After laying the pipes, they should be tested for water leakage and pressure.

(*f*) After testing, the back filling of the trenches should be done. The excavated soil should be filled back alround the pipe and should be well rammed, and the site should be cleaned.

10.19. SPECIFICATIONS FOR LAYING AND JOINING OF PIPES

(*a*) **Unloading of pipes.** Unloading of pipes upto 60 kg should be done by two persons. Heavier pipes should be unloaded by holding them in loops, formed with ropes and sliding over planks set not steeper than 45°. Usually one pipe should be unloaded at a time. Under no circumstances pipes be thrown down from the carrier or dragged or rolled along hard surfaces.

(*b*) **Storing.** To avoid damage to pipes and accessories they should be handled carefully and stacked separately. They should be lined up on one side of the alignment of the trench. The socket should remain facing the up grade when line runs up hill and up stream when line runs on level ground. Each stack should contain pipes of the same class and size.

(c) Cutting of pipe.

1. At the cut point a line should be marked allround the pipe:
2. The cutting plane should be at right angle to the longitudinal axis of the pipe.
3. The pipe should be held on two parallel rafters nailed to cross beams.
4. The portion of pipe to be cut should not remain over hanging and the cut mark should remain in between the parallel rafters. The over hanging is liable to tear off due to its own weight before the cutting is complete.
5. The pipe should be neatly cut either by a hacksaw or carpenter's saw.

(d) Trenches.

1. The trench should be dug at the correct alignment upto the required depth.
2. The bed of trench in soft soils should be well watered and rammed and depressions if any should be properly filled and consolidated in 20 cms layers.
3. If the trench bottom is extremely hard, rocky or loose stoney soil, then the trench should be excavated at least 15 cms below the trench grade.
4. The hard materials from the bed should be removed and it should be filled up to the grade of trench with good fine soil or sand and it should be compacted well to provide a smooth bedding to the pipe.
5. At the position of sockets of the pipes, hollows are cut upto sufficient depth so that pipes could be jointed easily.

(e) Laying. The pipes should be lowered into the trenches by means of pulley block, or ropes. In no case pipes be rolled or dropped into the trench.

2. After lowering the pipes they should be so arranged that the spigot of one pipe is centered into the socket of the other pipe and pushed to the full distance, it can go.

3. In expansive soils, an envelop of minimum 10 cms of tamped sand should be provided all-round the pipe line to protect the effect of expansion and contraction of the expansive soils.

(f) Thrust blocks. These blocks are used to transfer the hydraulic thrust on a larger load bearing soil section. These blocks are needed when the pipe line ends at a dead end or at the place of change in direction etc. They also be provided at the place of valves.

(g) Back filling and tamping

1. To protect the pipe line from falling boulders, lifting up of pipe due to flooding of open trench and shifting pipe out of line due to caved in soil, the back fitting of trench should go side by side of pipe laying.
2. To provide a firm and continuous support to the pipe line, the soil below the pipe and around should be properly tamped. To compact the back fill, use of water is the most effective method.
3. In marshy places, gravel or crushed stone should be used as back fill material.
4. The back fill should be placed in layers of 10 cms thickness and properly consolidated.
5. Final cushion at bed should be at least 30 cms.

10.20. HYDROSTATIC TEST

After laying, joining and back filling a new pipe line, it is subjected to the following tests:

1. **Pressure test.** This test is carried out to ensure whether the joints are water tight or not. In the test atleast double the maximum working pressure in the pipe line is applied. If the pipes and joints are found perfectly water tight under the test, then the line is perfectly alright.
2. **Leakage test.** This test is carried out after the pressure test. In this test pressure is applied as authorised by the competent authority for a duration of two hours. During laying of pipe line hydrostatic test is done in parts to detect any error in workmanship. Usually the length of a section to be tested is kept upto 500 m. The error in workmanship can be rectified at minimum cost. during laying of pipe line.

0.20.1. Procedure for leakage test

Leakage is defined as the quantity of water to be supplied into a newly laid pipe line or any valved ection to maintain the specified leakage test pressure after the pipe line has been filled with water and the ir has been expelled. No pipe line can be said satisfactory if the leakage is more than the quantity letermined by the following formula.

$$Q = \frac{ND\sqrt{P}}{3.3}$$

vhere

Q = Allowable leakage in cm^3/hour.

N = Number of joints in the length of pipe line

D = Diameter of the pipe

P = Average test pressure during leakage test in kg/cm^2

0.21. VALVES AND METERS

To make the distribution of water easy and effective, valves are required in the distribution pipe lines. Jsually following types of valves are used in distribution system.

1. Sluice valves
2. Pressure relief valves
3. Check valves
4. Air relief valves
5. Drain or wash out valves
6. Reflex valves
7. Fire hydrants
8. Air valves
9. Bib cocks
10. Stop cocks
11. Water meters.

1. Sluice valves. These valves are also known as stop valves or gate 'alves or shut off valves. These valves are most commonly used in water vorks system. These valves offer less resistance to the flow of water than ther type of valves and are cheaper in cost. (Fig. 10.15)

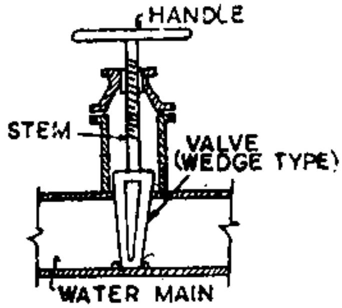


Fig. 10.15. Sluice valve

Sluice valves are fitted in the main lines dividing the pipe line into uitable sections. These valves generally are placed at about 120 to 150 m nterval and at all junctions. For long straight main lines, they may be fixed t intervals of one kilometers. In special circumstances they may be fixed t intervals of 3 to 5 kilometers.

During repairs only one section can be cut off by closing the valves at both ends. This valve is made f cast iron with brass, bronze or stainless steel mountings. Its ends are screwed, flanged or spigot and ocketed on the pipe. Mainly it consists of a wedged shaped circular disc, fitted closely in a recess against he opening in the valve. This is connected to a wheel above, by neans of a threaded spindle passing through a gland and stuffing box rrangement. When the wheel rotated, the spindle rises, raising the lisc along with it. Thus the opening in the valve is uncovered and the vater passes from one section of pipe line to the other section. The 'alve can be closed by rotating the spindle in the opposite direction.

2. Pressure relief valve. These are also known as automatic cut ff or safety valves. These valves relieve high pressure in pipe line. These valves are fitted at every point along the pipe line where naximum high pressure is likely to be developed. (Fig. 10.16.)

This valve essentially consists of a disc controlled by a spring, vhich can be adjusted for any pressure. When the pressure in the pipe ine exceeds the allowable or desired pressure, the disc lifted up and he excess pressure is relieved through the cross pipe. After this, the

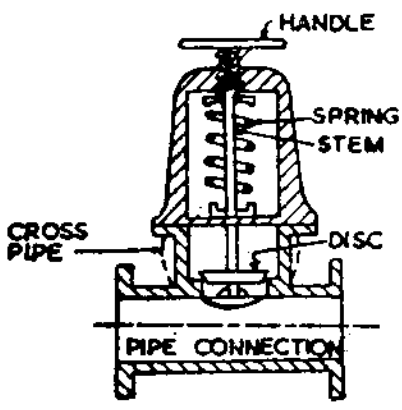


Fig. 10.16. Pressure Relief valve

disc comes down automatically due to the force of the spring, saving the pipe line from bursting.

Check or Reflex valves

These values are also known as non return valves. These valves are automatic device which allows water to flow in one direction only and prevents its flow in the opposite or reverse direction. The valve consists of a metallic disc hinged from the crown which fits tightly against the annular valve seat. Fig. 10.17. This valve is widely used in practice.

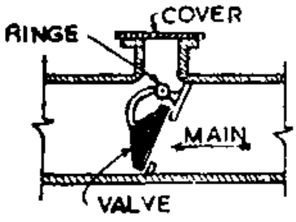


Fig. 10.17. Reflex valve

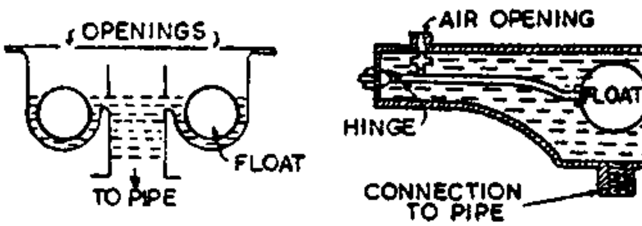
When water flows in the direction of arrow, the valve rotates around its pivot and due to the pressure of water remains in an open position and water passes through the pipe with out any obstruction. If the flow reverses, the valve will occupy its position or seat automatically and remains tightly pressed against the valve seat by the pressure of water it self and does not allow the water to flow in the reverse direction.

Reflex or check valves are invariably placed in water pipe lines which obtain water directly from pump. In case the pump fails, in that case water will not run back to the pump and thus the pumping equipment will be saved from damage.

Air valve

These valves are also known as air relief valves. When water enters into the pipe line, it also carries some air along with it. This air accumulates at the high points along with the water pipe line. When the quantity of air increases, it causes serious blockage to the flow of water. Thus it becomes essential to remove this air. Hence air relief valves are provided at summits along the water pipe line. These valves should be located at points which are close or above the hydraulic gradient. Provision of air valves along water pipe line also helps in admitting air quickly when vacuum occurs in water pipe due to sudden breakdown of water pipe line at low points.

Air valves consist of a cast iron chamber, float, lever, puppet value etc. The cast iron chamber is bolted on the pipe over the opening in the crown. The weighted float and lever are so adjusted that when the chamber is filled with water under pressure from the pipe line below, the float and lever remain raised up, preventing the flow of water through the valve. But when air goes on accumulating at the top and builts up pressure, water level gets depressed and the float sinks down with the lever, opening the valve. The accumulated air escapes out through this opening, the water level in the chamber rises again, raising the float with it and closes the valve. Thus these valves are automatic. Fig. 10.18 (*a*) shows double float air relief valve and Fig. 10.18 (*b*) shows single float air relief valve.



(*a*) Air valve double float (*b*) Air valve single float

Fig. 10.18

Drain valves

These valves are also known as scour valves or wash out or flow off valves. These valves are ordinary sluice valve. These valves are located at the lowest point of pipe line or dead ends or depressions. Some times suspended impurities or sand, silt etc. are deposited in the water pipe and cause obstruction in the flow of water. In the distribution system at dead ends, if water is not taken out, it will stagnate, resulting in the development of bacteria. Hence to clear the stagnant water and depositions in the pipe line, these valves are opened.

Fire Hydrants

These are out lets or devices provided in water pipe lines for tapping water for fire fighting, flushing sewer lines, washing streets, watering in gardens etc. The number and location of hydrants in a distribution system depends on population of area, utility of buildings, requirement of water for fire fighting etc. Generally hydrants are provided at all junctions of roads and at about 100 to 130 m apart along the roads. (Fig. 10.19)

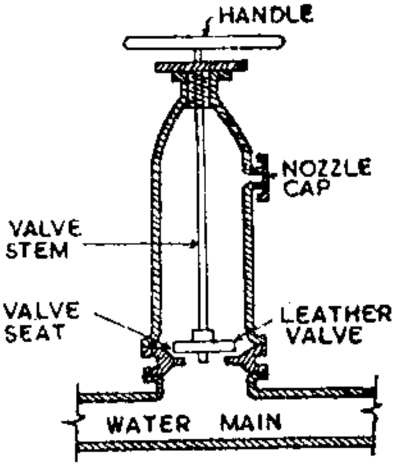


Fig. 10.19. Fire Hydrant

In case of breaking fire in a locality, the fire fighting squad connects their hose pipes with the fire hydrant and draws water from them for exlinguishing the fire. To take water upto multistoryed buildings, high pressure is required. For developing higher pressure, the fire hose is attached to the fire engine, which develops the required pressure in the fire hose. Usually the diameter of fire fighting hose nozzle is 2.8 cm and the pressure needed in it, is of the order of 35 m.

In big cities pressure in fire hose pipes needed is of the order of 100 m, hence engines, fire hose, nozzles etc. must be designed to withstand this high pressure. Generally pressure is maintained in the pipe lines at fire hydrants locations as follows:

(*a*) 7 to 14 m head of water, if pumped through motor.

(*b*) 35 to 50 m head of water, if no pumps are used and water flows directly.

(*c*) In case of major fire, water is drawn from many fire hydrants of the locality.

A map indicating the positions of fire hydrants in the locality should be prepared carefully and well preserved.

10.22. REQUIREMENTS OF A GOOD HYDRANT

Followings are the requirements of a good hydrant:

(*a*) It should be easily accessible and should be easy to connect with the fire hose pipe.

(*b*) Its cost and maintenance should be cheap.

(*c*) It should be reliable to supply required quantity of water in need.

(*d*) It should be in a position to supply sufficient quantity of water needed for fire fighting.

(*e*) It should be easily detachable during panicky atmosphere at the time of fire.

10.23. TYPES OF HYDRANTS

Fire hydrants are of the following two types:

1. Flush hydrant
2. Post hydrant

1. **Flush hydrant.** This hydrant is provided below the street or foot path level and is protected by a cast iron box or brick masonry chamber. It is more safely attached to water pipe, hence can not be dislocated easily. As it is not prominently visible, some distinct arrangement should be made to locate it. Usually a sign board with letters F.H. written on it in bold letter should be installed near the side of the hydrant or a plate with letters F.H. (Fire hydrant) be attached on nearby permanent structures such as building, light or telephone post, big tree etc.
2. **Post hydrant.** This hydrant is provided projecting above the road level upto a height of about 1 m. This hydrant is more prominent and can be easily located when needed. How ever it is liable to be damaged easily by miscreants and misuse.

To regulate the flow of water, a long stem with screw and nut is provided at the top. The hydrant is connected to the main pipe through a branch pipe. It can be operated by means a gate valve. When the nut is operated by a key, the valve goes up and it allows water from water pipe to rise in the band to fill it. The water then delivered from the out let. The diameter of the outlet should be compatible to the diameter of the hose to be attached to it. The usual diameter of outlet is abut 60 to 63 mm. After use of hydrant the nut is operated in reverse direction by the key. The valve lowers down and prevents the water entry from the water pipe to the barrel. Water remained in the barrel of the hydrant is drained by opening the plug of the drain hole.

10.24. BIB COCKS

These are water taps and are attached at the end of service pipes from which consumers obtain water. They are usually used for taking water in side the buildings and street stand post. Bib cocks of several types are available in the market. The most common type of Bib cock is shown in Fig. 10.20. It is operated with the help of its handle. On turning the handle, the valve is raised opening the gate from which water comes out. For closing the water supply, the handle of the Bib cock is turned in reverse direction and the valve closes the gate stopping the water supply. For public or street stand posts push type Bib cocks should be used which are less liable to wastage. It opens on pushing upwards and closes on withdrawing the push.

Bib cocks should be leak proof or water tight. Leaky Bib cocks are a source of wastage of treated water. The idea of wastage may be got from the following Table 10.4.

Table 10.4. Loss of water due to leaky Bib Cocks

S. No.	*Leakage*	*Loss of water in litres per day (24 hours)*
1.	30 drops per minute	8
2.	60 drops per minute	17
3.	120 drops per minute	36
4.	13 mm thick solid stream	153
5.	38 mm thick solid stream	333

Thus the leaky Bib cocks either should be repaired or replaced immediately to check wastage.

Stop Cocks

These are small sized sluice valves and are installed in service pipes, serving the same purpose as Bib cocks. They operate on the same principle of sluice valves. Usually these are used upto sizes about 38 mm. They are used on water pipes leading to wash basins, water tanks and flushing tanks etc.

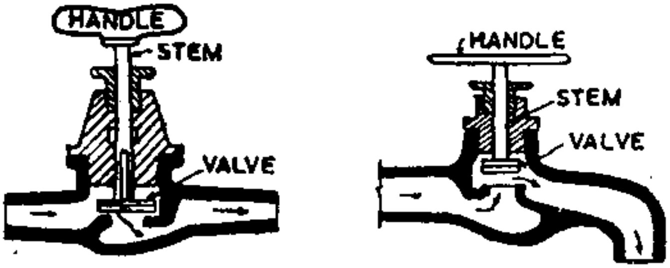


Fig. 10.20. Stop cocks

10.25. MAINTENANCE OF VALVES

Valves should be inspected periodically. After inspection, usually valves are found suffering from the following defects.

1. **Jamming of pivot and moving parts.** These pivots and moving parts should be lubricated periodically.
2. **Valves may have cloged.** These valves should be opened and cleaned.
3. **Valves would have rendered unserviceable.** Unserviceable valves should be replaced immediately.
4. **Washers or packing might have worn out.** The worn out parts should be replaced.

Lubrication of valves is essential to reduce the possibility of loss of pressure due to partial opening, to avoid wear and tear of moving parts and for their easy operation.

10.26. WATER METERS

The devices installed on pipes to measure the quantity of water flowing at a particular point along the pipe is known as water meters. With the help of these meters the quantity of water supplied to a particular consumer is estimated and charged accordingly. Now a days water meters are installed to supply water to residential houses, Hotels, industries and big installations etc.

10.26.1. Classification of Water Meters

Water meters may be classified into the following two categories:

1. Positive displacement type
2. Velocity meters

1. **Positive displacement type meters.** These meters are used to measure small quantity of flow of water. These meters provided in residential buildings. These meters record the number of times a container of known volume is filled with water and emptied. Depending upon the motion of moving parts of the device these meters are further classified as rotary, oscillating, reciprocating and nutating disc type meters. The maintenance and installation of domestic water meters is governed by I.S. 2401-1963.
2. **Velocity or Inferential type meters.** These meters are generally of venturi or turbine type. They work on the principle of velocity of entering water. Higher the velocity of the entering water, more will be the discharge through the meter. For detailed study of these meters reader is advised to refer some text on "Hydraulics".

10.27. MAINTENANCE OF DISTRIBUTION SYSTEM

In order to ensure smooth working with out interruption the distribution system, the equipment used in the system should be properly maintained. In the absence of proper maintenance even a well designed and properly laid water supply system may prove to be highly inefficient.

Items to be attended during maintenance are

1. The storage tanks should be inspected regularly and cleaned when ever necessary.
2. The cracked pipes should be attended immediately.
   (*a*) *In case cracks are small.* If the crack in pipes is small, usually it is repaired by clamping. Two clamps are placed around the cracked pipe and tightened with nut and bolts. If necessary a packing material be placed over the cracked portion to get complete packing.
   (*b*) *In case the crack is large.* In this case the affected length of the pipe is replaced.
3. The water pipes should be cleaned periodically using scraping devices and incrustation formed on the inside surface of the water pipe should be removed.
4. Flushing of water pipes should be carried out as and when necessary, especially at places where unfiltered water is supplied and at dead ends of the pipe lines.
5. The hydrants, valves and other appurtenances installed on the water mains should be checked regularly and maintained in perfect running condition.
6. The wastage of water through pipe joints should be brought down to the minimum possible extent by adopting suitable measures.
7. All the valves should be opened and checked periodically.
8. The joints of pipes should also be inspected periodically and minor leakage through cast iron pipes can be checked by inserting the lead wool in the joint by caulking tool. The lead wood should be protected from oxidation by packing it in polythene or wax paper.
9. Water meters installed on distribution system should be inspected periodically and any meter found defective should be repaired or replaced immediately.
10. All over flow pipes should be inspected periodically and kept free from any obstruction.
11. The drawings showing the pipe line lay out, position of valves and hydrants with their diameter etc. and record of number of hydrants, number of service connection and all other relevant data in connection of the distribution system should be maintained in good condition in the office.

10.28. MAINTENANCE OF PIPES

The leakage through G.I. pipe may be either due to joints or due to corrosion in pipe. The joints may be sealed by applying sealent and the corrugated pipe is replaced by a new pipe.

The leakage through cast iron fittings normally occur below the water closet or the floor trap. These defects occur due to the seepage through the gap between the floor and the P trap or the floor trap. This leakage can be repaired and plugged by the application of a suitable sealent in the gap.

The joints are filled with lead to close the gap in collar if it is difficult to insert a new pipe in some section. Collar can be utilised in forming lead joint on both sides of the collar. In case collar does not provide a proper joint then an other method of inserting a new pipe is to melt the existing lead joints both from above and below the pipe piece or to cut the defective piece of the pipe. When ever a new pipe is to be jointed, then a long socket joint pipe is arranged which has double the ordinary depth. The new fitment is placed into position and all joints are caulked (filled) with lead.

10.29. REPAIR OF TAPS

When a tap fails to completely close to stop water, there may be following probable causes for it:

(*a*) Seat has broken or worn out.

(*b*) The washer has deteriorated or broken and has become incapable to block he opening properly.

(*c*) The handle has become incapable of pressing the washer properly against the seat.

The life of a good quality tap normally is 10 years. In most of the cases the defect is due to the deterioration of washer, which needs to be replaced. To replace the washer, take out the upper part of the tap along with the washer spindle assembly. Remove the damaged washer and fix a new washer to the spindle with a screw or plier as the case may be.

If the tap stem has developed defects, the handle should be removed and threaded properly. The stem should be checked again for proper working. If the stem has worn out beyond repair, it should be replaced.

Many a times the tap handle rotates freely with out changing the rate of water flow, in such, situations the handle has developed defects and it should be replaced.

It has been observed that a good quality tap normally is capable for one lakh operations of turning on and turning off. Many a times the tap becomes noisy when water is running through it. There are four probable causes for it as follows—

(*a*) The packing of the tap has deteriorated

(*b*) The washer of the tap has become loose

(*c*) The stem handle has worn out

(*d*) Seat base has worn out

The tap should be properly checked and the defective item is set right.

10.30. REPAIR OF W.C. CISTERNS

The problem in W.C cisterns is of two types. Either the water is flowing continuously or water is not flowing at all. The problem of continuously flowing water has developed on account of improperly adjusted ball valve or punctured float ball.

A valve is expected to shut off water intake valve, when water level has reached to its normal level mark just below the over flow out let in the tank. Ball cock should be adjusted by bending the rod connecting the valve. In case the ball of the float valve has developed a leak, then either the ball be replaced or the puncture of the ball be sealed.

2. In case water does not flow at all, it indicates that syphon type or ball type arrangement is out of alignment. In this case the ball which induces the syphonic action, jumps out of seat, which needs resetting and placing back in proper position. When syphonic type flushing system is either broken or worn out severely, then it should be replaced.

Thus the different parts of cistern such as flush valve, intake valve and float should be checked frequently and repaired and re setting is done as they get deteriorated easily.

10.31. REPAIR AND MAINTENANCE OF OVERHEAD AND UNDER GROUND WATER TANKS IN BUILDINGS

Water tanks in buildings are provided to facilitate the water supply to the inhabitants. The size of the tank depends on the number of occupants and the water requirement. To avoid air locking the out lets to the overhead tanks should always be provided with anti syphonage pipe.

10.31.1. Likely defects in over head as well as under ground tanks

(*a*) Seepage from walls or bottom or from both. It is the most common problem of water retaining structures.

(*b*) Cracks in brick masonry or R.C.C. work.

(*c*) Rusting of reinforcement in R.C.C. works.

(*d*) Appearance of dampness on the walls of the tank.

(*e*) Corrosion of mild steel tanks.

(*f*) Uncontrolled over flow.

(*g*) Cracks or punctures in plastic tanks.

10.31.2. Remedial measures in brick masonry and R.C.C. tanks

The main problem in masonry and R.C.C. tanks is that of seepage which is most important. In these tanks even hair cracks need immediate attention. If cracks are observed on outer face of the tank, they should be cleaned with wire brush and cracks are sealed with cementitious or epoxy grout. After the grout has set the face should be provided with a 25 mm thick layer of ferro cement lining all round the tank or lining of rich cement mortar may be provided.

10.31.3. In side surface

Prepare the inside surface of the tank and allow it to dry. Then following treatments may be applied:

(*a*) Two coats of solvent free epoxy resin may be applied. It should be ensured that the material is not reactive with water.

(*b*) After preparing and drying the surface, two coats of cement and gur (gagry) may be applied. The composition of paste should be as 200 gram of gur per one kg of cement with a suitable water proofing compound. The quantity of water proofing compound should be taken as per the instructions of the manufacturing company. The paste should be of thick consistency. After drying the first coat, second coat should be applied. After drying the surface for 24 hours, water may be filled. This practice is quite prevalent in Rajasthan and adjoining areas.

10.31.4. Repairing of wide cracks

The loose concrete is chipped off and the surface cleaned with dilute hydraulic acid. The rusted surface is cleaned by sand blasting method. After preparing the surface, two layers of gunniting may be provided. In between these two layers steel welded mesh may be provided. The thickness of total guniting layer should not be more than 30 mm in case of out side face, not in contact with water. In case of wide cracks in brick work, the surface should be prepared carefully. After preparing the surface the cracks may be filled with expanding cement mortar or stitching may be provided with M.S. dowel by putting across the crack and covering with cement mortar or concrete of about 20 mm to 30 mm thickness.

In case tank needs strengthening, then wire mesh or reinforcement mesh is provided either on inside or out side of the wall and the prepared surface is gunited with water proof cement mortar.

10.32. GALVANISED COLD WATER TANKS

The leakage of these tanks is the most common and widely noted problem. The leakage may be either from sides or from the bottom. The point of leakage usually is from the rusted point. This can be confirmed by visual examination even from out side. Though not all rusted point will leak, but to control and take remedial measures number of rust stains should be observed.

For tracing the leaking hole from inside, the inside of the tank should be inspected for signs of iron fillings, after emptying the tank. The iron fillings either sticked to the surface around the hole or might have fallen down the tank wall. Such defects occur due to acid or soft waters which may destroy the zinc coating. The attack may be through out or at isolated places. Pieces of iron fillings, or metallic tools may cause localised corrosion. If dissimilar metals are used in the fittings connected to the tank, especially which are in contact with water, bimetallic may be developed. For the repair of miner cracks of metallic tanks ready made sealers are also available in the market.

10.32.1. Remedial measures

The remedial work depends upon the extent of rusting and the number of rusted spots not actually leaking. If there is only a single leak, it may be patched suitably. After patching the spot, the whole interior surface of the tank may be painted with a suitable non toxic bitumen paint. Now a technique has been developed for lining a metallic tank with a plastic sheeting in the form of a bag. This lining provides a remedy for correcting a badly corroded tank needing replacement. This plastic lining adheres to steel tank walls with out leaving any air pocket in between the metallic plate and plastic lining. The lining should be attached using non toxic epoxies and thermosetting plastics.

10.33. PLASTIC TANKS

In plastic tanks cracks, holes and damages can be treated using non toxic thermosetting plastics to seal these cracks and openings. If these defects are due to structural failures, then the deficiency can be removed by applying steel rings or vertical stiffeners to strengthen them.

Generally small cracks and punctures can be repaired by sealing with non toxic epoxy injection and plastic paints. Usually plastic tanks are of circular shape, they can be strengthened by using plastic mouldings of box rings or vertical sections. Simple rectangular sections may be used for additional vertical or ring stiffeners.

QUESTIONS

1. What general considerations should be considered while planning a distribution system.
2. Describe different methods of distribution of water giving their merits and demerits.
3. Name different types of pipes used in water distribution system. Give the advantages and disadvantages of cement R.C.C. and cast iron pipes.
4. Give the names of different types of joints provided in water distribution system and explain with sketch the bell and spigot joint.
5. Discuss different tests carried out to detect the water wastage.
6. Give reasons for the followings:
   (*a*) There are chances of water pollution in case of dead end water supply system.
   (*b*) Usually intermittent water supply system is adopted.
   (*c*) The wastage of water should be brought to a minimum possible extent.
   (*d*) Scour valves are provided at dead ends in the tree distribution system.
7. Identify the correct statement/statements
   (*a*) Reflex valve invariably is placed in water pipe line which gets water supply directly from the pump
   (*b*) Air valves are provided at the summit along the water pipe line
   (*c*) Bib cocks should be water tight
   (*d*) In the barrel of a fire hydrant a drain hole with plug is provided
   (*e*) All are correct

8. Identify the incorrect statement
   (*a*) Cement concrete pipe is flexible
   (*b*) Cement concrete pipe is rigid
   (*c*) Plastic pipes are not prone to freezing and thawing and are cheap in cost
   (*d*) Galvanised pipes are easy to join and handle
   (*e*) Usually lead pipes are used for conveyance of water
9. Identify the correct statement/statements
   (*a*) Cost of cast iron pipes is very high
   (*b*) Cast iron pipes are not easy to join
   (*c*) Cast iron pipes are subjected to corrosion very much
   (*d*) Breakage of cast iron pipes is least
   (*e*) None of the above
10. Identify the incorrect statement/statements
   (*a*) Corrosion imparts odour, colour and taste to the flowing water
   (*b*) Corrosion leads disintegration of pipe
   (*c*) Corrosion of pipe does not affect the carrying capacity of pipe
   (*d*) The maintenance cost of steel pipes is least
11. For checking the minor leakage through cast iron pipe joints material used is
   (*a*) Cement (*b*) White lead
   (*c*) Lead wool (*d*) Grease
12. For repairing the large crack in a cast iron pipe, method adopted is
   (*a*) Painting the crack with bitumen paint
   (*b*) Providing thick cover of cement plaster
   (*c*) Clamping the damaged portion with suitable clamps
   (*d*) Replacement of the damaged portion
13. Booster is used in the main water pipe line to
   (*a*) Increase the velocity of flow (*b*) Increase the pressure
   (*c*) Increase the discharge (*d*) None of the above
14. Give the reason for the followings
   (*a*) Usually intermittent method of water supply in adopted
   (*b*) Distribution system of water supply should be properly maintained
   (*c*) A hard rubber gasket is used in a flanged joint
   (*d*) Lead pipes can not be used for carrying acidic water
   (*e*) Corrosion of pipe affects their carrying capacity
   (*f*) The repairs of cement concrete pipe joints are difficult
15. Identify the incorrect statement/statements
   (*a*) Water supply line should be laid more than 90 cms below ground surface
   (*b*) The pipe line should be started from the upper end to out fall
   (*c*) Flexible joint in pipe line is best suitable at locations where settlement of soil is expected or on curves etc.
   (*d*) Victaulic joint is used for metallic pipe line in exposed places

ANSWERS

7. (*e*)	9. (*e*)	11. (*c*)	13. (*b*)	15. (*b*)
8. (*a, e*)	10. (*c, d*)	12. (*d*)	14.	

11

Sanitation System and its Maintenance

11.1. INTRODUCTION

The main aim of sanitation is to maintain the environment which will not affect the public health in general. Sanitation is a preventive measure for the preservation of health of community in general and individual in particular. It includes the collection of refuse and garbage etc. and their proper disposal. In this chapter sewers, their construction and maintenance will be discussed.

11.2. SEWER

The under ground drains or conduits through which sewage is conveyed or carried are called sewers. Sewage always is carried in closed drains or pipes so that the foul gases and odour may not pollute the atmosphere.

11.2.1. Shape of sewers

Common shapes of sewers are as follows:

1. Rectangular
2. Circular made of brick or circular pipes
3. Semi elliptical
4. Horse shoe type
5. Basket handle type
6. Egg shaped or oval shape section

Though every shape has its own advantages, and disadvantages, but circular and Egg shaped sections have been found more popular in practice. Advantages of circular and other shaped sewer sections are shown in tabular form below in Table 11.1.

Table. 11.1. Comparision of circular and non circular shapes of sewers

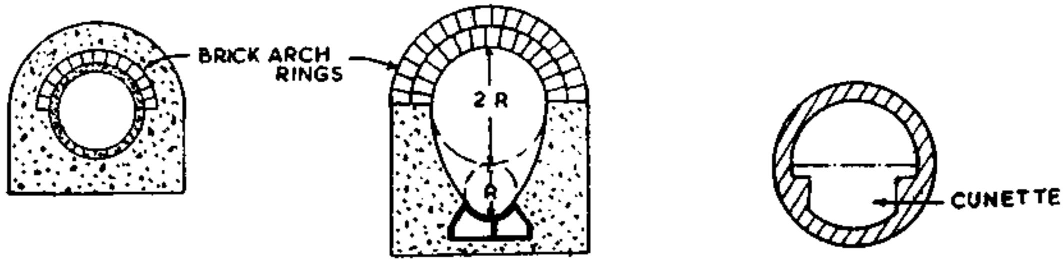
S. No.	*Circular shape*	*Other shapes*
1.	This section gives the least perimeter for a given area, hence it has maximum hydraulic mean depth for running full and half depth of the section.	Other shapes are used for the following considerations. 1. To simplify the process of construction.
2.	The section requires less material of construction, hence economical.	2. To secure more structural strength.
3.	The section is easy to cast and lay.	3. To have large size, so that man can enter to clean and repair.
4.	It has no corners, hence less chances of deposition of organic matter.	4. To improve the velocity of flow during dry weather flow.
5.	For concrete pipes, there is no hoop tension, hence requires no reinforcement.	5. To reduce the cost of construction.

Circular shape

Now a days precast asbestos cement concrete pipes reinforced with steel are widely used for sewers due to the advantages mentioned in Table 11.1 and laying of these pipes is very simple, but this section has been found more useful for separate system of sewerage, where discharge more or less is uniform. It is not suitable for combined system of sewerage as in dry weather it is very difficult to develop self cleaning velocity. This velocity is also known as self cleansing velocity.

Egg shaped sewers

This section is most suitable for combined system of sewerage as it develops self cleaning velocity even during dry wealth flow. This section is equally suitable for separate system of sewerage, as it can easily accommodate the flow of sewage with the development of the town. This section has good hydraulic properties, even better than circular section with low discharge. From the Fig. 11.1 it will be seen that the



CIRCULAR SHAPE OVAL SHAPE CUNETTE SHAPE

Fig. 11.1. Shapeof sewer

depth of these sections is 1½ times of their width. In the present day practice the smaller radius is used at the bottom and it serves as cunnettee in which self cleaning velocity is developed during dry weather flow due to the greater depth of the section in comparision of other sections. These sections are always constructed at site with concrete and brick arch or R.C.C. having special invert at bottom.

Disadvantages

1. Their construction is difficult.
2. It has been found less stable than circular section, hence requires good masonry support.
3. It is constructed at site only. It can not be manufactured in factories.

11.3. CHARACTERISTICS OF SEWERS

As sewage from industries having acids, alkalis and other chemicals also flow through sewers, hence the materials of sewers should possess the following characteristics.

1. **Resistance to corrosion and abrasion.** The sewer material should be resistant to chemical reactions and abrasion.
2. **Durability.** The material of sewer should be durable, so that no frequent replacement of sewer is required.
3. **Imperviousness.** The material of sewer should be sufficiently imperious.
4. **Strength.** As generally sewers are laid under ground, hence they are likely to be subjected to heavy loads. Hence the material should be strong enough to withstand these loads.

11.4. TYPE OF SEVERS

The sewer material should be of moderate weight so that sewer may be handled and carried easily. Sewer materials with their advantages and disadvantages are shown in tabular form in Table 11.2 below:

Table 11.2. Weight of sewer materials

S. No.	*Materials*	*Advantages*	*Disadvantages*
1.	**Asbestos cement sewers.** These sewers are available in sizes upto 50 cms diameter.	1. These sewers are easy to cut and join. 2. These sewers are resistant to corrosion, acids, salts and other corrosive materials. 3. The inside surface is exceptionally smooth, hence offer least frictional resistance. 4. These sewers are light weight, hence easy to handle.	1. These sewers are brittle, hence can not withstand impact forces during their handling. 2. Their structural strength is poor.
2.	**Stone ware or vitrified clay sewer.** These pipes are manufactured in sizes upto 600 mm in diameter and 60 to 90 cms in length by moulding special clay in the circular shape. 1st they are dried in warm air and then fired to a temp of 150°C in the beginning for several hours. After wards the temperature is raised to about 750°C. Finally the temp. is raised upto 1200°C. During burning, sodium chloride is thrown on the surface of these sewers. The salt vaporises at this high temperature forming a gloss like glazed surface of the pipes, The exterior surface of spigot end and the in side surface of socket end are not glazed to make the joint water tight. The crushing strength of these pipes usually is 2600 kg/cm^2 but pipes of higher strength of the order of 2800 kg/cm^2 are available. **Use.** These pipes are generally used for house drainage connections and branch sewers.	1. The interior surface of the sewers is smooth and impervious. 2. If laid properly, they are strong enough to withstand the load of traffic and back filling. 3. The over all perfermance of these sewers in carrying sewage is very good. 4. These sewers are cheap and easily available. 5. These sewers are quite durable and offer resistance to corrosion from most acids and erosion due to sand, grit and high velocities of flow. 6. These sewers are capable to withstand hydraulic pressures upto 1.5 kg/cm^2 and can bear the load of soil about 4.5 m depth	1. These sewers are brittle in nature, They are likely to be damaged during transport and handling operations. 2. They are not strong to allow the flow of sewarage under pressure. 3. These sewers are heavy in weight and bulky. 4. They are difficult to handle, transport and lay.

11.4.3. Cast iron sewers

Cast iron sewers possess high strength They are durable and are water tight. These pipes are available in sizes ranging from 15 cms to 75 cms in diameter. Cast iron sewers are likely to be affected by the acids contained in the sewage. To safe guard these sewers from acidic action, the inside surface should be coated with cement concrete or paint.

11.4.3.1. Uses

Their use has been found more useful under the following conditions:

1. Cast iron sewers are adopted where sewers are laid over or below the water pipe lines. Thus the

danger of contamination of under ground water due to leakage in sewers is avoided.

2. Where sewer line is to be carried in exposed position over trestles and piers.
3. Where the sewage is to be pumped or carried under pressure.
4. As they do not require frequent repairs, they are preferred under hard surface roads as cement concrete roads.
5. Cast iron sewers are more suitable at places where they have to bear heavy external loads as under railway lines or foundations of buildings.
6. Cast iron sewers are more useful when to be laid at less depth and the sewer has to bear heavy loads due to the movement of vehicles.
7. Cast iron sewers are preferred when the ground is likely to be subjected to heavy vibrations and movement.
8. Cast iron pipes are more suitable when to be laid in wet ground. In this case the rate of infiltration would be reduced to a great extent.
9. Cast iron sewers are also found useful in unstable soils which are likely to sink.

Thus the cast iron pipes are more durable and their durability can be increased by coating them with coal tar.

11.4.4. Steel sewers

Steel sewers are flexible and can absorb vibrations and shocks in a better way. These sewers can withstand impact of loads and internal pressure much better than cast iron sewers. These sewers being ductile can withstand water hammer.

These sewers are generally used for mains, out falls, and trunk sewers having a diameter more than 75 cm. The use of these sewers has been found useful in situations as under water river crossings, bridges crossing, railway crossings, pressure mains pen stocks, connections for pumping stations, small aqueducts etc.

11.4.5. Cement Concrete sewers

Cement concrete is becoming popular these days in all types of constructions. Now a days cement concrete is widely used in the construction of sewer lines. Cement concrete sewers may be plain or reinforced. The plain cement concrete sewers are used upto diameter of 60 cms.

The cement concrete sewer pipes may be precast or cast in situ. Precast pipes are manufactured in factories by centrifugal method using steel reinforcement. These pipes are known as "HUMES" pipes. The diameter of these pipes may vary from 10 cms to 250 cms and length from 1 to 3 metre. These pipes are light in weight and strong having smooth inside surface. R.C.C. sewers are found useful for combined system of sewerage and where sewage does not contain heavy acidic contents and erosive material.

R.C.C. sewers are not durable and have short life as they are corroded by the gases developed in the sewerage obtained from industrial houses. The organic and inorganic matter is contained in the sewerage. The insoluble matter is deposited at the bottom of the sewer, which increases the roughness coefficient and decreases the velocity of flow. Under aerobic or anaerobic conditions sulphates present in the sewerage chemically are reduced to sulphide (C_2S) by the bacteria. Hydrogen sulphide gas is very pungent having unpleasant smell like rotten eggs. The blackish colour of sewage and sludge is due to the hydrogen sulphide gas. This gas combines with iron present in sewerage and sludge forming ferrous sulphide which is converted into sulphuric acid by the bacteria.

The sulphuric acid is deposited at the top of the sewer in the form of moisture droplets. This acid reacts with concrete forming calcium sulphate. As the droplets fall down, the layers of calcium sulphate also fall down with the droplets making the sewer surface uneven and its thickness gets reduced. This phenomenon is known as *crown corrosion*. In due course of time the sewer becomes weak and gets damaged.

11.4.5.1. Cast in situe R.C.C. sewers

Concrete sewers are constructed at site where they are economical or where non standard sections or special shape is required. The design of sewer should be economical and the shape should be easy to construct and maintain. The hydraulic characteristics of the sewer should be good. The bottom of the sewer should be flat with the central portion of V shaped called cunnettee. The minimum depth of central V shaped portion should be 15 cms, so that even dry weather flow may develop self cleaning velocity. For its construction steel collapsible form work should be used to get good surface of the sewer.

11.4.6. Brick sewers

Brick sewers are used where large sized sewers are required. Though now a days brick sewers have been replaced by cement concrete sewers, but have been constructed at few places. Brick sewers are used as bricks are available at all places easily. The bricks to be used should possess following characteristics.

(*a*) Bricks should be wedged shaped to give mortar joints of uniform width.

(*b*) The invert block of the sewer should be made of hard, dense and strong bricks. These sewers should be plastered on out side surface and inside surface should be lined with vitrified blocks to prevent entry of tree roots, and ground water etc.

(*c*) Under special conditions, protection against corrosion also should be given.

11.5. SEWER JOINTS

Due to the weight and handling difficulties, the sewer units or pipes are manufactured in small lengths ranging from 1 to 3 m and then joined at site to make the sewer line. Hence the necessity of joining the sewer units. Joints are provided after placing the sewer units in position. The type of joint to be provided depends on the material of the sewer unit or pipe, internal pressure likely to be developed, external load likely to come on sewer line, type of support etc.

11.5.1. Requirement of good sewer joint

A good sewer joint should possess the following characteristics:

1. The joint should be easy to construct and maintain.
2. It should be economical and cheep.
3. It should be flexible and should not get damaged due to settlement of soil below.
4. It should be water tight and highly resistant to infiltration of ground water and out gress of sewage.
5. It should be non absorbent and durable.
6. It should offer good resistance to the penetration of tree roots inside the sewer line.
7. It should be resistant to corrosion due to acids, alkalis and gaseous action of sewage and erosion due to grit etc. of the flowing sewerage.
8. It should not be easily broken or damaged, cracked by the traffic etc. *i.e.* it should be reliable.

11.5.2. Types of sewer joints

Depending on the way of making joints, they may be of the following types:

1. Cement mortar joints
2. Collar joints
3. Flexible joints
4. Bandage joints
5. Mechanical joints
6. Open joints
7. Flush joints

1. Cement mortar joints

These joints are widely used in the construction of sewers and are found satisfactory. For making this joint cement sand mortar of proportion of 1:1 or 1:2 is used. (Fig. 11.2).

Procedure

(*a*) The spigot end of the pipe is properly cleaned with wet brush or cloth and inserted into the socket end of the other pipe and held in proper position maintaining the alignment of the sewer line.

(*b*) To maintain the alignment of sewer line a gasket or packing piece may be placed.

(*c*) A closely twisted hemp or jute dipped in cement slurry is placed in the socket and spigot annular space in short length necessary to prevent the cement mortar from falling in side the pipe.

(*d*) Cement mortar of the proportion 1:1 or 1:2 prepared as above is filled in the annular space around the circumference of the spigot. The mortar is filled properly and rammed into the joint with a caulking tool.

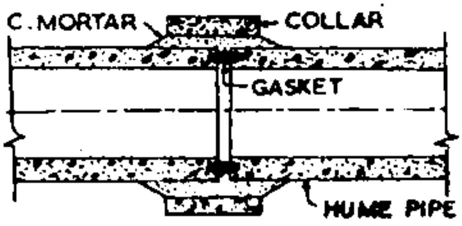


Fig. 11.2. Cement joint

(*e*) The joint is finished by giving a 45° slope at the out side of socket end and beveled off.

(*f*) Larger diameter pipes are also given smooth finish in the inside also.

(*g*) In case of smaller diameter pipes, the joining matter is squeezed inside or fallen material is cleaned by fixing a cloth at the end of a long rod or bamboo and forced at the open end and inside surface is cleaned.

Disadvantages of Cement mortar joint

Cement mortar joints suffers from the following defects:

(*a*) They are likely to be affected by corrosion due to acidic corrosive soils, hydrogen sulphide in the sewage.

(*b*) These joints are rigid in nature. They may result in breakage of sewer or joint, due to settlement of soil or its movement.

(*c*) It requires skilled labour for its construction.

2. Collar joint

Collar joints usually are used for large sized diameter pipe sewers *i.e.* more than 50 cm diameter pipe sewer line and light hydraulic pressure. Collars are 15 to 20 cms wide. In this case the sewer pipes used have plain ends. The ends of the sewers are placed near each other and then a collar slightly bigger in diameter is placed over the sewers. The annular space between the sewers and the collar varies from 1.3 cm to 2.0 cm depending on the diameter of the sewer pipes. This space is filled with cement mortar of 1:1 proportion and rammed with a caulking tool. Fig. 11.3.

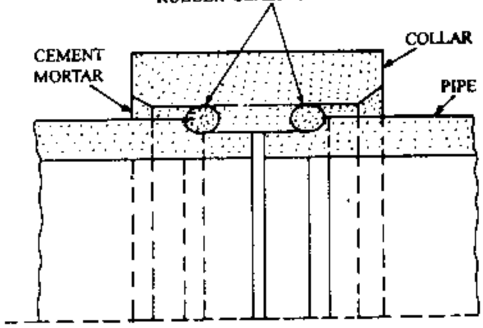


Fig. 11.3. Collar joint (semi-flexible)

3. Flexible joints or bituminous joints

In this class of joints bitumen is used instead of cement mortar. These joints are flexible and used where sewers are liable to settlement.

4. Semi flexible and collar joints

(*a*) This type of joints generally are used for large diameter hydraulic pipes. In this case the pipes are manufactured with special ends. The loose collar covers both the specially shaped pipe ends. A rubber ring is provided on each end, which when compressed between the spigot and collar seals the joint.

(*b*) *Semi flexible spigot and socket joint.* This joint is used for cement concrete sewers. The spigot and socket ends of pipes are made of special shape. A rubber ring is placed on the spigot which is forced into the socket of the other pipe laid. As the spigot moves into the socket of the other pipe, it compresses the rubber ring and forms a flexible and water tight joint.

5. Mechanical joints

In this type of joint mechanical devices such as flanged rings, bolts etc. are used to join the two ends of the sewer. This class of joints are usually used for metallic sewers as cast iron or steel etc. In case of steel sewers usually welded or riveted joint is provided. The riveted joints have the following dis advantages.

(*a*) The cost of riveting is high.

(*b*) The head of rivets remain on interior surface of sewers, which makes the inside surface of sewer rough and may got corroded by the action of acids and alkalis of the sewerage.

6. Bandage joint

Mostly this joint is used for cement concrete pipes. The pipes to be jointed are placed in position. To give support to the joint, the soil below the end of the pipes is scooped out upto a depth of about 25 mm, 75 mm under the pipe and 75 mm ahead of the pipe end. This space is now filled with mortar upto the bed level or inverted of trench. On this mortar a wire net is placed. On this wire mesh a layer of cement mortar of 6.5 mm thickness is laid. After coating the ends faces of the pipes they are butted aganst each other. Now wire mesh is wrapped tightly around the pipe and strands are hooked securely together squeezing the mortar firmly on the pipes. Finally the wire mesh is covered with 20 mm thick layer of cement mortar.

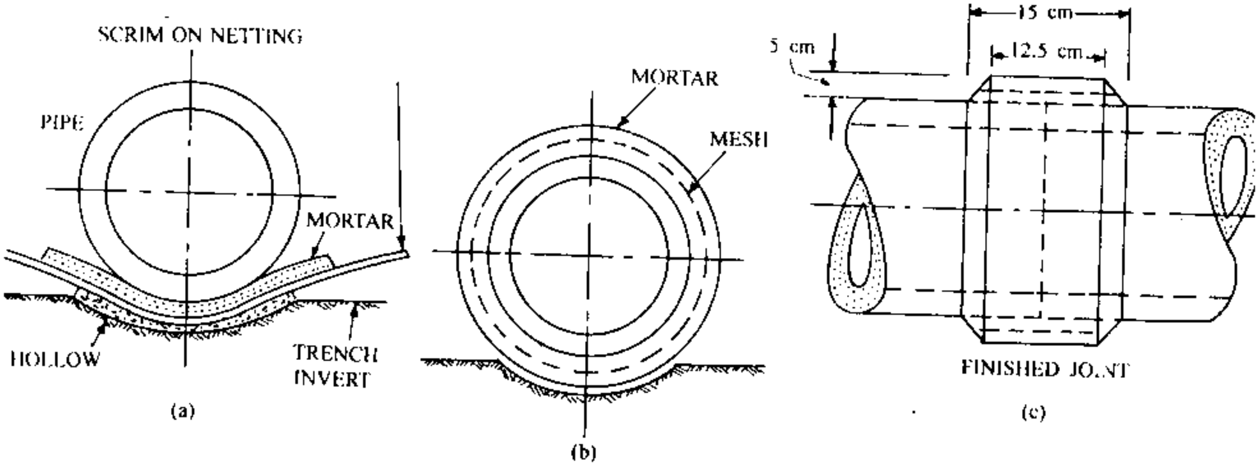


Fig. 11.4. Bandage joint

11.6. CONSTRUCTION OF SEWERS

Actual construction of sewers consists of the following works:

1. Marking of centre line of sewers and locating positions of sewer appurtenances.
2. Excavating trenches, removal of road pavement and disposal of excavated materials.
3. Bracing, sheeting and dewatering of water if required.
4. Laying of sewer pipes and their joining.
5. Testing of sewer lines.
6. Back filling of trenches.

11.6.1. Marking of centre line

1. The centre lines of sewers are marked on the ground from the plan of the scheme starting from the lowest end or the out fall of the main proceeding upwards.
2. From the longitudinal section of the sewer line, the positions of the manholes are studied and located on the ground. Generally the sewer line is laid between two manholes.
3. The setting out of work is done with the help of theodolite and chains or by compass. The centre line pegs are driven in the ground.

4. The centre line pegs are driven at a interval of 7.5 to 10 m. The distance may be adopted as per convenience.
5. The centre line should be properly maintained during the sewer construction. For this purpose following two methods may be adopted.
   (a) *Locating off set line.* This method is adopted for short duration of time to avoid inconvenience to traffic during the trench excavation work. In this method a line parallel to the centre line of sewers is marked at a distance of about 2 to 3 m to help in locating the sewer centre line during excavation operation to lay the sewer. This line is called off set line.
   (b) *Sight rail method.* This method is the universal method and is adopted in all cases for taking levels of invert of proposed sewer line. In this method two vertical posts are driven into the ground at a known distance from the centre line pegs. One horizontal rail called as sight rail is fixed between these two posts at a convenient height from ground level as shown in Fig. 11.5. To check the levels of sewer pipes and their alignment, temporary bench marks may be established at an interval of 200 to 400 metres apart and their reduced levels may be marked on the sight rail.

11.6.2. Excavation of trenches

If sewers are to be laid on roads or streets already in existence, then they are removed starting from the lower end and proceeding up wards. After removing the road or streets, trenches are excavated. The width of the trench depends on the diameter of the sewer pipes.

For large size sewers the width of the trench should be at least 15 cm more than the external diameter of the sewer for ease in lowering and adjusting the sever pipes. The minimum width of trench may vary from 60 cm to 100 cm for easily laying and jointing the sewer pipes. At ends of pipes the width is kept more for joining the pipes. Depth of trench should be such so that sewer line may be laid below the water distribution system lines to avoid contamination from sewerage.

11.6.3. Bracing and dewatering of trenches

If sufficiently deep trenches are to be dug in soft soils then they need bracing to support soil and to prevent it from falling into the trench. When sewer lines are to be laid below the ground water table, the ground water enters the trenches during excavation and causes difficulties. Thus dewatering of trenches becomes essential in such conditions. Any suitable method of dewatering may be adopted for this purpose.

11.6.4. Laying of sewers

Usually sewer pipes are not laid directly on the soil in the trench. To distribute the load on the soil uniformly actually the bottom of the trench is prepared to receive the sewer pipe. Usually before laying the pipe in the trench, concrete bedding is provided below the sewer pipe. Sewer pipe bedding may be of various types depending on the site conditions.

The centre line of sewers and their grades are transferred from the ground by means of sight rail and bonding rod. Sight rail is shown in Fig. 11.5. The bonding rod consists of a cross head at top and shoe at the bottom as shown in Fig. 11.5 (*a*). The length of the bonding rod is adjusted according to the reduced levels of the sewer line.

The centre line of sewer line is marked on the sight rail as shown in the Fig. 11.5 and small nails are fixed on the sight rails at the position of centre lines. Usually the sight rails are fixed at an interval of 7.5m centre to centre, at all junctions and change of grade or alignment. Now a strong string or wire is stretched between the nails fixed in two sight rails. This line is parallel to the grade of sewer and lies in the vertical plane passing through the centre line of the sewer. Now the bonding rod is placed with its shoe touching the invert of the sewer. The verticality of bonding rod is checked by hanging a plumb bob from the top. If the top of the bonding rod touches the string, then sever is laid at proper gradient. In case it remains above or below the string, then thin the filling in trench or excavation is carried out to bring the top of bonding rod in level of the string.

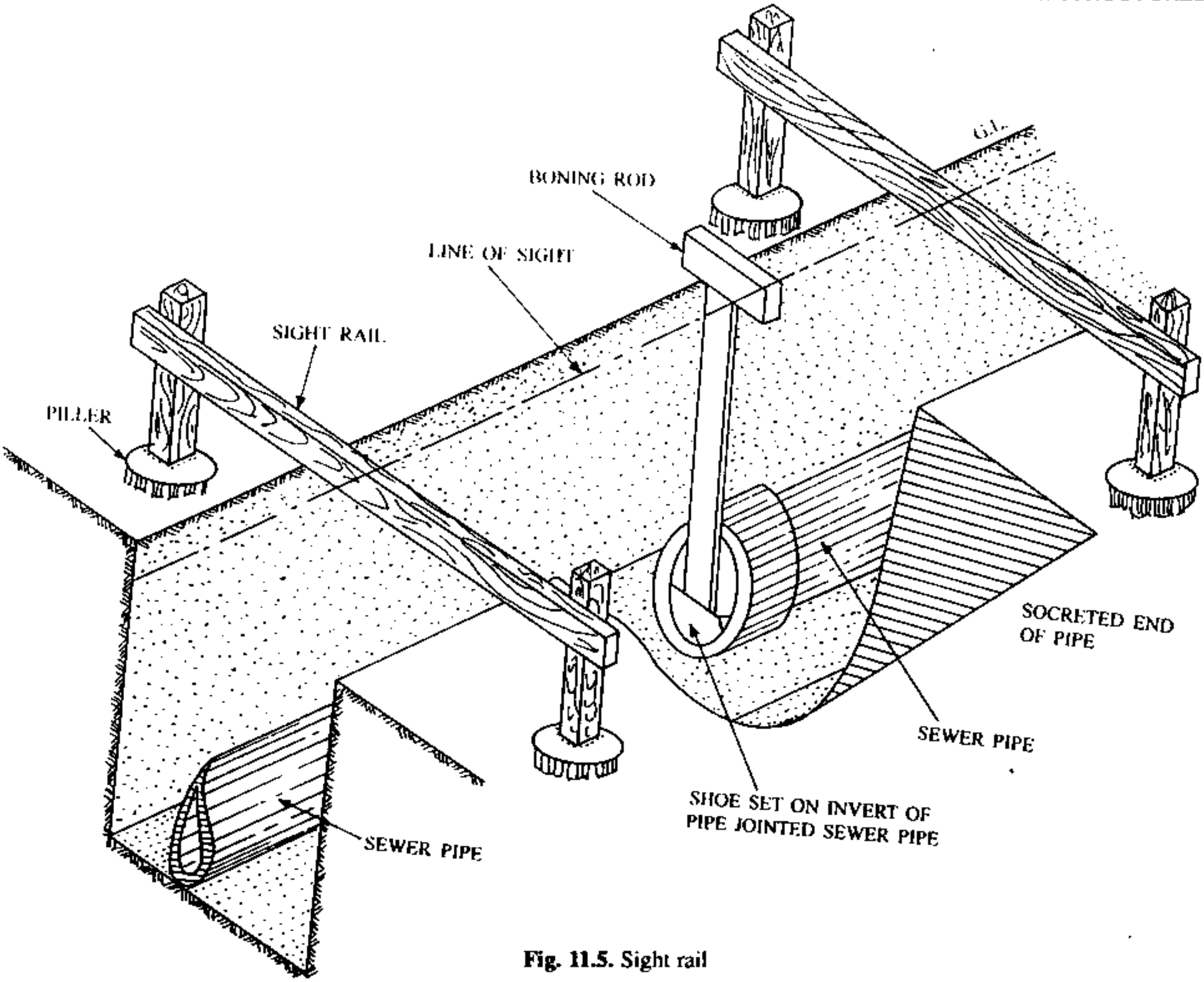


Fig. 11.5. Sight rail

11.6.5. Testing of sewer pipes

For testing the sewer pipes for water tightness of joints usually following two tests are carried out.

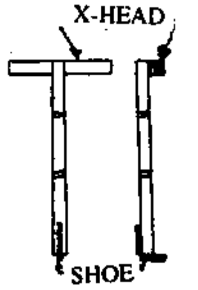


Fig. 11.5 (*a*) Bonding rod

1. Water test. length of sewer line between two consecutive man holes is selected and the upper end is plugged with provision of an air outlet pipe with stop cock. Water in the sewer pipe is filled through a funnel at the lower end provided with a plug. The air is expelled through the air valve or out let, the stop cock is closed and the water level in the funnel is raised upto 2 m above the invert at the upper end. After 30 minutes water level in the funnel is noted. Quantity of water required to restore the original level in the funnel is determined. Now the sewer pipe line under water pressure is inspected while the funnel is still in position with water. There should be no leakage either through pipes or joints except small sweating on the pipe surface. Leakage in 30 minutes is determined by measuring the replenished water in the funnel. The leakage should not be more than 15 c.c. in small diameter sewer pipes and 60 c.c. in larger diameter sewer pipes per centimeter diameter of sewer per 100 m length. Any sewer pipe not found to satisfy this test is emptied, repaired or replaced and retested.

2. Air test. This test is adopted for large diameter sewer pipe line where the required quantity of water is not available. In this case air is used in place of water. In the test the sewer pipe is subjected to air pressure of 100 mm of water by means of a hand pump. If the pressure remains constant at 75 mm of water. then the joint is taken as water tight. In case the pressure drops more than 25 mm then there is possibility of leakage and it is traced and suitably repaired to ensure water tightness. The exact point of leakage can be traced by applying soap solution at all joints in the sewer line and leaking air bubbles are observed. The development of air bubbles indicates leakage.

11.6.6. Back Filling of Trenches

Refilling of trenches should be started after the sewer line has been laid properly and tested. The pebbles, stones pieces etc. should be removed from the soil and the soil should be filled equally on either side of the sewer in layers of about 15 cm thickness and consolidated properly using water. When the thickness of back fill and rammed soil reaches 60 cm above the crown of the sewer, it should be stopped at least for one weak for weathering. After one week, back filling may be started till the trench is filled at least 15 cm above the ground level. In due course of time, soil will be compacted and fill level will come down to the general ground level. Back filling should be started after 7 days for precast pipes and 14 days for cast in situ sewers. Tamping should be done carefully, more specially when compacting near the crown of the sewer. Reconstruction of pavement should be started after about two months after the proper consolidation of back fill when there is no danger of settlement of pavement.

11.6.7. Points to be remembered at the time of laying sewer line

1. The sewer line should be laid preferably near the centre line of the road. This will make the length of house drainage on both sides equal.
2. The sewer line should be provided with proper appurtenances as required.
3. The road metal removed during the laying of sewer line should be preserved carefully and should be reused while relaying the pavement after refilling the trench. If this precaution is not observed, additional expenditure of arranging new road material will be required.
4. As far as possible sewer line should avoid water pipe lines, foundations of structures, electric poles etc.

11.7. SEWER APPURTENANCES

For the proper functioning and maintenance, sewer system has following appurtenances:

(*a*) Man holes (*b*) Drop man holes (*c*) Catch basins
(*d*) Clean outs (*e*) Flushing tanks (*f*) Lamp holes
(*g*) Grease and oil traps

11.8. MAN HOLES

It is a construction, provided to connect the ground level with the opening made in the sewer line, to enter a man in the sewer line easily and safely to carry out the usual maintenance and inspection of the sewer line. Man holes are provided to carry out inspection, cleaning and maintenance of sewer lines. Man holes also allow joining of sewers or changing of direction or changing of alignment or both.

11.8.1. Location

Man holes are provided on straight sewer lines at intervals depending upon the diameter of the sewer line. For sewer line having its diameter upto 50 cms, the interval usually is kept as 75 m. For sewer lines having diameter of 90 cms, the distance is kept as 120 m, for sewers of 150 cm diameter the distance is kept as 250 m, sewers having diameter more than 150 cm, the distance may be 300 m or more. For larger sewers the distance may be more as a man can enter the sewer for inspection. Man holes are also provided at every bend, junction, change of diameter of sewer line, change of gradient etc. As far as possible sewer line between two man holes should be laid straight with even gradient.

11.8.2. Classification of man holes

Man holes may be classified as follows:

(*a*) *Shallow man holes.* These man holes are constructed at the beginning of branch sewers or places not subjected to heavy traffic. These man holes are also known as inspection chambers. The depth of such man holes varies from 0.75 m to 0.9 m and size 0.75 × 0.75 m. It is provided with light. A cover at top is provided.

(*b*) *Normal man holes.* The depth of such man holes may be about 1.5 m. It's size may be 1.0 × 1.0 m or 0.8 × 1.0 m. It is of rectangular or square in shape. Its section is not reduced. It has heavy cover at top.

(*c*) *Deep man holes.* The depth of such man holes may very from 1.5 m to 2.0 m and its section 1.2 × 0.9 m rectangular or 1.4 m diameter with heavy cover at top. Fig. 11.6 shows a deep man hole with intercepting trap. Its size is reduced and offset is constructed of brick masonry or cement concrete.

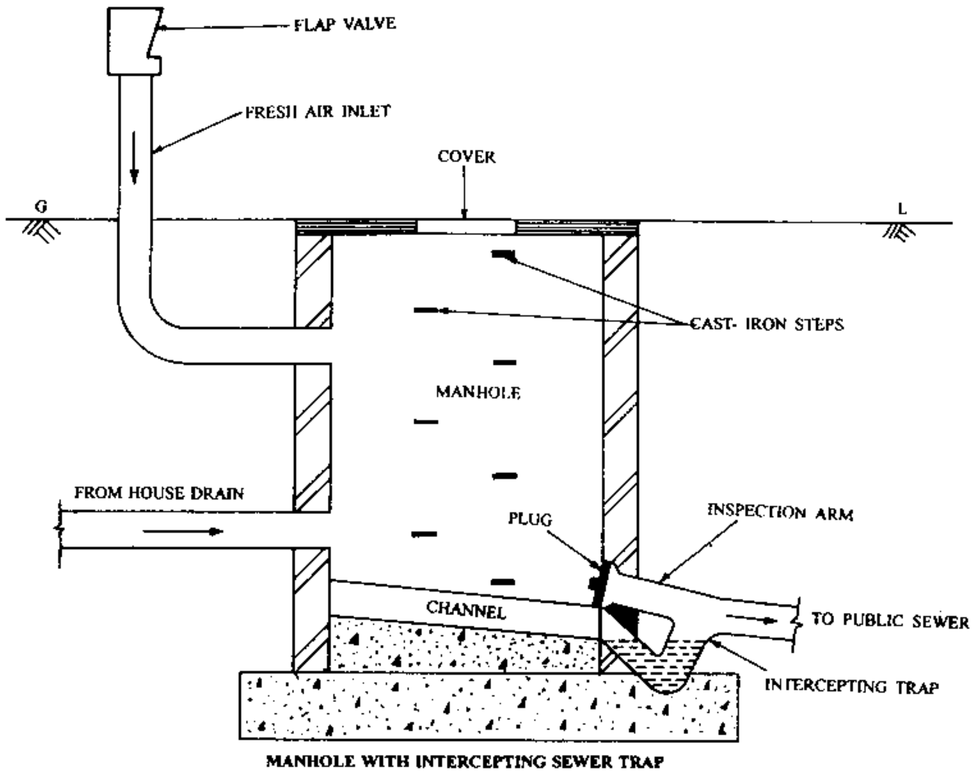


Fig. 11.6. Deep manhole with inter cepting trap

11.8.3. Principles of design

(*a*) A man holes should be structually strong, stable to resist all forces likely to act on it:

(*b*) It should be safe for workers to enter in it.

(*c*) The walls and floor of man hole should be impervious. The surface of walls should be cement plastered.

(*d*) The man hole should not be an obstruction for the smooth flow of sewage and should not unnecessarily become a source of foul gases.

(*e*) In case the inlet and out let of the sewers are of different diameters, then the crown of sewers should be kept at nearly the same level by giving required slope in the invert of the man hole chamber. If this precaution is not taken then the smaller sewer will get back flow while larger sewer will run full.

Steps or ladder in man holes

The steps should start from about 40 cm below from ground or road level and upto 30 cms height from bottom level of man hole. Fig. 11.7 shows man hole with steps, section and plan.

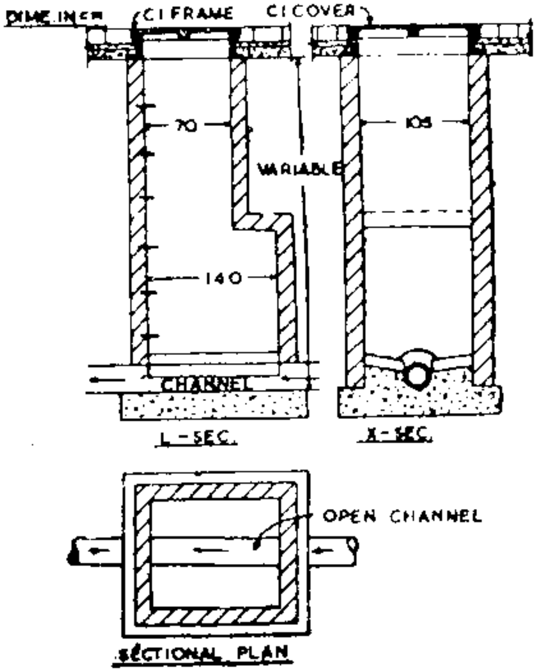


Fig. 11.7. Man hole with steps plan & section

Walls

Walls of man hole may be made of brick, stone masonry or cement concrete. Usually brick walls are very common. The thickness of wall should not be less than 20 cm. The brick wall thickness may be found out from the following thumb rule—

$$t = 10 + 4d$$

where

t = wall thickness in cm

d = depth of excavation in metres

Cover to man holes

The weight of cover and frame of light duty and medium duty traffic should be as follows. Further the cover should not create noise on passing vehicles over it. If it makes noise, it should be attended and its seal should be replaced.

Table 11.3. Approximate weight of man hole frame and cover

Clear opening mm	*Grade designation*	*Approximate weight in kg*	
		Single seal	*Double seal*
Light duty	450 × 450 mm	18 – 31	34 – 43
	600 × 450 mm	26 – 38	37 – 51
	600 × 600 mm	32 – 57	60 – 75
Medium duty	500 mm dia	102	—
	600 × 450	142	—
	600 × 600	178	—

11.9. DROP MAN HOLES

An opening constructed to connect a high level branch sewer to low level main sewer with minimum disturbance is called a drop man hole as shown in Fig. 11.8.

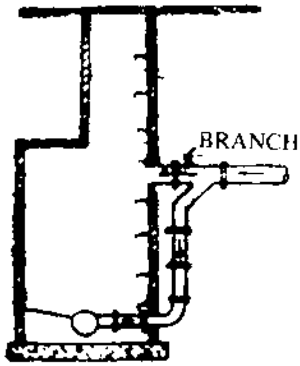


Fig. 11.8. Drop man hole

11.9.1. Functions of drop man hole

A drop man holes serves the following functions:

1. We know that a main sewer usually is laid at greater depth below ground level and a branch sewer situated near the ground level. Thus to join the branch sewer with the main sewer, construction of dropman hole avoids unnecessary steep gradient of the branch sewer and thus reduces the quantity of earth work.

2. Construction of drop man hole, allows the discharge of branch sewer to fall at the bottom of the man hole and avoids the possibilities of sewage being falling on the person who enters the chamber of man holes for inspection.

11.9.2. Working

As shown in Fig. 11.8, the horizontal length between the wall of man hole and the vertical pipe is known as inspection arm. On opening the plug, it can be used as inspecting or cleaning the branch sewer. In case the distance between the branch and main sewer is not more than 60 cm, then the branch pipe it self may be taken upto the bed of man hole giving slope to it which is called ramping.

11.10. CATCH BASIN

A structure provided along the sewer line to admit clean rain water free from girt, silt, debris etc. into the combined sewer is called catch basin.

Functions. Following are the functions of the catch basin:

1. To prevent the escape of sewer gas.
2. To prevent the entry of silt, grit, debris etc. contained in the rain water.

Disadvantage. The catch basin provides a temporary storage of impurities contained in rain water. Hence it requires periodical cleaning and maintenance. If it is not cleaned periodically, it will become breeding place for mosquitoes and will cause nuisance to the people living nearby. Further the organic matter on decomposing will emit foul smell causing annoyance to passer-by.

11.11. CLEAN OUTS

A pipe connected to the under ground sewer is called clean out. The other end of this pipe is brought upto the ground level and a cover is placed on it at ground level as shown in Fig. 11.9. Generally it is provided at the upper ends of lateral sewers in place of man holes.

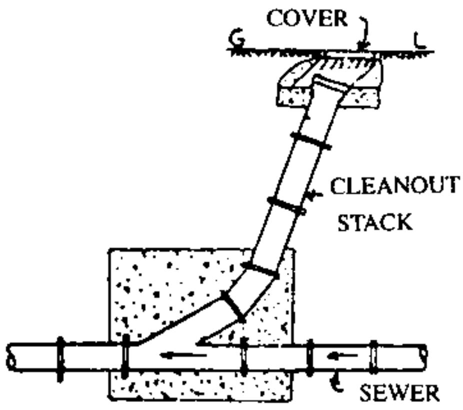


Fig. 11.9. Clean out

Working. Its working is simple. To remove the obstacles in the sewer, the cover of the upper end is removed and water is forced through the clean out pipe into the lateral sewer. If obstacles are large, flexible rod is inserted through the clean out pipe and moved to and fro (forward and backward) to remove the obstacles.

11.12. FLUSHING TANKS

It is a device made to hold and throw water into the sewer for flushing it.

Objects

1. Flushing tanks are provided near the dead ends of sewers.
2. They are provided on sewer lines which are laid on such gradients that will not produce self cleansing velocity.
3. To store sewage temporarily.

The capacity of the flashing tank should be enough to hold water required for flushing the sewer line. Generally the capacity of flushing tank is kept about 1/10th of the cubical contents of the sewer line to be served by it. There may be hand operated and automatic flushing tanks.

11.13. GREASE AND OIL TRAPS

These are chambers provided on the sewer lines to exclude Grease and oil from sewage before it enters into the sewer line. The grease and oil traps are provided near the sources contributing grease and oil to the sewage. Thus they are located near the automobile repair workshops, Grease and oil producing industries, kitchens of hotels and garages.

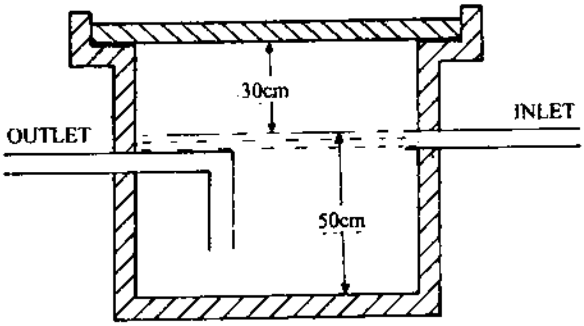


Fig. 11.10. Oil and Grease chamber

11.13.1. Working

The grease and oil being lighter than water float on the surface of sewage. If out let draws sewage from lower level, the grease and oil are excluded. Thus the out let level is kept near the bottom of the chamber and inlet level near the top of the chamber as shown in Fig. 11.10. In case sand is also to be excluded from the sewage, then space for its deposition should be kept at the bottom of the chamber. Fig. 11.11 shows a combined silt grease chamber.

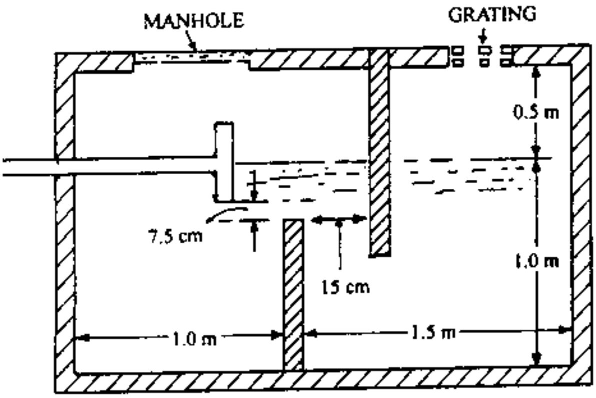


Fig. 11.11. Combined silt, oil and grease chamber

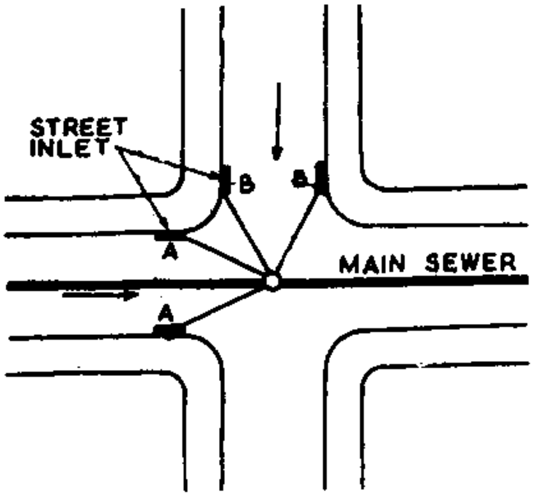


Fig. 11.12. Road showing arrangement of gullies

11.14. INLETS

An opening through which the storm water and surface wash flowing along the streets are admitted and conveyed to the storm sewer or combined sewer by means of pipes is called inlet. It is simply a concrete box. It may have openings or gratings in the horizontal or vertical direction as shown in Fig. 11.12. This figure show road inlets.

The inlet having openings in the vertical direction is known as curb inlet or vertical inlet. In case the opening is horizontal, then it is called horizontal inlet. Fig. 11.3 shows a kerb grating.

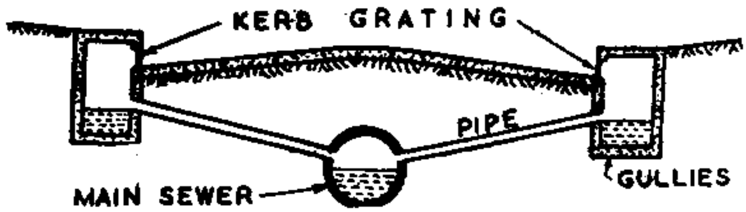


Fig. 11.13. Road inlet

11.15. LAMP HOLE

An opening constructed in a sewer line for the purpose of lowering lamp is known as lamp hole. A lamp hole is constructed to achieve the following objectives:

1. Inspection. At the time of inspection an electric bulb or lamp is inserted in the lamp hole and its light is observed from the man hole. If the light is visible, then the sewer is unobstructed.

2. **Flushing of sewer line.** Some times lamp holes may be used as flushing device.
3. **Ventilation.** If the cover at the top of lamp hole is perforated, then it works as ventilator for sewer, such a lamp hole is also known as fresh air inlet.

Location

1. If the construction of manhole is difficult, then a lamp hole may be provided in its place.
2. When in a short distance between two man holes the sewer line has to be made on different gradients and change of direction also takes place, in such a case provision of lamp holes is economical.
3. When sewer line is straight for a considerable distance beyond the usual spacing between man holes, then provision of lamp hole should be made.

11.16. VENTILATION OF SEWERS

Sewer ventilation is essential due to the following reasons:

Sewage flowing in the sewers contain organic and inorganic matter which on purification or decomposition produces gases known as sewer gases. Sewer gases include carbon monoxide, carbon dioxide, methane, nitrogen and Ammonia etc. These gases are very foul in nature and harmful in many ways. These gases like methane are very foul in nature and harmful in many ways. These gases like methane are very explosive and may cause fatal accidents to the maintenance gang. If the sewer is not properly ventilated the man hole cover may be blown off. Secondly these gases being light move upwards and cause air pollution when they escape into the atmosphere. They also interfere with the natural flow of sewer. Hence sewer ventilators are provided along the sewer lines at an interval of 80 to 150 m or so. Ventilator shaft may be of cast iron, steel or R.C.C. pipes of internal diameter ranging from 15 cm to 25 cm as shown in Fig. 11.14.

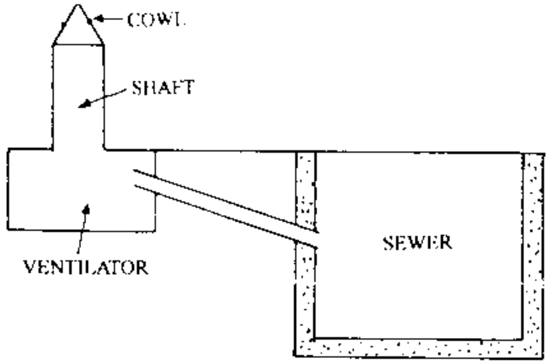


Fig. 11.14. Sewer ventilation

11.17. MAINTENANCE OF SEWERS

For efficient and proper working of sewer lines, their proper maintenance is essential. All sever lines are liable to corrosion, erosion and deterioration. Maintenance of sewers mainly consists of removal of stoppages, cleaning of sewers and other sewer appurtenances and repair work. Maintenance of those sewers is costly which are laid on flat slopes as they are more prone for heavily clogging and the self cleansing velocity is not developed. Sewers which are liable to be clogged by the entrance of tree roots through faulty joints are costly to maintain.

Cleaning of clogging sewers due to silt, grease and oily materials is one of the major problem of maintenance of sewer line. It is also most costly operation. Major causes of cleaning a sewer line are their breakage, clogging and odours. The breakage of sewer may take place due to poor foundation, excessive super imposed loads, impact due to vibrations etc. The corrosive matter of sewage eats away slowly the material of the sewer resulting in its failure or breakage.

The clogging mainly occurs in small sized sewers, where a man cannot enter into them to clean. The clogging may be due to the deposition of sand, silt, grit, and waste building materials and ashes etc. It may also be caused by the deposition of grease and oily materials contributed by hotels, garages, soap industries etc. Odours in sewers is developed due to the decomposition of organic matter present in the sewage. Thus it is essential to clean the sewer line.

For good maintenance of sewer system, its upto date plans showing location of manholes and other appurtenances, direction of flow, house sewers and grades of sewer line etc. should be available. Before starting actual cleaning and repair work, the inspection of the sewer line and its appurtenances must be carried out. In some cities inspection and maintenance works are carried out when difficulties arise, where as in some cities inspections and repair works are carried out periodically as per schedule. The period of inspection generally followed is as follows:

1. Sewers on flat grades	3 months
2. Sewers not likely to be affected by tree roots	3 months
3. Trouble free sewers	6 to 12 months
4. Intercepting sewers	One to four weeks
5. Flushing tanks	1 month
6. Storm water over flows	during rains only

11.18. CAUSES OF DAMAGES TO SEWERS

Main causes of damages to sewers are as follows:

1. Use of poor quality materials and bad workmanship.
2. Excessive super imposed loads and faulty design.
3. Settlement of foundation due to low bearing capacity of soil.
4. Small soil cover on the crown of the sewer to withstand the shock, impact, vibrations due to moving vehicles.
5. Explosion in side the sewer due to improper ventilation of the explosive gases developed in side the sewer.
6. Abrasion of sewers due to grit, sand etc. flowing with the sewage and corrosion of sewer pipe due the corrosive gases which eat away the sewer material resulting in its breakage.
7. Breakage due to old age etc.

11.19. PROBLEMS OF SEWER MAINTENANCE

Following are the main problems of sewer maintenance:

Clogging of sewers

Clogging of sewers takes place due to the following reasons:

(*i*) Deposition of silt, grit or other such material cause stagnation of sewage causing to decompose organic matter present in the sewage, producing poisonous gases and unpleasant odour in the sewer. The oily and greasy matter from the discharge of hotels kitchens, garags, soap factors etc. deposit on the side of the sewer, reducing its cross section, which in course of time clog the sewer.

(*ii*) Penetration of tree roots through faulty joints or cracked sewer pipes chock the sewer.

(*iii*) Growth of fungii forms a net work of tendril which floats on the surface of the sewage and obstracts its free flow.

(*iv*) Stagnation of sewage in sewers due to improper working of pumping units leads to the settlement of grit and other materials and dumping of solid waste in the man hole clogs the sewer line.

11.20. HAZARDS

The staff engaged in the operation and maintenance operations of the sewerage system is exposed to different kinds of hazards such as physical injuries caused by chemical and radio active wastes, infections caused by pathogenic bacteria present in the sewage, damages from explosive vapours and oxygen deficiency. These hazards can be minimised to a great extent by adopting suitable safe guards at the time of designing sewers, their appurtenances and pumping stations. Hazards at the time of maintenance still can be reduced by using safety equipment and taking precautions against likely hazard. Maintenance work should be supervised and executed by trained personels.

As stated above also, sewerage contains high percentage of carbon dioxide, methane, hydrogen sulphide, hydrogen and low percentage of oxygen. The main hazard is due to the presence of high level of methane forming an explosive mixture or oxygen deficiency or hydrogen sulphide in excess of permissible limit. Gases like ammonia, chlorine and sulpher dioxide are also found in the sewer and man holes.

When gases like nitrogen, methane, and hydrogen breathed in high concentration act mechanically by excluding oxygen. When carbon monoxide inhaled, combines with the hemoglobin of the blood, either prevent oxygen from reaching the blood or its tissues or prevents tissues from using it. Chlorine is an irritant substance which when inhaled injures the air passage and lungs and produces inflammation on the surface of the respiratory tracts.

11.20.1. Precautions against hazards

Before entering a manhole for inspection and cleaning an obstruction in the sewer, it should be ensured that the sewer and manhole is free from all injurious gases and vapours. Following precautions should be taken before entering a manhole either for inspection or cleaning the obstruction.

1. No smoking should be allowed inside the man hole or sewer. No flames and sparks should be allowed near the manhole.
2. While cleaning the sewer, traffic warning sign board should be placed on road near the work.
3. In the man hole safety explosion proof electric lighting equipment or light reflection mirrors should be used.
4. Atmosphere should be tested for the presence of noxious gases and oxygen deficiency.
5. When the atmosphere is normal, the worker should enter the manhole or sewer with safety equipment and two persons should be deputed at the top for emergency help.
6. In case oxygen deficiency or presence of noxious gases, is detected, emergency or forced ventilation should be resorted using portable blowers.
7. In case, forced ventilation is not possible and workers have to enter into the sewer in emergency then they should wear the gas mask and carry only the permissible safety light and should wear rubber shoes and non sparking tools should be used.
8. Only the experienced persons fully equipped with safety equipment should be allowed to enter the sewer in such conditions.

11.20.2. Precautions against infection

1. All concerned workers should be well informed about the hazards of water born diseases through sewage and tetanus through the cuts and wounds.
2. Workers should be instructed to use rubber gloves in side sewer and no sewage should come in direct contact of the hands.
3. Workers should be provided with working dress which should be worn while working in sewers or man holes. They should also wear rubber shoes.
4. Workers should be educated about the importance of hygienes. Their nails should be well trimmed. They should wash their hands with soap and warm water before taking meals. While working they should keep fingers away from nose, mouth and eyes.
5. First aid kit should be available for emergency and minor needs. Services of qualified doctor should be available.

11.21. SAFETY EQUIPMENT

Usually following equipment is used by workers connected with sewer maintenance:

1. **Gas mask.** A gas mask consists of face cloth, small cylinder (canister) containing purifying chemicals, a timer for indicating duration of service and a support piece. The gas mask provides necessary respiratory protection against organic vapours, acid gases, carbon monoxide upto 2%. Concentration, toxic dust fumes and smokes. How ever they can not be used in oxygen deficient atmosphere or unventilated locations etc.

2. **Oxygen breathing apparatus.** This apparatus protects the workers fully against all gases, vapours, fumes, dust, smokes, oxygen deficiencies etc. This is a dependable device.
3. **Portable lighting equipment.** Portable hand lamps of permissible type as explosion proof flesh lights, and electric cap lamps etc.
4. **Portable air blowers.** To provide forced ventilation in man holes, tanks etc. portable air blowers may be used.
5. **Non sparking tools.** During sewage maintenance works, tools made of alloy (containing at least 80% copper) should be used as they will not produce spark when struck against other objects and metals.
6. **Inhalators.** These are used to bring back to consciousness drowned or electric shoked or collapsed persons. It contains a mixture of oxygen and carbon dioxide. Carbon dioxide used in small percentage stimulates deep breathing, so that more oxygen is inhaled. Pure oxygen should be used only when the collapse of person has occurred due to clorine or hydrogen sulphide gas known as irritant gas.
7. **Safety belt.** This belt is consists of a body belt with a buckle and shoulder harness or device. The life line is of a steel cable or high quality manila rope, anchored with rings on each side of the belt and with safety straps for securing to a stable support. The length of life line should be 15 m and it should be capable to with hold a load of 2000 kg. The safety belt and life line should be tested daily before use.

11.22. SEWER CLEANING

The cleaning of large sewers is done manually. The worker enters the sewer through man hole and scrapes the sides with tools carried for this purpose. The bottom is cleaned of rubbis by phawara and collected at the platform of man hole. This scraped material is taken out through man holes. All necessary precautions as stated above should be taken when entering the sewer.

Small sewers are cleaned by flushing with the help of automatic flushing tanks. The automatic flushing tank is installed on the sewer line and a fire hose with nozzle is inserted in the sewer. Water under pressure is discharged through the nozzle to clean the sewer. When flushing is found inadequate to clean the sewer other methods are employed to clean the small sewers.

11.23. METHODS OF SEWER CLEANING

Following methods may be employed for this purpose.

1. Flexible rod

A flexible road about 30 m length is inserted into the sewer and pushed to and fro (back ward and forward). The movement of the rod dislodges the obstruction, which is removed easily by flushing. In place of flexible rod a steel tape may also be used. The steel tape may be 3 mm thick and 20 mm to 50 mm wide. This method is found useful for small sewers where a man can not enter the sewer.

2. Use of balls (pills)

In this method balls made of wood, hollow metal balls or rubber balls covered with canvas are used. A small ball is put in the man hole above the obstruction. The ball floats in the sewage and when it comes in contact of the obstruction it is caught there and blocks the passage of sewage. Thus sewage starts collecting there behind the obstruction raising the head up stream side. When the sufficient head is developed, it exerts a force on the obstruction and dislodges it. The dislodged obstacle flows with the sewage. The ball is collected in the next man hole. Then a ball slightly larger diameter than the previous one is used and the process is repeated. A ball having diameter about 25 mm less than the diameter of the sewer passes easily from one man hole to the other.

Now a days some improved version of this method has been adopted. The balls used generally are made of rubber, which can be inflated upto varying degree of inflation. The balls are available from 150mm to 750 mm in diameter when fully inflated. For cleaning the sewer, the ball is inflated and covered in a canvas cloth and the edges of the cloth are sewed to getter. A trail line little longer than the distance between two man holes is attached to the covering cloth securely. The size of inflated ball with cover should be such so that it may fit into the sewer tightly.

Immediately after placing the ball in the sewer, sewage starts heading up in the manhole till the pressure developed is sufficient enough to force sewage under the ball and moving it to down stream side. The ball acting as compressible floating plug, affords enough obstruction to produce a continuous high velocity jet of sewage under the ball and to some extent around it moving the material ahead to the next man hole. If the ball encounters an immovable obstruction, it indents as per need and moves forward. By this method, bricks, bottles, broken pieces of pipes, gravel, sand etc. can be moved ahead easily and collected at man holes and removed manually out side. When the ball stops momentarily, a pull is exerted on the trial line to set the ball in motion again.

3. Use of portable pump set

These pumps are used to clean the sewer in situations where sewers are blocked completely and sewage has accumulated in man holes. These pumps should be self primed and non clogging type.

4. Sectioned rods

These rods are used for cleaning small sewers. These rods may be of bamboo, teak or light metal of about 10 m length. At the end of these rods a coupling is attached which remains intact in the sewer but can be taken out or disjointed easily at man hole. Sections of rod are pushed in sewer line till the obstruction is reached and dislodged. To cut and remove the obstacle, the front edge of the rod is fitted with a cutting edge. These rods may also be used to locate the obstruction from either manhole.

5. Use of sandwiched flexible rods

Such flexible rods are used for routine sewer cleaning work. This type of rod is made by sand wiching a manila rope between bamboo strips and tying at short intervals. The end of this rod is tied with a thickener rope.

The flexible rod is lowered into the manhole by a person standing on top, while an other worker in side the man hole pushes the rod into the sewer in the direction of flow. As soon as the end of the 60 m rod is thrust into the sewer it is connected to a thick manila rope. The worker deputed in the next down stream manhole receives the end of the rod and pushes it out of the manhole. He catch holds the manila rope end and drags through the sewer. This manila rope is got coiled at the down stream end manhole. When the rope is dragged through the sewer, the silt is drawn out of the sewer into the down stream manhole, from where it is taken out manually. Now the process is repeated for the next section and continued till the full sewer line is cleaned. Along with cleaning, other repairs in side the man hole, foot steps etc. can be done simultaneously.

6. Use of ferret and fire hose

As shown in Fig. 11.15 a fire hose is attached to the fire hydrant and the nozzle of the hose pipe is inserted into the sewer throw man hole. This method is used for breaking and removing sand blockade. From the fire hydrant a high velocity jet stream of water is sent towards

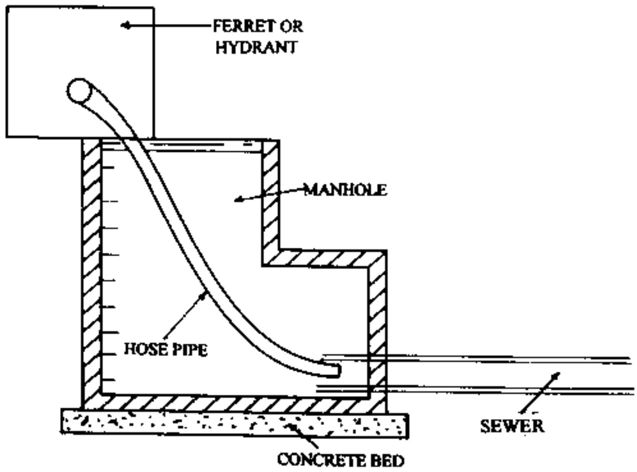


Fig. 11.15. Ferret and hose pipe method

upstream and down stream side of the sewer. The forward stream loosens the accumulated sand debris ahead of the ferret tool and the rear jets of ferret admit water to wash the sand back to down stream. This sand can be removed from the next nanhole manually.

7. Sewer cleaning bucket machine

This machine consists of two power driven winches and a cable between them. For cleaning an section of the sewer the winches are placed over the two adjacent manholes. Cable from one winch to the other has to be taken through the sewer line by means of sewer rods. The cable from the drum of each winch is tied

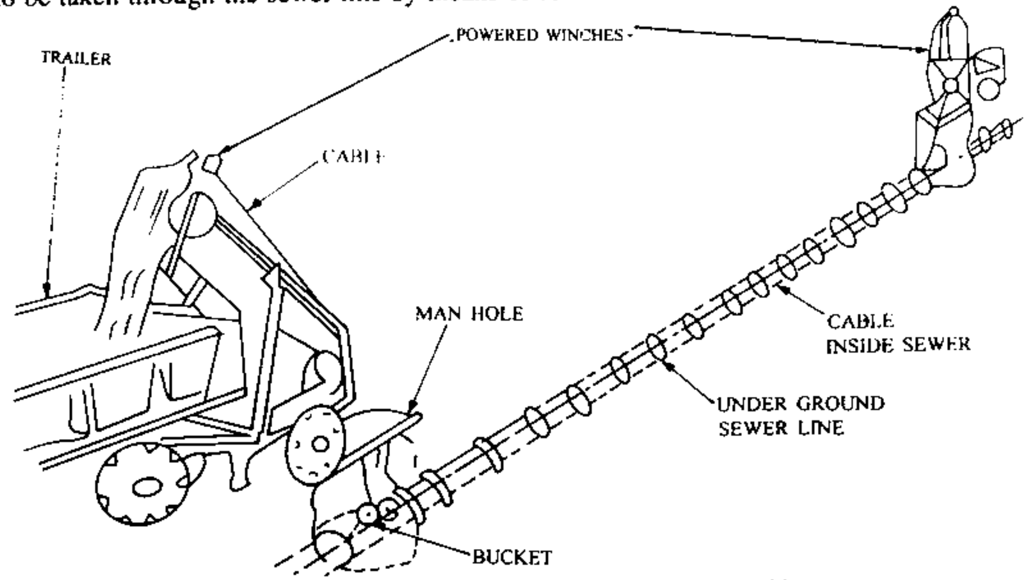


Fig. 11.16. Sewer cleaning bucket machine

or fastened to the barrel on each end of an expansion sewer bucket. This bucket is also fitted with a closing device. This bucket can be pulled in either direction by the machine on the appropriate end. The bucket is pulled into the loosened material of the sewer till it is full with the debris. Now the motor is thrown out of gear and the appropriate winch is operated. On the application of opposite pull, the bucket automatically closes and the debris is put in a truck or trailer. This operation is repeated till the sewer line is clear. This machine can also be used with other scraping instruments for loosening sludge banks of detritus or cutting roots and removing obstructions from the sewer line.

8. Rodding machine with flexible sewer rods

This machine consists of a flexible rod to which the cleaning tools are attached. The flexible rod consists of a number of steel rods with screw couplings. The flexible rod is guided through the man hole by a vent pipe. The rod is rotated by the machine with the help of a tool attached to one end. The rotating rod is pushed manually into the bent pipe with clamps having long handles, holding the rod near the coupling. While the tool is loosening the obstruction the rod is moved to and fro at a high speed. After cleaning the obstruction, rod is pulled out by means of clamps keeping the rod rotating which facilitates the quick and easy removal of the obstruction.

9. Sewer Scrapers

For sewers of more than 750 mm diameter scraper is used for cleaning the sewer. It consists of wooden planks assembled in the sewer shape of slightly smaller size than the sewer to be cleaned. The scraper can be assembled out side and lowered through the man hole. If it is not possible to lower it through the man hole, then it can be assembled in the man hole. The scraper chain is attached to a central chain in the man hole where it is lowered. Now this chain is connected to a winch on the next down stream man hole by means of a chain.

Now the winch is operated to push the debris ahead of the scraper. The heading up of the flow behind the scraper also helps in pushing the debris in the forward direction. The movement of the scraper ensures the thorough cleaning of sides and bottom of the sewer. The scraped debris can be removed manually from the sewer through man holes.

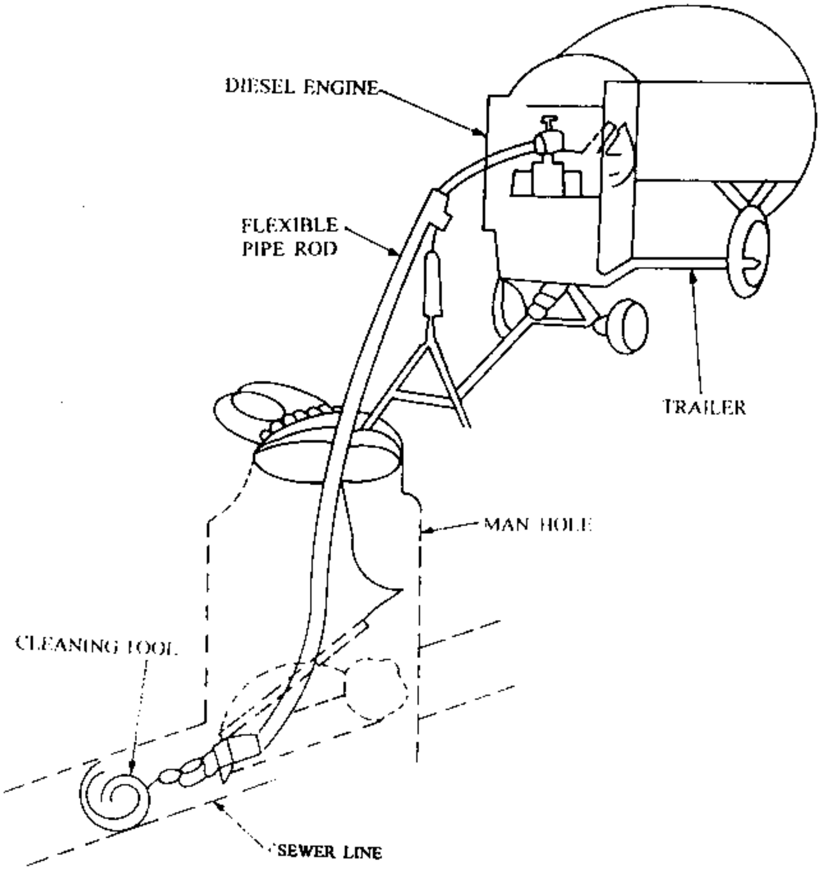


Fig. 11.17. Rodding machine with flexible sewer rods

10. Dredger

Dredgers are used for cleaning large diameter sewers. The system consists of a crane pulley block and grab bucket. The grab bucket is lowered into the sewer with the help of pulleys. The bucket is draged in the opposite direction of the flow. In this operation, the bucket scrapes the bottom deposits. The bucket is raised when it is full of debris. In this operation, the bucket closes and does not allow the debris to fall. The bucket is brought on the ground over the truck, where the bucket opens and drops the debris into the truck automatically. However a dredger can not clean the corners deposits of the man holes.

11. Flush bags

In situations where rods can not be used for cleaning the small sewers, this method has proved a very effective tool for cleaning the sewers. The flush bag is a rubber or canvas bag. At one end of this bag a fire hose coupler is attached while on the other end a reducer. The flush bag is connected to the fire hose and is placed on the down stream side of the chocked location. The bag is allowed to fill with water till it expands and seals the sewer fully. Due to the blockage of sewer, water heads up on up stream side and creates water pressure and breaks the obstruction. Pressure should not be allowed to develop so high, which may cause the flow of sewage back into the house connections or break the sewer or its joints.

12. Sewer scooter

This is an improved version of the scraper method and consists of two jacks, a controlling rope and a scooter with a light shield. The scooter completely stops the flow of sewage. The scooter is attached to the control rope and lowered into the sewer line through the man hole. The downstream manhole jack is lowered into place from the road and the upstream manhole jack is set across the top of the manhole.

When the scooter is lowered into the sewer, it stops the flow of sewage and builds up a head behind the shield. The resulting pressure makes the scooter to move through the sewer till it accumulates enough debris to stop its movement. The head is allowed to build upto 1.0 m of water approximately, before the control rope is pulled to fold back the shield to allow the accumulated sewage to gush to the down stream flushing the sewer debris to the next man hole. Now again the control rope is released, cleaning the shield against sewage and causing the scooter to advance further till the debris stops its movement. The process is repeated till the scoter reaches the down stream man hole, where it can be taken out or allowed to continue through the next section.

11.24. PREVENTIVE MAINTENANCE

The clogging of sewer may be prevented by periodical removal of silt etc. from the sewer line and repairs of manholes. Sewer maintenance gang should work under the supervision of a competent and experienced person well trained in the use of necessary tools and equipment etc.

11.25. CLEANING OF CATCH BASINS OR PITS

Catch pits are provided for collecting storm water and should be cleared after every storm. Catch pits contain silt, sand and debris etc. Water contained in catch pits may become the breading place of mosquitoes. The traces of organic matter in the silt of catch pits will give unpleasant odour. The oil and grease traps should also be periodically cleaned to avoid nuisance due to unpleasant odour.

11.26. PERIODICAL REPAIRS

To prevent the heavy damage and deterioration of the sewers, periodical repairs are necessary. The sections of sewer which need repairs should be marked during the inspection and they should be attended immediately. Usually following repairs are required.

1. **Brick sewers.** Brick sewers require frequent repairs of the following elements:
   - (*a*) Pointing of joints and replacement of fallen arch bricks.
   - (*b*) Plastering and painting of manholes.
   - (*c*) Replacement of manhole frames and covers that have worn out or broken and have become noisy.
   - (*d*) Replacement of broken or cracked and crushed portions of pipe.
   - (*e*) Raising or lowering the man hole heads to keep them flush with the road level due to change in roads and street levels.
   - (*f*) Tightening of manhole covers which have become loose and give noise under the vehicular traffic.
   - (*g*) Replacement of broken pipes.
   - (*h*) Re construction of damaged house connections etc.
   - (*i*) Repair of defective house sewer connections and street sewers.
   - (*j*) The vetilating shafts should be checked frequently to ensure their proper functioning.
   - (*k*) The joints of lateral sewers with branch sewers should be made water tight periodically.

11.27. EXPLOSION IN SEWERS

If the sewers are not properly ventilated, there are chances of occurring explosions in sewer lines blowing manhole covers into the air. The main cause of such explosions is the presence of combustible gases produced due to the presence of gasoline, methane gas, neptha, grease solvents etc. These materials come to the sewer line from the discharges of filling stations, garages, chemical industries etc. Calcium carbide may also cause explosion in sewer line.

11.28. PRECAUTIONS TO BE TAKEN BEFORE ENTERING INTO THE SEWER LINE

Before entering a sewer line, the workers should take the following precautions:

1. The covers of at least three consequitive man holes should be opened at least one hour before entering into the sewer line.
2. Before entering into the man hole, a burning candle should be lowered into the man hole to check the presence of explosive gases. If there are explosive gases, an explosion will take place, giving a warning to the workers.

3. Only Electric lamps or dry cell torches should be used inside sewer line for light.
4. The presence of hydrogen sulphide gas may be detected by lowering a wet lead acetate paper in side the man hole.

11.29. DAMP PROOFING TREATMENT OF DEPRESSED FLOORS

In bath room, kitchen and other such areas depressed R.C.C. slab should be provided to accommodate the Indian Pan, floor traps etc. This location is particularly vulnerable to dampness due to any leakage in the pipe or ingress of water of the sunken slab portion from w.c., or bath room floor etc. The leakage is known when the unsightly patches of dampness have appeared on the walls and ceiling. During repair period the facility would have to be kept out of use causing inconvenience to the occupants.

Precautions to be adopted

Following precautions should be adopted for the damp proofing of sunken floors:

1. The slab should not be depressed much beyond the necessity. The portion of R.C.C. which accommodates the pan and the trap should be depressed and a suitable slope should be given to take the water to the rear portion of the w.c. pan. A corrosion resistant G.I. pipe of 25 mm diameter should be provided to drain off any water accumulated in the depressed area as shown in Fig. 11.18.

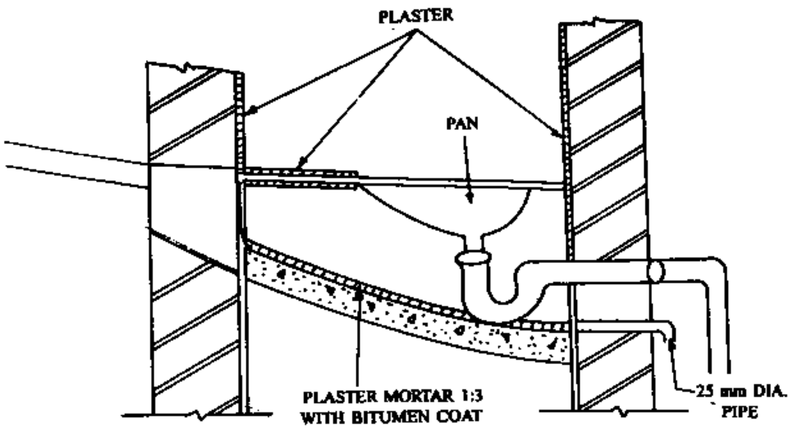


Fig. 11.18. Damp proofing of depressed slab

2. The depressed area should be made water proof. The surface of the slab and the walls should be thoroughly scraped and cleared of all loose materials etc. It should be completely dry and smooth before the application of the damp proof treatment.
3. The bottom of the depressed slab and walls should be plastered with a 1:3 cement sand mortar with 2% water proofing compound. The minimum thickness of the plaster should be 20 mm and it should be given a floating coat of neat cement.
4. The treated surface should be cured for 7 days. After curing, it should be allowed to get completely dry.
5. The dry surface of the slab should be given a coat of hot bitumen of grade 85/25 at the rate of 1.5 kg/m^2. This coat also be continued on the vertical surface of the walls.

11.30. DAMP-PROOFING OF FLOOR TRAPS

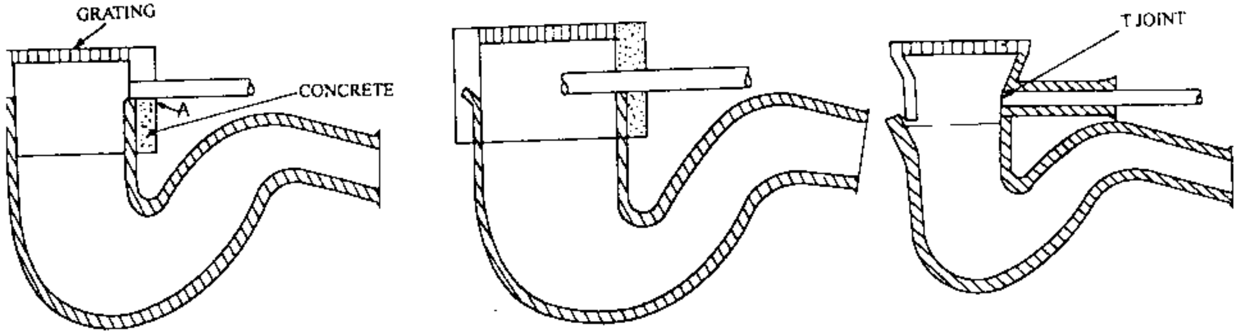
Though sanitary appliances differ from each other in the case of water closet, bath room and kitchen, but floor trap is a common fitment to all. Improper design and installation of floor traps causes dampness and leakage in the building. Hence to avoid dampness and leakage following precautions should be taken.

1. The level of the floor trap should be fixed in relation to the finished floor level. If there is a gap between the floor level where the Jali grating of floor trap is kept and the main body of the floor trap, the gap between the two should be properly water proofed, other wise it will be a vulnerable

spot for the penetration of moisture during the use of the facility.

To avoid any gap between the floor level and top of the trap an additional piece of pipe may be provided. For this purpose a G.I. pipe or UPVC pipe of required length should be cut and properly jointed with the floor trap. Alternatively the area surrounding the gap should be filled carefully with 1:4 cement sand mortar with 2% water proofing compound and finished with neat cement plaster and cured for seven days. It should be finished with two coats of water proofing paint after the cement punning (plaster) has dried fully.

2. The faulty jointing of the trap with the drain pipe is a common cause of dampness and leakage in a building. Hence the waste pipe must be cut to the correct size so that neither it is too short Fig. 11.19 (*a*) nor over shorts Fig. 11.19 (*b*) the edge. The correct methods is to have a T junction as shown in Fig. 11.19 (*c*).



(*a*) (*b*) (*c*)

Fig. 11.19.

3. When floor trap is almost at the floor level, when ever a great amount of water is split, a pool of water is created around the trap, which may cause dampness. To prevent this dampness, the floor around the trap should be sunk by 25 mm and should be finished with impervious material.
4. The depression in R.C.C. slab for fixing the floor trap in Kitchen and bath should be adequate.
5. Smoke or air test may be carried out before covering the joints from the trap to the stack.

11.31. SEPTIC TANK

A septic tank is a combined sedimentation and digestion tank, where sewage is held for some time and the suspended solids settle down to the bottom of the tank. The sludge is digested by the anaerobic bacteria. By this action the sludge is reduced in volume sufficiently and a liquid is released as effluent. In this reaction gases as carbon dioxide, methane and hydrogen sulphide are released. The smell of hydrogen sulphide is very pungent. The effluent though clarified to some extent, but still contains considerable amount of dissolved and suspended putrifiable organic solids and viable pathogens. Thus the disposal of effluent requires a careful disposal. Due to the difficulty of disposal of effluent and difficulty in providing a proper system of disposal for it, the septic tanks are recommended to be adopted for isolated buildings, small institutions and big hotels and camps. Thus septic tanks are suitable for isolated or un developed areas of the locality where municipal

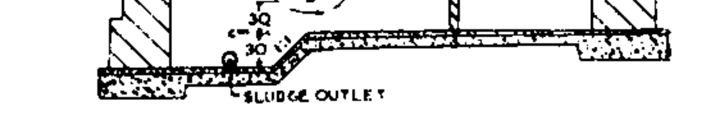


Fig. 11.20. Septic tank for one family

sewers are not laid and there is no facility to convey and treat the sewage in the public sewage treatment plants.

For the satisfactory functioning of septic tanks, adequate water supply is essential. Water containing excessive detergents and disinfectants is un suitable for treatment of septic tanks and should not be allowed to enter in septic tanks. Septic tanks should not be located in swampy areas or areas prone to floods.

The septic tank effluent should not be allowed to flow into open drainage system as it can cause health hazards, nuisance and mosquito breeding. Fig. 11.20 shows a septic tank for a family and Fig. 11.21 for public.

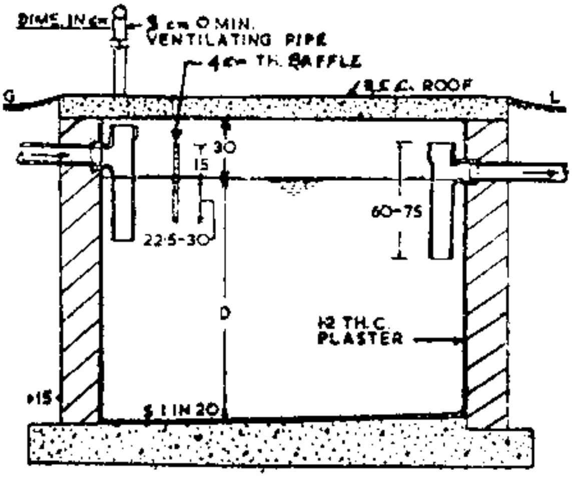


Fig. 11.21. Public septic tank

11.31.1. Disposal of effluent

As the effluent from the septic tank is highly odorous, it should be disposed off carefully. It can be disposed off in the following ways.

1. It may be disposed off through under ground trenches. If the soil of underground trench is porous, it is best as the effluent will be absorbed by it.
2. Gardening. After proper treatment, this effluent may be used for gardening.
3. Soak pits. A soak pit is a hollow circular or rectangular pit. It is lined from inside as in a well with brick masonry having open joints. The depth of soak pit may vary from 1.2 m to 1.8 m or more depending on the situation. The effluent falls in the pit and is allowed to be absorbed by the surrounding soil. The pit may be filled with brick bats etc.

11.31.2. Design aspects of septic tank

1. **Capacity.** The volume of septic tank can be decided on the following two considerations.
   (*a*) By the consideration of quantity of flow and the detention period. The volume per head may be kept form 57 to 85 lit.
   (*b*) It can also be designed on the per capita flow, which varies from 60 to 110 litres per person per day to be served by the tank. The space for sludge usually is kept at the rate of 15 to 45 litres per capita per year.
2. **Detention period.** Detention period varies from 12 to 72 hours. The common period is taken as 24 hours.
3. Free board. 40 to 60 cm free board is sufficient.
4. **Shape of tank.** Generally septic tanks are designed as rectangular, with length to breadth ratio as 1:2 to 1:4.
5. **Height.** Height of septic tank may be kept from 1.8 m to 3.0 m. The height for smaller septic tanks may be kept as 0.9 m. The dimension of septic tank depends on the number of users.

For different groups of users, septic tank dimensions may be adopted as shown in the table 11.4 below.

11.31.3. Construction of septic tank

The constructional details are shown in Fig. 11.20 and 11.21 Following points should be noted with the construction of septic tank.

1. The materials of construction of septic tank should be corrosion resistant.
2. The construction of septic tank should be such that no direct current is established between inlet

and out let. This is achieved by providing baffle walls near the inlet and out let ends. The level of out let should be about 15 cm lower than the inlet.

3. Septic tank should be properly ventilated by means of air vent pipes.
4. The top cover of septic tank usually is made of R.C.C. A man hole is also provided in R.C.C. slab for inspection and cleaning it. Cast iron steps may also be provided to facilitate the descending down in the tank.
5. The sludge is allowed to accommodate at the bottom of the tank and can be removed either manually or by pumping at desired interval of 6 month or 1 year.
6. At the start of working of the tank, it should be filled with water. Effluent of the tank should be disposed off properly.
7. A septic tank combines the function of a sedimentation tank, a sludge digestion tank and a sludge storage tank.
8. A septic tank should be cleared every 6 to 12 month as the deposition of sludge at the bottom decreases its capacity. But the period of clearance should not be more than 3 years in any case.

Table 11.4.

No of users	*Length L m*	*Breath B m*	*Liquid Depth D min in m*	*Liquid capacity to be provided m^3*	*Free board min in cms*	*Sludge to be removed m^3*	*Recommended interval of cleaning*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
5	1.5	0.75	1.0	1.12	30	0.18	6 months
			1.0	1.12	30	0.38	1 year
			1.5	1.18	30	0.72	2 years
10	2.0	0.9	1.0	1.8	30	0.36	6 months
			1.0	1.8	30	0.72	1 year
			1.4	2.52	30	1.44	2 years
15	2.0	0.9	1.0	1.8	30	0.54	6 months
			1.3	2.34	30	1.08	1 year
			2.0	3.6	30	2.16	2 years
20	2.3	1.1	1.0	2.53	30	0.72	6 months
			1.3	3.3	30	1.44	1 year
			1.8	4.55	30	2.88	2 years
50	4	1.4	1.0	5.6	30	1.8	6 months
			1.3	7.28	30	3.6	1 year
			2.0	11.2	30	7.2	2 years

11.32. SOAK PIT/WELL

Soak pits or wells usually are built of brick masonry. Their usual depth is 3.0 m and diameter varies from 1.0 to 1.5 m. The walls are built in dry brick work so that water may seep in the adjoining soil. The top 1 m height is built in cement. The well is filled with over burnt brick bats or cinder. The top is covered with R.C.C. slab with a man hole.

The effluent from the septic tank is taken to the soak well throw S.W. pipes which trickles through the brick bats filled in. When the brick bats become saturated it seeps into the soil through dry brick joints.

Soak wells require periodic cleaning when the filled material becomes saturated and clogged and the well does not function efficiently. The filled material is taken out through the manhole, cleaned and dried. The well walls are repaired if found damaged. It is filled with dry fili as before for normal function Fig. 11.22.

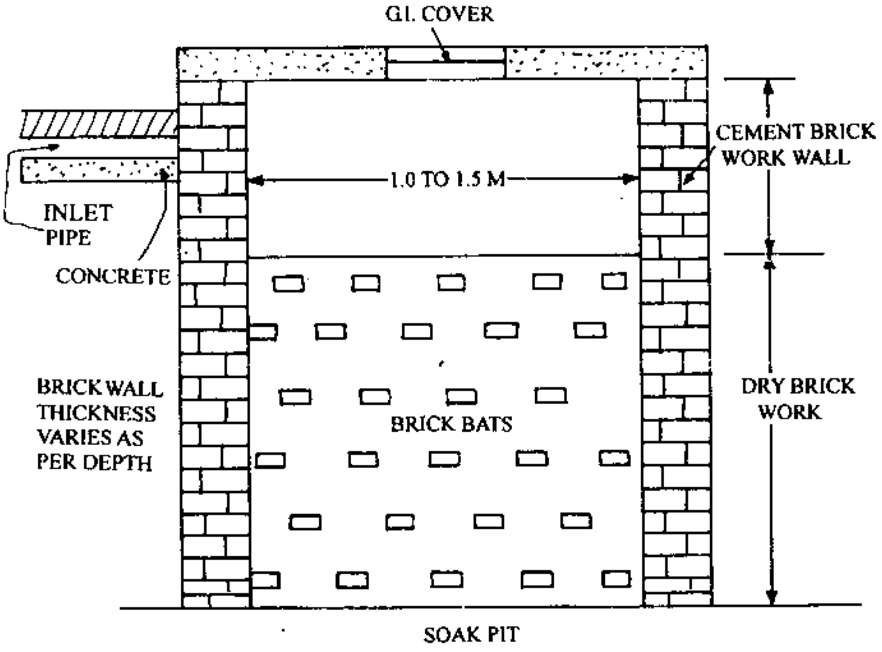


Fig. 11.22.

Example 1. *design a septic tank for a hostel having 150 students. The rate of water supply is 135 litre per day per head. Also find out the size of soak well, if whole of the effluent is discharged into it.*

Solution. Assuming that whole of water supply goes as sewage.

Then flow of sewage per day

Assuming 18 hours as detention period, $= 150 \times 135 = 20250$ lit.

Capacity of tank $= \dfrac{20250}{24} \times 18 = 15187.5$ litres

Assuming that tank is cleared every two years, the studge storage capacity per person is taken as 1 litres per year.

$= 150 \times 15 \times 2 = 4500$ litres

$\therefore$ Total tank capacity $= 15187.5 + 4500 = 19687.5$ litres

Keeping future expansion in view provide 25% allowance in the capacity.

$\therefore$ Total capacity $= 19687.5 + 4922 = 24609.5$ litres

$=$ say 25000 litres

$= 25\text{ m}^3$

Let the depth of tank be kept as 1.4 m

Then area of the tank $= \dfrac{25}{1.4} = 18.0\text{ m}^2$ says

Let the ratio of length to width of the tank be 1:3,

then $3B \times B = 18$

or $B^2 = 6$

or $B = \sqrt{6} = 2.5$ m say

then length of tank $= 2.5 \times 3 = 7.5$ m

Provide free board as 35 cms,

then height of tank $= 1.40 + 0.35 = 1.75$ m

Hence the dimension of the tank are $L = 7.5$ m

$B = 2.5$ m

$H = 1.75$ m

Soak well. Let the percolating capacity of the filter media of the well be 100 litres per m^2 per year.

then volume required for soak pit $= \dfrac{25000}{1000} = 25\ \text{m}^3$

Let the depth of soak well be 2.5 m,

then Area of soak well $= \dfrac{25}{2.5} = 10\ \text{m}^2$

Let diameter of soak well $= d$

the $\dfrac{\pi}{4} d^2 = 10$

or $d = \sqrt{\dfrac{40}{\pi}} = 3.6$ m

Diameter of soak well may be adopted as 3.6 m.

If depth is taken as 3.0 m, than adopt diameter as 3.25 m. **Ans.**

QUESTIONS

1. Define sewer. What factors govern the choice of selection of sewer material?
2. Name different shapes of sewers. Give the merits and demerits of circular and non circular sewers.
3. Enumerate the requirement of a good sewer joint.
4. Give the procedure of laying and testing of sewers.
5. Why sewers should be ventilated? Give a method of ventilating of a sewer with sketch.
6. Why is cleaning and maintenance of sewers is essential?
7. Give different methods of cleaning of sewers.
8. Give reasons for the followings:
   (*a*) Sewage may be erosive
   (*b*) For steel sewers riveting is objectionable
   (*c*) Circular shaped sewers are usually adopted
   (*d*) Sewers usually are laid below water mains
   (*e*) Sewers laid at flat slopes are more prone to clogging
9. Identify the incorrect statement/statements
   (*a*) Circular sewer section has more perimeter than other shapes of sewers
   (*b*) Circular sewer section requires more construction material
   (*c*) Circular sewer section has more hoop tension, hence needs more reinforcement
   (*d*) Circular sewer sections have least hydraulic properties
   (*e*) None
   (*f*) All
10. Identify the correct statement/statements
    (*a*) Cement asbestos pipes can be cut and join easily
    (*b*) The internal surface of stone ware sewers is smooth and impervious
    (*c*) Stone ware sewers are brittle and likely to be damaged during transport and handling operations
    (*d*) Cast iron sewers are liable to be affected by acids of sewage
    (*e*) All are correct
    (*f*) Non is correct

11. Identify the true/false statements
    (*a*) Cast iron sewers are used where sewers are laid under or over the water pipe lines
    (*b*) Cast iron sewers are desirable when sewers are liable to vibrations and heavy over burden pressure
    (*c*) Steel sewers are not-desirable for situations where they are likely to with stand heavy vibrations and shocks
    (*d*) Riveting joints steel sewers are advantageous
    (*e*) R.C.C. sewers have long life.
    (*f*) Egg shaped sewer section is the best shape for carrying combined flow
    (*g*) Cement mortar joints are not widely used in the construction of sewers
    (*h*) Collar joints are used for small diameter sewers.
    (*i*) Mechanical joints are provided in cement concrete sewers
    (*j*) Flexible joints are provided where sewer line is liable to settlement
    (*k*) Steel sewers are usually used for main and trunk sewers having diameter more than 750 mm
    (*l*) The sulphuric acid fumes formed in the sewer, attack the concrete and reduce its strength resulting in its failure
    (*m*) Riveting joint in steel sewers enhances the efficiency of flow of sewage

ANSWERS

9. (*f*), 10. (*e*)
11. T—(*a*), (*b*), (*f*), (*j*), (*k*), (*l*)
11. F—(*c*), (*d*), (*e*), (*g*), (*h*), (*i*), (*m*)

12

Maintenance of Canals

12.1. INTRODUCTION

In order to make canals capable to carry their designed quantity of water efficiently, their proper maintenance is essential. All channels whether lined or unlined require proper maintenance. In earthen channels the main trouble is due to the silt deposition on side slopes and bed in some sections and erosion of slopes and bed at other sections. It is inherrent property of water to carry silt quantity along with it as per its silt carrying capacity. The banks of canals are damaged by rain water and traffic over it. During rainy season banks and service road gets covered with vegetation and have to be cleared after every rainy season. Hence the requirement of maintenance.

12.2. WORKS TO BE MAINTAINED

Under canal maintenance usually following works are carried out.

(*a*) Maintenance of canal profile.

(*b*) Maintenance of banks and service roads.

(*c*) Repairs and control of breaches in canals.

(*d*) Weed control.

(*e*) Repair of canal lining

(*f*) Seepage control

(*g*) Gauging of canal

(*h*) Maintenance of regulation and drainage works.

12.3. MAINTENANCE OF CANAL PROFILE

In order to maintain the designed carrying capacity of the canal, it is essential to maintain its designed profile. Profile of canal includes its side slope, berm and bed slope. The silt in suspension in flowing water deposits on sides and bed. The over hanging berms may fall in the canal when running full, raising its bed and reducing its carrying capacity. The berm should be maintained at a slope of 1/2:1. Thus to indicate the designed profile of the canal section, permanent marks are constructed at an interval of 200 m in the case of small channel and 1 km in case of larger channels. These marks are called bed bars. Thus bed bars are constructed to indicate the theoretical level of bed of the channels. For small channels usually bed bars are constructed of brick masonry wall at the bottom of the channel flushed with the theoretical level of bed and slope of the channel as shown in Fig. 12.1.

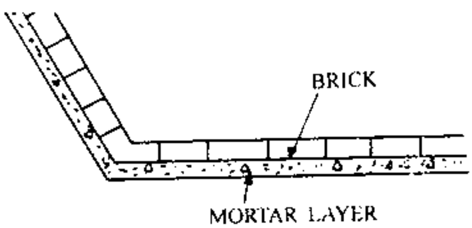


Fig. 12.1. Brick masonry bed bar

For main canals and branches, a bed bar consists of masonry or concrete block with its upper face flush with the theoretical level of the bed of the canal. The cross section of the bed bar should be sufficiently strong to withstand the thrust of the flowing water. A size of 1.0 × 1.2 × 1.5 (breadth, length and depth) has been found satisfactory. The centre of the bed block indicates the centre line of the canal.

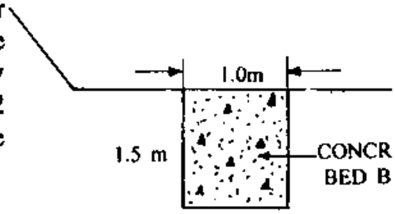


Fig. 12.2. Concrete bed bar

12.4. REPAIR OF SERVICE ROADS, BANKS AND BERMS

12.4.1. Berms

Berm is a narrow strip of land left on either side of the canal parallel to the direction of flow between the upper edge of the cutting and the inner toe of the bank. Fig. 12.3.

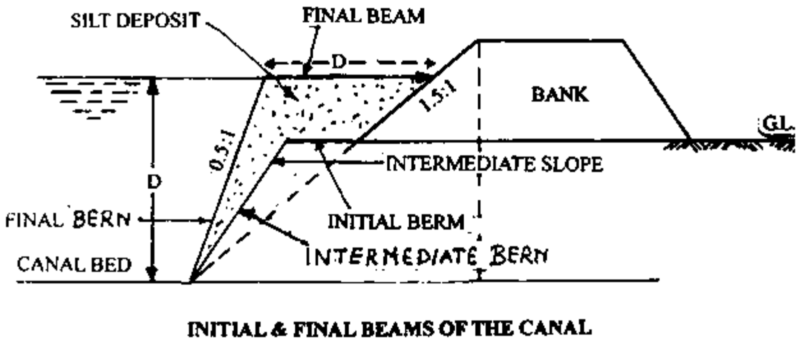


Fig. 12.3. Berm

Functions of berms

Berms serve the following functions:

1. Berms provide wider wa:er way and increase the capacity of the canal to absorb more water fluctuations.
2. Berms bring the saturation line more in side in the body of the banks reducing the possibility ‹ leaks and breaches as turf grown on berms makes them more compact and strong.
3. Berms save the banks from wave erosion by keeping the banks away from waves.
4. The width of berms for canals carrying upto 28 m^3 discharge may be taken 1.25 + 0.5 D m whe D is the depth of canal.
5. The over hanging berm should be cut at a slope of 0.5:1, otherwise it may fall in the running wat to reduce the cross section of the canal.

12.4.2. Service or inspection road

In order to have access to all parts of a canal system, inspection roads are provided. The level of the roads should be 0.5 to 1.0 m above the FSL of the canal depending upon the size of the canal. The servic roads are provided on both banks of main and branch canals. The left bank road is known as *service inspection road* and the right bank road as *transport road* for material. Where only one road is provided in case of small canals and minors, they are known as inspection or service roads and provided on the le bank only. The banks of the canal are classified as left or right by facing the canal along the direction the flow.

Initially the inspection roads were provided on the left bank due to the fact that canals in Northe plains had the general course from North to South. Thus the left bank of canal is the Eastern bank of th canal. In the morning, the visibility will be very good from this eastern bank, being in the direction of su rays and not against sun rays as would be from the right bank. Later on it became an convention even f canals running from South to North. The width of service road should be 6 m.

12.4.3. Repair of banks

Any bank to be widened should be cut in steps. Silt obtained from berms may be used to repair th banks, specially on the outer slopes. To drain off the rain water from the top of the bank, suitable drai should be provided. If service roads are not properly drained by providing suitable cross slopes, the rain water will collect over it and form holes on it. These holes should be filled and repaired and any vegetation grown on it should be removed. On service or driving bank, silt or sandy soils should not be used, instead good soil from spoil banks should be used.

As a rule, bank slope should not be cut and loose earth should not be left lying on the top of the bank. The tops of banks should be smooth and free from clods. To remove the rain water from banks the outer slopes should be provided a slope of 1 in 80.

In the maintenance of service roads following items should be attended.

1. The level and surface of the road should be properly maintained.
2. Vegetation should be cleared from the road.
3. No water should be allowed to stand on the service road.
4. Earth barriers provided at both the ends to check the unauthorized vehicles should be well maintained with a side slope of 1:4.

12.5. SILT CLEARANCE

Silt clearance is adopted to bring the canal profile to such a section through which designed discharge may be carried. Thus by desilting the canal, its cross section is enlarged to enable it to carry the designed discharge by keeping the same general slope as shown in Fig. 12.4.

Silt clearance may be necessary once or twice a year depending on the silt load in the channel with reference to the bed bar. The depth of silt deposited may be estimated by measuring it with reference to the top of the bed bar. Berms trimming and silt clearance brings the channel to its original slope. According to lacey's regime theory of flow in alluvial channels, it is unnecessary to clear the silt upto the theoretical bed level and sides as the existing silted channel indicates the correct profile.

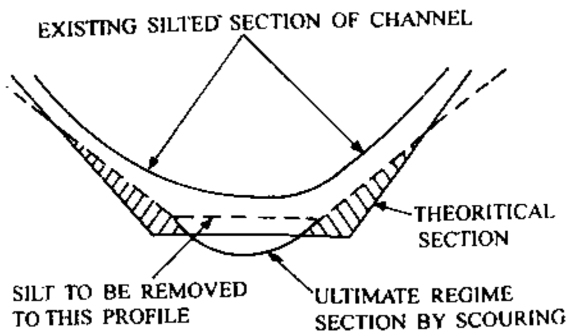


Fig. 12.4. Silt clearance

Fig. 12.4 shows the theoretical as well as silted profile of the canal. The correct profile to which the silt be cleared has been shown by dotted line. From the figure it will be seen that if the clearance is done upto the theoretical profiles, the area shown by hatched lines would silt up again and will no longer help in increasing the discharge. The simplest method is to allow the channel to establish its regime by scouring the bed and sides.

12.5.1. Methods for removing silt from canal

Before starting the silt clearance, the longitudinal and cross sections of the silted channel at the site of bed bar are prepared and the depth of silt to be excavated is marked on them. Then according to these cross sections, silt is removed and all curves and kinks in the alignment removed. Silt removed from the channel bed may be spread over the banks and outer slopes. Removed silt should not be allowed to reenter the canal and spoil it.

12.6. BREACHES IN CANAL BANKS

Breaches in canal banks may be of the following two types:

1. Natural breaches
2. Artificial breaches

12.6.1. Natural breaches

Natural breaches may take place due to the following causes:

(*a*) Due to the weak and low banks
(*b*) Due to piping
(*c*) Leakage of water through rat holes
(*d*) Running full or over flow of canal specially in rainy season

12.6.1.1. Method of checking natural breaches:

(*a*) Breaches due to weak and low banks can be checked by strengthening and raising the bank height.
(*b*) Breaches due to piping may be checked by reducing the exit gradient.
(*c*) Leakage of water through rat holes does not develop into a breech all of a sudden. It can be detected by proper inspection and checked by immediate repair of holes.
(*d*) Same as for '*a*'.

12.6.2. Artificial breaches

As the name suggests, they are man made. During the period of keen demand, some times cultivators cut the canal banks in small length, which due to water action develop into big breaches, washing away substantial length of the bank.

12.6.2.1. Remedial measures

Methods of breach closing on small and big canals are slightly different depending on the discharge in the canal. In cutting and light embankments, breach closure is easy where as in heavy embankments it is very difficult.

A. Breach closure on a small distributary or minor

In such cases closure of the channel is not necessary. In such cases earth is collected on the bank on both sides of the breach in sufficient quantity and then filled in the opening quickly from both sides. The earth may be taken from the berm pits of the channel or cutting the outer slope of the bank. The earth filled in the opening should be properly compacted. In the earth, there should be no grass or tree roots etc. The filled section should be kept under vigilance for few days.

12.7. BREACH IN A BRANCH CANAL OR LARGE DISTRIBUTARY

In such cases the breach closing can be done in the following steps:

1. Water supply should be reduced either by diversion of closing gates at the head.
2. For providing good bond between the old bank soil and new soil to be deposited steps in bank on both sides of the opening should be cut.
3. Two rows of wooden pegs or ballies are driven in the breached portion and wooden planks or tree branch, bushes etc. are placed against these stakes. These planks etc. are supported in position by pilling or stacking gunny bags filled with sand or soil. The earth work is started when the flow through the breached portion has reduced sufficiently.
4. The earth is collected on both sides of the breached portion on the bank as above and a ring bund is formed as shown in Fig. 12.5. As the ring bund reaches its completion, the velocity of water increases. Thus the last gap should be closed very quickly.
5. After the completion of the ring bund, the main gap of the breach is filled in layers and compacted properly and it is kept under vigilance for few days.

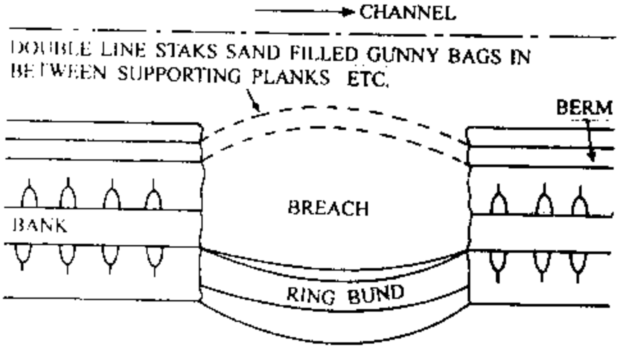


Fig. 12.5. Breach closing

12.7.1. Method of closing breaches on main canals

The method of closing breach on a main canal practically is the same as discussed above under B, with a minor difference. The only difference is that after driving the two lines of stakes or ballies gunny bags filled with sand or soil are staked against stakes instead placing wooden planks or tree branches, bushes etc. Formation of ring bund and further procedure is same as above for branch canal.

12.8. WEED GROWTH AND ITS ERADICATION

Water weeds are unwanted plants which grow profusely in water under favorable conditions of temperature and water turbidity. These weeds grow very rapidly and clog the canal system and reduce the discharge in some cases even below 15%. This causes great inconvenience to farmers. These weeds also increase the evaporation losses. Hence their removal is very essential.

12.8.1. Classification of weeds

Generally weeds can be divided into the following two categories:

(*a*) Seasonal (*b*) Perennial

(***a***) **Seasonal.** This class of weeds start growing from september october and grow to their full growth by the end of December. They propagate by seeds and once their tops are killed, the roots have no capacity to regenerate.

(***b***) **Perennial weeds.** These weeds do not die seasonally and create more trouble. Some times their height goes even more than 4.0 m. The most favorable temperature for their growth is between 20°C to 30°C. Extreme temperatures have adverse effect on their growth. Thus their eradication is very essential.

12.8.2. Prevention of weed growth

Weed growth in canal system can be prevented by adopting following measures:

(***a***) **Keeping the optimum velocity.** The velocity of flowing water in canal system should be such, which may keep the silt particles in suspension, to obstruct the sun rays to reach the root zone of weeds as sun rays are essential for their growth.

(***b***) **Avoidance of ponding.** Ponding of water should not be allowed in the canal system as still clear water is quite favourable for the growth of weeds. The bed slope should be such as not to allow the ponding conditions there. The weeds should be destroyed during closing period of the canals.

(***c***) **Adoption of rush rotation.** Running canal at some time at full supply level and then closed for some duration is known as rush rotation. It helps the prevention of weed growth in the following way.

(*i*) During dry run period the scorching sun rays will burn the weeds. During this period weeds may be plucked and burnt.

(*ii*) When the canal is running full, its velocity is high and turbidity is more. Due to more turbidity it does allow sun rays to reach the root zone of weeds which is essential for their growth. Druring full supply, the depth of water is more which cut off the sun rays preventing the weed growth.

(*iii*) Due to alternate flow and dry conditions of canal affect the growth of weeds to a great extent.

12.8.3. Eradication methods of weeds

Basically there are three methods of weed eradication as follows:

1. Mechanical method

(***a***) **Weed growth is in isolated patches.** If the weed growth is in insolated patches in main and branch canals then it can be removed by manual labour.

(*b*) **Weed growth is wide spread.** In such situation, the weeds may be cleared by dredging or chaining by mechanical machines such as drag line etc. The submerged weeds may be controlled by drying. This is done by closing the water to the canals and exposing the surface of the weeds to the sun rays. The top surface will get burnt by sun heat in the absence of water.

(*c*) **Increasing the turbidity of water.** Increase of turbidity will retard the penetration of sun rays through water. The decrease or cut off of sun rays to the root zone of weeds will destroy them as the weeds will not get sufficient nutrition for their growth.

2. Chemical method

In this method certain chemicals are used to destroy the weeds. The use of the following chemicals has been found very effective in the eradication of weeds.

(*a*) **Diesel oil.** It can be used with 3% to 5% concentration with the following chemicals:

(*i*) Penta-chlorophenol
(*ii*) 2, 4 Dichloro-phenoxy-acitic acid
(*iii*) 2, 4 dinitro-butyl phenol
(*iv*) Dinitro or Thio cresol etc.

The above chemicals have been found very effective in weed eradication if they are sprayed at the rate of one litre per square metre and then the soil is left undisturbed at least for four days. The US Bureau of Reclamation (U.S.B.R.) recommends the spray of poly borochlorate solution in water on the sub grade at the rate of 270 c.c. per square metre of surface area.

(*b*) **Sodium chlorate.** 5% solution of sodium chlorate in water when sprayed at the rate of 2 litres per square metre of area has proved very effective in weed eradication.

(*c*) **Ammate and Benochor.** These chemicals also have been found very effective in weed eradication.

3. Biological method

In this method the weed destroying agent used is known as *Cochineal*. This agent was introduced in South India in about 1940 and has been found very effective in destroying certain varieties of weeds.

12.9. CANAL LINING AND ITS REPAIR

Canal lining is a protective cover of impermeable material provided over the wetted perimeter of the canal section to check seepage of water. It has been observed that water flowing through unlined canals in U.P. and Punjab reaches the field upto 50% of the supplies at head of the canal.

12.9.1. Advantages of Canal lining

Following are the main advantages of the canal lining:

1. **Reduction of seepage**. Canal lining reduces the seepage of water resulting in saving of water which can be used to irrigate more land.
2. **Reduction in water logging.** Canal lining reduces the percolation of water to the ground water reservoir, checking the rise of ground water level.
3. **Increase in the velocity of the flowing water.** The hard and smooth surface of lining reduces the coefficient of roughness, resulting in the increase of velocity. It also helps in reducing the silting of canal. It also reduces the evaporation losses.
4. **Saving in land.** For the same volume of discharge, higher velocity needs less area of cross section. Thus the cost of land is reduced.
5. **Prevention of weed growth.** Lining of canal eliminates the growth of weeds, resulting less maintenance of canal system.
6. **Increase in stability of banks.** Due to lining with strong and hard materials, the stability of banks is increased.
7. **Prevention of erosion and breaches.** Lining protects the canal from erosion and breaches.

8. **Increase in duty of water.** Due to lining, water losses are less during transit, hence the duty of canal water increases.
9. **Improvement of command.** Due to higher velocity in lined canals, flatter bed slope of canal can be provided. Thus higher heads can be kept on outlets which increases the irrigated area by the same out let.

2.9.2. Essential requirements of lining

Following are the main requirements of the good lining:

1. **Water tightness.** The seepage losses in a lined canal should not be more than 10% of the unlined channel.
2. **Hydraulic efficiency.** The coefficient of rugocity of the lined section should be less.
3. **Initial cost and maintenance cost.** The initial cost should be moderate and maintenance should be cheap and easy.
4. **Strength and durability.** The lining should be strong and durable. Bank slopes may be $1\frac{1}{2}$:1.
5. Ability to check weed growth and attacks of burrowing animals.
6. **Ease in construction.** Construction of lining should be easy.

2.10. TYPES OF LINING

Generally lining is classified based on the material used in its construction. Following are the main ypes of lining used on canal system:

1. Cement concrete lining
2. Lime concrete lining
3. Shot crete or guniting
4. Brick or tiles lining
5. Asphaltic lining
6. Lining of earth materials

2.10.1. Cement Concrete lining

This is the most popular type of lining and has been successfully used almost in all parts of the world. Aost efficient hydraulic properties are obtained by its use. As it is a hard surface lining, its success depends o a great extent on the performance of the sub grade. The base or sub grade should be firm. Natural soils n cutting usually are satisfactory, but the embankments on which the lining is to be laid should be horoughly compacted.

Mix Proportion. Generally 1:3:6 proportion of cement concrete is used for canal lining.

Thickness. Though thickness of concrete lining depends on the requirements of imperviousness and tructural strength, but generally it varies from 5 to 11 cms. On small channels 5 cm thickness is sufficient nd on larger channels on an average 8 cms thickness is sufficient.

Bank slope. In average soils, self supporting stable slope should be $1\frac{1}{2}$:1 to $1\frac{1}{4}$:1, but it should not be latter than 1:1.

Method of Construction. The embankment should be compacted at the optimum moisture contents in 5 cm thick layers with light tractors. The compacted section should be more than the final section by 30 o 80 cm. The excess portion should be removed care fully just prior to concrete laying. The section to be concreted next day should be made saturated with water upto a depth of 5 cm in ordinary soils and upto 30 m in sandy soils. Use of oil paper over the sub grade has proved very successful.

Joints. Following construction joints may be provided in the concrete lining:

(*a*) Lap joint with separate fillet
(*b*) Butt joint
(*c*) Lap joint
(*d*) Tong and groove joint
(*e*) Asphaltic joint etc.

12.10.2. Lime Concrete lining

It is not as durable as cement concrete lining. However it is less likely to crack due to temperatur variation.

Mix proportion. In lime concrete usually kanker lime is used. Generally 1:2:6 mix proportions ar adopted.

Joints. In the bed, joints are spaced at 20 m and on sides 8 m apart. V shaped joints 25 mm at top an 6 mm at bottom are provided.

Sub grade. Same as for cement concrete.

12.10.3. Short Crete or Guniting lining

It is one of the best lining for canals. The procedure of applying cement sand mortar or concrete on th back up surface under pneumatic pressure through hose fitted with a nozzle is known as shot creating o guniting, and the cement sand mortar or concrete is known as shot crete or gunite. To the cement san mortar nozzle a water hoes nozzle is also attached. The air and water pressure at nozzle are kept as 2.2 t 3.6 kg/cm^2 for air and 3.0 to 4.6 kg/cm^2 for water.

Sand. The maximum size of sand should not be more than 6 mm and the fineness modulus may var from 2.5 to 3.3. If the sand is vary fine, it will produce weak layer subject to excessive shrinkage. On th other hand if the sand is very coarse, the amount of rebound will be excessive.

For satisfactory operation, the sand should have a moisture content between 3.0 to 6.0%, but in no cas it should exceed 8.0%. 4.0% moisture has been found to give best results. If it is two wet, it will clog th nozzle and too dry a sand will produce more rebound.

Mix Proportion. A proportion of 1:4 by volume has been found very satisfactory. It should be mixe thoroughly for about $1\frac{1}{2}$ minutes till uniform colour is obtained before putting it in the machine. One type of guniting equipment is shown in Fig. 12.6.

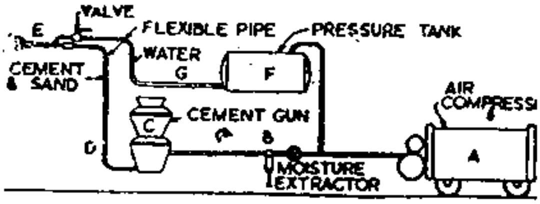


Fig. 12.6.

Thickness of lining. A thickness of 4 to 5 cm is quite satisfactory. In short crete lining joints are not provide3ed. In shot crete lining generally reinforcement also is not provided unless required for structural stability. if required it can be provided in the form of wire mesh of 12 gauge.

Placing. For placing the mortar, usually the length of the hose should not be more than 30 to 45 m, bu it has been used upto 110 m. Longer hose pipe requires greater air and water pressures. For shorter length the air and water pressures at nozzle should be 3.5 kg/cm^2 and 4.5 kg/cm^2 respectively. For a long hos both air and water pressures should not be more than 5.25 kg/cm^2 at the nozzle. Actually the volume of ai required depends on the size of the nozzle and air pressure, but for an average work using 3 cms diamete nozzle about 7.25 m^3 of air per minute is required. For details refer chapter 23.

12.10.4. Brick or tile lining

Brick lining is becoming popular in India due to paucity of cement. For the first time, brick lining i India was used on Haveli canal in Punjab in 1937. The specifications of lining adopted were, two layers o 30.5 cm × 14.7 cm × 5.35 cm tiles, sand witched layer of 1:3 cement sand proportion of 1.25 cm thick wa provided. The bricks were reinforced with 6.3 mm mild steel round bars forming a grid of 3.7 × 3.7 m o the sides and 7.4 × 7.4 m on bed. These specifications did not prove satisfactory.

Then for further lining works specifications were revised and following specifications were adopted.

Two layers of tiles of 30 × 15 × 15 cms with a sandwitch layer of 1:3 cement sand mortar of 1.0 cr thickness was adopted.

The bottom layer was laid on 1.25 cm thick layer of 1:5 cement sand mortar. Before placing second layer of tiles, a layer of 1:3 mix of 6 mm thickness was also placed over the sandwitched layer. These specifications also did not prove satisfactory. Hence finally following specifications were adopted.

(*a*) The thickness of bottom layer of 1:5 mix was reduced from 1.25 to 1.0 cm.

(*b*) The thickness of sandwitched layer of 1:3 mix was increased from 1.0 cm to 1.5 cm.

(*c*) Thickness of cement layer for laying the top tile was kept the same.

(*d*) Thickness of tile was not changed.

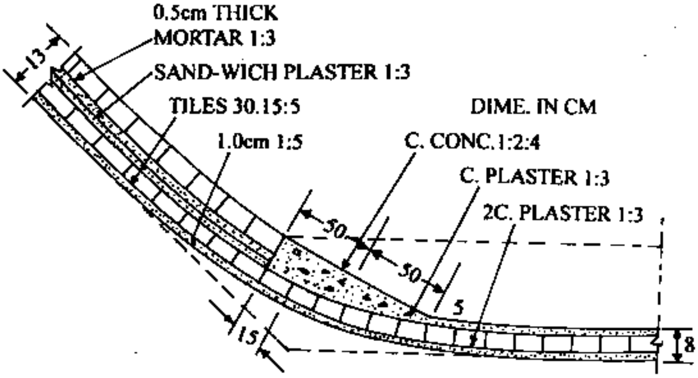


Fig. 12.7. Brick lining section of Rajasthan canal

Thus the total thickness of lining was kept 13.0 cm. Though the total thickness of lining was not changed appreciably, but the thickness of sand witched layer played an important role in checking the seepage. Thus it can be said that the sand witched layer is most effective in checking the seepage from canal lining. A typical double tile lining cross section of channel is shown in Fig. 12.7 and to check the leakage of rain water behind the lining of the slope coping of cement concrete is shown in Fig. 12.8.

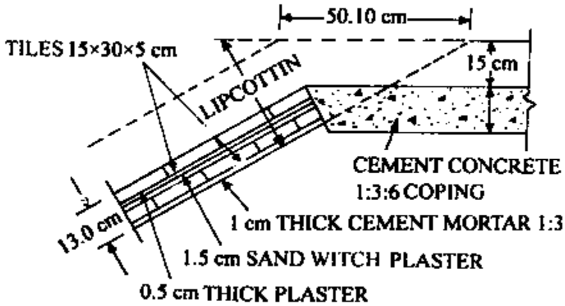


Fig. 12.8. Coping to brick lining

On Rajsthan canal, the longest canal of Asia has been provided single layered brick lining with the following specifications.

Bed. Single tile 30.5 × 15 × 5 lining with 2 cms thick 1:3 cement sand mortar plaster on top.

Sides. Two layer of 30.5 × 15 × 5 cm tiles sand witched with 1:3 cement sand mortar of 1.5 cm thickness.

12.10.5. Asphaltic lining

Following two types of lining have been developed and used successfully.

(*a*) **Asphaltic membrane lining.** The sub grade is well prepared and then asphalt is heated upto 200°C temperature and spayed over the subgrade in hot condition in a thin film of 6 mm. The asphaltic film is covered with a 30 cm thick layer of soil to provide protection against wear and tear. This protection is essential as the asphaltic film has a very short useful life. To accommodate the covering layer of earth, the channel section has to be over excavated to the extent of the required cover.

(*b*) **Asphaltic concrete.** It is a mixture of asphalt and graded aggregate. It is mixed while asphalt is hot and placed in position and compacted well to give a water tight hard surface lining.

12.10.6. Clay material lining

Clay puddle is produced and water is added to it to attain optimum moisture condition, as at this moisture contents, puddle lining has been found to give maximum insperviousness. A 30 cm thick layer is provided on the canal section and another 30 cm layer is provided as a protective layer.

The advantages and disadvantages of all these linings are shown in tabular form in Table 12.1.

Table 12.1. Showing the advantages and disadvantages of different lining

S. No.	*Name of Lining*	*Advantages*	*Disadvantages*
1.	Cement concrete	(*a*) It has longer life than any other type	(*a*) Its initial cost is high
		(*b*) Most resistant to erosion	(*b*) It requires skilled supervision and skilled labour for construction
		(*c*) Low maintenance cost	(*c*) Greater possibilities of temperature cracking
		(*d*) Faster construction with mechanisation	(*d*) Difficult to repair
		(*e*) Higher velocities can be allowed	(*e*) Easily affected by adverse sub grade conditions
			(*f*) Standardization of canal section is necessary
			(*g*) Requires expansion joints
2.	Brick lining	(*a*) Its initial cost is cheaper	(*a*) It is not as smooth as cement concrete lining
		(*b*) No skilled labour is required for its construction	(*b*) It is less impervious than cement concrete lining
		(*c*) Less requirement of cement	(*c*) It's life is less than concrete lining
		(*d*) Expansion joints are not required as coefficient of expansion of brick work is half that of concrete	
		(*e*) It is more flexible	
		(*f*) No rigid control is reqired	
		(*g*) Thickness remains constant	
		(*h*) It is easy to repair in case of subsequent damage	
		(*i*) It can be laid in round sections with out form work	
3.	Shot Crete	(*a*) It can be placed in position from a distance of at least 1m under pressure	(*a*) It is more costly than concrete lining of equal thickness
		(*b*) It is more useful for rock cuts where trimming to exact shape and slope is more difficult and expensiove	(*b*) It is less durable than concrete lining of equal thickness
		(*c*) It is more useful in tunnel operations	(*c*) More readily demaged by expansion, settlement, hydro-static pressure and shrinkage etc.
4.	**Asphaltic lining**	(*a*) It is quite flexible and readily conforms to the sub grade	(*a*) It does not decrease the coefficient of rugosity
	(*a*) Burried asphaltic lining	(*b*) It retards weed growth for some period	(*b*) Trained personels are required for its spraying
			(*c*) Special equipent is required for heating and spraying asphalt
	(*b*) Asphaltic concrete lining	(*a*) When well compacted gives water tight hard surface	(*a*) It gives high coefficient of rugosity

S. No.	Name of Lining	Advantages	Disadvantages
		(*b*) It is quite durable	(*b*) It allows certain type of weeds to grow
5.	Clay puddle	(*a*) It is cheap to construet and maintain	(*a*) It is less impervious about 75% of other type of lining
		(*b*) No skilled labour is required for its constrution and supervision	(*b*) It is cheap when clay is available locally or at a small lead from the location of channel

2.11. CAUSES OF DAMAGES TO CANAL LINING

1. Development of shrinkage cracks due to variations in temperature.
2. Development of hydrostatic pressure behind lining due to high sub soil water table above the bed of channel and differential head on lining, specially during draw down conditions. Most of the canal lining failures have occured due to this reason.

2.11.1. Remedial measures

1. Cracks developed due to variation in temperature may be sealed by the deposition of silt present in the flowing water.
2. These cracks may also be sealed by swelling of concrete on absorption of water.
3. The development of shrinkage cracks may be checked by providing contraction joints at intervals fifty times the thickness of lining.
4. Development of hydrostatic pressure behind lining can be checked by providing drainage system behind the lining.

2.12. CONDITIONS WHEN DRAINAGE ARRANGEMENTS ARE NECESSARY

In this regard following three conditions of water table before the entry of water in the canal should be onsidered:

1. **Water table is below the canal bed.** In this condition if the sub grade is free draining, then there is no need of any drainage arrangement. In case the sub grade is poorly draining, then canal banks shall be saturated upto the F.S.L. after running water in canal for some time. At the time of draw-down the pressure will be exerted behind the lining. Hence drainage arrangement is necessary.
2. **Water table is in between the bed and F.S.L. of the canal.** In this condition irrespective whether the back fill is free draining or not, canal lining will be subjected to hydrostatic pressure when the canal is with out water, depending on the elevation of ground water table. Further it will also be subjected to draw down pressure. The magnitude of draw down will depend on the permeability of back fill and the rate of draw down.
3. **Water table is above the F.S.L. of canal.** In this case the canal lining will be subjected to differential head between water table and F.S.L. while canal is running. When the canal is with out water, the differential head will be developed between water table and bed level of canal.

2.13. MEASURES TO CHECK SEEPAGE

Seepage head development can be checked by the following measures

2.13.1. By providing seepage drains

If the compacted sub grade soil is backed by a more porous soil in the bank fill; which in turn, lies on highly pervious strata, in that condition no artificial drainage is necessary as natural drainage will utomatically will take place, so long as the ground water table in the vicinity of canal remains below the ed of canal. The necessity of artificial drainage arises in case of cutting reaches, as in this condition, the npervious strata comes under banks. In such situations of low permeability soil, longitudinal drain of 60 × 60 cm section should be provided along the canal below the outer edge of the canal. These drains should be filled with shingle or gravel. These drains should be connected to near by depression or any other simila drains in the adjoining reaches at canal bed level which ever is higher. This arrangement has been foun very satisfactory for draining the canal banks.

12.13.2. Elimination of berms on lined channels

Elimination of berms also has been found effective measure against seepage troubles of banks.

12.14. TYPES OF DRAINAGES

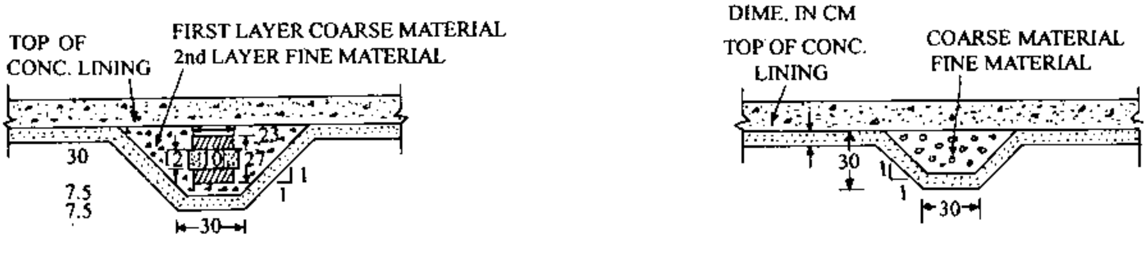
For drainage of banks of a canal following drainage arrangements can be adopted:

(*a*) French drains (*b*) Continuous blanket (*c*) Boulder pitching

(*d*) French drains with continuous blanket (*e*) Porous concrete

12.14.1. French drains

This system consists of transverse drains along the side slope of the canal discharging into tw longitudinal drains at the junction of side slopes and the bed. A third longitudinal drain is provide along the centre line of the canal below the bed. The longitudinal drains empty into the can through valves which open only when differential head is caused. The horizontal drains are mac of open jointed brick work, open jointed pipes, or slotted pipes stranded with gravel to preve clogging. The gravel should be provided on the basis of design criterion of filter. Fig. 12.9.



(*a*) (*b*)

Fig. 12.9. French drains

12.14.2. Continuous blanket

It is designed as a filtre.

12.14.3. French drain with continuous blanket

This arrangement is a combination of French drain and continuous blanket. In this case a 7.5 cm thick sand layer has been provided between the transverse drains as shown in Fig. 12.10.

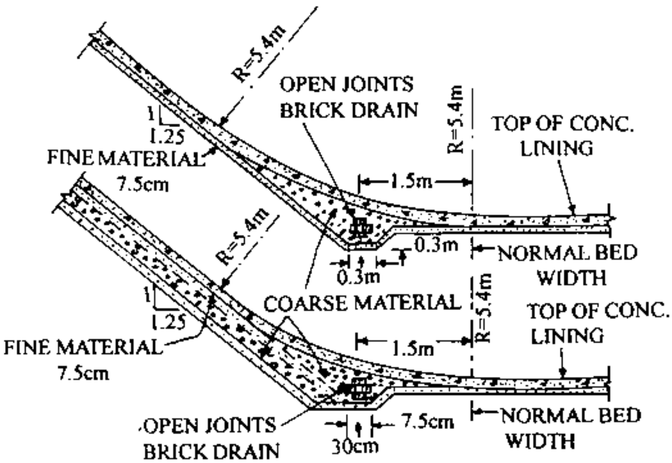


Fig. 12.10. French drain with continuous blanket

12.14.4. Boulder pitching

In order to reduce the cost of lining due to high water table, boulder pitching of side slopes may be adopted in place of lining. Boulder pitching also acts as drainage. Grouted ribs provide stability the pitching.

Some times weep holes are provided in the lining to act s drainage, but they also have been found as a great source f seepage from the canal. Thus as far as possible, weep oles should be avoided. A typical weep hole is shown in ig. 12.11.

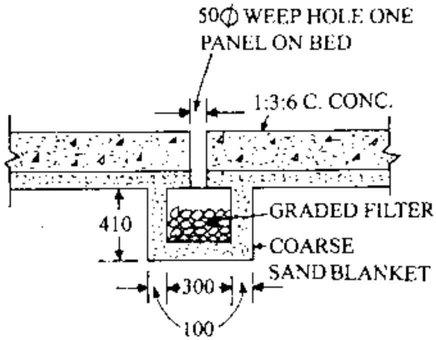


Fig. 12.11. Weep hole

2.15. PROVISION OF PRESSURE RELIEFS

When the canal passes through a tract of high sub soil /ater table, in such situations to minimise the uplift pressre problems, pressure reliefs are provided at suitable ıterval all over the bed of the canal. These reliefs will also e useful in draining the saturated banks behind the lining uring sudden draw down condition.

2.16. TYPES OF RELIEFS

Reliefs may of the following types:

2.16.1. Inverted filtre.

Inverted filtre may be provided under the bed of canal › reduce the pressure behind the lining. These filtres may e connected to a system of under ground drains connected › sump wells out side the canal. This system needs high ıaintenance and also is difficult to repair in case the system ets chocked.

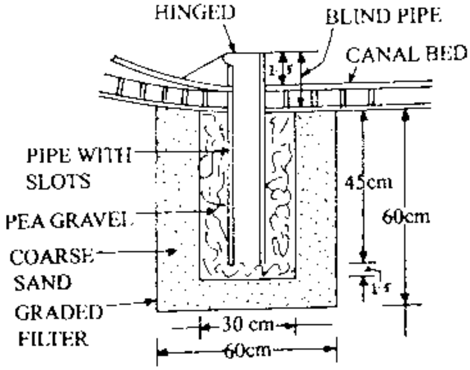


Fig. 12.12. Vertical pressure relief well

2.16.2. Vertical pressure relief pipes

This system consists of sinking usually 22.5 cm iameter pipes vertically at a distance of about 6 to 9.0 m part. Water may percolate through the open ends of pipes artly reducing the advantage of lining. This disadvantage is over come by providing a flap valve at the top f the vertical pipe. This valve only will open under the pressure in the pipe and will remain in closed osition during the canal flow. The top of relief pipe should be kept above 15 cm about the designed bed evel of the canal to prevent it being burried under silt.

2.16.3. Hump or dwarf wall

These are provided when water table remains constantly high and conventional methods of pressure elease can not be lepended upon. By the onstruction of these valls, some water emains standing on he bed of canal even luring closure period f the canal. These valls should be designed as falls. The eight and spacing of hese walls will lepend on the minimum depth of water

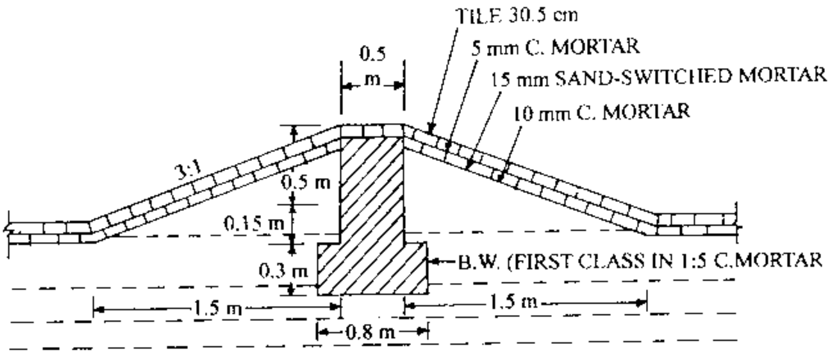


Fig. 12.13. Dwarf wall or hump

required to be maintained in side the canal to counter balance the under ground residual pressure.

12.17. MAINTENANCE OF PERMANENT STRUCTURES IN CANAL SYSTEM

Usually all canal systems need the following permanent works:

1. Canal head works
2. Regulators
3. Cross drainage works
4. Falls
5. Outlets
6. Sediment control

12.17.1. Canal head work

The layout of a typical diversion head work is shown in Fig. 12.13. It consists of the following parts:

(*a*) Weir
(*b*) Under sluices
(*c*) Divide wall
(*d*) Fish ladder
(*e*) Canal head regulator
(*f*) River training works

12.17.1.1. Weir

It is an obstruction of permanent structure. Failure of weirs has been found due to the following causes:

(*i*) Formation of deep scours down stream of apron due to heavy retrogression
(*ii*) Formation of hydraulic jump out side the floor.
(*iii*) Excessive up lift pressure on the floor.
(*iv*) Piping or under mining due to excessive exit gradient
(*v*) Faulty construction
(*vi*) Faulty regulation
(*vii*) By sliding
(*viii*) Settlement of foundation
(*ix*) Development of tension in the structure.

12.17.1.2. Remedial measures

1. **Failure due to deep scour.** It may be prevented by providing sufficient length of loose apron and driving deep sheet piles lines below the maximum depth of scour.
2. **Failure due to under mining or piping.**
   (*a*) It may be prevented by providing sufficient length of floor such that the exit gradient is less than unity. Generally the value of exit gradient is taken as 0.25 to 0.5.
   (*b*) Provision of piles at upstream and down stream ends reduces the exit gradient.
3. **Failure due to uplift pressure.** Failure due to up lift pressure can be prevented by providing sufficient thickness of floor based on Dr. Khosla's theory. Floor should be laid in one massive layer instead of thin layers. The thickness may be kept as 0.6 m.
4. **Failure by dynamic energy of falling water.** This failure can be prevented by providing concrete blocks on the down stream side to dissipate surplus energy.
5. Failure due to sliding, tension and settlement etc. are due to faulty design. Proper provision should be kept in design. It can be checked easily. Fig. 12.14 shows different components of a weir, and its protective works.

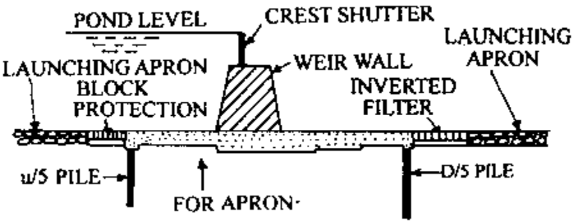


Fig. 12.14. Weir

6. **Failure due to u/s and d/s aprons.** Piles should be driven beyond the scour depth. The scour depth may be taken as 1.25 times the normal depths of water. At u/s side it may be taken as 1.0 to 1.25 times the normal depth *i.e.* length of sheet piles at u/s should be greater than 1.25 R and d/s side greater the 1.25 to 1.5 R. Where R is the normal depth of scour.

12.17.2. Under sluice

They are openings in the weir wall and are fully controlled by gates. These gates slide in grooves on both sides.

12.17.2.1. Maintenance of gates

(*a*) Gates should be checked periodically. The rubber seal of gates found damaged should be replaced and wheels should be oiled or greased. If gates found damaged they should be repaired.

(*b*) Winch which operate the gates also should be inspected periodically and oiled or greased for smooth functioning. Wires or ropes attached to getes should be tested, if found weak or defective should be replaced.

12.17.3. Divide wall

It is simply a long wall made of stone masonry or concrete. Usually it does not need frequent repair. It is a massive structure. If found some defects, they should be rectified by replacing missing or loose stones etc.

12.17.4. Canal head regulator

It is provided at the head of the off take canal. It serves the following functions:

(*a*) It regulates the supply of water in the canal. It regulates the water supplies with the help of gates.

(*b*) It controls the entry of silt into the canal.

12.17.4.1. Maintenance of gates and winches

Same as above.

12.18. RIVER TRAINING WORKS

These shall be discussed along with bridges. Other structures like regulators, cross drainage works, falls etc. suffer mostly by uplift pressure and scouring. They may be treated as discussed above.

12.19. MAINTENANCE OF CROSS DRAINAGE WORKS

Some time during floods cross drainage works get-damaged and get washed away due to heavy floods causing heavy losses. During floods these works should be watched through out day and night and necessary regulation should be adjusted. Damage caused, should be assessed after the floods and necessary repairs should be carried out based on sound design and experience.

12.20. OUT-LETS

It is a device built at the head of water course to control the flow of water in water course and connect the water course with the distributing field channel.

It should be inspected periodically and if found damaged due to the silt deposition or by cultivators, it should be repaired or replaced immediately.

12.21. CONTROL ON SILT ENTRY INTO THE CANAL

Following measures may be taken to prevent the entry of silt into the canals and its silting.

1. Discharge in the canal may be increased to carry higher silt charge.
2. Slope and velocity of canal may be increased to increase the silt carrying capacity of the canal.
3. Silt or sediment load entry may be reduced.

Measures (1) and (2) affect the design of the canal (channel) which is not a practical proposition. The only practicable method to prevent the silting of channels is to reduce the sediment load by any suitable method.

12.21.1. FACTORS AFFECTING THE ENTRY OF SEDIMENT FROM THE RIVER INTO THE CANAL

Following two factors affect the entry of silt from river into the canal.

1. Alignment of approach channel of the river. The alignment of approach channel has a market influence on the entry of sediment into the canal, which may be checked by the following measures:

(*a*) The main river channel should be kept-away from the head regulator of the canal.

(*b*) The canal head regulator should be located on the out side of the river curve as shown in Fig. 12.15 as the concentration of sediment will be more on the inside of the curve.

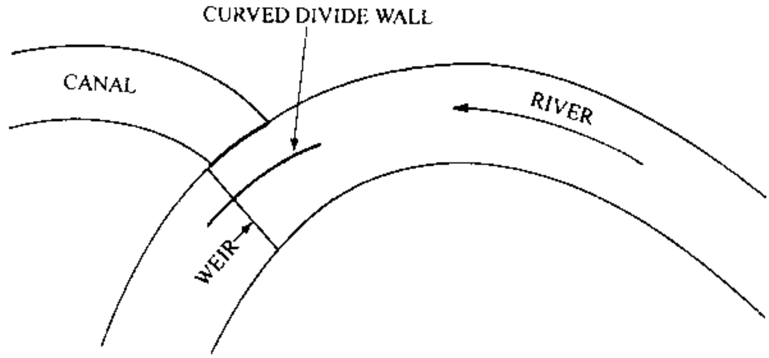


Fig. 12.15

2. Design of the head regulator.

(*a*) The canal head regulator should be aligned properly with respect to the angle and splay of the off take. Its alignment should be such that no back flow and no pockets are formed.

(*b*) A high crest level above the under sluice has been found advantageous.

12.22. RIVER REGULATION

River regulation has a great effect on the entry of silt into the canal. Silt entry into the canal may be minimised by adopting the following principles of regulation.

(*a*) The main stream of the river should be kept away from the head regulator of the canal. This can be done by passing the major portion of the discharge through the bays away from the head regulator of canal.

(*b*) Only a limited discharge sufficient for feeding the canal and excluder should be allowed to pass through the approach channel.

12.22.1. Methods of regulation

Following two methods may be adopted to regulate the water supplies into the canal:

1. **Open flow system.** In this method the gates of the under sluice in the pocket are kept open to the required extent to escape the surplus water which enters into the pocket infront of the head regulator. The top water is allowed to pass into the canal. In this method a certain velocity is maintained by the water entering the pocket, which keeps the silt into suspension. The turbulence created enables even coarse silt to rise up and enters into the canal and excessive silt enters into the canal.
2. **Sill pond regulation.** In this method the gates of the under sluices are kept closed when the canal is running. Only as much water is allowed to enter in the pocket as is necessary for the canal. The surplus water is escaped over the other section of the river. Thus the velocity of water in the pocket is very small as smaller discharge is allowed to pass over the same water way. Thus the silt settles down in the pocket and relatively clear water enters into the canal. This system is practicable where the canal head regulator has a high crest above the upstream floor of the under sluices. The silt is allowed to accumulate in the pocket till it accumulates about 50 cm below the crest level. At this stage the canal is closed and the silt is scoured out by opening the gates of the under sluices. It takes about 24 hours to scour out the deposited silt. This system has been tried in Panjab and found quite satisfactory.

Advantages. In this method the canal gets clear water and no frequent desilting of canal is required. Thus a large amount of money is saved.

Disadvantage. To scour out the deposited silt, the canal has to be closed for 24 hours which interrupts the irrigation and causes inconvenience to cultivators. Secondly every month large quantity of useful water is wasted for 24 hours to scour out the silt, resulting a huge loss of revenue also.

12.23. SPECIAL WORKS TO CONTROL SILT ENTRY INTO THE CANAL

Following two types of special works are constructed to control the entry of silt into the canal:

1. **Silt-excludes.** These are constructed in the river bed infront of the head regulator. Their function is to prevent coarse silt from entering into the canal. The section and plan of a silt exculder are shown in Fig. 12.16.

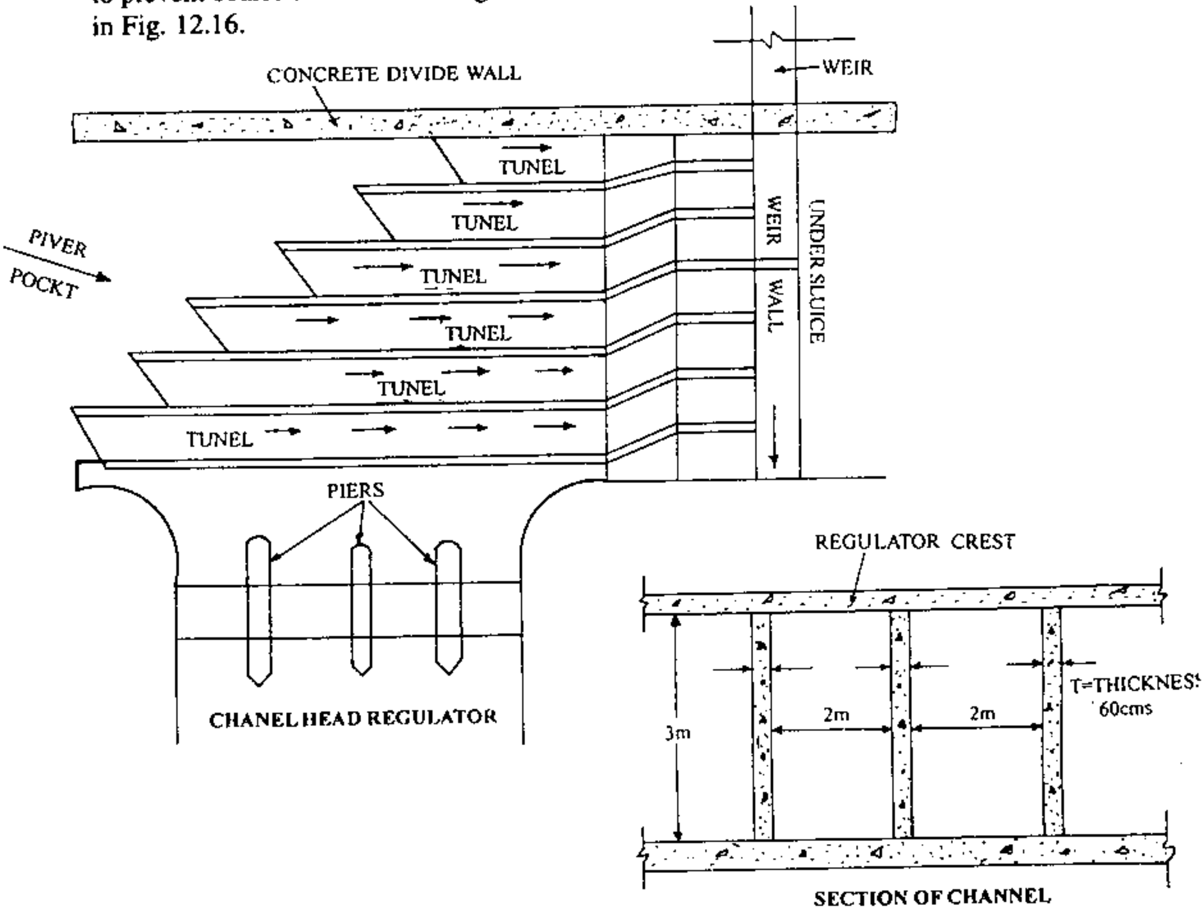


Fig. 12.16. Silt excluder

2. **Silt ejections or silt extractor.** These are constructed in the canal at some distance down stream from the head regulator. Their function is to remove silt which already has entered into the canal from the head. Fig. 12.17.

Silt Exclusion devices used for distributory heads

Following devices are used for silt exclusion for distributary heads:

1. Raised silt regulators
2. King's vanes
3. Curved Vanes
4. Cantilever skimming platforms

12.24. MEASUREMENT OF CANAL DISCHARGE

Necessity of Canal discharge measurement. To make the water distribution of canal effective, it is necessary to know the discharge of the canal at a point. This can be done easily at the head regulator, if it is metered. In practice head regulators are not metered. hence the assessment of water discharge may be made at a distance of 200 m down stream of the head regulator by gauging and preparing a graph between depth of water or gauge height and discharge.

The discharge rate of flow in a canal is the quantity of water flowing through a given section of the canal in a unit time (second). It can be determined by the area velocity method. This method is very common and is applicable for river and canals both. In this method only area of section and velocity at that section is needed to be determined. Thus discharge Q = Area of section × Velocity.

Hence $$Q = A \times V$$

12.24.1. Site selection for gauging

At the gauging station, the canal section should have the following characteristics:

(*a*) The canal section should be straight at least for a length of 10 times of its average width.

(*b*) The section should be clean and regular. Preferably it should be lined or brick pitching be provided at bed as well as onsides for a sufficient length.

(*c*) The site should be away from mansory structures as bridge, fall etc. The minimum distance should not be less than 200 m.

(*d*) The alignment of cross section should be normal to the direction of flow.

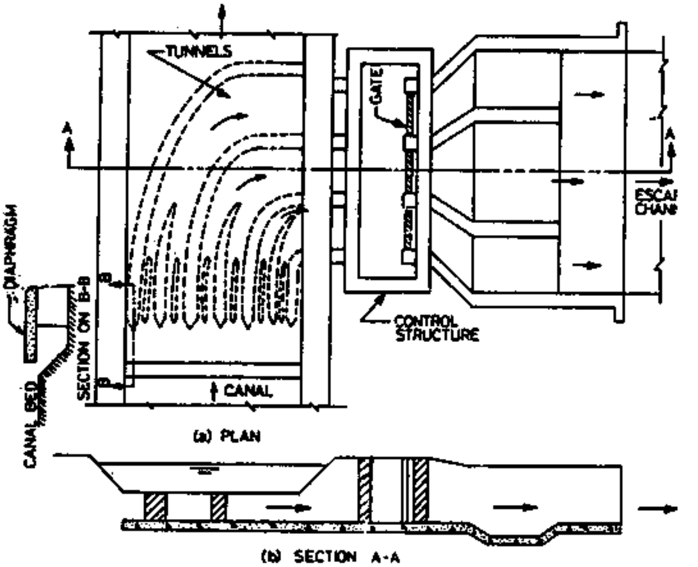


Fig. 12.17. Silt ejector

Demarcation of site. After site selection, it should be marked by erecting concrete or brick masonry pillars on both banks and a flag is erected at the centre of each pillar. The distance between two sections should be at least 30 m.

Measurement of cross-section area. To determine the area of cross section the width of the cross-section and depth of water is determined.

Measurement of width. For channels upto 150 m width it can be measured by stretching suitable rope or cable across the channel and measuring it with steel tape. The effects of thermal expansion and catenary etc. should be accounted for. In case the width is more than 150 m then it can be determined with the help of theodolite and a levelling staff.

Measurement of depth. Depths less than 5 m can be measured with the help of a sounding rod. It consists of a bamboo or wooden rod. To prevent it from sinking into the bed of the channel, a base plate is attached at its lower end. It is placed at the point of measurement and direct depth is read from it. Markings on the rod can be hand painted or enameled gauge plates fixed. These rods may be used upto 7 m depth in exceptional cases. For depths more than 5 m, other methods like hand line or long line, sounders etc. may be used.

Measurement of Velocity. Velocity of flow can be measured by any of the following methods:

(*a*) Float method (*b*) Pitot tube method

(*c*) Current meter (*d*) Chemical method

For the measurement of velocity of water in a canal usually float method is used.

12.25. WATER LOGGING AND ITS PREVENTION

An agriculture land is said to be water logged when the ground or sub soil water rises high and saturates the root zone of the crop normally grown in that area and cuts off the normal circulation of air in the soil of the root zone, which is essential for the development of plants. Thus water logging reduces the yield of the land and makes it uncultivable. The depth of water table at which it starts harming the crop, depends upon the type of crop and height of capillary fringe. The height upto which the soil water may rise by capillary action is known as the height of capillary fringe. The height of capillary fringe depends upon the type of soil. It is more for fine grained soils and less for coarse grained soils. For agriculture soils the height of capillary fringe varies from 0.9 to 1.5 m.

For water logging it is not necessary that water table itself should rise upto the root zone of the crop. It is the combined effect of water table rise and height of capillary fringe. In India about 33.42 lakh hectares of land is estimated affected by water logging.

12.25.1. Causes of water logging

Probable causes of water logging are as follows:

(*a*) Excessive rainfall in the area
(*b*) Seepage from canal system
(*c*) Over irrigation
(*d*) Low permeability of soil
(*e*) Impervious stratum at a small depth below ground surface
(*f*) Construction of reservoirs
(*g*) Inadequate drainage system
(*h*) Topography of the area

(*a*) *Excessive rain fall.* In areas where the drainage system is not good, rain water will percolate into the ground, raising the ground water table. This rise of ground water table will cause water logging in the area.

(*b*) *Seepage from canal system.* It has been estimated that the volume of water diverted at head to a unlined canal about 50% supply is lost in the transit increasing the ground water table leading to water logging.

(*c*) *Over irrigation.* Plants draw water for their growth from their root zones only. Thus water which has percolated below the root zone of the plant is useless for them and adds only to water logging.

(*d*) *Low permeability of soil.* Due to low permeability of soil water will take more time to percolate down, resulting in raising capillary action which will add to water logging.

(*e*) *Impervious stratum below ground surface.* This will also not allow water to perlocate down. The excess water will form local reservoirs, saturating the top layers of the soil. This causes water logging.

(*f*) *Construction of reservoirs.* Seepage from reservoir will increase the water supply to ground water, raising its water table, which will add to increase water logging.

(*g*) *In adequate surface drainage.* If there is no proper drainage system in the area, the excess rain water will add to water logging problem.

(*h*) *Topography of the area.* In flat topography of the area, percolation of water will be more, which will add to the water logging problem.

12.25.2. Effect of water logging

Following are the ill effects of water logging:

1. **Absence of aeration.** For the survival and growth, plants need nutrients like nitrates. These elements are maintained in soil by the process of nitrification which is possible only with the help of bacteria. This bacteria can survive and function in the presence of oxygen only. As in the water logging conditions, supply of oxygen is cut off and the activity of nitrification is also stopped which results in reduced yield or no yield.
2. **Difficulty in carrying out cultivation activates.** In constantly wet soils proper tillage and preparation of soil is not possible, which results in reduced yield.
3. **Growth of wild vegetation.** Certain types of plant grow in abundance in water logged land,

surpassing the useful crop sown in the field, making the cultivation uneconomical.

4. **Rise of salts in upper layers of soil.** In water logged areas, water evaporates constantly, which is replenished from ground water. This ground water brings dissolved salts along with it to the surface. In this way the concentration of salts increases in the soil. This increased salt concentration hampers the growth of the plants.
5. **Fall in soil temperature.** Due to constant wetness of the soil, the temperature of the soil falls resulting in reduced actively of the bacteria.

12.25.3. Measures to prevent water logging

To prevent and control the water logging, following measures may be adopted:

1. Reducing the inflow of water to the ground water reservoir
2. Increasing the out flow from ground water reservoir

1. Reducing the inflow

Inflow of water to ground water reservoir can be reduced by the following measures:

(*a*) **Lining of canal and water courses.** Seepage from unlined canals is found as much as 50% of the supply at head and in water courses about 20%. By lining canals and water course this seepage can be checked. This provision will be effective if water so saved is not used for over irrigation in the same area.

(*b*) **Lowering F.S.L. of canal.** It will have effects as follows:

(*i*) Losses will be less.

(*ii*) Due to low difference in head at water courses it will draw less supply.

(*c*) **Constructing intercepting drains along the canal.** This provision is useful to arrest seepage in areas having high embankments or high water table.

(*d*) **Controlling intensity of irrigation.** In water logged areas, intensity of irrigation should be reduced from 40% to 10% or so.

(*e*) **Educating farmers to make economic use of water.** Farmers should be educated about the hazards of excessive use of water. They should make economic use of water for irrigation.

(*f*) **Change of crop pattern.** Dry crops do not need water, hence in water logged areas such crops should be grown which either do not need water or need very little water.

2. Increasing the out flow from ground water reservoir

To increase the out flow from ground water reservoir following measures may be adopted:

(*a*) **Improving the natural drainage of the area.** For speedy disposal of rain water and less percolation, the drainage system of the area should be kept clear of weeds, vegetation and silt etc. Proper slope of the drainage system must also be maintained.

(*b*) **Pumping out from the sub soil.** Pumping out of sub soil water for irrigation and other such purposes has proved useful to mitigate the water logging problem to a great extent.

12.25.4. Drainage of water logged area

Drains have proved an effective means of reducing water logging problem in the area. Drains may be of the following types:

1. Open drains
2. Closed drains

1. Open drains. These drains are further classified as follows:

(*a*) Shallow surface drains (*b*) Deep surface drains

(*a*) **Shallow surface drains.** Such drain system has proved very useful to drain away the excess irrigation water applied to the field and expedite the removal of stream water. Actually this class of drainage is found useful to counteract water logging rather than relieving the water logged land.

(*b*) **Deep open drains.** Generally this class of drains is used as out let drains for closed drain system for the reclamation of water logged land. In very pervious soils they can also be used to reduce water logging with out providing tile drains. In this case the spacing of deep drains may be kept from 750 m to 800 m. How ever these deep drains interfere with agricultural operations and occupy considerable land. Hence their use is limited.

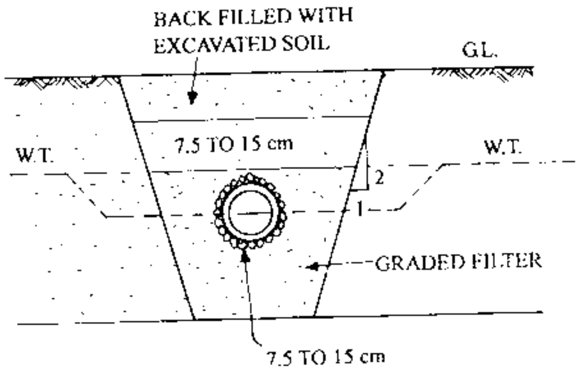


Fig. 12.18. Tile drainless pervious soil with graded filter

As far as possible the alignment of drainage should follow the natural drainage and low contours of the area. The drain should not be aligned across a pond or marshy land. The slope to such drains is governed by the location of the out fall. The capacity of such drains system should be such as to remove the excess surface water with in 3 to 5 days as crop flood tolerance period is taken as 3 to 5 days.

2. Closed Tile drains. These are tile drains, usually made of porous earthen ware. They are laid below ground level and covered with earth. They do not obstruct any agricultural activity or operation. They have been found more useful to drain agricultural land.

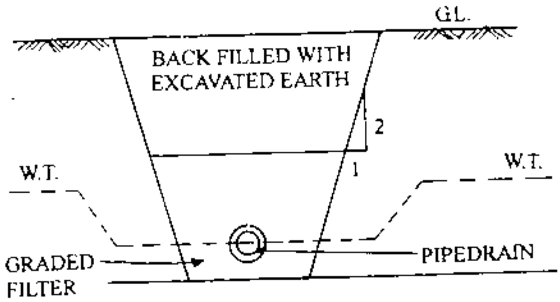


Fig. 12.19. Tile drain in pervious soil without filtre

These pipe drains are laid in trenches. The pipe drains are laid in the trenches and then trenches back filled with sand and excavated materials. To ensure better and effective drainage, the tile drains should be placed under a permeable stratum or shrouded with graded filtre material. Closed drains may be located about 30 cm lower than the desired highest water table at a spacing of 30 to 90 m interval in sandy loam. The general spacing may be 15 m to 50 m. Fig. 12.18 shows cross section of tiled drain in less pervious soil with graded filtre, while Fig. 12.19 shows tile drain in pervious soil without filtre.

QUESTIONS

1. Explain the process of maintaining canal profile.
2. Explain the procedure of desilting of a canal section.
3. Give the types of canal lining and discuss fully how cement concrete lining is done.
4. State causes of failure of canal lining and suggest remedial measures.
5. What are French drains? Explain with neat sketch.
6. Draw a general lay out of a head work and name its various parts.
7. Canal profile is maintained intact as per original design due to
   (*a*) Increase the life of the canal (*b*) Avoid overflow of water
   (*c*) Carry the designed discharge (*d*) Strengthen the section
8. Berms are provided in unlined canals to
   (*a*) Increase the capacity of canal to absorb fluctuations
   (*b*) Bring the saturation line in side the body of banks
   (*c*) Widening canals at a later stage

(*d*) Save banks from erosion
(*e*) All the above
(*f*) Non of the above

9. The causes of natural breaches in a canal are due to
(*a*) Piping (*b*) Low and weak banks
(*c*) Leakage of water through rot holes etc. (*d*) Running full or over flow
(*e*) All the above (*f*) Non of the above

10. The breach of canal can be stopped by
(*a*) Providing dry brick masonry in the breach
(*b*) Dumping large boulders in the breach
(*c*) Dumping sand bags in the breach
(*d*) Reducing water flow in the canal and then driving double line of stakes. After this the gunny bags filled with soil or sand are filled in between the planks

11. Weed growth can be prevented by
(*a*) Keeping the optimum velocity of water in the canal
(*b*) Avoiding ponding in any reach of canal
(*c*) Adopting rush rotation
(*d*) All the above
(*e*) None of above

12. Weed control in canal system is necessary to
(*a*) Prevent obstruction to flow (*b*) Increase velocity
(*c*) Prevent canal seepage losses (*d*) Prevent water logging near by the canal

13. Weed growth can be checked or destroyed by
(*a*) Increasing the turbidity of flowing water
(*b*) By the use of diesel oil
(*c*) By the use of sodium chlorate
(*d*) By co chinal insect
(*e*) All are correct
(*f*) None is correct

14. Lining in canal is provided for
(*a*) Reducing the seepage (*b*) Prevention of weed growth
(*c*) Increasing bank stability (*d*) Increasing of duty of water
(*e*) All are correct

15. For minimising the loss due to percolation and absorption of water through canal, the most effective way is to
(*a*) Reduce the cross section of canal
(*b*) Increase the longitudinal slope of the section
(*c*) Provide an impervious coating on sides and bed
(*d*) Increase the velocity

16. The exit gradient is called critical when
(*a*) The uplift water pressure is more than the down ward pressure or weight
(*b*) The uplift water pressure is less than the down ward pressure or weight
(*c*) Both upward water pressure and down ward weight or pressure are equal
(*d*) All are correct

17. Undermining of a structure starts at
(*a*) Upstream end (*b*) Middle of the structure
(*c*) Down stream end (*d*) Any where

18. Weir failure can be safe guarded by providing
(*a*) Sufficient length of loose apron and driving sheet piles below the maximum scour depth
(*b*) Reduced exist gradient by providing long sheet piles and pucca floor
(*c*) Providing concrete blocks on the down stream side to dissipate surplus energy
(*d*) All are correct

19. Water logging conditions are called when
    (*a*) Ground water level reaches upto the ground level
    (*b*) Ground water level plus capillary fringe reaches upto the ground level
    (*c*) Ground water level plus capillary fringe level reaches upto the root zone of the crop of the area
    (*d*) All are correct
20. Identify the incorrect statement/statements
    (*a*) Water logging increases the fertility of soil and its yield
    (*b*) Water logging helps in the growth of wild vegetation and weeds
    (*c*) Water logging give rise to salt in upper layers of soil
    (*d*) Water logging creates hindrance in agricultural operations

ANSWERS

7. (*c*)	10. (*d*)	13. (*e*)	16. (*c*)	19. (*c*)
8. (*e*)	11. (*d*)	14. (*e*)	17. (*c*)	20. (*a*)
9. (*e*)	12. (*a*)	15. (*c*)	18. (*d*)	

13
Maintenance of Earth Embankments

13.1. INTRODUCTION

In the present day life, structures such as roads, railways, and irrigation works are very important for the development of mankind. All these works are constructed with earth which is available in abundance naturally through out the world. These works may be in cutting or filling. The maintenance of such works is very important. In this chapter maintenance of earth works shall be discussed in detail.

13.2. TYPES OF MAINTENANCE

Maintenance may be of the following two types:

1. Routine maintenance
2. Specific maintenance

1. **Routine maintenance.** Routine maintenance of earth works is very important due to the following reasons:

(*a*) Earth can not stand vertically with out support. It attains a slope depending upon its angle of repose. This slope or inclination needs to be preserved.

(*b*) The shear strength of soil depends on its moisture content. The moisture content which gives the maximum shear strength of the soil is known as optimum moisture content (O.M.C.).

(*c*) Earth is not an elastic material like rubber and is quite unstable.

(*d*) It can be eroded very easily by atmospheric agencies like rain, wind etc.

13.3. CLASSIFICATION OF ROUTINE MAINTENANCE

Routine maintenance may be classified as follows:

1. Preservation of profile
2. Drainage or Removal of water

13.3.1. Preservation of Profile

To safe guard against failure due to natural and applied forces such as erosion and deformation, it is essential to preserve the form, shape and slope of the structure. Slopes of embankments against erosion and deformation can be safe guarded by providing afforestation or turffing and pitching the slopes. Slopes in cuttings can be safeguarded by constructing breast and retaining walls.

13.3.1.1. Afforestation or turffing

The process of growing vegetation as short grass over the surface is called afforestation or turffing. This vegetation provides a cover to the soil, which reduces the impact of falling rains and wind, resulting in reducing the scouring effect of the soil in the following ways.

(i) The roots of the plants penetrate deep into the soil and bind soil particles together, enabling the soil to resist the erosive effect of rain and wind.

(ii) The plants offer resistance to the flow of water and reduce the velocity of flow. The reduction in velocity minimises the scouring effect of surface run off.

(iii) The cover of grass provides a cushion to the falling rain and thus reduces its impact and consequent damage due to erosion of soil.

13.3.1.2. Methods of turfing

Turfing can be effected in the following two ways:

(a) **Seeding.** In this method the seeds of grass and soil mixed with manure is laid over the slope. Then at proper interval, water is sprinkled over it to facilitate the germination of grass seeds. This method is preferred in areas of scanty rain fall and facilities of sprinkling water are there. In ares of heavy rainfalls this method is not found useful.

(b) **Sodding.** In this method the plants grown some where else are planted on the slopes of the embankment.

13.3.2. Pitching of slopes

When the soil of the embankment is not cohesive, having sufficient shear strength, the slopes of embankments are provided a cover of harder and coarser material such as bricks, boulders, etc. The thickness of this cover may very from 10 to 100 cm, but normally 20 to 45 cm thickness is quite satisfactory, if hand picked boulders, bricks are laid carefully.

13.3.2.1. Functions

Pitching protects the slope in the following ways:

(a) Pitching cover protects the earth work from temperature variation and moisture etc. It avoids development of cracks.

(b) Pitching works as a blanket, protecting the earth work from piping action.

(c) It protects the earth work from the action of water as rainfall or waves effect.

High embankments also should be provided with longitudinal drains to collect rain water. Proper cross slope should be provided for proper drainage of the embankment. Water collected in longitudinal drain should be discharged through transverse drains flushed with slope provided at suitable interval.

In cuttings and mountainous regions the slopes are protected from weather effects.

13.4. BREAST WALL

It is provided in cutting portion of the natural ground to support the solid ground. The section of the wall to be adopted depends upon the slope of the cutting, height of the wall and nature of the backing. The front and back batters may vary from 1 in 4 to 1 in 2. The minimum top width of wall may be provided as 60 cm.

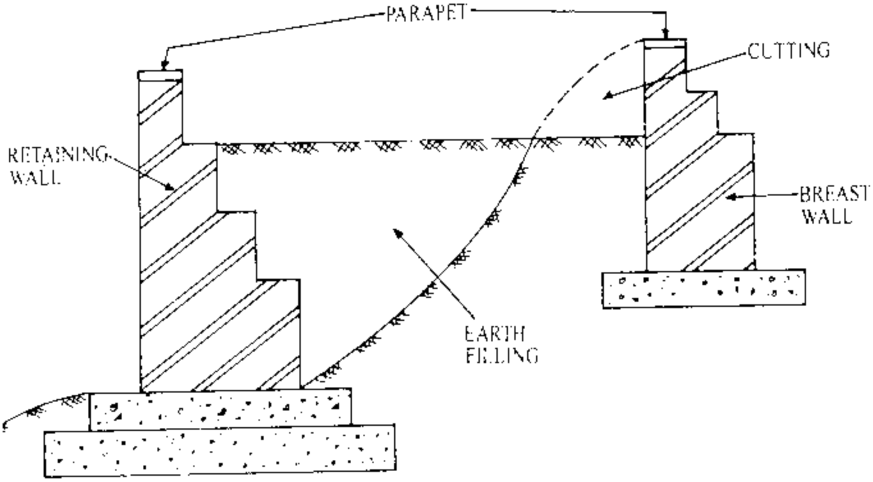


Fig. 13.1. Retaining and breast walls

13.5. RETAINING WALLS

These walls are built to retain earth behind them. It resists the forces of sliding and over turning due to the thrust of the earth fill and over burden etc. Usually it is provided in the construction of hill roads, abutments and wing walls of bridges, and masonry dams etc. It may be constructed of brick or stone masonry, plain or reinforced concrete, and dry stone masonry depending upon its height, nature of material to be retained and site conditions. For the stability of the wall, its section is made very thick. Usually they are not-constructed more than 6 m in height. The top width of concrete and masonry walls should not be kept less than 60 and 45 cm respectively. Bottom width will vary as per its height.

From the considerations of stability and safety, it is necessary to provide drainage to the retaining wall. For draining the backfill 5.0 to 7.5 cm square weep holes are provided at every 2.0 m centre to centre interval vertically and horizontally both. The lowest weep hole should be provided 30 cms above the ground level. To safe guard against blockage, a 45 cm thick filtre layer of gravel or such material should be provided behind the wall right from bottom to the top covering the full area of the back of the wall and filling material. The walls are shown in Fig. 13.1.

13.6. MAINTENANCE OF DRAINAGE

In order to maintain the shear strength and protect against erosion, it is essential that earth works are properly derained. Drainage may be either surface drainage or under ground drainage. The treatment of drainage of railway and road embankments and formations in cutting shall be discussed in detail in the respective topics. Here the maintenance of earth dams shall be discussed in detail.

13.7. EARTH DAMS

Earth dams are massive embankments made of earth to retain water for irrigation and power generation etc. Earth dams have been built since early days of civilization all over the world, but their height was limited to about 20 m, but after 1930 earth dams have been built as high as 310 m. Though earth dams can be built on all types of foundations, but their height depends on the type of foundation.

13.7.1. Types of earth damps

Based on the method of construction earth dams can be classified into the following two categories:

1. Rolled filled earth dams
2. Hydraulic filled earth dams

13.8. ROLLED FILLED EARTH DAMS

These dams are constructed by compacting mechanically suitable material in successive layers. Suitable materials are brought at site from borrow pits and moisture is brought upto optimum moisture content by sprinkling water over the spread material. The thickness of each layer of material may vary from 15 cm to 30 cm. To compact this layer 8 to 10 passes of roller are sufficient to give desired dry density. Depending upon the type of material, method of construction, rolled filled dams can be further sub divided as follows:

1. Homogeneous Embankment type
2. Zoned Embankment type
3. Diaphragm Embankment type

13.8.1. Homogeneous Embankment type

A purely homogeneous earth dam is mainly composed of one type of material as shown in Fig. 13.2. The height of such dams generally is kept upto 30 m. In such dams action of seepage is not favourable

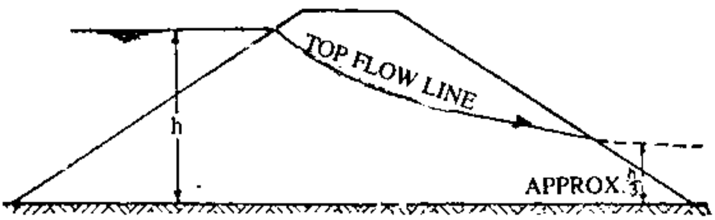


Fig. 13.2. Purely Homogeneous dam

and their slopes have to be kept flatter. In a homogeneous dam the seepage line emerges on the down stream slope at about 1/3rd water depth, regard less the permeability of material and flatness of slope. This results in greater base length and more construction material. To bring the seepage line with in the body of the dam section, new a days modified homogeneous embankments have been adopted.

13.8.1.1. Modified homogeneous embankment

In such embankments an internal drainage system as horizontal filtre drain or toe drain has been provided. The provision of this drainage system controls the action of seepage and keeps the phreatic line well with in the body of the embankment. Thus the provision of drainage system allows the use of steeper slopes which result in saving of material and land cost. This type of section is most suitable where available soils practically have some permeability.

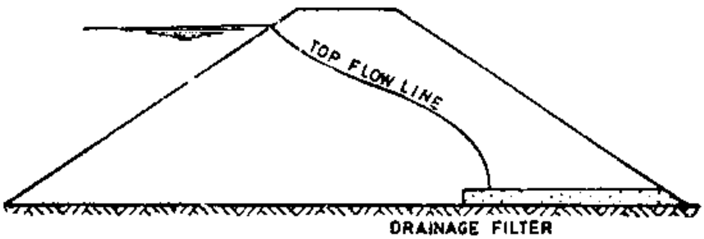


Fig. 13.3. Modified Homogeneous dam

13.8.2. Zoned Embankment

This type of earth dam is made of more than one type of material. This type of embankment contains a central imperious core which is flanked by shells made of considerably more pervious material. The central core controls the seepage through the dam. This section also is provided with a drainage system as horizontal filtre or toe drain. Fig. 13.4 shows the details of a zoned embankment section.

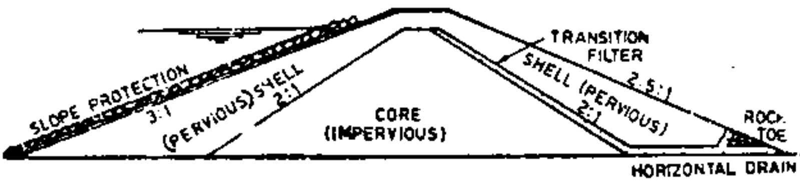


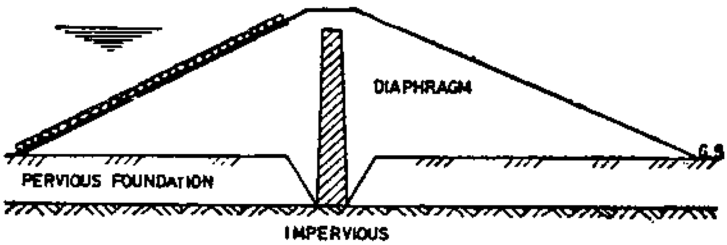
Fig. 13.4. Zoned embankment

The shells are made of pervious and freely draining material. These shells enclose, protect and provide stability to the core. The u/s shell provides stability against rapid draw down and down stream shell acts as a drain which controls the seepage line.

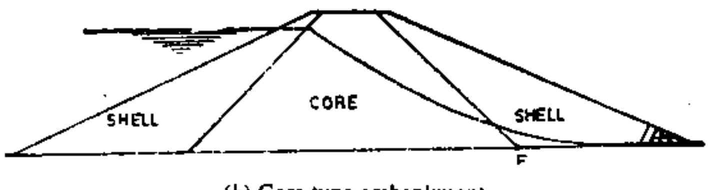
For more effective control of seepage, the section should have increasing permeability from the core towards each slope. The minimum base width of the core in the zoned section should not be less than the height of embankment.

13.8.3. Diaphragm type embankment

In this case the entire section is made of pervious material as gravel, sand or rock with a central diaphragm of impervious material to check seepage The central diaphragm made of cement concrete, earth or puddle clay. This diaphragm may be placed either in centre of the section as central vertical core or at the up stream face as blanket.



(*a*) Diaphragm type embankment



(*b*) Core type embankment

Fig. 13.5. Influence of central core on phrentic line

The base thickness should be 30 to 50% of the height of the dam. Thus if the base thickness is equal to the height of the dam it is called a zoned dam and if the base thickness is 30 to 50% of the height, then it is called as diaphragm dam. Fig. 13.5 (*a*) shows a vertical puddle clay diaphragm, Fig. 13.5 (*b*) a central core Fig. 13.6 (*a*) & (*b*) show central and 13.6 inclined core diaphragm dam respectively.

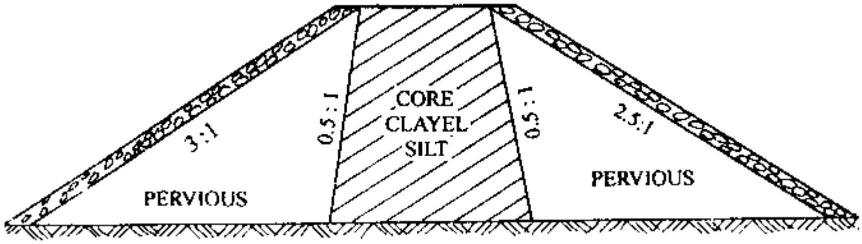


Fig. 13.6 (*a*)

13.9. SALIENT DIMENSIONS OF AN EARTH DAM

13.9.1. Top width

Top width of an earth dam is decided on the requirement of road way across the section to carry machinery required for maintenance. For maintenance point of view minimum top width should be 4 m, but for major and important dams the crest width may vary from 6 to 12 m.

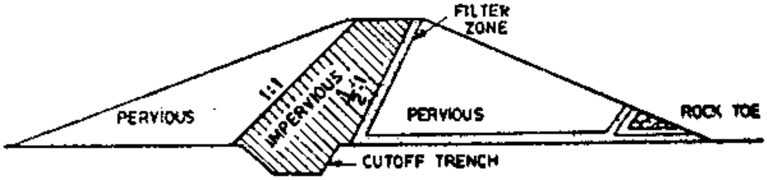


Fig. 13.6 (*b*). Sloping core in earth dams

13.9.2. Free board

Minimum value 2.0 m and maximum value 3.0 m may be adopted.

13.9.3. U/s side slope

Though it may vary from 2:1 to 4:1, but usually a slope of 3:1 is sufficient.

13.9.4. D/s side slope

2:1 to 2.5:1 may be provided, but usually 2:1 slope is sufficient.

13.9.5. Central impervious core

1. **Core width at base.** For all types of soils and heights of dam, core width varying from 30% to 50% of the water head have proved satisfactory.
2. **Slopes.** Both u/s and d/s slopes of 0.5:1 are sufficient.
   Top width. Usually equal to the width of the dam section.
3. **Trench slope.** Usually 1:1 slope is provided.
   Base width. As per side slopes.

13.10. CAUSES OF FAILURE OF EARTH DAMS

Investigations carried out for the failure of earth dams all over the world have revealed following causes:

13.10.1. Hydraulic failure 40%

(*a*) *Over topping failure:*

(*i*) Due to insufficient capacity of spillway

(*ii*) Due to Insufficient free board

(*iii*) Settlement of embankment

(*iv*) Settlement of foundation

(*v*) Faulty operation of gates

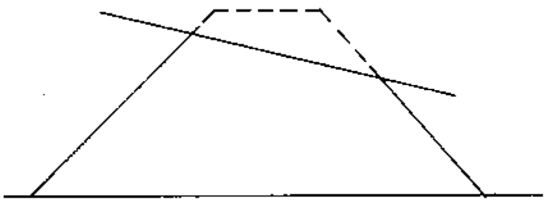


Fig. 13.7. Failure due to over topping

(*b*) *Wave erosion failure:*

(*i*) Erosion of upstream slope if not properly protected with rip rap.

(*ii*) Roller and slip failure. Fig. 13.8 (*a*), (*b*).

(*c*) *Toe erosion:*

(*i*) Due to tail water

(*ii*) Due to current from spillway bucket

(*d*) *Gullying.* Down stream slope may fail due to gullying formation due to heavy rainfall.

(*a*) Roller action

(*b*) Upstream slip

Fig. 13.8.

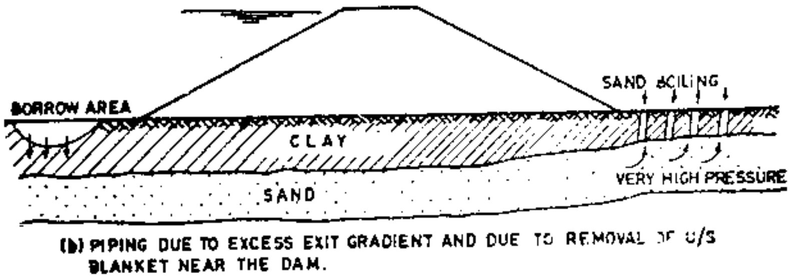
13.10.2. Seepage failure 30%

(*a*) *Due to piping:*

(*i*) Due to the presence of highly permeable material in the foundation as gravel and sand.

(*ii*) Presence of fissures and cavities in the foundations. More than 25% failure have occured due to piping.

(*b*) *Leakage through embankment.* Leakage through embankment causing piping may be due to the following causes:



(*a*) Piping through foundation

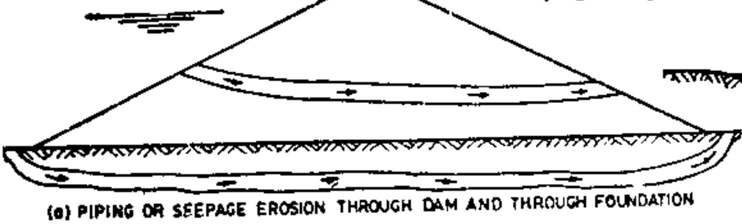


Fig. 13.9. (*b*) Piping through dam section

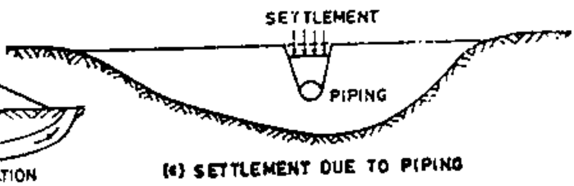


Fig. 13.9 (*c*) Piping due to foundation settlement

(*i*) Poor bond between foundation and embankment.

(*ii*) Poor bond between successive layers of the embankment.

(*iii*) Poor compaction adjacent to outlet conduits.

All these defects develop due to poor control during construction of the embankment. Fig. 13.9 (*a*) shows piping through embankment, Fig. 13.9 (*b*) shows piping through foundation due to removal of upstream blanket and Fig. 13.9 (*c*) shows piping due to foundation settlement.

(*c*) *Cracking in embankment or conduit.* Due to foundation

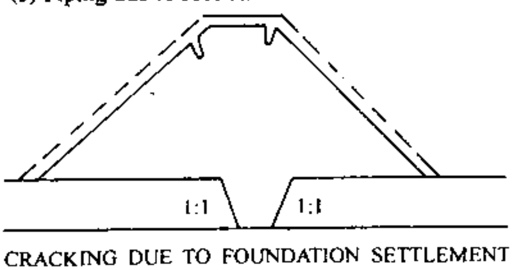
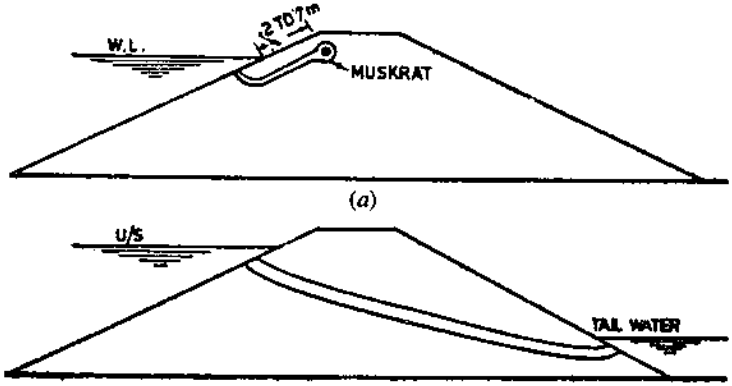


Fig. 13.10. Embankment cracking due to foundation settlement

settlement. Fig. 13.10 shows cracking of embankment due to differential settlement of foundation.

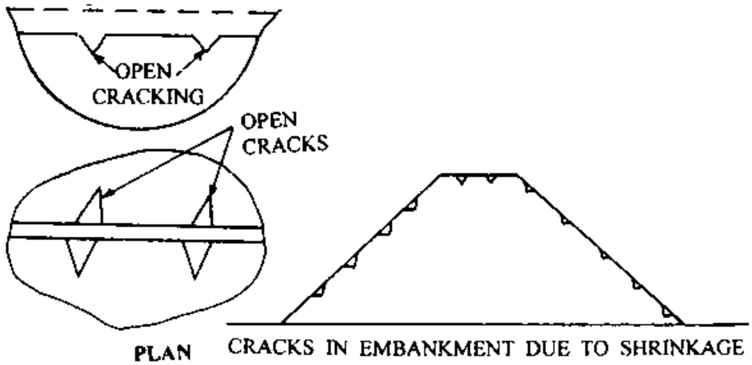
(*d*) *Animal borrows.* Small animals dug burrows into embankment to make their sheltre or passage from one side to other as shown in Fig. 13.11.



(*b*)
Fig. 13.11. Failure due to animal burrows

(*e*) *Shrinkage and drying cracks.* Cracks in dams develop due to differential settlement of the dam. Cracks may develop parallel or transverse to the axis of the dam and may form cracks in horizontal or vertical planes.

The vertical cracks which form a path for concentrated seepage through the core are most dangerous. They are caused by differential settlement between adjacent length of embankment. Usually they are developed between the portions located at the abutment and in the centre of the valley. The worst cracking develops when the foundation under the higher portions is incompressible and the abutment consists of steep and relatively incompressible rock. Fig. 13.12.



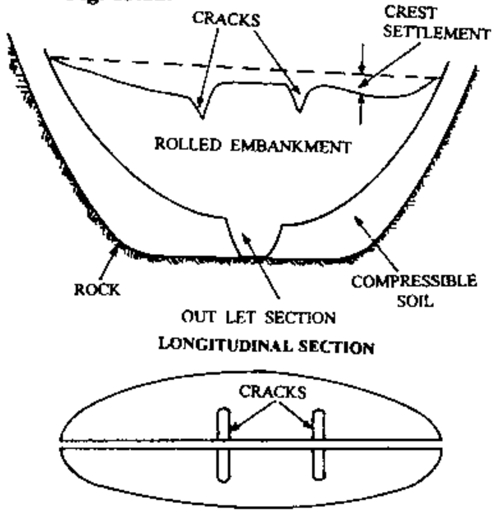
(*a*) Transverse differential settlement cracks (*b*) Shrinkage cracks
Fig. 13.12.

(*f*) Presence of tree roots, pockets of gravel, boulders in the embankment also cause piping.

(*g*) *Conduit leakage:*

(*i*) Contact seepage along the out side of the conduit which develops into piping due to poorly compacted zone of soil or a gap between conduit and embankment.

(*ii*) Seepage through conduits leaks which are caused by differential settlement or by over loading of the embankment.



(*b*) PLAN
Fig. 13.13. Longitudinal cracks due to differential settlement of foundation

Sloughing. This failure takes place when the down stream toe of the dam becomes saturated either due to the presence of highly pervious layers in the body of the dam or due to chocking of filtre drain. The down stream toe remains saturated under full reservoir condition.

The process of sloughing begins when a small amount of material at down stream toe is eroded producing a small slide. This small slide leaves a relatively steep face, which becomes saturated by the seepage from the reservoir and slumps again forming a slightly higher and more unstable face. This process is continued till the section becomes too thin to resist the pressure of water and total failure takes place suddenly.

13.10.3. Structural failure

Structural failure which is found 30% of the total failure of dams may occur due to the following reasons:

1. Up stream and down stream slope failure due to construction pore pressure. This type of failure takes place if the construction material of the dam is relatively more impervious and compressible. In such situations the drainage from the section will be externally low, which will cause the excessive pore pressure in the body of the dam during and immediately after the construction of the dam. This excessive pore pressure may cause the slides of slopes. Thus under such conditions the construction stage is more critical from the stability considerations.

2. Upstream slope failure. The failure of upstream slope generally takes place during sudden draw down stage. Emptying the reservoir water suddenly with out allowing any appreciable change in the water content or level with in the saturated soil mass of the section is called *sudden draw down condition.* This is the critical condition for the upstream slope. In this condition of sudden draw down, the hydrostatic force acting along the up stream slope at the time of full reservoir is removed with out counter acting the hydrostatic pressure in the slope. How ever up stream slope failure does not cause complete failure of the dam. Fig. 13.14.

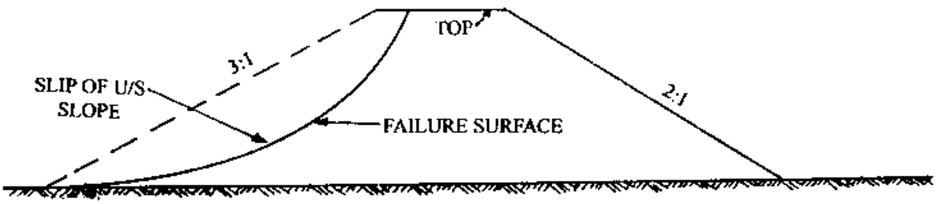


Fig. 13.14. Upstream slope failure

The size of stone used for hand placed rip rap should be such, which could be lifted up easily by one labourer for ease of work and speedy construction. How ever theoretically the size of the stone may be found from the following relation.

$$d = 2.23\, C \cdot hw\ \frac{\gamma_w \sqrt{1 + S^2}}{\gamma - \gamma_w S\,(S+2)}$$

where, d = diameter of stone converted to form a ball

γ_w = unit weight of water in tone/m^3

γ = unit weight of stone in tone/m^3

S = slope of embankment

hw = height of wave in metres

c = a coefficient. The value of C may be taken as 0.54 for hand placed rip rap and 0.80 for dumped rip-rap.

To prevent the wave erosion of under lying embankment material a layer of gravel or crushed stone of thickness varying from 22.5 cm to 75 cm should be placed under this rip-rap. This pitching should be done over the entire face upto the top of embankment. The thickness of pitching depends on the height of dam. It may be adopted as follows:

Table 13.2.

S. No.	*Height of dam*	*Thickness of pitching*
1.	10 to 15 m	30 cm stone pitching over 15 cm graded shingle
2.	15 to 25 m	50 cm stone pitching over 25 cm graded shingle
3.	25 to 50 m	50 cm stone pitching over 30 cm graded shingle
4.	50 to 75 m	75 cm stone pitching over 50 cm graded shingle
5.	Above 75 m	100 cm stone pitching over 75 cm graded shingle

Fig. 13.15 shows up stream slope protection

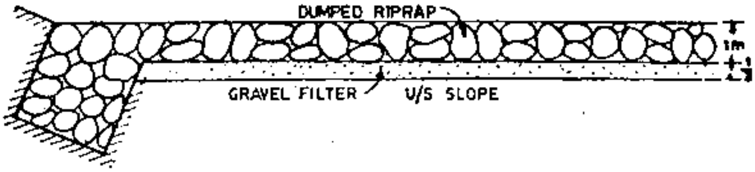


Fig. 13.15. U/s slope protection

3. Down stream slope failure. For down stream slope condition becomes critical when the percolation reaches at its maximum rate and the reservoir is full. In this condition the pore water pressure acting on the soil mass below the saturation line reduces the stability of the dam and causes slides. These slides may be of the following two a types.

(*a*) **Shallow slide.** These slides do not extend into the embankment and thus are not harmful.

(*b*) **Deep slides.** Generally these slides pass through the clayey foundation and reduce free board, resulting in the failure of the dam as shown in Fig. 13.16.

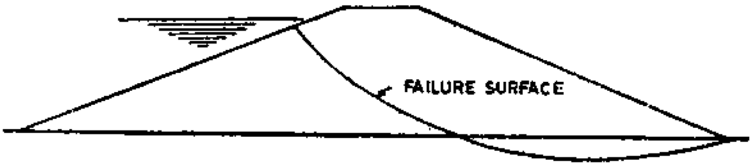


Fig. 13.16. Deep d/s slides during steady seepage

4. Foundation slide. When a dam is founded on a soft clay, shell or seams of weathered rock, the dam can slide over it causing complete failure. Excess water pressure on confined sand and silt seams in foundation may also cause foundation failure.

5. Failure due to spreading. When the dam is founded on stratified deposits consisting of layers of soft clays, this type of failure may occur. Fig. 13.17.

Fig. 13.17. Failure by spreading

6. Failure due to earth quake. Earth quake may cause the following effects:

(*a*) Development of cracks in the core of the dam leading to leakage and piping.

(*b*) Settlement of crest due to compression of foundation or embankment or both resulting over topping of the dam due to reduced free board.

(*c*) Shaking of reservoir bottom and producing waves leading to failure due to over topping.

(*d*) Sliding natural hill side causing over topping and damaging appurtence structures.

(*e*) Liquification of foundation sand, causing foundation slide.

(*f*) Slide of slopes due to accelerations.

7. Slope protection failure. Generally slopes are protected by rip-rap laid over a layer of gravel or filtre blanket. During storms, waves strike the rip rap of the slopes constantly above the reservoir level.

During this period waves may penetrate the voids of the rip-rap and wash away the filtre layer causing settlement of the rip-rap. This may lead to slope failure as sown in Fig. 13.18. This failure may also take place if rip rap of proper size is not placed. Hower failure of filtre layer is more common.

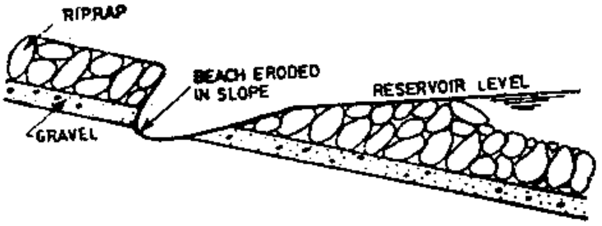


Fig. 13.18. Typical failure of riprap

8. Damage due to water soluble materials. Dams founded on foundations having materials which are soluble in water, may cause settlement of foundation, if these salts leach out from the natural deposits. At certain sites the presence of gypsum has proved very troublesome.

9. Failure due animal borrowing. Small animals dug burrows for hiding them selves or crossing from one side to other. Water may start passing through these holes and may result in the collapse of the dam.

13.11. SUMMARY OF FAILURE OF EARTH DAMS

S. No.	*Cause of failure*	*% of total failure*
1.	Over topping	30%
2.	Seepage due to piping and sloughing	25%
3.	Slides due to excessive internal fluid pressure or weak soil strength	15%
4.	Leakage along outlet conduits	13%
5.	Foundation failure	7%
6.	Miscellaneous	5%
7.	Unknown	5%

13.12. SAFETY OR REMEDIAL MEASURES OF FAILURE

1. Over topping. Over topping of dams takes place due to the following reasons:

(*a*) **Inadequate capacity of spillways.** The capacity of spillway be determined carefully, so that sufficient free board is available in all conditions. The free board is the height of the top of dam above the maximum flood level.

(*b*) **Insufficient free board for wave action.** To avoid over topping due to wave action the value of free board should be provided as 1.5 hw, where hw is wave height. The value of wave height may be determined from the following formulae:

(*i*) $$hw = 0.032\sqrt{FV} \qquad \text{for } F < 32 \text{ km}$$

(*ii*) $$hw = 0.032\sqrt{FV} + 0.763 - 0.271\,(F)^{1/4} \qquad \text{if } F < 32 \text{ km}$$

where F is the fetch of reservoir in km and v is velocity of wind in km per hour.

The minimum value of free board should be 2.0 m and maximum value 3.6 m.

Over topping due to settlement. Settlement due to foundation consolidation or the fill, may cause over topping of dams. To safe guard against settlement an allowance of 2% should be provided. However in case of earth dams more than 30 m in height 3.0% allowance should be adopted.

2. Seepage Control. Seepage ill effects are wide spread through the body or embankment and through the foundation of the dam.

A. Seepage control through embankment

Seepage through embankment can be controlled by the following measures:

1. By providing toe drain

2. By providing horizontal drainage filtre
3. By providing protective filtre down stream of toe
4. By providing down stream coarse section
5. By providing chimney drain extending upwards into the embankment

1. By providing toe filtre. Rock toe drains facilitates the drainage of the embankment and keeps the phreatic line well with in the section. Rock drains have proved better in highly stratified embankments.

Height of rock toe drain

(*i*) The minimum cover between the seepage line and the down stream slope must be 1 m. Thus generally the height of rock toe to be effective should be kept 1/3rd to 1/4th of the height of the dam.

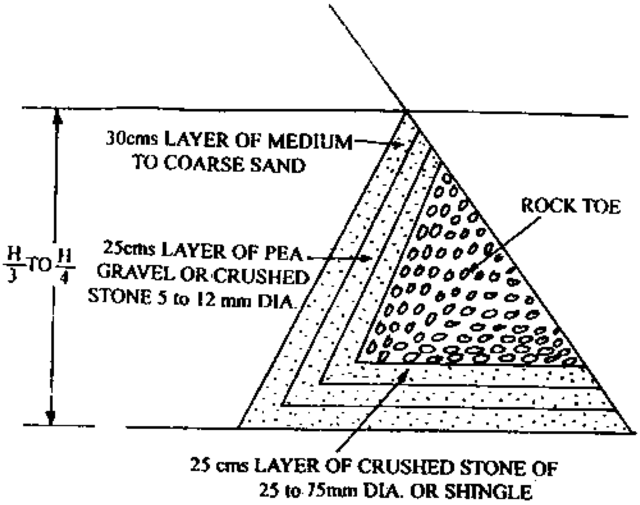
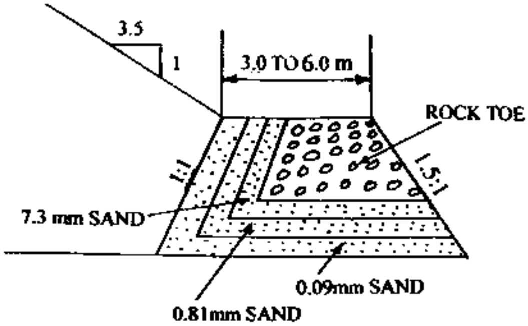


Fig. 13.19.



ROCK TOE WITH TRANSITION FILTER

Fig. 13.20.

(*ii*) The rock toe must be sufficiently higher than the tail water level to prevent any wave splashes on the down stream face. If it is not economical to raise the height of rock toe, then stone pitching upto a height of 1.5 m above high flood level on down stream side should be provided. The slope of the inward face of rock toe should be provided as 1:1 and down stream slope of rock face is kept same as that of down stream side slope of dam.

In case of high dams, a berm of 3 to 6 m and slope of 1:1 and 1.5:1 may be provided as shown in Fig. 13.20. Transition filtre between the homogeneous fill and the rock toe is provided comprising layers as below:

(*a*) 20 cm thick layer of fine sand of 0.09 mm size.
(*b*) 45 cm thick layer of coarse sand of 0.81 mm size
(*c*) 60 cm thick layer of gravel of 7.3 m size.

2. Horizontal drainage filtres. These drainages may be extended from 25% to 100% of the distance

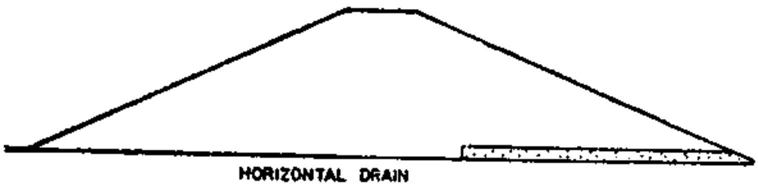


Fig. 13.21. (*a*) Horizontal filter

from down stream toe to the centre line of the dam as show in Fig. 13.21 (a).

Purpose. They serve the following purpose:

(a) They provide drainage to the foundation.

(b) They keep the phreatic line well with in the body of the embankment.

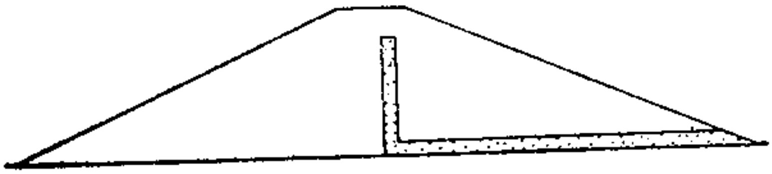
(c) They give greater seepage being shorter in length.

(d) They accelerate consolidation.

3. Filtre down stream of the toe. The provision of down stream toe filtre makes the upward flow of ground seepage more safe and checks the piping phenomenon due to its weight. Fig. 13.21 (b).

(b) Filtre down stream of the toe

(c) Down stream coarse section



(d) Chimney filter drain intercepts embankment seepage

Fig. 13.21. Seepage control

4. Down stream coarse section. It also intercepts the flow through embankment and makes the down stream slope safe against piping. Fig. 13.21 (c).

5. Chimney drains. In situations where horizontal permeability is higher than the vertical, a correctly built vertical drain can fully intercept the seepage of the embankment, irrespective of the degree of stratification of the embankment. It is resistant to earthquake effects also. Fig. 13.21 (d).

B. Methods of foundation seepage control for pervious foundations

For foundation seepage control, following measures may be adopted:

1. Grouting of foundation and provision of grout curtains. The use of grouting materials and sequence of grouting depends on the type of foundation and its conditions. Cement grouting is used extensively for rock foundations, while clay or chemical grouting can be used for pervious foundations. In India chemical grouting was used for the first time in 1960-62 at Kota dam. The use of curtain grouting has been found more useful in gravel and boulder strata.

2. Provision of cut off trenches. A trench is a ditch provided for checking the seepage of water through foundation. This treatment is applied for shallow pervious foundations. Usually the sloping side trench is used with side slopes as 1:1. The minimum width of these trenches should not be less than 6.0 m, so that excavating machine may work easily while digging the trench. These trenches are back filled with impervious materials and well compacted.

These trenches should be located well up stream of the centre line of the dam, but with in point where the cover of impervious embankment above the trench is sufficient to resist the perlocation at least equal to the extent offered by the trench itself.

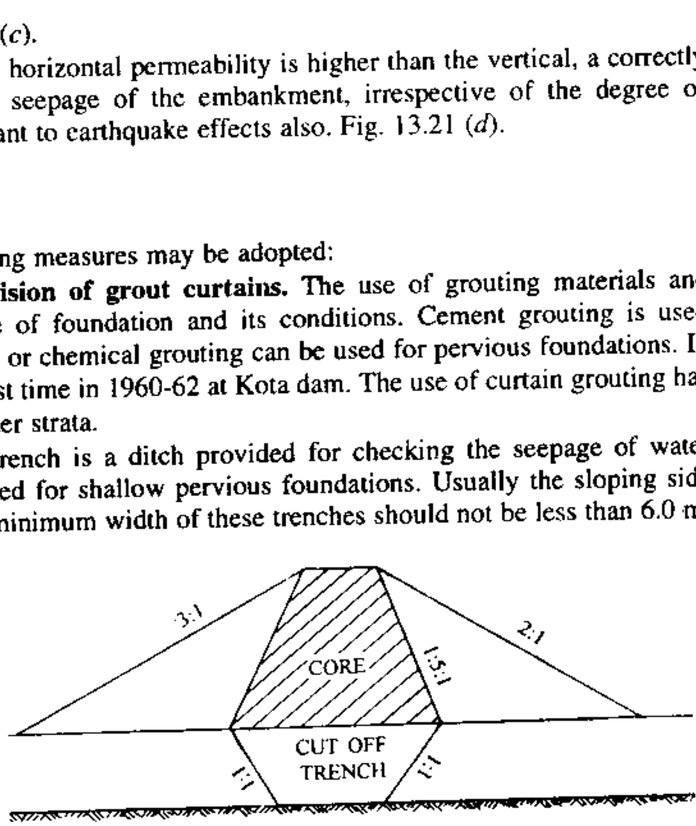


Fig. 13.22. Cut off trench

The centre line of the trench should be kept parallel to the central line of the dam. If economically feasible, the depth of the trench should be taken upto the bed rock or other suitable impervious strata. If the over lying depth of over burden over the impervious strata is upto 45 m, then cut off trench method of seepage control is most economical. The treatment of shallow pervious foundations is shown in Fig. 13.22.

3. Provision of partial cut off trenches. A partial cut off trench is effective in stratified foundations by intercepting the more impervious layers in the foundation and increasing the vertical path of seepage substantially. In a uniform pervious strata the rate of seepage or percolation reduction is very limited. It has been observed that 50% penetration of partial cut off will reduce seepage by 25% only and 85% penetration 50% seepage. Hence reliance on partial cut off can not be placed to reduce the seepage. Fig. 13.23 (*a*) shows treatment for moderate deep pervious foundation while Fig. 13.23 (*b*) shows treatment of a deep pervious foundation.

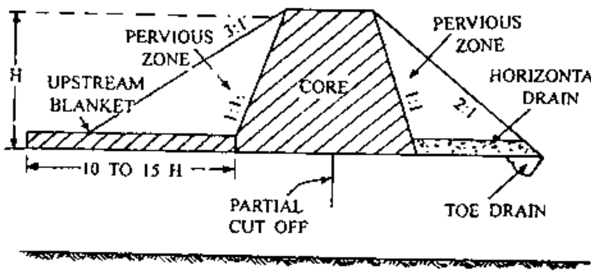


Fig. 13.23. (*a*) Partial cut off trench

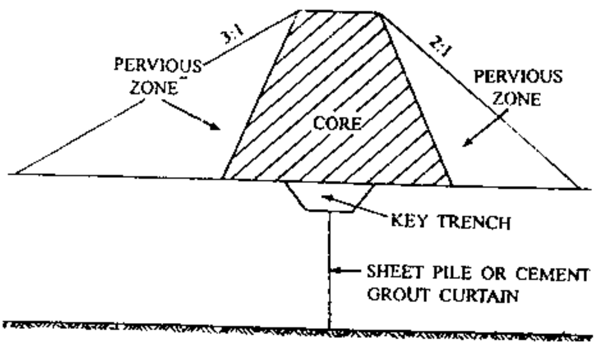


Fig. 13.23. (*b*) Provision of sheet pile

4. Sneet piling. If the depth of the over burden is more than 15 m and there are no boulders in the foundation, sheet piling is the best treatment of seepage control. Occasionally sheet piling is used in combination with partial cut off trench to increase the depth of cut off at a relatively lower cost. Under certain conditions it may be used in lieu of cut off trench, but practically sheet piling is limited to be used in foundations in silt, sand and fine gravel. Under best combinations of sealing, inter locking and good contact with imperious layers of foundation sheet piling will be 80 to 90% effective in checking seepage. Poor workmanship will reduce their effectiveness to about 50%. If the foundation strata contains boulders, then driving sheet piles will be difficult. Further to make the sheet pile cut off water tight will be difficult.

5. Cement bound curtains. In this method the cement sand grout is mixed with the foundation material. This is a relatively new development. This type of cut off can be used in pervious foundations which do not contain large boulders. In this process the grout is pumped through a hollow rotating drill rod. A mixing head is attached at the end of this rod. This mixing head has vanes which mix the grout with the foundation material as the head is forced down through the foundation. To ascertain thorough mixing of grout, the grout is pumped in both downward and upward travel of the head. In this process a cylindrical element of cement bound sand and gravel is formed. The successive overlapping of such cylindrical elements form a continuous curtain.

6. Cast in situ concrete diaphragm. In India this process was used for the first time at Obra dam in U.P. This method is suitable for making cutoffs in sandy foundations. In this process a 1.2 m wide and 5 to 10 m long tube is attached to the drill. Through this tube mud slurry is forced from bottom to top. The mud slurry makes slopes of the trench stable *i.e.* to stand in their position. This mud slurry exerts hydrostatic pressure as well as forms a layer on the sides of the trench. The excauated material is sucked out through he rigid tube along with the mud slurry. The mud slurry collected at top is taken to a tank, where the excauated material settles down at the bottom of the tank. The mud slurry is replenished with bentonite and reused in the drill. The excauating machine and the pipe move horizontally to and fro over the length of the panel. After executing the trench upto full depth, the trench is back filled with concrete in alternate panels in the first instant. The intermediate panels are filled subsequently.

7. Provision of up stream blanket. This method is adopted in situations where the foundation is pervious upto more than 30 m depth and the rock under dam is fissured and seepage control is not economically feasible. For normal conditions the thickness of the blanket may be kept from 1.5 m to 3.0 m and length about 10 times the head of the ponded water. In case of silty and sandy foundations, the length may be adopted as 15 times the head of ponded water. Fig. 13.23 (*a*). The thickness and length of the blanket may be determined from the following relations.

Thickness of blanket

The thickness of the blanket is a function of the following factors:

(*a*) Depth of foundation

(*b*) Permeability of foundation material

(*c*) Permeability of blanket material

The thickness t of the blanket at a distance b from the u/s toe of the blanket is given as

$$t = \frac{K_2}{K_1} \times b \times \frac{B}{d}$$

where

t = thickness of blanket

b = distance from u/s toe of the blanket to the point under consideration

B = length of blanket from u/s toe to imperious section

d = depth of pervious stratum in metres

K_1 = average permeability of foundation

K_2 = permeability of blanket

Length of blanket L

$$L = \frac{K \cdot h \cdot d - P \cdot Q \cdot b}{P.Q.}$$

where

K = mean horizontal coefficient of permeability of pervious stratum

h = head on impervious u/s blanket in metres

d = depth of pervious stratum in metre

Q = water flow under dam with out a blanket per meter of dam

b = length of impervious portion of base of dam in metre

p = % of seepage under dam with out blanket to which it is desired to be reduced. Say it is desired to reduce the seepage to 25% of the original, then p = 0.25.

8. Pressure relief wells. The problem of up lift pressure is excessive in situations, where impervious layer over lies a pervious stratum and the thickness of impervious layer is less than the height of impounded water. In such situations the provision of pressure relief well is the best solution. To get better pressure relief, these wells should penetrate into the principal pervious stratum, specially where the foundation is stratified to a great extent. (Fig. 13.24)

In case of shallow depths 6 to 9 m depth, they should penetrate upto the full depth. In case of thicker aquifers atleast 50% thickness should be penetrated. If the penetration of wells is less than 50% of the thickness, then their effectiveness is reduced to a great extent. In general, relief wells should be penetrated

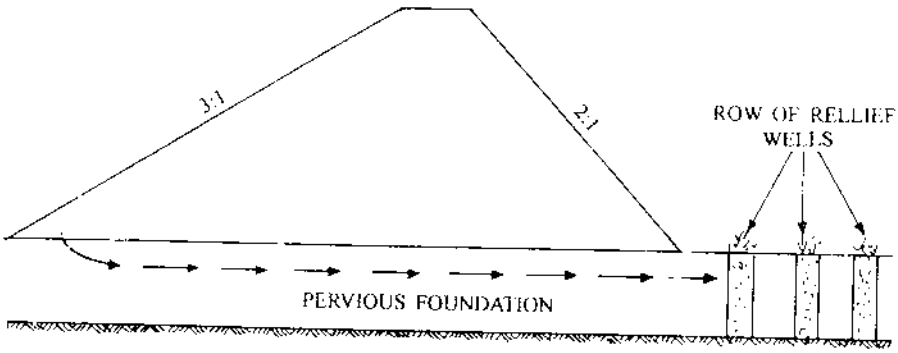


Fig. 13.24.

upto 1.5 times the depth of impounded water or 20 m. This penetration has given best results. The minimum internal diameter of well may be adopted from 10 to 15 cm, hower 60 cm diameter has been tried. To ensure better results their spacing may be kept from 15 to 30 m.

13.13. MAINTENANCE OF EARTH DAMS

Proper maintenance of earth dams is very essential as any small lapse may cause breach in dam resulting serious damage to the dam and devastation in the surrounding area. Generally following problems of earth dams need timely attention.

1. Horizontal piping through the embankment and foundation.
2. Boils on down stream side of the dam.
3. Cracks in the embankment.

1. Horizontal piping. Piping starts at the exit point of seeping water. The seeping water erodes and carries soil particles along with it, causing hollow around the passage of water. As more and more water flows, more soil is washed away forming sufficient wide channel. This phenomenon starting from down-stream side of dam advances towards its up stream side. Due to insufficient upward support, the dam settles down due to its own weight, resulting collapse of the dam due to its over topping.

Horizontal piping in embankment may develop due to insufficient compaction and poor bond between successive layers or poor bond between embankment and foundation. It may also develop through cracks and burrowing of holes. What ever may be the cause of its development, it is not possible to check it, once it is started. In such situations the material of inverted filtre on the down stream of seepage face is pumped out and an improved drain and filtre is provided to check piping.

Remedial measure. As soon as the reservoir level falls down, the upstream face above the seepage should be opened

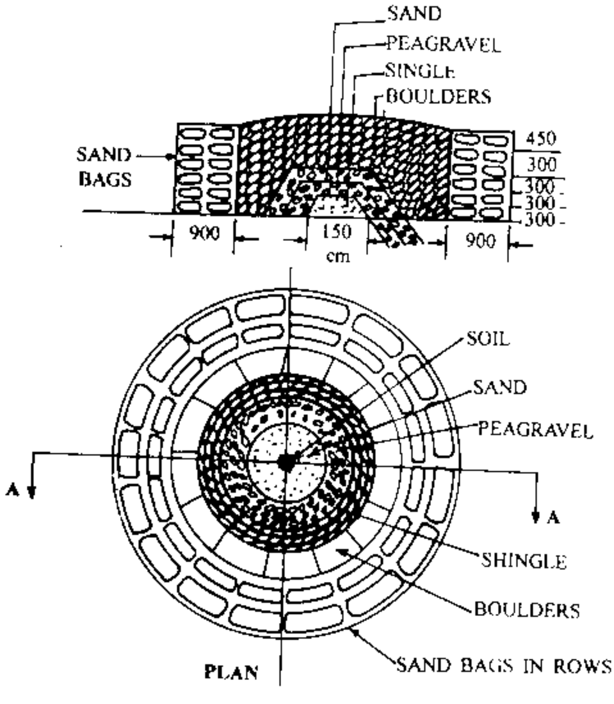


Fig. 13.25.

and pervious layers causing seepage should be located and pervious material removed. The space is refilled with impervious soil and properly compacted.

2. Boils. These boils always occur on the down stream side of the hydraulic structure due to high hydrostatic pressure from below the foundation. In this condition the up lift pressure becomes just equal to the down ward pressure due to the weight of the overlying material, *i.e.* the exit gradient attains the critical condition. If it is not checked the dam may be washed away.

Remedial measures. The most effective method of controlling the boils is to increase the overlying weight by providing ring bund of sand bags around the boil. The diameter of the ring bund should be at least 10 times the diameter of the boil. The area of ring bund should be large enough to avoid blow ups (boils) in the adjacent area. The height of ring bund should be such that it may cause sufficient head (weight) to reduce the flow through soil *i.e.* exit gradient may be less than unity (1/4 to 1/2). After formation of still pond in side the ring bund, filtre material should be laid in layers in the pond as shown in Fig. 13.25.

The permanent remedy of boils control is the provision of relief wells on the down stream side and blankment on the upstream side of the dam. It has been observed that embankments constructed of clay with plasticity index greater than 15, exhibited higher resistance to piping, while embankments constructed of fine uniform cohesion less sand with plasticity index less than 6 showed lowest resistance to piping.

3. Cracks in embankments. Cracks in embankments are caused due to differential settlement. Before actual treatment of cracks, they should be examined thoroughly to determine the depth and nature of cracks by actual inspection. Cracks may be longitudinal or transverse. Out of the two types, transverse cracks are most dangerous as they can create concentrated seepage. In low to medium height dams cracks usually occur in the upper portion of the dams.

Remedial measures. If the depth of cracks is more than 1.5 m and they are located above the water level of the reservoir, then they should be excavated in the form of the trench upto their depth and the trench is refilled with good soil and compacted well. The compaction should be done at about 4% higher moisture content than the optimum moisture content. For fine cracks upto 12 mm width, they should be grouted from top surface by clay grout of thin consistency of about 1:3 clay water ratio.

(*b*) In case the depth is more than 1.5 m and goes upto below reservoir water level then a trench of 1.5 m to 2.0 m width should be executed along the crack. From the execution level of the trench grouting of clay or clay cement of 1:8 to 1:1 soil water ratio depending upon the width of the crack should be injected. After grouting, the trench should be filled with clayey soil and compacted well. To increase the fluidity of the grout 3 to 5% bentonite may be added to both types of grouts.

Foundation treatment

1. Rock foundations. Usually rock foundations do not present any problem of bearing strength. However they can present problems of heavy seepage through joints, fishers, crevices, permeable strata and along the fault planes etc.

Remedial measures. Cement grouting is the best remedy of seepage through sound rock foundations.

2. Pervious foundations. In case of pervious foundations, following two problems are critical:

(*a*) Excess seepage (*b*) Piping and boils

Remedial measures. The remedial measures of the above problems depend upon the thickness of pervious strata, which have already been discussed above. Loose fine sand or coarse silt-deposits in foundations present one of the most important problems. This difficulty does not arise due to low strength or high compressibility of such strata, but due to the phenomenon known as liquification of sand. When due to earth quake or any other such reason, sudden vibrations are developed, then certain fine uniform sands in a loose state lose all their shear strength and behave as thick viscous fluid. This phenomenon is exhibited by uniform sands consisted of round grains having relative density less than 0.4. Development of such conditions may cause the collapse of the dam.

Remedial measures. To counter this phenomenon hydrostatic uplift pressure has to be reduced by providing more creep length to the seeping water. This can be achieved by driving long sheet piles to reduce seepage and to increase the creep length of seeping water.

QUESTIONS

1. Enumerate the causes of failure of earth dams. Suggest measures to check over topping failure.
2. Enumerate different measures of seepage control of an earth dam.
3. Draw neat sketches of:
   (*a*) Homogenous type earth dam
   (*b*) Zoned embankment type earth dam
4. Slipping down stream side slope of earth dam is known as
   (*a*) Boiling (*b*) Sloughing
   (*c*) Piping (*d*) Breaching
5. Failure of the earth dams due to sloughing takes place due to
   (*a*) Saturation of d/s toe of the dam (*b*) Saturation of the central core of the dam
   (*c*) Saturation of the u/s toe of the dam (*d*) Saturation of the foundation of the dam
6. Process of sloughing beings when
   (*a*) Wave erosion of u/s slope starts
   (*b*) Seepage line through the dam cuts the d/s slope at some height
   (*c*) Piping takes place through the foundation
   (*d*) A small amount of material at the d/s toe is eroded producing a small slide
7. Sheet piling for controlling the seepage can be used most successfully in situations
   (*a*) When foundation material contains sufficient quantity of big boulder
   (*b*) When foundation is founded on fissured rock
   (*c*) When soil below foundation is clayey
   (*d*) When foundation material consists of silt, sand and fine gravel
8. If the foundation is pervious upto more than 30 m and bed rock is fissured. the best method of seepage control is
   (*a*) Provision of partial cut off (*b*) Provision of u/s blanket
   (*c*) Use of sheet piles (*d*) Provision of relief wells
9. If under the foundation an impervious layer over lies a pervious layer and the thickness of impervious layer is less than the head of impounded water, the best method of reducing uplift pressure is
   (*a*) Provision of u/s blanket (*b*) Provision of relief well on d/s
   (*c*) Provision of sheet piles (*d*) Any of the above
10. Identify the incorrect statement/statements
    (*a*) 50% penetration of partial cut off will reduce seepage by 25% and 85% penetration 50% seepages, hence not retable process
    (*b*) Poor workmanship of sheet piling will reduce its effectiveness to 50%
    (*c*) Sound rock foundations usually present more bearing strength problems
    (*d*) Excessive seepage is a critical problem in pervious foundation
11. Identify the correct statement/statements
    (*a*) Boils always occur on the down stream side of a hydraulic structure
    (*b*) Boils occur when uplift pressure is equal to the down word pressure
    (*c*) Boils can be checked by reducing the exit gradient less than critical gradient
    (*d*) All are correct
    (*e*) None is correct

ANSWERS

4. (*b*)	6. (*d*)	8. (*b*)	10. (*c*)
5. (*a*)	7. (*d*)	9. (*b*)	11. (*d*)

14

Highway Drainage, its Failure and Maintenance

14.1. INTRODUCTION

Highway maintenance can be defined as to up keep and preserve each component in their original condition as far as possible and add such works, which are necessary to keep the traffic moving safely. The location, design and construction of a high way has direct bearing on its maintenance cost and condition. During design stage it is essential to know the probable defects likely to develop during construction. At the time of alignment, the problem of drainage, stream crossings, land slide conditions, suitability of soil and directness of route etc. must be investigated fully. Insufficient thickness of a pavement or base or improper construction may result in serious damage very soon. At locations of narrow road widths force the heavy traffic to shoulders, causing serious damage to them.

Further it is well known that moisture content in base or sub base has a direct bearing on the durability of the road surface. The increase in moisture content reduces the bearing capacity of soil to a great extent. Thus the stability of a high way is a function of the quantum of moisture. Hence high way drainage is one of the most important aspect of its durability. The process of collecting and removing the excess surface and sub soil water of the right of way of the high way is known as highway drainage. Thus it is an integral part of the design, construction and maintenance of high ways.

Thus at the time of construction, proper investigations of site conditions, proper design and quality control is essential for proper and economical maintenance of the high way system. Before discussing the maintenance aspects, the drainage and causes of failure of high ways have been discussed briefly.

14.2. MODE OF DAMAGES CAUSED BY WATER

Damages to highway may be caused by water in the following ways:

1. Earth and water bound macadam roads are damaged by softening the road surface.
2. Erosion of side slopes, damaging side drains, washing out unprotected top surface and forming gullies etc.
3. Softening the sub grade soil and decreasing its bearing capacity.
4. Causing land slide by softening the soil along the high way.

14.3. CLASSIFICATION OF DRAINAGE WORKS

High way drainage may be classified as follows:

1. **Surface drainage.** If surface water is not intercepted and diverted to a natural channel or depression, it will flow along the road or across it, causing erosion.
2. **Sub surface drainage.** In this case, the seeping water is intercepted and diverted to a safe place.
3. **Cross drainage works.** In this case, water of natural drainage under the high way is intercepted and disposed off.

14.4. REQUIREMENTS OF A GOOD DRAINAGE SYSTEM

The drainage system of high way should possess the following characteristics:

1. The surface water from the carriage way and shoulders should be drained off effectively as soon as possible with out allowing it to percolate to the sub grade.
2. Surface water from the adjoining land should not be allowed to enter the road.
3. Side drains should have sufficient capacity and longitudinal slope to discharge maximum surface water collected in the region.
4. Flow of water along the slope or across the road should not be allowed to erode them or form ruts there.
5. The seeping water or capillary rise water should be drained off at the earliest other wise it will lower the bearing capacity of the sub grade.
6. The highest ground water table level should be 1 to 2 m below the sub grade level of the highway.
7. In water logged ares, special precautions are to be taken as discussed later.

14.5. SURFACE DRAINAGE

Surface water due to rain etc. generally is collected in side drains and disposed off in near by depressions, river, etc. For the disposal of surface water, cross drainage system such as culverts, bridges etc. are required. Surface water from road surface may be removed by providing cambler or cross slope to the road surface. Road surface should also be made impervious to prevent surface water to seep into the sub grade. The rate of camber depends on the type of road surface and amount of rainfall. For different types of pavement the range of camber is recommended as follows:

Table 14.1. Showing camber for different surfaces

S. No.	*Type of surface*	*Range of Camber*
1.	Cement concrete road surface	1 in 60 to 1 in 72
2.	Bituminous surface	1 in 48 to 1 in 60
3.	Water bound Macadem	1 in 35 to 1 in 48
4.	Gravel roads	1 in 25 to 1 in 30
5.	Earth roads	1 in 20 to 1 in 25

14.6. DRAINAGE OF RURAL PLAIN AREAS

In rural highways, it is common practice to allow surface water to flow across shoulders before it is collected in side drains. The shoulders of rural roads are also provided with a suitable cross slope to drain off the water quickly. The side drains generally are unlined of trapezoidal cross section The cross section and longitudinal slope is provided depending on rainfall of the area. Generally these side drains are provided parallel to the road, hence they are called parallel drains. Fig. 14.1 shows a typical cross section of a rural road. The disposal of surface water depends whether the road is on embankment, in cutting or on ground surface.

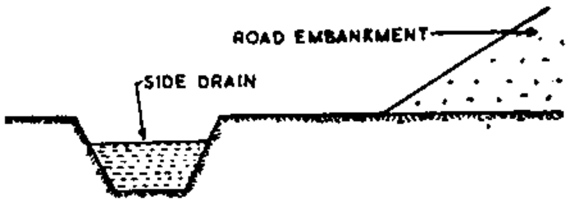


Fig. 14.1. Cross section of drain of rural road

14.6.1. Road on embankment

For drainage of roads on embankment higher than 2.0 m, the common practice is to allow the surface water to flow across the shoulders and down to the side slope to the side drains or natural ground. In such cases due care is needed to protect the side slope and shoulder from erosion. In situations where side slope are properly protected by grass or turf and the flow from the road surface is well distributed to give a fairly uniform sheet of water, there is no danger of erosion.

In case side slopes are not properly protected, and sheet flow is not possible or shoulders or pavement irregularities concentrate the flow into small streams, then side slopes are damaged badly and washed away. In such situations, V shaped longitudinal side drains are provided. Water from these drains is disposed off at suitable points to the natural ground by paved drain. In such situations sloping drains are provided with lining or pitching. At the foot of the slope aprons are also provided to check damage of the natural ground there.

On embankments, generally drains are provided on both sides. The minimum distance of the drains from the formation should not be less than 2 m. Such situation are met generally on approach roads to bridges.

On embankments about 1.8 to 2.0 m high, side slopes should be given slopes of 4:1 and protected by turffing or vegetation. The velocity of flow can be reduced by giving flat slope to the shoulders and corners should be rounded off as shown in Fig. 14.2 (*a*).

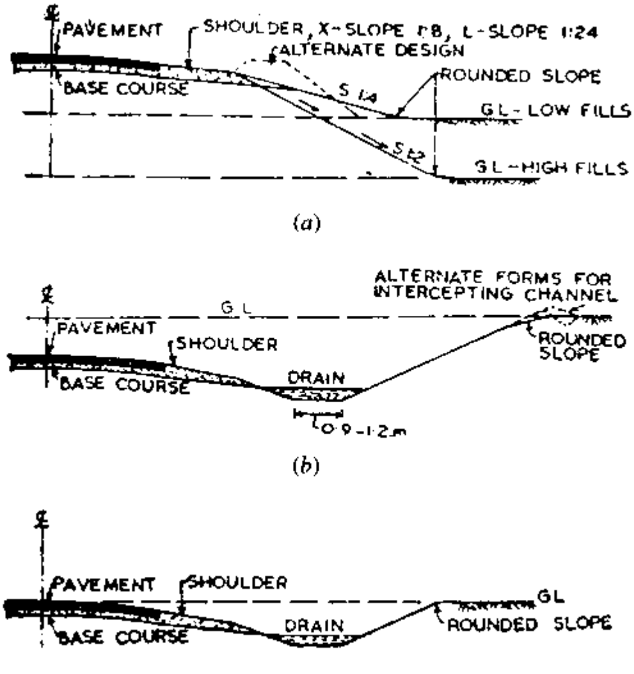


Fig. 14.2. Drainage arrangement of a road embankment

14.6.2. Road in cutting

When the road is in cutting, drains on both sides of the formation should be provided as shown in Fig. 14.2 (*b*). In this case the drains should be just after the edge of the formation. In case there is restriction of space, then in place of open deep drains, covered drains or drain trenches filled with gravel and coarse sand layers should be adopted. Fig. 14.2. (*b*).

14.6.3. Road on ground line

In this case water is disposed off by side drains as shown in Fig. 14.2 (*c*).

14.7. DRAINAGE IN URBAN PLAIN AREA OR CITY DRAINAGE

The drainage problem of urban areas is more complex and difficult due to the following reasons:

(*a*) Due to non availability of natural water course.

(*b*) Due to limitation of land width due to high cost of land for open drains.

(*c*) Due to presence of foot path, dividing islands and other road facilities.

(*d*) Due to impervious character of city area, results high run off.

(*e*) Due to undesirability of open drains due to unsightly appearance and risk to users. Thus due to the above reasons surface water from city roads is taken through under ground pipes called sewers or storm water drains for a long distance and then released as surface run off.

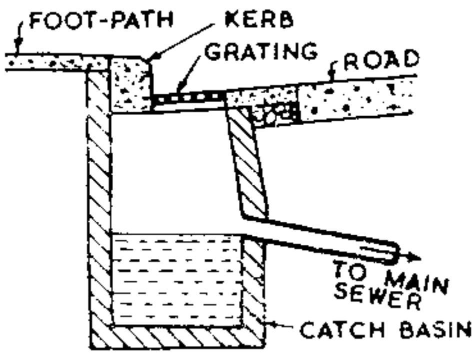


Fig. 14.3. Typical cross-section of Grating catch basin

The surface water enters the storm drains through inlets.

The inlet system consists of either a filtre system or a grating provided for the entry of water. Fig. 14.3 shows a grating catch basin. The grating is provided at the edge of shoulders which reduce the carriage way. Some times they are broken due to impact of heavy vehicles. Due to these drawbacks of grating system, hollow Kerbs known as kerb inlets are preferred than gratings. Fig. 14.4 shows a Kerb inlet Fig. 14.5 shows road inlet where rain water is drained through a central under ground pipe. Hence water is admitted through gullies. Fig. 14.6 shows the arrangement of gullies for road junction when both road ways have their normal arched cambers. The water is disposed off in main sewer line. Water is collected at A.A. and B.B. It should never be collected at the crossing.

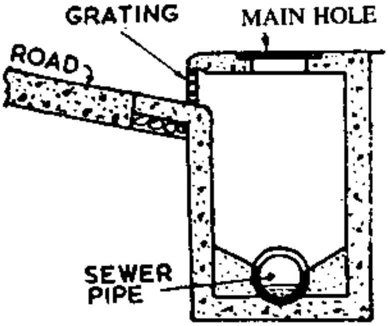


Fig. 14.4. Kerb inlet

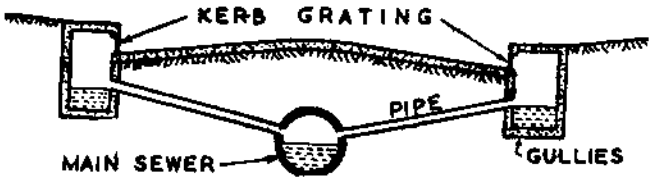


Fig. 14.5. Road inlet

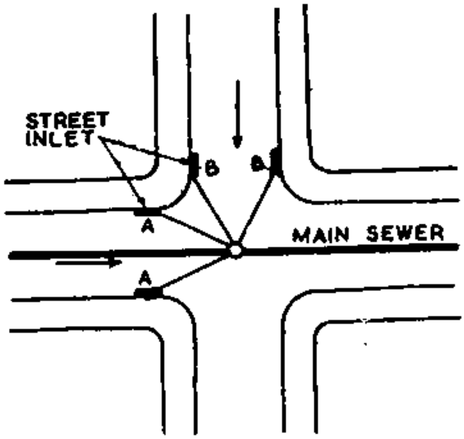


Fig. 14.6. Road gullies

14.8. CROSS DRAINAGE

When ever a high way crosses a river or stream, cross drainage works have to be provided. On high ways usually culverts and bridges are used as cross drainage. If the cross drainage is upto 6 m wide then they are known as culverts. For higher discharge and greater lineal way the structure is known as bridge.

14.9. TYPES OF CULVERTS

According to construction, culverts may be classified as follows:

(*a*) **Slab culverts.** If the span is limited to 3 m, then usually slab culvert is adopted. In this case a R.C.C. slab is placed over abutments made of brick masonry.

(*b*) **Arch culverts.** For spans more than 3.0 m, arch culverts are adopted. In such conditions the slab culvert will be costlier due to greater thickness of slab.

(*c*) **Box culvert.** If water is to be passed at ground level then square or rectangular R.C.C. box culverts are adopted.

(*d*) **Pipe culverts.** If the discharge is low, then a pipe of minimum diameter of of 75 cm is embeded below the road to carry the discharge. This pipe is called the pipe culvert. Pipe may be of steel or R.C.C.

Bridges. These have been discussed in chapter 23.

14.10. SUB SURFACE DRAINAGE

The changes in the moisture content of sub grade are caused by the seepage and percolation of rain water, fluctuations in ground water table and capillary fringe etc. The ill effects of moisture increase in sub grade are well known. Thus the aim of sub soil drainage of high way is, to prevent changes in moisture content of sub grade to preserve its bearing capacity and shear strength.

14.11. TYPE OF SUB SOIL DRAINAGE SYSTEM

The choice of effective system of sub soil drainage depends on the following factors:

(*a*) Position of ground water table

(*b*) Position of seepage zone, if any

(*c*) Type of soil and thickness of different strata *i.e.* profile of soil

14.12. CONTROL OF SUB SOIL FLOW

Following controls have been found effective for sub soil flow:

(*a*) **Control of seepage flow.** In case the seepage zone exists with in one metre depth below ground surface, then installation of intercepting drains has been found very useful as shown in Fig. 14.7.

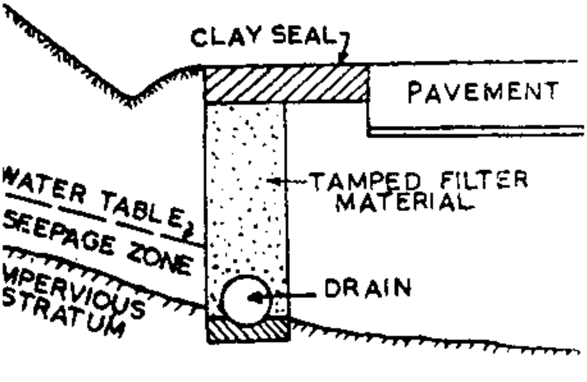


Fig. 14.7. Intercepting drains

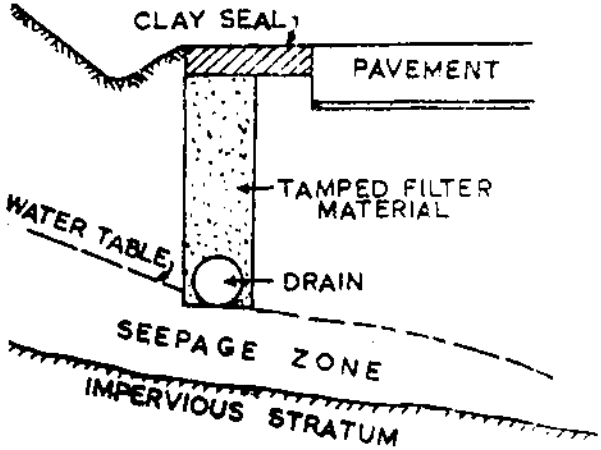


Fig. 14.8. Deep drains

(*b*) In case the seepage zone is wide or impermeable strata is deep, then provision of drain to keep the water table about 1.3 m below the formation has been found very effective as shown in Fig. 14.8.

In such situations it is not economical to take the trench upto the impervious strata and intercept all the seepage. In such situations provision of a drain at a depth of 1.3 m to 1.5 m below the formation has been found very effective.

14.13. CONTROL OF HIGH WATER TABLE

(*a*) To avoid excessive pressure on sub grade and pavement, it has been found based on experience that water table be kept at least 1.2 m below the sub grade.

(*b*) In case water table touches the ground level during a particular period of the year, then the best remedy is to take the road formation on an embankment. In such cases the height of embankment should not be less than 1.2 m.

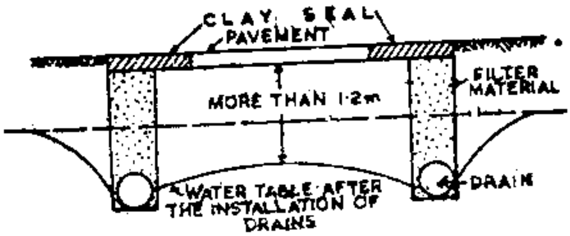


Fig. 14.9. Arrangement of sub surface drainage—Longitudinal and Transverse Drains

(c) In case the road formation is to be kept at general ground level or lower than it, in that situation lowering of water table is essential.

(d) In case of relatively less permeable soils, the lowering of ground water table can be done by providing longitudinal and transverse drains as shown in Fig. 14.9.

(e) In case the soil is more permeable, then water table may be lowered by constructing longitudinal drainage trenches with drain pipes and sand filtres etc. The depth of trench will depend on the type of soil and requirement of lowering of ground water table Fig. 14.10.

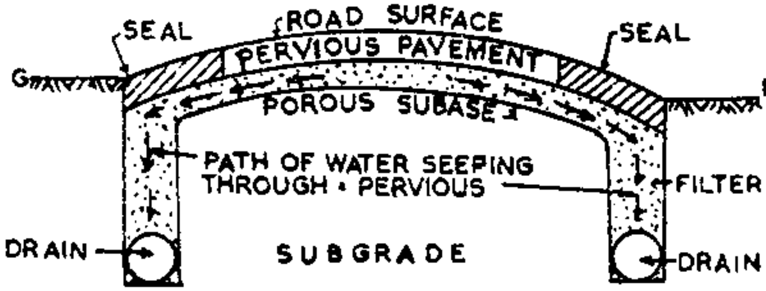


Fig. 14.10. Drainage with porous sub base

14.14. CONTROL OF WATER ENTERING THE SUB GRADE THROUGH PERVIOUS PAVEMENTS

Actually in practice it is not possible to have perfect imperious road surface. The entry of water may be checked by the following methods:

1. By the provision of porous sub grade. In this case a porous sub base of thickness varying from 15 cms to 50 cms is provided between the sub grade and the pavement as shown in Fig. 14.10. The sub base is to be laid on porous bed as sand or gravel. The sub base intercepts the seeping water from above and leads it to the side trench and drain. For effective working the sub base should be given proper camber and there should not be any depression in it.
2. By the provision of stabilized sub grade. A sub base of 7.5 cm to 15 cm of stabilized material such as cement, bitumen or other suitable material may be provided.

14.15. CONTROL OF SEEPAGE WHEN THE ROAD IS IN CUTTING

When the road is in cutting, the seepage of sub grade is checked by providing catch drains at Ground level and side drains at road level. For these drainage either ordinary trenches of suitable section or pipes of 10 to 15 cm diameter are provided at an interval of 10 to 12 m. Fig. 14.11 shows the arrangements of drainage in cutting, while Fig. 14.12 shows drainage when the road is partially in cutting and partially in fill as in the case of hill roads.

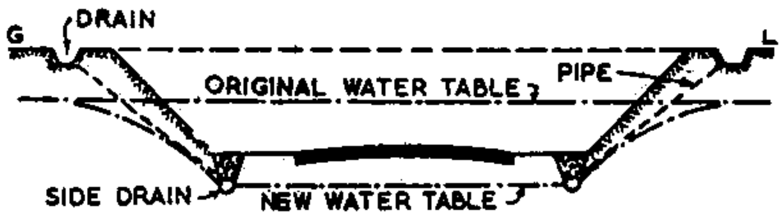


Fig. 14.11. Drainage arrangement in cuttings

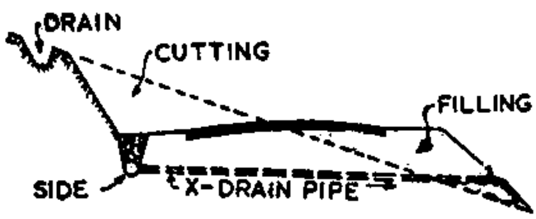


Fig. 14.12. Drainage in partially in cutting and partially in filling

14.16. CONTROL OF CAPILLARY RISE

If capillary rise is found detrimental to the sub grade, then arresting of capillary rise is more effective than lowering the water table level. Capillary rise may be arrested by the following methods.

1. By the provision of a granular layer. In this method a layer of granular material of suitable thickness is laid between the sub grade and highest surface water level during construction of the road. The thickness of granular layer should be such that the capillary rise should not go above the granular layer or cut off layer as shown in Fig. 14.13.
2. In place of granular layer, an impervious layer of bituminous or other suitable material may be placed between the sub grade and highest water table as shown in Fig. 14.14.

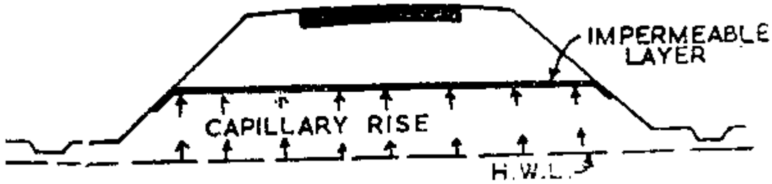


Fig. 14.13. Control of capillary rise by grannular layer

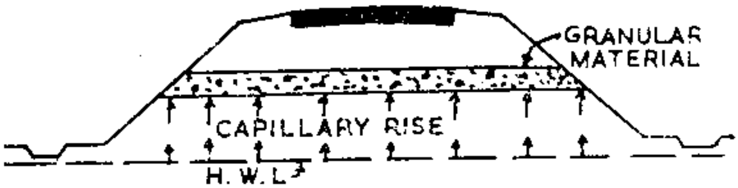


Fig. 14.14. Control of capillary rise

14.17. ROAD CONSTRUCTION IN WATER LOGGED AREAS

Some times roads have to be constructed in water logged areas. In such areas, the sub grade always remains saturated with water due to high ground water table and capillary rise etc. Some times road remain flooded with water for a considerable period. In addition to water logging, if the area is infested with harmful salts such as sulphates etc. then the construction and maintenance of roads is very difficult.

14.17.1. Remedial measures

Case 1. Water logging only without salts. In such cases following measures may be adopted.

(*a*) Road formation may be raised by constructing embankment.

(*b*) Water level may be lowered by any suitable drainage system.

(*c*) Capillary rise may be arrested by providing capillary cutoffs.

(*d*) Thickness of pavement may be increased depending upon the condition of sub grade.

(*e*) To ensure speedy drainage of foundation soil, horizontal sand blanket at top and vertical sand drains may be provided at suitable intervals.

Case 2. In addition to water logging, area remains flooded for a long period. In such situation in addition to the above mentioned measures, the road surface may be provided of cement concrete. If the traffic is light in that case bituminous surface with a seal coat may be provided.

Case 3. In addition to water logging, flooding, detrimental salts are also present. In such situations following measures may be adopted:

(*a*) Measures as suggested in case 1, should be adopted carefully.

(*b*) Superior construction materials should be used.

(*c*) An effective capillary cut off should be provided below the sub grade.

(*d*) Proper water proofing course should be provided on the pavement surface.

(*e*) In case of low permeability soil, gravitational drainage system should not be adopted.

14.18. FAILURE OF FLEXIBLE PAVEMENTS

The failure of a flexible pavement is defined as the localized depression and heaving up in its vicinity. The sequence of depression and heaving up develops wavy surface of the pavement. The settlement of any of the component layer as sub grade, sub base course, base course and wearing course of the flexible pavement develops waves and corrugations or longitudinal ruts and shoving on the pavement surface. The excessive unevenness of the pavement surface may itself be considered as a failure. Thus to make a pavement durable and to maintain its stability each layer should be made stable. Fig. 14.15 (*a*) shows the failure of sub grade, Fig. 14.15 (*b*) shows failure of base course and Fig. 14.15 (*c*) shows failure of wear course. The failure of sub grade may be due to the following two causes.

1. Inadequate stability
2. Excessive stress application

1. Inadequate stability. It may be caused due to the following factors:

(*a*) Inherent weakness of soil itself

(*b*) Excessive moisture in the sub grade

(*c*) Inadequate compaction of the sub grade

2. Excessive stress application. Excessive stress develops due to the application of more load than designed load and provision of inadequate thickness of pavement. The deformation of sub grade soil increases with increase in number of load application.

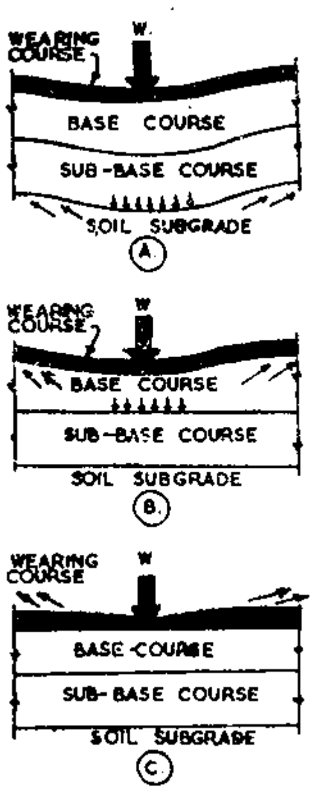


Fig. 14.15. Failure of flexible pavement

14.19. FAILURE OF SUB BASE OR BASE COURSE

The failure of sub base or base course takes place due to the following reasons:

1. Inadequate strength or stability
2. Loss of cohesion
3. Loss of material
4. Inadequate thickness of wearing course
5. Use of inferior material
6. Crushing of base course
7. Lack of lateral support to the base course

1. Inadequate strength. Following factors contribute the inadequate strength to the sub base:

(*a*) Improper mix design or proportion

(*b*) Inadequate thickness of sub base or base course

(*c*) Use of soft variety of stone aggregate

(*d*) Poor quality control during construction period

2. Loss of cohesion Due to the repeated application of load or stress the internal movement of the aggregates in the sub base takes place, which disturbs the composite structure of the layers. The disturbance in the structure of layers results in loosening of total mass. Thus the loss in cohesion results in low stability and poor load distribution property of the pavement layers.

3. Loss of base course material. Due to the fast moving vehicles on the road, suction is caused between the exposed base course material and pneumatic tyres. This suction causes removal of binding material in W.B.M. base, leaving the stone aggregate in loose state. The exposed aggregates of the base course also form dust due to abrasion. The repeated use of such pavements results in loss of stone aggregates forming pot holes. The removal of material is known as *revelling.*

Inadequate thickness of wearing course. Inadequate thickness of wearing course or its absence exposes the base course to the ill effects of climatic variations due to rain, frost action and traffic action as well. Depending upon the intensity, type, and volume of traffic, suitable thickness of wear course should be provided.

5. Use of inferior material. Many failures of highways have been observed due to the use of inferior construction material. The characteristics of many materials change with time, hence construction materials should be tested as per I.S. specifications before use.

6. Crushing of base course. The thickness of base course should be kept sufficient as per design and no loss of material from it should be allowed.

7. Lack of lateral support to base course. Adequate lateral support to base course should be provided by providing sufficient shoulder width of good material.

14.20. FAILURE OF BITUMINOUS WEARING COURSE

Failure of bituminous course may take place due to the following factors:

1. Improper mix design
2. Inadequate quantity of binder material
3. Inferior quality of binder material
4. Oxidation of bituminous binders
5. Poor quality control during construction

14.21. TYPICAL FAILURE OF FLEXIBLE PAVEMENTS

Some of the typical failures of flexible pavements are discussed below:

1. Map or Alligator cracking
2. Consolidation of pavement layers
3. Shear failure
4. Frost heaving failure
5. Longitudinal cracking
6. Lack of cohesion in different layers
7. Formation of waves and corrugations

14.21.1. Alligator or Map cracking.

This is the most common type of failure of bituminous surfaces. Generally it occurs due to fatigue. It may also occur due to localized wetness of the under lying base course. In the beginning, the map cracking develops over a small area of the road surface and if it is not repaired in time, it may extend to the entire surface of the road, resulting in pot holes. Map cracking is attributed due to the following causes:

(*a*) Hardening of asphalt

(*b*) Low temperature of the surrounding region

(*c*) Lack of asphalt

(*d*) Plastic deformation of the supporting layers

(*e*) Lack of drainage

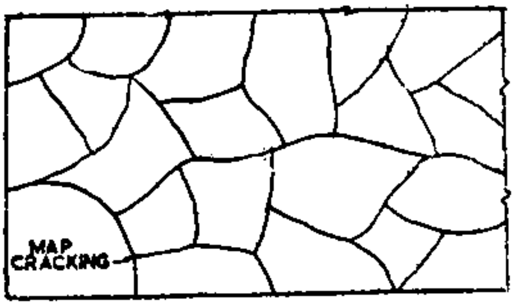


Fig. 14.16. Map or Alligator cracking

Fig. 14.16 hows a general pattern of map cracking

Remedial measures. Map cracking may be rectified by patching the affected area with bituminous material and sand. Rapid curing or medium curing cut back or emulsified bitumen should be used, so that it may thoroughly penetrate into the cracks. The bituminous patching should extend a little beyond the affected area.

14.21.2. Consolidation of pavement layers

The repeated application of loads on the same location of the road causes consolidation and deformation resulting in depression on the road. These depressions are called ruts. Thus ruts formation on roads are mainly due to the consolidation of one or more layers of the road or pavement. Fig. 14.17 shows a typical rut formation of the pavement.

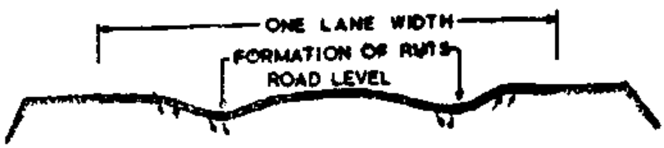


Fig. 14.17. Rut formation on a road

Remedial measures. Rut formation may be rectified by the following measures:

1. In depressed portion moorum may be spread.

2. The sub grade should be strengthened or thickness of road should be increased.
3. In case ruts are due to high camber, then camber should be reduced and ruts should be rectified.
4. Ruts are scarified and the surface is compacted well.

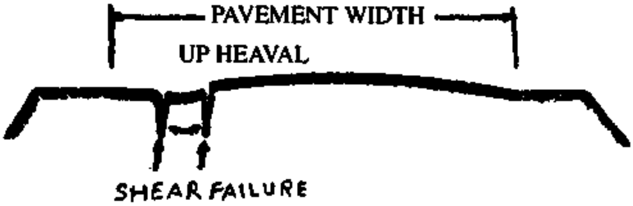


Fig. 14.18. Shear failure of road

14.21.3. Shear failure

This failure occurs due to the inherent weakness of pavement materials. Shear failure causes upheaval of the pavement materials resulting in cracking or fracture. Fig. 14.18 shows a shear failure.

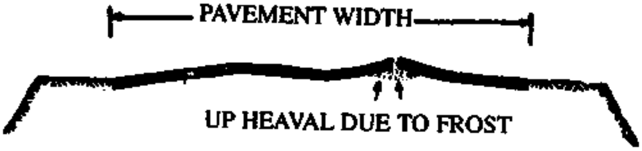


Fig. 14.19. Frost up heaval

14.21.4. Frost heaving

Frost heaving mostly is a localized heaving up of pavement portion depending upon the ground water table and climatic conditions of the area. The main difference between shear upheaving or other type of failure is that in shear or other failure the upheaval of the pavement is followed by a depression while in frost heaving it is a localized upheaval as shown in Fig. 14.19.

14.21.5. Longitudinal cracking

Longitudinal cracking in pavements develops due to differential volume changes or other reasons such as frost action, settlement of embankment or sliding of slopes etc.

14.21.6. Lack of cohesion between different layers

This type of failure occurs when there is no proper bond between the wearing course and underlying base course etc. This failure results in opening up and loss of material forming pot holes as shown in Fig. 14.20. Generally this type of failure takes place when the bituminous surfacing is provided over the existing cement concrete base etc.

Fig. 14.20. Cohesion failure

14.21.7. Formation of waves and corrugations

This type of failure occurs due to localized depressions followed by heaving up in the vicinity. The sequence of such depressions and heaving up results in waves and corrugations on the pavement surface.

14.22. FAILURE OF CEMENT CONCRETE PAVEMENTS

Failure of cement concrete pavements takes place due to the following reasons:

14.22.1. Deficiency of materials used

Under this head following factors are grouped:

(*a*) **Use of soft aggregate.** Poor and soft aggregate cause crushing and disintegration of cement concrete, and development of cracks.

(*b*) **Poor workman ship of construction joints.** This causes poor riding surface and spalling of joints.

(*c*) **Use of poor joint filler and sealer materials.** This also causes poor riding surface and spalling of joints.

(*d*) **Poor surface finish.** It may cause slippery pavement surface.

(*e*) **Inadequate curing.** It may cause reduced compressive strength and also may cause shrinkage cracks. Formation of cracks may allow the surface water to seep into the under lying layers causing further deterioration of the pavement.

14.22.2. Structural inadequacy of pavement system

Under this head following factors are classified.

(*a*) **Inadequate thickness of pavement.** It may result in cracking of slab at corners.

(*b*) **Inadequate sub grade.** It may cause settlement of pavement.

(*c*) **Poor soil of sub grade.** It may widen the joints.

(*d*) **In correct spacing of joints.** It may cause mud pumping in pavements.

14.23. TYPICAL FAILURES OF RIGID PAVEMENTS

In rigid pavements generally following failure have been observed:

1. Scalling of cement concrete
2. Development of shrinkage cracks in concrete
3. Development of wraping cracks
4. Structural cracks
5. Spalling of joints
6. Mud pumping

1. Scalling of Cement Concrete. Generally cement concrete scalling occurs due to the presence of chemical impurities in the mix or due to poor mix design. Further during construction of the pavement, if excessive vibration is given to the concrete, then the matrix or mortar comes upon the surface. This mortar gets abraded during the long use of the surface leaving the aggregate surface exposed. This makes the surface rough and unsightly in appearance.

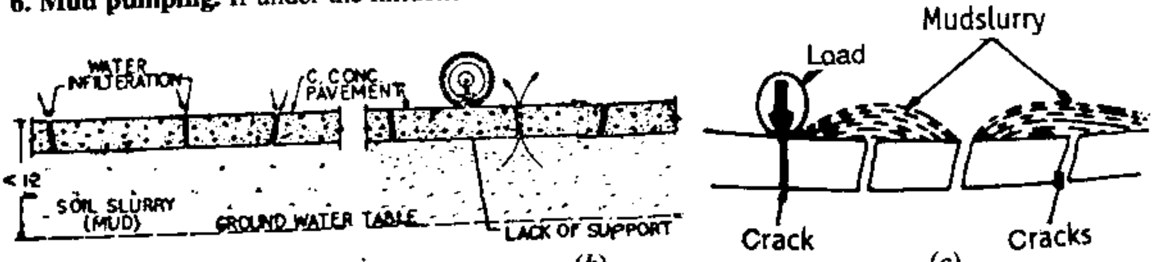
2. Development of shrinkage cracks. Shrinkage cracks in cement concrete pavements generally develop in longitudinal as well as transverse direction during curing period. These cracks may allow the ingress of moisture in the road, which may disintegrate the concrete.

3. Development of warping cracks. In case, the joints are not well designed to accommodate the warping of the slab at edges, the slab will develop cracks due to the development of excessive stresses in it. If longitudinal and transverse reinforcement is provided at the joints, it will take care of all structural defects.

4. Structural cracks. Structural cracks are developed due to the inadequate thickness of the pavements.

5. Spalling of joints. Some times during construction of cement concrete pavements, prepared filler materials are used at joints. Some times these fillers are disturbed and get tilted. If concreting is done on these fillers in the tilted position, an over hanging layer of concrete takes place on the top of the filler, subsequently this filler results in subsidence of soil under the joint and excessive cracking takes place near the joint.

6. Mud pumping. If under the influence of wheel load concrete pavement moves down ward and gets



(*a*) (*b*) (*c*)

Fig. 14.21.

cracked, the ejection of soil slurry in such a condition is known as mud pumping. Generally such phenomenon occurs in pavements placed on clayey soil sub grades. Due to the repeated application of loads pavement gets vibrations and the soil below concrete slab gets compacted and some space is left underneath the pavement slab. Water may seep through the joints and cracks into this space forming soil slurry. The subsequent application of heavy wheel loads deflect the pavement slab at critical locations and force out some soil slurry each time. This causes hollow underneath the concrete slab resulting in failure of the pavement.

14.24. MAINTENANCE OF HIGHWAYS

As already stated, maintenance of a highway can be defined as preserving and keeping each component of the high way in their original condition. Thus after studying various defects which may cause the failure of the pavement, different measures should be adopted to maintain and up keep the pavement in excellent condition. As a basic rule any pavement designed and constructed on scientific basis needs minimum maintenance.

14.25. FACTORS AFFECTING MAINTENANCE OF HIGHWAYS

Generally following factors affect the maintenance of pavements

1. **Increase in the intensity of traffic.** Since independence, the increase in road transport in India is about 8% per year which is more than even in U.S.A. and U.K. Further to cope with the transport demand, Government of India has allowed 25% increase in the axle load. Research Board of U.S.A. has established that an increase in 25% axle load has twice the destructive effect on the pavement.
2. **Inadequate thickness of pavement.** In adequate thickness of pavement will cause frequent failure of pavement, unevenness of surface and pot holes.
3. **Effect of number of lanes.** Road Research laboratory U.K. has established by experiments that concentration of load is almost 4 times larger on a single lane pavement than a double lane pavement section. Thus the pavement distress and maintenance requirements of a single lane pavement are higher than double lane pavement. In India more than 70% National highways and 80 to 90% state and other major district roads are single lane, hence they need greater care and maintenance.
4. **Increase in labour and material cost.** Paucity of funds and increase in prices of materials and labour has further aggravated the problem of maintenance and up keep.

14.26. TYPES OF MAINTENANCE

Generally following types of maintenances are carried out:

14.26.1. Routire or Periodic maintenance

As all kinds of highways are exposed to the adverse climatic and moving traffic conditions, resulting in wear and tear. Thus for economy, they need maintenance before further deterioration. Generally following works are carried out under this category of maintenance:

(*a*) Upkeep of carriage way

(*b*) Maintenance of shoulders and sub grade

(*c*) Maintenance of side drains

(*d*) Maintenance of bridges

(*e*) Improvement of high way geometric and traffic control

14.26.2. Special repairs

Special repairs are carried out for special problems as and when they occur due to failure of pavements. Some times special repairs are needed for some sub surface drainage system and cross drainage system.

14.27. SCHEDULE OF MAINTENANCE OPERATIONS

The schedule of maintenance operations, indicates the month in which different maintenance operations should be carried out. These schedules generally are drawn to suit the local conditions. A typical schedule of high way maintenance is given below.

April to June

In this period generally following works are carried out:

(*a*) Renewal of wearing coat as per plan.

(*b*) Repairs of bleedings, broken edges and patch work repair.

(*c*) Collection of material such as gravel, kankar needed for stabilization of berms.

(*d*) Improvement of berms by mechanical stabilization, where ever possible.

(*e*) Detailed inspection of culverts, bridges and their repairs where ever necessary.

(*f*) Removal of sand from carriage way and berms.

(*g*) Silt clearance of side drains and construction of new drains where ever necessary.

(*h*) Maintenance of road side trees.

July to September

(*a*) Attending to patch work

(*b*) Attending to cuts developed due to rains

(*c*) Draining of water from road where ever necessary by cutting the berms

(*d*) Stabilization of berms

(*e*) Attending to drains and other damages caused by rains

October to December

(*a*) Patch work repair

(*b*) Renewal of coats

(*c*) Repair of damages caused by rains

(*d*) Repair of scour of culverts and bridges and clearing silt etc.

(*e*) Attending to kilometer stones, Road sign boards, village name boards, direction boards etc.

January to March

(*a*) Patch work repair

(*b*) Repairs and inspection of bungalows and gang huts etc.

(*c*) Renewal and improvement works

14.28. MAINTENANCE OF EARTH ROADS

In earth roads usually following damages need maintenance:

(*a*) Formation of dust during dry weather

(*b*) Formation of cross ruts due to rain water

(*c*) Formation of gullies inside slopes

(*d*) Formation of longitudinal ruts

(*e*) Growing vegetation inside drains and their silting etc.

14.28.1. Remedial Measures

(*a*) Dust nuisance can be remedied either by frequent sprinkling of water or by treating the surface with certain chemicals such as calcium chloride.

(*b*) Formation of longitudinal ruts may be removed by spreading moist soil along the ruts and compacting it properly. If need be camber also may be resphaped.

(*c*) Cross ruts either be repaired after monsoon or stabilized layer may be provided.

(*d*) Formation of gullies in sideslope may be treated by dressing the side slopes.

(*e*) Side drains may be maintained by silt clearance and removing vegetation from them.

14.29. MAINTENANCE OF GRAVEL ROADS

Maintenance of gravel roads should be done on the same lines as that of earth roads, but in no case local soil be spread over the gravel surface. Only gravel should be spread. For this reason extra material should be stacked along the road on the berms before the on set of rains. The volume of gravel to be stacked should be sufficient to be spread over the full with of road in a thickness of 5 cm.

14.30. MAINTENANCE OF WATER BOUND MACADAM ROADS (W.B.M. ROADS)

Water bound macadam (W.B.M.) is the basic stage of the planned improvement of road surfacing. W.B.M. roads are damaged rapidly due to heavy mixed traffic and adverse conditions. The steel tyred bullock carts cause severe wear and tear to the W.B.M. surfaces. In dry weather dust and in rainy season mud is formed.

The fast moving vehicles suck up fine particles from the road surface, resulting in loss of binding particles in the surface. In rainy season rain water is soaked by the surface which makes it soft. In such conditions the movements of vehicles makes the surface layer loose. In this condition, some of the aggregates get displaced from their position causing ruts and pot holes on the surface.

14.30.1. Remedial measures

Following measure may be adopted for its maintenance:

1. To prevent aggregate from getting loose from surface layer, a thin layer of moist soil should be spread over the surface periodically, particularly after the rainy season.
2. The dust nauisance can be effectively eliminated by providing a surface dressing of bituminous materials.

14.31. DEFECTS IN ROADS

14.31.1. Ruts

Longitudinal depression in the road surface is known as *rut*. They are formed due to the following reasons:

(*a*) Track used by iron tyred bullock carts again and again

(*b*) Due to inadequate supporting power of the sub grade

(*c*) Due to excessive camber

(*d*) Insufficient compaction of the pavement

14.31.1.1. Remedial measures

(*a*) For repair of longitudinal depressions moorum may be spread over the surface.

(*b*) For insufficient sub grade either it should be strengthened or thickness of road should be increased.

(*c*) Ruts should be repaired as soon as possible and camber should also be rectified or modified.

(*d*) Ruts due to insufficient compaction should be scrified and the surface should be well compacted.

14.31.2. Pot holes

Isolated depressions developed in the surface of the pavement are called *pot holes*. They may develop due to the following reasons:

(*a*) Sinking of aggregates in relatively soft pockets of sub grade

(*b*) Surface irregularities are covered with out proper compaction

(*c*) Metalling over uneven stone soling

14.31.2.1. Remedial measures

(*a*) Pot holes are cut in rectangular or square shape upto the defective depth and the excavated material removed. The coarse aggregate of the same size is filled in the pot holes or patch work upto its full depth and compacted well by ramming. The level of this patched area is kept 1 cm higher than the general surface of the pavement. This allows further compaction of the patched area under traffic. Soil binder is applied to this patched area to fill the interstices and the surface is rammed again.

(*b*) Pot holes developed due to surface irregularities can be repaired by recompacting the surface and providing proper grade and section. For future compaction a little more material should be applied over the surface.

(*c*) In case of uneven stone solling, it should be removed completely, repacked and compacted conforming the normal line of grade and section and pot holes patched up.

14.31.3. Corrugations

Corrugations are longitudinal waving in the road surface. These are formed under following conditions:

1. Initial waving produced during rolling
2. Due to use of sandy moorum
3. Provision of very thin crust

14.31.3.1. Remedial measures

(*a*) Initial waving produced during rolling can be rectified by finishing the surface to the required line and grade while compacting renewal coat.

(*b*) Defect due to the use of sandy moorum can be rectified by using better quality moorum at the time of remetalling.

(*c*) Defect due to thin crust can be rectified by building up proper crust during successive renewal coats.

14.31.4. Ravelling

Removal of material from the surface is known as *ravelling*. Generally it is caused by the following factors:

(*a*) Use of too sandy binder

(*b*) In sufficient compaction

14.31.4.1. Remedial measures

In early stages of pavement construction, ravelling can be detected by the presence of hair cracks along the interstices. At this stage it can be checked or arrested by blending the surface with good moorum. In case the defect has progressed too for, all floating metal should be removed and good blinding with better quality moorum should be given.

14.31.5. Fraying Edges

Damage to edges is known as Fraying. Fraying of edges is caused by lack of shoulder support which may result by wearing down by traffic or gullying by rain water.

14.31.5.1. Remedial measures

First the shoulder support is improved and then frayed edges are patched up. Where shoulders are maintained in a good and stable condition, smooth and flush with the pavement through out the year, the chances of breaking pavement edges are very remote.

14.32. RENEWAL OF SURFACE

After the useful life of the pavement or when the surface fails extensively to such an extent, that it can not no longer be maintained by routine maintenance operations, then renewal of surface is adopted. Normally a good W.B.M. surface will require renewal after every 3 to 5 years depending upon the traffic load and weather conditions. Generally 8 cms thickness in loose stage of renewal layer is sufficient. If the thickness of W.B.M. is adjudged insufficient, then it can be increased at the time of renewal or resurfacing.

The frequency of renewal depends upon the load and the intensity of traffic.

14.32.1. Methods of renewal

Renewal is carried out in the following steps:

1. Picking or removal of old surface.
2. Spreading of 15 cm thick layer of metal and rolling it by suitable road roller.
3. Over this surface, a 12 mm thick layer of moorum or sand is spread as a blindage layer and rolled. While rolling, sufficient quantity of water is sprinkled over the surface. The amount of blindage material may be 1 m^3 material per 160 to 180 square metre of surface.
4. Dry rolling of metal should start from edges towards the centre.
5. Next day a 5 cm thick sandy soil layer is spread over the prepared surface. The soil is saturated by sprinkling of water. Usually for this operation 40 to 60 litre of water is sufficient per square metre of surface. For complete consolidation, sufficient rolling should be done and while rolling sufficient quantity of water also should be sprinkled.
6. Surface may be opened for traffic after seven days.

14.33. UPDATING

The improvement effected by any treatment render to enable the road surface to better and efficient services to the road users, is called up *dating of road*. It can be achieved by any of the following treatments.

(*a*) Oiling on W.B.M. surface. In this process coal tar is sprayed under pressure on the surface in suitable number of spraying or coat to obtain suitable thickness. Spraying material may be petroleum with 5% coal tar, suitable oil or coal tar.

(*b*) **Tarring on W.B.M.** The use of tar macadam is the best and most preferable to either water bound renewal coat or initial metalling. It is preferable to either oiling or tar surfacing. In this method the dry stone aggregate is mixed with hot tar and then laid on the road and rolled. It requires less consolidation than W.B.M. It is preferable to apply a coating of oiling on the surface after it has been used by the traffic for several weeks.

14.34. MAINTENANCE OF BITUMINOUS SURFACES

In bituminous surfaces usually following repairs are carried out:

1. Patch work
2. Pot holes
3. Surface treatment
4. Resurfacing

Remedial measures

14.34.1. Patch repairs

Patch work is carried out on damaged road surface. During rainy season binding material is damaged, which further aggravates damage to the road surface. Further inadequate or defective binding material causes removal of aggregate and forming pot holes. Thus to remove the inequalities in shape and surface, filling the pot holes etc. (patch work) is taken after rainy season to have a smooth riding surface.

14.34.2. Pot holes

Pot holes in bituminous surfaces generally are developed due to the following causes:

(*a*) Non uniform distribution of binding material (asphalt)

(*b*) Movement of base due to inadequate thickness

(*c*) Yielding of sub grade

(*d*) Lack of proper maintenance of the surface

14.34.2.1. Remedial measures

Pot holes may be rectified by the following methods:

1. **Paint patching.** This method can be adopted to hold up the pot hole formation in the intial stage by correcting the surface.

2. **Penetration patching.** In this method, the pot holes are cut in a square or rectangular shape and excavated upto the depth till the sound materials are encountered. The excavated material is removed. The bottom and sides of the cut portion are slightly primed with a primer. When the hole is ready, a premixed patching material is placed in it as soon as possible and compacted well by ramming. Generally packing mixture consists of cut back emulsion as a binder and well graded stone aggregate of maximum size 20 mm to 12.5 mm. The process is known as pre mix patching.

   In case the depth of pot hole is less than 8 cm, then the full depth maybe filled in one operation and compacted well. While filling depression an allowance of 20% compaction should be made. For this allowance generally compacted material is kept 1 cm higher than the existing surface of the pavement. In case the depth is more than 8 cms then patch material should be filled in layers. The thickness of one layer should not be more the 6 cms.
3. **Surface treatment.** If the binder such as bitumen is in excess in the surface, it will come upon the surface during summer season. The process of bitumen coming up on surface is called *bleeding*. Due to the bleeding of the bitumen, the pavement surface becomes patchy (non uniform quality) and slippery causing corrugations or shoving in the surface. In such situations to rectify this condition, usually coarse sand or aggregate chips of maximum size 1.25 mm is spread over the surface during summer season. After spreading sand or gravel chips, light rolling should be done to develop bond between the existing surface and the material spread.
4. **Resurfacing.** Due to constant atmospheric changes, the binder of the black surface gets oxidized and becomes stiff, forming minute cracks on the pavement surface. In such circumstances a new seal coat or renewal coat is applied on the pavement surface. If the surface gets damaged seriously due to oxidation of binder, then surface may be provided with more than one layer of surface treatment.

When the road base is structurally sound and only the mat or riding course has deterioted resulting in poor riding surface, then providing an additional mat on the existing surface will be most economical. In such situations after repairing the existing road surface, a light tack coat is applied and new surface is laid and finished. This process is called resurfacing.

14.35. FORMATION OF WAVES AND CORRUGATIONS

In bituminous surfaces the wavyness and corrugations are formed due to the following factors:

1. **Defective rolling.** During construction stage defective rolling will cause formation of waves and it will continue indefinitely, which will further aggravate by the traffic movements. In this case small aggregates together with an excess of binder build up a mat.
2. **Poor sub grade.** If the sub grade is consisted of poor soils such as organic soils or highly plastic soils, and ground water table exists close to sub grade, then it may cause the sub grade surface non uniform and of inadequate stability. If boulders are used in soling course in sub grades then differential settlement will take place. This differential settlement will also contribute to the formation of corrugation and waves.
3. **In adequate surface course.** If the surface course of the pavement is inadequate to bear the intensity of the traffic, then waves and corrugations will be developed in it.
4. **Poor gradation of the mix.** Defective gradation and poor mix used for the surface also will cause waves and corrugation.
5. **Compaction temperature.** The viscous property of binder (bitumen) greatly depends upon the temperature. High temperature during mixing and compaction of bitumen mix will result in very low stable pavement surface.
6. **Weak under lying layers.** Week under lying layers also cause formation of waves and corrugations due to repeated plying of vehicles on them.

14.35.1. Remedial measures

Corrugations may be rectified by cutting the high ridges upto the designed section. The inequalities and waviness may be removed by filling the depressions with pre mixed material after applying the tack coat over the cleaned surface and finished.

14.36. BASE FAILURE

Structural failure of base course in flexible pavements may result due to the following factors:

1. Inadequate base thickness
2. Inadequate sub grade support
3. Excess moisture in base or sub grade
4. A combination of two or more of the above factors.

The failure may result either due to consolidation developing shear in the sub grade or base course or surface course. In case the failure is due to consolidation of pavement layers, in this case ruts will not be developed by any upheaval of the surface. In case failure is due to sub grade shear, then surface upheaval will be exhibited at some distance from the depressed rut.

1. Shear failure of surface course will develop upheaval relatively close to tyre track. Hence proper investigation of the causes should be made before carrying out any repair work.
2. If the failure is due to excessive moisture, then proper drainage should be provided.
3. If the failure is total and it is felt to increase the base thickness, then old surface and base should be loosened by scarifying upto full depth and sub grade removed upto the depth necessary to give the needed additional thickness to the new base. Now the pavement is brought upto the proper cross section and compacted.

14.37. MAINTENANCE OF SHOULDERS

Shoulder is a portion of the road way on each side of the pavement between the edges of pavement and top of the inner ditch slope in cuts and of the top of the fill slope in case of embankments.

14.37.1. Functions of Shoulders

Following are the functions of the shoulders:

(*a*) They provide space for parking vehicles in emergency and overtaking moving vehicles
(*b*) They facilitate draining water from pavement surface
(*c*) They support edges of the pavement
(*d*) They provide lateral support to the pavement

14.37.2. Defects of shoulders

Following are the defects of shoulders:

(*a*) Depression in the shoulder along the edge of the pavement is the most important defect of the shoulder. It creates traffic hazards. It collects and holds water and cause loss of support to the pavement.
(*b*) Development of slippery surface, holes and deep ruts in the shoulder
(*c*) Development of cuts and gullies.

14.37.3. Remedial measures

1. Shoulders should be maintained in smooth condition in their full width flush with edges of the pavement.
2. To drain off the pavement surface water, shoulder should be given proper cross slope. Generally for earth roads a cross slope of 1 in 24, for gravel road 1 in 35 is sufficient.
3. Shoulders should be dressed frequently and depressions and cuts should be filled with good soil.

4. According to traffic, shoulders of stabilized soil, gravel or W.B.M. should be provided for a width of 40 to 60 cm from the edges of the pavement. The depth of shoulder may be kept 10 to 20 cm.

14.38. MAINTENANCE OF SIDE DRAINS

Side drains or side ditches draw away water from pavement surface and sub grade. Thus side ditches should be kept clear. They should be cleared periodically atleast once a year before the on set of monsoon. Any silt or vegetation should be cleared from them so that they function effectively during monsoon period.

14.39. MAINTENANCE OF CEMENT CONCRETE ROADS

Generally cement concrete roads need very little maintenance. As already stated under rigid surfaces concrete roads suffer from the following defects:

(*a*) Scalling of cement concrete
(*b*) Development of shrinkage cracks in concrete
(*c*) Development of warping cracks
(*d*) Structural cracks
(*e*) Spalling of joints
(*f*) Mud pumping
(*g*) Settlement
(*h*) Blow up

14.39.1. Remedial measures

1. Scalling of cement concrete. It can be checked by the use of lower water/cement ratio as practical:

(*a*) By proper design of mix

2. Development of shrinkage cracks. The cracks should be cleaned of dirt, sand and loose materials etc. by any suitable means such as air blowing by air blower etc. To facilitate the good bond between the old and the sealing material, cleaned surface is given a coating of keroscene oil and the crack is filled with suitable grade of bitumen in liquid form. The sealing material is provided 3 mm extra height than the required height and the treated surface is covered with sand.

3. Development of warping cracks. These cracks develop due to faulty design of joints. To remedy these cracks provide suitable reinforcement in both directions longitudinal as well in transverse direction at the joints.

4. Structural cracks. These cracks develop due to inadequate thickness of the slab. To remedy these cracks provide suitable thickness as per design.

5. Spalling of joints. Chipping or splintering of joint is called *spalling of joint.* It occurs along the joint due to faulty construction. It can be remedied by cutting the defective edge upto a depth not less than 5 cm and to width normal to the joints varying from 9 cm to 15 cm and the cut is provided a form work. The cut surface is cleaned with wetted wire brush. After this, a neat cement slurry coat is applied. The thickness of cement slurry coat should be 3 to 6 mm. Immediately after applying cement slurry a cement concrete of 1:1½:3 mix proportion with low water/cement ratio is filled, compacted and finished.

6. Mud pumping. Seeping water collected under road base is forced up through the joints or cracks under the influence of wheel loads. This water brings some soil with it, forming cavity under the base. This process of coming out water from base is known as mud pumping. It causes depression in the road surface.

Remedial measures. Mud pumping can be checked by the following measures:

(*a*) By providing granular base
(*b*) By providing adequate sealing of joints
(*c*) By proper maintenance of joints and cracks
(*d*) By providing proper drainage of the base

7. Settlement of the road. It may be developed due to the following factors:

(*a*) Inadequate foundation

(*b*) Non uniform and incomplete compaction

(*c*) Change in moisture content

(*d*) Working in wet conditions

Remedial Measures. Settlement due to defective sub grade can be rectified by the process of mud jacking. In this process a mixture of bituminous substances of proper consistency or cement sand grout of thin creamy consistency is sent under pressure through a series of holes of about 40 mm diameter. This grout fills up the voids of subgrade and also raises the slab up.

8. Blow ups. This defect occurs at joints or transverse cracks due to longitudinal expansion and raises the pavement off the sub grade.

Causes:

(*a*) Due to lack or inadequate expansion joints.

(*b*) Use of unsound aggregate which expand with the rise in temperature.

Remedial measures. It can be remedied by the following provisions:

(*a*) Provision of expansion joints at 15 to 20 m intervals.

(*b*) In winter season expansion joints should be filled up more frequently and maintained properly.

(*c*) Use of sound, strong and tough aggregate in concrete.

14.40. MAINTENANCE OF ROAD USER SERVICES

Various road user services should be inspected periodically and maintained in good condition. Following are some of the important road users services:

1. Sign and direction posts. These are provided for the safe and efficient movement of the traffic. Properly designed traffic sign boards and placed suitably help the road users to know the direction of a particular destination, and also prevent accidents. Sign are grouped into the four groups as follows:

(*a*) Warning sign (*b*) Prohibitory sign

(*c*) Mandatory sign (*d*) Informatory sign

2. Painting traffic lanes. These lanes divide the traffic into specified path and reduce the chances of collisions.

3. White washing of parapets and painting of guard stones, rails.

These are painted so that they may remain visible from a distance even at night. They are painted totally in white or in alternate bands of black and white.

4. Kilometre stone. These stones are provided to show the position of a particular destination, distance of rest houses, junctions, bridges, culvert etc.

5. Arboriculture. Growing of trees along the road side is called road side *arboriculture.* It serves the following purposes:

(*a*) To provide shade to travellers and break monotony of the road.

(*b*) To protect the road from scorching heat of the sun in dry countries and beautify the roads, which makes the journey pleasant.

(*c*) It is a source of income to the government from the sale of fruits and the trees.

(*d*) They provide food reserve.

14.41. MAINTENANCE OF ROAD SIDE ARBORICULTURE

Following works are under taken for the maintenance of road side arboriculture:

1. **Pruning and deforking of trees.** This operation is necessary from the second year of planting. It should be repeated every 5 to 6 years. The object of pruning and deforking is to keep the trees straight.

The best time of pruning and deforking is winter season when trees are not growing. The cut spot should be coated with ash or coal tar.

2. **Looping.** It is done to keep the tree in the proper shape. In this operation the branches which may interfere with the traffic or other trees are removed. The best time for looping is September or February. Immediately after looping the wound of the surface should be painted with coal tar.
3. **Mulching.** To protect the young plants from excessive heat or evaporation of water a 10 to 15 cm thick layer of fibrous manure is laid on the root of the plants.
4. **Disposal of leafs.** The leaves of the trees are collected and disposed off manually. These leaves are placed in a pit to produce manure or burnt.
5. **Numbering.** In order to have proper record of trees, every tree is numbered.
6. **Tree guards.** Tree guards are provided around the young trees to safeguard them against any damage by animals etc.

QUESTIONS

1. Explain the requirements of a good drainage system.
2. High way drainage is important to
   (*a*) Maintain its stability (*b*) Increase riding quality of highway surface
   (*c*) Increase the stability of highway (*d*) All the above
3. The slope on embankment upto 2 m height should be provided
   (*a*) 1:1 (*b*) 2.5:1
   (*c*) 3:1 (*d*) 4:1
4. The most economical and usually adopted method of slope protection is by
   (*a*) Turfing (*b*) Cement concrete lining
   (*c*) Mud puddling (*d*) Boulder pitching
5. Capillary rise of moisture to sub grade can be checked by
   (*a*) By providing a layer of suitable granular material between sub grade and highest ground water table
   (*b*) By providing a impervious layer of suitable material between the sub grade and highest ground level.
   (*c*) None is correct (*d*) Both are correct
6. When a highway is in cutting, drainage is provided
   (*a*) Catch drain at ground level and side drain on one side
   (*b*) Catch drain at ground level and side drains on both sides
   (*c*) Only side drains are provided
   (*d*) All are correct
7. In partly filling and partly in cutting high way, drains are provided
   (*a*) Catch drain only
   (*b*) Catch drain along with side drain on cutting side
   (*c*) Side drains in cutting as well as in filling
   (*d*) All are correct
8. The maintenance of roads is carried out
   (*a*) To maintain them in their original condition as far as possible
   (*b*) To increase the riding quality of the surface
   (*c*) To effect economy in plying the vehicles
   (*d*) All the above
9. Maintenance of high way is affected by
   (*a*) Increase in the intensity of traffic (*b*) Inadequate thickness of pavement
   (*c*) Width of the lane (*d*) All the above
10. In W.B.M. surface ruts and pot holes develop due to
    (*a*) Inadequate foundation (*b*) Inadequate camber
    (*c*) Excessive gradient (*d*) Atmospheric agencies
    (*e*) All the above

11. The mud pumping defect develops in concrete surfaces if the sub grade has beneath it
    (*a*) Sandy soil (*b*) Clayey soil
    (*c*) Silty soil (*d*) Moorum
12. In a bituminous road surface the bleeding develops due to
    (*a*) Settlement of top surface
    (*b*) Melting of bitumen due to high temperature and coming up to surface
    (*c*) Oxidation of binder
    (*d*) Yielding of sub grade
13. Skidding of vehicles due to bleeding of binder can be checked by
    (*a*) Providing an other tack coat (*b*) Spreading an blotter material such as moorum
    (*c*) Removing bleeding surface (*d*) Using anti skidding tyres
14. The purpose of maintaining road side arboriculture is to
    (*a*) Provide lateral support to the road surface
    (*b*) Prevent deterioration of shoulders
    (*c*) Provide services to road users
    (*d*) Increase the revenue of the P.W.D.
15. Which of the following work can be termed as 'Road users services"
    (*a*) Repairs of side drains (*b*) Installing of road side tea stalls
    (*c*) Filling of ruts and pot holes (*d*) Repanting traffic lanes and sign boards etc.
16. Generally on approach roads drums filled with soil are buried on both sides of the road and painted in white and black bends for
    (*a*) To provide sitting place to passer by (*b*) To give aesthetic look
    (*c*) To serve as protectors (*d*) To guide the drivers at night
17. Identify the correct statement/statements
    (*a*) No of lanes affects greatly maintenance of highways
    (*b*) A single lane pavement is stressed four times more than two lane pavement
    (*c*) 25% increase in axle load has double the destructive effect on pavement
    (*d*) In adequate thickness causes frequent failure of pavements
    (*e*) All are correct
    (*f*) None is correct

ANSWERS

2. (*a*)	5. (*d*)	8. (*d*)	11. (*b*)	14. (*c*)	17. (*e*)
3. (*d*)	6. (*b*)	9. (*d*)	12. (*b*)	15. (*d*)	
4. (*a*)	7. (*b*)	10. (*e*)	13. (*b*)	16. (*d*)	

15

Railway Track Drainage

15.1. INTRODUCTION

Railway is one of the biggest means of transportation of man and material. It is also a source of revenue to the government. Actually it is the back bone of Indian economy. Hence it is utmost important that railway system should work continuously with out any break. Thus railway track and rolling stock needs constant maintenance. Here maintenance of track only shall be discussed. A rail track consists of mainly of two parts. The part of the track over which track components such a ballast, sleepers and rails are laid is called formation. In this chapter track drainage problems shall be discussed. Problem of the formation are same as those of highways formation.

15.2. TRACK DRAINAGE

It can be defined as the interception, collection and disposal of water from over or under the track. It is accomplished not only by surface interception and drainage but also by sub drainage system. Proper drainage of sub grade is very important as excess water reduces the bearing power as well as its shear strength.

15.2.1. Sources of Water in a Railway Track

The various sources of moisture which affect a railway track are as follows:

1. Percolation of water by gravity. Actually this is the rain water which moves under gravity into the sub grade. It is also known as surface water. The movement of this water is resisted by the permeability of the soil. This water may be removed by providing drainage system on the top of the embankment in the shape of cross fall, side drains and lowering of cess etc.

2. Percolation of water by capillary action. Capillary action depends upon the size of soil grains. Finer the soil grains, higher the capillary rise. By capillary rise water can rise upto 1 m height. The effect of capillary rise can be checked by reducing the ground water table and providing a pervious layer under the embankment.

3. Seepage of water from adjacent area. In this case water seeps into the sub grade by seepage from the near by water sources. The seepage of water may be

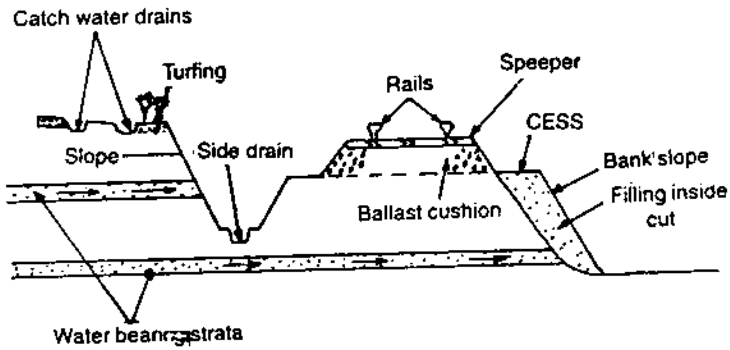


Fig. 15.1. Seepage of water due to bearing strata

reduced by the following measures as shown in Fig. 15.1.

(*a*) By providing more effective paved catch water drains.

(*b*) By diverting the original source of water.

(*c*) By providing inverted filtres and under ground drains.

3. (*a*). Drainage of seepage water in case track is in cutting. In this case water may seep from adjacent area to the sub grade. In this case the seeping water may be arrested by providing catch water drains at top of cutting, and side paved drains. The side drains may also be provided with perforated or blind pipes underneath to lower the ground water table as shown in Fig. 15.2.

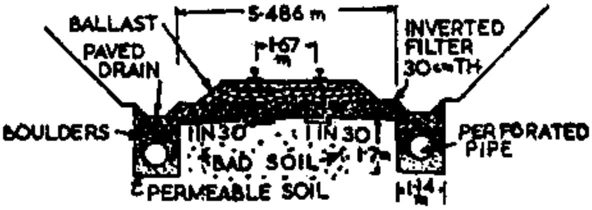


Fig. 15.2. Inverted and Under ground filter

15.3. FAILURE OF TRACK EMBANKMENTS AND THEIR REMEDIAL MEASURES

Failure of track embankments may be due to the following causes:

1. Failure of the natural ground
2. Failure of fill material of the embankment
3. Failure of the top of formation

What so ever may be the cause of failure, following symptoms give an idea of the failure of the formation:

(*a*) Slips in the bank slopes

(*b*) Loss of ballast

(*c*) Variation in cross levels

(*d*) Upheavals of the ground beyond toe of embankment

15.3.1. Failure of Natural ground

This failure may occur in the following ways:

1. **Failure due to excessive settlement.** This failure generally is associated with the up heaval of ground beyond the toe of the embankment.
2. **Shear failure.** Shear failure of natural ground generally takes place during construction period or just after construction. After the stabilization, the ground failure under the existing embankment does not take place.

15.3.1.1. Remedial Measures

To check the failure of natural ground following measures have been found useful:

1. **Provision of sand drains.** They help in quicker consolidation.
2. **Provision of balancing embankment.** To check the heaving tendency, load on the natural ground is increased. Thus increasing of load on the embankment is called *balancing of embankment.*
3. **Driving sheet piles or ordinary piles on both sides of the embankment at suitable interval.** To check the shear failure piles driving has been found useful.

15.3.2. Failure of fill material of the embankment

Some times due to the failure of embankment material both shear and settlement failures take place. The main reasons of this type of failure is as follows:

1. **Heavy traffic.** Heavy traffic produces excessive stress in the soil beyond its safe limit.
2. **In adequate slope of embankment.**
3. **Percolation of water in the embankment.** Perlocation of water into the embankment increase the

weight of soil on one hand and decreases its bearing power and shear strength on the other hand. The shear failures of existing embankments are quite common and occur by slips. The forces which cause this failure are weight of the soil of embankment and the weight of the rolling stock comming on it. The cohesion and internal friction of the embankment material resist this failure. The slip failure may occur along with different planes as shown Fig. 15.3.

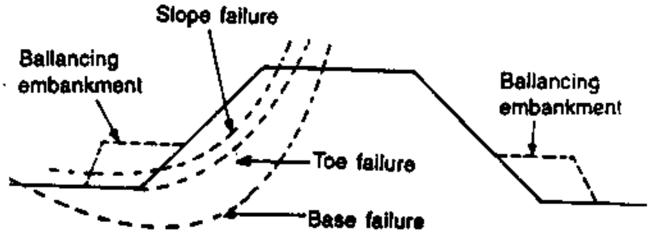


Fig. 15.3. Slope Failure

1. Passing through the toe of the embankment known as toe failure.
2. Passing above the toe of the embankment through its slope and is known as slope failure.
3. Passing below the toe of the embankment through its base and is known as base failure.

15.3.2.1. Remedial measure of fill material failure

To check the above failures, following measures may be adopted:

1. Flatter side slopes may be adopted
2. Height of embankment may be reduced
3. The older heavy material in the top of embankment may be replaced by lighter material.
4. To check the ingress of rain water into the slopes, they should be stone pitched.
5. Proper surface and sub surface drainage may be provided.
6. On either side of embankment, balancing embankment may be provided.
7. To check shear failure, vertical piles on either side of the embankment should be provided at suitable interval.

15.3.3. Failure of formation top

This type of failures are common in clayey type of soil during or just after rainy season. In some locations this type of problem is encountered through out the year.

15.3.3.1. Causes of failure

The main causes of such failure are as follows:

1. **Low bearing capacity of the soil.** Due to the low bearing capacity of the formation soil, the ballast as well as track sinks into the soil, resulting in heaving up of cesses and bulging of side slopes. The penetration of ballast into the formation develops ballast pockets.
2. **Pumping action.** During rainy season rain water seeps into the formation through the ballast section and the top layer of soil becomes saturated with water forming slurry under the track. As the rolling stock moves on the track, soft soil and mud slurry gets pumped under the weight of the rolling stock, resulting further sinking of ballast. By pumping out of slurry and soft soil, ballast gets clogged and looses its drainage property.
3. **Weather effect.** During summer season, due to high temperature, top soil moisture evaporates resulting in shrinkage cracks in the top layer of the formation. Ballast enters in these cracks, resulting in the settlement of the track. During monsoon, water penetrates through these cracks forming slush with mud in the upper layers of the formation, resulting in the formation of deeper ballast pockets.

Due to the development of hydrostatic pressure and the impact of moving loads, pumping of track takes place, which further deepens the ballast pockets. Some times ballast penetration results in bulging of the side slopes leading to slips in extreme conditions. These failures present considerable problem in the maintenance of the track. Due to these failures, huge quantity of ballast is lost every year, whose replacement is not only difficult, but very expensive also.

15.3.3.2. Remedial measures

To check above failures, following measures may be adopted:

1. Provision of an inverted filtre. The bearing capacity of the soil can be improved by providing an inverted filtre of adequate thickness between the ballast and the top of week formation.

The material of the first layer which is in contact with formation should consist of graded silt grain size of 0.07 to 0.002 mm. The next layer above it should consist of graded fine sand of 0.2 to 0.7mm grain size. The third layer of graded coarse sand of 0.2 to 2.0 mm grain size and the last layer in contact with the ballast should be of graded gravel of 2.0 mm to 20 mm size. This arrangement will not allow the soil water to take soil particles along with it. The soil particles are retained and only clear water is allowed to collect at the top of gravel layer which is drained by any suitable method Fig. 15.4.

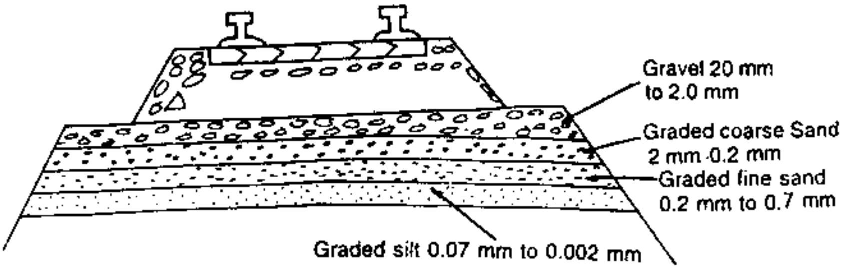


Fig. 15.4. Inverted filter

2. Improvement of drainage. Surface drainage can be improved by the following methods:

(*a*) By diversion of ground water

(*b*) By providing catch water drains

(*c*) By providing sub surface drainage system

3. By cement grouting. For improving the bear capacity of soil, cement grouting is one of the best method. However this method is quite expensive. In this method a cement and soil slurry of 1:3 to 1:6 proportion is injected in the embankment under a pressure of about 4.36 Kg/cm^2 by an pneumatic machine. The slurry of cement and sand is injected through a 25 mm dia steel pipe and a rubber hose. The injection points are kept near both ends of the sleeper in a staggered position about 1.7 m apart. The grout pumping is continued till the grout or slurry appears through the ballast upto the top surface. Cement slurry fills the cracks and seals off the pores through which water and moisture seeps into the sub grade and stabilizes it, developing better properties and strength. This method is considered to be very effective for improving the soil properties.

4. Sand piling. It is an effective and cheaper method of improving the bearing power of soil. In this method a series of holes of about 30 cm diameter are drilled vertically inside and out side of the rails upto a depth of 2 to 3 metres by any suitable machine or device. After drilling the holes, they are filled with clean sand and the track resurfaced. These piles are so arranged that their cross-sectional area is about 20% of the area of the formation. Sand piles compact the soil and provide mechanical support to the sub grade like wooden piles. Sand piles improve the drainage of the sub grade. Water rises to the surface through sand piles by capillary action and evaporates. Fig. 15.5.

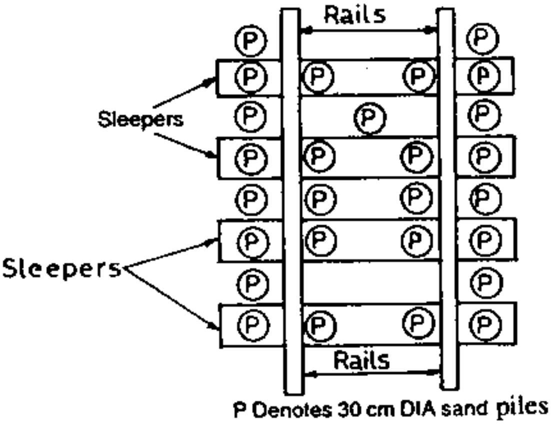


Fig. 15.5. Sand piling

5. Deep screening of ballast and drainage of water pockets (Problem of ballast pockets). To tackle this problem, first the depth of ballast penetration is ascertained. To have a complete picture of drainage condition of the sub surface structure, about five vertical holes are bored. After ascertaining the depth of ballast penetration, any of the following procedure may be adopted depending upon the situation.

A. Problem just started i.e. depth of penetration is less

In such cases following measures may be adopted:

(*a*) It can be remedied by deep screening of ballast.

(*b*) It can be remedied by providing a pervious layer of 30 to 60 cm on the cess as shown in Fig. 15.6.

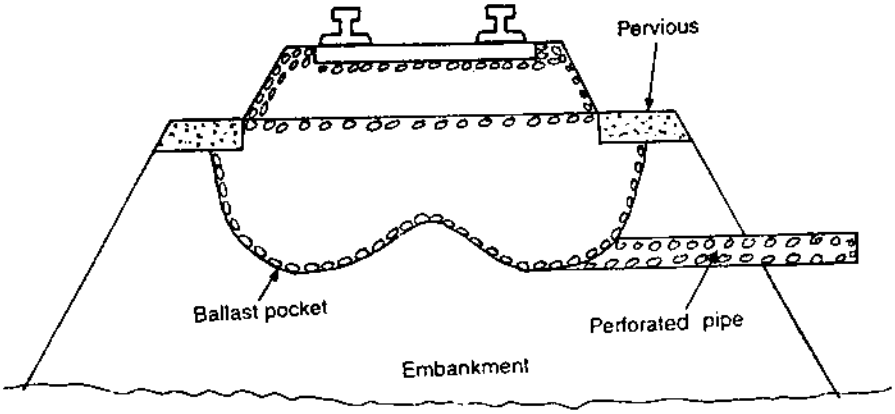


Fig. 15.6. Drainage of ballast pocket

B. Under ground water table exists below the track

If an under ground water pocket exists due to hollow basin over a thick impervious layer under the track, then water may be drained by providing perforated pipe drain into the water basin as shown in Fig. 15.7.

C. The Trouble is excessive and there is an impervious soil layer under the water pocket

In such situations following measures may be adopted:

(*a*) First deep screening of ballast is done and then water is drained by perforated pipe as in case Fig. 15.7.

(*b*) An inverted filtre of about 30 cm thickness may be provided.

(*c*) If the water pocket has been formed due the presence of ridges on all sides and moisture can not escape in any way. In such cases the water pocket will seriously affect the stability of track and embankment. For it, simple remedy is to drain off the water as shown in Fig. 15.7 under problem B.

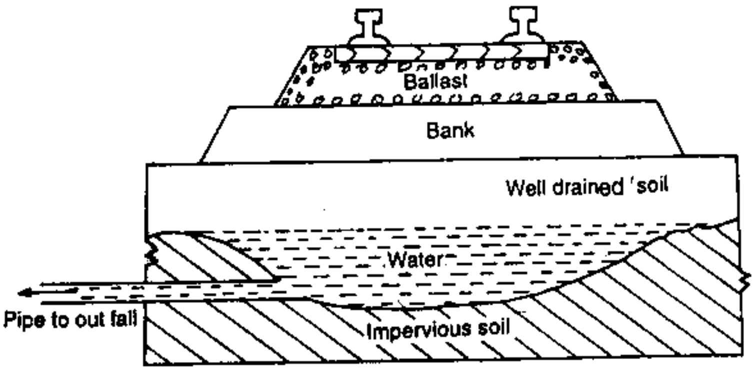


Fig. 15.7. Drainage from water pocket formed deep

D. Underground water pocket exists over thin impervious layer which rests on fissured strata

(*a*) In such situation the best remedy is to puncture the impervious layer to provide an easy escape to

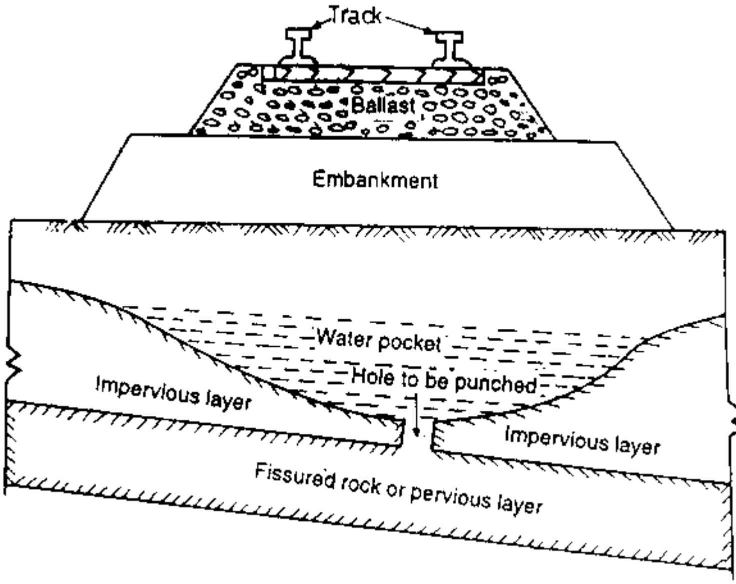


Fig. 15.8. Drainage of water by punched hole pocket

impounded water to the fissured strata below as shown in Fig. 15.8.

(*b*) Some times counterfort drains of 60 cm thickness are provided to drain off the pocket water. Such drains should be provided at an interval of about 10 m.

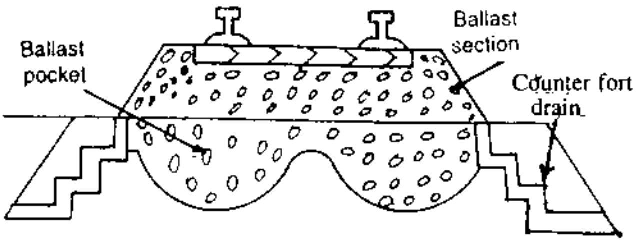


Fig. 15.9. Counter fort drain

E. The Problem of water pocket is due to capillary rise

In such situations the provision of capillary break is the best solution. The capillary break is a pervious layer of about 30 cm thick provided above high water table, but it is not possible in already built up embankments.

F. If water Pocket formation causes excessive trouble

In such situations following measures may be adopted:

(*a*) First screen the ballast.

(*b*) Drain off water pocket.

(*c*) Provide a 20 cm to 60 cm thick inverted filtre blanket. If inverted filtre blanket is not possible then a sandy layer of same thickness may be provided as shown in Fig. 15.10.

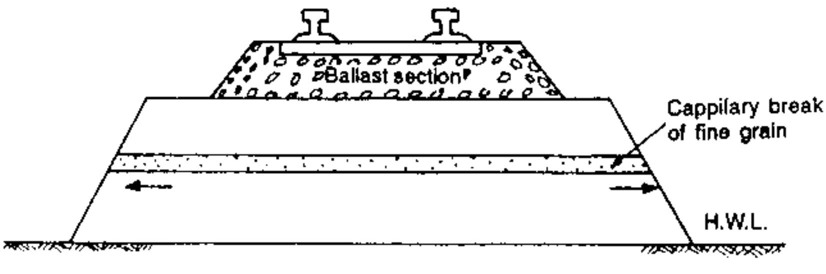


Fig. 15.10. Capillary Break

15.4. SOIL STABILIZATION BY GEOTEXTILE METHOD

Geotextile is a new material having unique property of allowing water to pass through it, but it does not allow the soil particles to pass. Geotextiles works not only as separators and filtres, but also drain the water and provides reinforcement to the soil bed. This material has been used extensively in America for soil stabilization of rail and road formations.

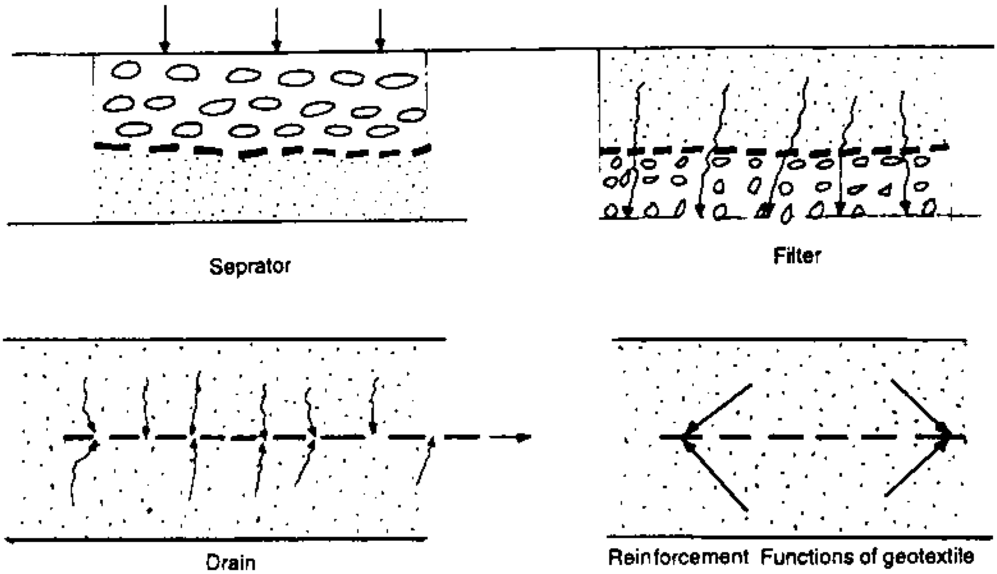


Fig. 15.11 Functions of Geotextiles

The layer of geotextile normally is laid either directly under the ballast or sand witched between layers of sand. On American railways it is laid directly on ballast, while on Indian railways it is sand witched with 5 cm layer at top and 2.5 cm layer at bottom to avoid direct contact with ballast. By this method the

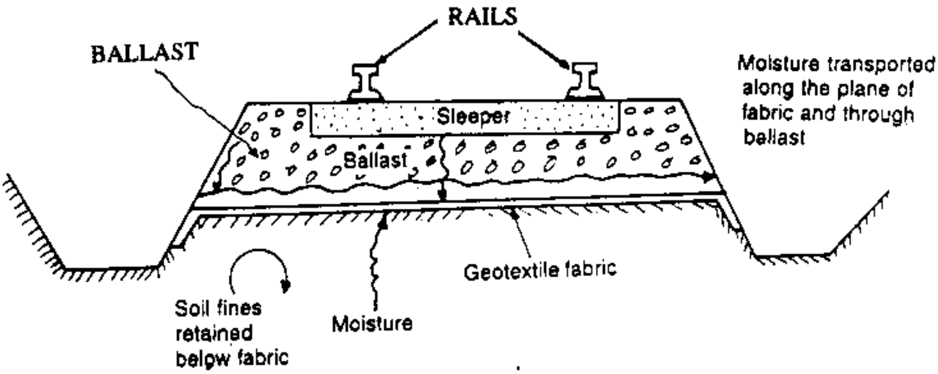


Fig. 15.12. Laying of Geotextile

incidence of tear and puncture of geotextile is reduced. The cost of such geotextile comes to Rs. 300/- per metre for single track of B.G. Fig. 15.11.

15.5. BLACK COTTON SOIL

This soil is made of lawa obtained from volcanoes. It is a shrinkable soil, which changes its properties to a great extent with the variation of moisture content. With the addition of water, these soils swell losing their strength and with the decrease of moisture contents they shrink resulting in the development of cracks. During dry season, ballast penetrates into these cracks and the track sinks. Due to the hydrostatic pressure and impact of rolling stock deeper ballast pockets are formed. This undesirable property of swelling and shrinking with the variation of moisture content of black cotton soil presents lot of maintenance problems of proper levels of sub grade.

15.5.1. Remedial measures

For different problems of black cotton soil, following measures are suggested:

1. **Black cotton soil is cohessive.** The cohesive properties of black cotton soil can be reduced by treating the top layers of soil with quick lime. Quick lime reduces the black cotton soil into granular soil reducing its harmful effects.
2. **Seepage problems.** Seepage problems may be reduced by the following treatments:
   (*a*) The provision of graded inverted filtre at the top of embankment has been found very effective to reduce the ill effects of black cotton soil.
   (*b*) Consolidation of black cotton soil at optimum moisture content also has been found very useful.
   (*c*) Provision of some intercepting medium such as polythene sheets or bituminous carpet which may intercept the surface water from penetrating into the soil has been found very effective.

15.6. SITE DATA COLLECTION

For determining the proper treatment of the formation in black cotton soil, following data should be collected:

1. **History of the section.** The history of the affected section will give sufficient idea of the steps to be adopted for its treatment. Under this head following information should be collected.
   (*a*) Period of construction
   (*b*) Method of construction
   (*c*) Type of soil
   (*d*) Date of opening of track to traffic
   (*e*) Bank settlement if any
   (*f*) Slips
   (*g*) Speed restrictions due to formation etc.
2. **Site details.** Under this head following information should be collected:
   (*a*) Height of embankment
   (*b*) Depth of cutting
   (*c*) Nature of existing slopes
   (*d*) Drainage conditions
   (*e*) Stagnation of water
   (*f*) Condition and proximity of borrow pits
   (*g*) Signs of movements and bulging of slopes
   (*h*) Ground water level and its position during rainy season
3. (*a*) Details of maintenance for the last five years
   (*b*) Man days spent on maintenance per km
4. **Ballast penetration profile.** Ballast penetration and its condition should be clearly indicated. It should be taken at regular intervals of one telegraph post.
5. Exact nature of present problem should be noted carefully.

15.7. SUGGESTED REMEDIAL MEASURES FOR DIFFERENT PROBLEMS OF FORMATION

Based on site investigations and soil testing relevant remedial measures should be formulated. Some remedial measures are listed in the following Table 15.1.

Table 15.1. Suggested remedial measures for different problem of formation

S. No.	*Nature of problem*	*Suggested remedial measures*
1.	Inadequate drainage due to high cess and dirty ballast	Lowering of cess and screening of ballast will improve the drainage.
2.	Weakening of soil at formation top due to contact with rain water.	(*a*) Injecting bituminous emulsion below ballast. (*b*) Provision of moorun or sand blanket of 20 cm to 30 cm thickness below ballast. (*c*) Laying Geotextile below ballast.
3.	Strength failure below ballast causing heaving up of cess or heaving up between sleepers.	(*a*) Provision of 20 to 60 cm thick blanked below ballast. (*b*) Provision of sub ballast.
4.	Seasonal variation of moisture in formation top in expansive soils causing alternate heaving and shrinkage of formation.	(*a*) Lime slurry pressure grouting. (*b*) Moorun blanket of 30 cm to 45 cm thickness with moorum lining.
5.	Gradual subsidence of bank under live loads due to inadequate initial compaction of embankment	(*a*) Cement grouting of ballast pockets if ballast pockets are permeable. (*b*) Provision of boulder or sand drains.
6.	Gradual consolidation of earth below embankment	(*a*) Lime piling in the sub soil. (*b*) Sand drains in sub soil.
7.	Creep of formation soil.	Flattening of slopes.
8.	Coal ash pockets due to treatment of pervious slips with coal ash.	(*a*) Sand drains below deepest level of coal ash (*b*) Cement pressure grouting.
9.	Instability of bank and cutting slopes due to:	
	(*a*) Inadequate side slopes causing bank slip after prolonged rains	(*a*) Flattening of slopes and provision of berms (*b*) Improvement of drainage.
	(*b*) Consolidation/settlement of sub soil causing bank slip	(*a*) Provision of sand drains to expedite consolidation
	(*c*) Hydrostatic pressure built up under live loads in ballast pockets containing water causing bank slips	(*a*) Draining of ballast pocket by sand or boulder drains (*b*) Cement sand pressure grouting of ballast pockets.
	(*d*) Creep of soil	Reducing stresses by providing side berms or flattening side slopes.
	(*e*) Swelling of over consolidated clay, side slopes in cutting causing loss of shear strength and slipping.	Flattening of slopes.
	(*f*) Erosion of slopes.	Provision of turffing, mats etc.

QUESTIONS

1. Discuss the problem of track drainage and suggest its remedial measures.
2. Discuss the failure of fill material of the formation and suggest its remedial measures.
3. Discuss the causes of formation failure and name suitable measures.
4. Suggest different measures of drainage improvement.
5. How the bearing capacity of soil under a railway track can be improved.
6. Discuss different problems of deep screening of ballast and suggest water drainage with sketch of different stages of deep pockets of ballast.
7. Write short notes on:
   (*a*) Soil stabilization by Geotextile method

(*b*) The problems of railway track in black cotton soils.

8. In a railway track formation moisture may penetrate
   (*a*) By gravity (*b*) By percolation and by capillary action
   (*c*) By seepage (*d*) Any of the above
9. The failure of track embankment can be judged by
   (*a*) Slips in the slopes of banks (*b*) Loss of ballast
   (*c*) Variation in cross levels (*d*) Upheaval of the ground beyond the toe of the embankment
   (*e*) From any of the above
10. Failure of the fill material of the embankment may take place due to except
    (*a*) Light traffic on the track (*b*) Heavy traffic on the track
    (*c*) Inadequate slope of the embankment (*d*) Percolation of water in embankment
11. Geotextile is used for
    (*a*) To check the seepage of water
    (*b*) To check the soil particles flowing along the seeping water
    (*c*) To allow the soil particles to flow with seeping water
    (*d*) All are correct

ANSWERS

8. (*d*) 9. (*e*) 10. (*a*) 11. (*b*)

16

Maintenance of Railway Track

16.1. INTRODUCTION

The Indian railway system is the largest state owned railway system in the world under unitary management. On Indian railway system about 11000 trains run each day. It is the most important mode of transportation and is the back bone of the Indian economy. Due to the movements of heavy rolling stock, track system gets vibrations and impact. Due to vibrations ballast gets compacted and loses its elasticity and drainage property. Fittings become loose. Rails also develop some defects due to moving of heavy rolling stock. Hence to keep all component of the track system in good condition to render desired services they need frequent maintenance.

16.2. NECESSITY OF MAINTENANCE OF RAIL TRACK

Necessity of maintenance of rail track arises due to the fact that due to constant use railway track under goes considerable wear and tear. Hence to keep the track in good and proper condition to render the desired services it is essential to carry out periodical maintenance.

16.3. CLASSIFICATION OF MAINTENANCE

Track maintenance may be classified mainly in two groups as follows:

1. Manual maintenance
2. Mechanised maintenance

In this chapter manual maintenance shall be discussed.

16.4. ADVANTAGES OF MAINTENANCE

Following are the advantages of good maintenance:

(*a*) A well maintained track provides comfortable ride to the passengers and safety to goods.

(*b*) Good maintenance increases the life of track as well as of rolling stock.

(*c*) Safety of passengers and goods increased.

(*d*) Operating cost is reduced as fuel consumption by locomotive is less.

16.5. TRACK MAINTENANCE COMPONENTS

It includes the following components:

1. Surface of rails
2. Track alignment
3. Gauge
4. Proper drainage
5. Track components
6. Bridges and their approaches
7. Rolling stocks
8. Points and crossings
9. Level crossings
10. Tunnels

16.6. MAINTENANCE OF SURFACE OF RAILS

1. Straight track. On straight tracks the top of surface of the rails should be kept at the same level whether the track is on level stretch, or on a rising gradient or falling gradient.

2. On Curves. On Curves proper super elevation must be maintained. The maintenance of surface of rails involves the following operations:

(*a*) Packing
(*b*) Surfacing of track
(*c*) Boxing and dressing of the track
(*d*) Levelling of the track
(*e*) Lifting of the track
(*f*) Surface defects
(*g*) Spot packing and track lifting

16.7. PACKING

Due to the vibrations developed by running of trains and their heavy loads, ballast gets loose under sleepers, forming depressions in the plane of rails. These depressions get further aggravated due to non uniform grade support. Due to the repeated blows of the passing trains, rail joints are affected severely. Thus to provide comfortable ride and better life to rolling stock, the ballast under sleepers should be regularly packed. Thus packing is the operation of forcing the ballast under the sleepers. This can be done by any of the following methods:

1. Through packing
2. Scissor packing
3. Shovel packing

16.7.1. Through packing

Under this head following works are carried out sequentially:

(*a*) Opening of the road
(*b*) Examination of component parts such as rails, sleepers and fastening
(*c*) Squaring of sleepers
(*d*) Aligning the track
(*e*) Packing of sleepers
(*f*) Repacking of sleeper joints
(*g*) Boxing of ballast sections
(*f*) Dressing of section

(*a*) **Opening of road.** The width of ballast packing under sleepers depends upon the gauge of the track. The width of opening from the end of the sleeper should be 45.72 cm for B-G, 35.6 cm for M-G and 25.4 cm for N-G. tracks. The ballast should be opened out on either side of the rail seat for a depth of 5 cm to 7.5 cm below the bottom of the sleeper.

(*b*) **Examination of rails, sleepers and fastening**. Rails, sleepers and fastening are examined thoroughly. During long use, rail may develop defects as head worn out, kinks and fractures etc. discussed latter. Defective rails should be replaced. Similarly any sleeper found defective is replaced and loose fastenings tightened and oiled. Missing fastenings are provided.

(*c*) **Squaring of sleepers.** Due to the kinks and variations in gauge, sleepers get out of square very often. Such sleepers are corrected in the following way.

For squaring of sleepers, one of the rails is selected as sighting rail and the correct positions of sleepers and their spacing is marked on this rail. The position of sleepers under the other rail is checked with reference to the sighting rail with the help of T square. The sleepers found out of square are attended.

(*d*) **Aligning the track.** It is done usually by the eye judgment, sighting the rail from a distance of about 50 m. The small error is corrected by slewing the track with the help of craw bars. The work should be started from the middle portion of the bulge in the track and quarter points should be attended after wards. If the shift is considerable, then the full length of the track is moved by a fraction of the shift and the process is repeated till the full shift is covered or track is reached to its final position.

(*e*) **Packing of sleepers.** Packing of sleepers can be done by any of the following methods.

1. Beater method
2. Scissor method
3. Shovel method

1. Beater method. In this method the ballast round the sleeper is pulled aside first upto a depth a little below the bottom of the sleeper. Then sleeper is raised upto the desired height with the help of crow bars and the ballast is packed under the sleeper with pick axes having one heavy blunt end known as beater. The ballast is packed under the sleeper till the rail level is raised upto the desired height.

The packing should be started from each rail seat to the end of the sleeper and then for an equal distance in the inter rail space. The packing should be done first under the rail seat and care should be taken that beater does not strike any sleeper during packing process. Thus during the process of packing sleeper should be kept away so that sweep of beater is not hindered by the adjoining sleeper. In this method only one person is required. In this method sleeper is likely to have uneven packing.

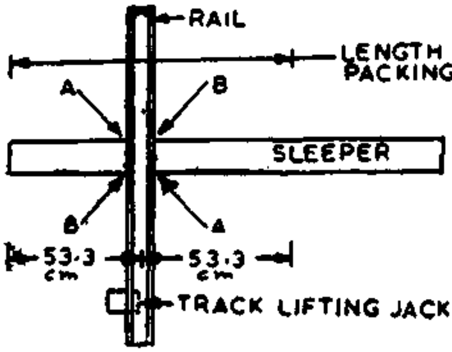


Fig. 16.1. Scissor method of packing

2. Scissor method of packing. In this method two persons take position back to back on the same sleeper as shown in Fig. 16.1. One man stands on the inner rail space and other on the shoulder and pack diagonally under the rail seat. For better and sound packing blows must be simultaneous. Fig. 16.1.

3. Shovel method. In this method, bed of the sleeper is not disturbed. In India this method is not in much use. It is used at points and crossings where beater method is difficult due to close spacing of sleepers. In this method the track is lifted with the help of jacks or tommy bars and the ballast varying in size from 6 mm to 10 mm is evenly spread in requisite quantity under the sleeper by shovels. This method is better for wooden sleepers, but not suitable for steel or concrete sleepers.

16.8. CHECKING OF LEVELS

The rail levels should be ascertained carefully. Rail levels may be checked by the following methods:

1. By the eye judgment. This is a rough method of checking levels.

2. By the use of sighting boards. In this case three sight boards at the two ends and centre of the rail are used. If the top of all the three boards are at the same level then the sleepers are packed to the desired level. After packing one rail for a short distance, the other rail is also packed.

16.8.1. Checking of cross levels

Fig. 16.2. Checking cross level on straight track

To ensure the same level of the both rails on straight track a level board with spirit level is used. The board is placed on the two rails as shown in Fig. 16.2 and the spirit level is placed centrally over it and the bubble of the spirit level is brought to centre by lifting or lowering the rails.

16.8.2. Checking of cross levels at curves

On curves the inner rail should be levelled first and then the outer rail is provided correct super elevation with the help of a cant board and level board and spirit level. Cant board is shown in Fig. 16.3.

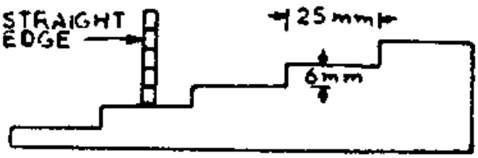


Fig. 16.3. Cant board

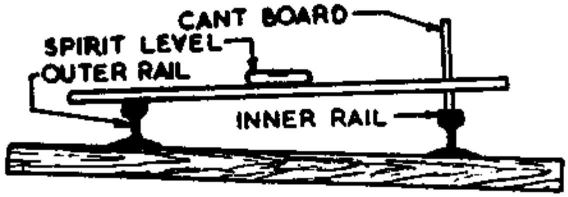


Fig. 16.4. Checking cross level at curves

The cant-board is placed under the level board at the inner rail as shown in Fig. 16.4. The level board is placed on the step corresponding to the correct super elevation and the sleeper is packed sufficiently to bring the bubble in the centre.

16.9. REPACKING OF JOINT SLEEPERS

After packing the sleepers, the joint sleepers are once again packed and their cross levels checked, because the ballast under the rail seat is depressed more at joint than at the centre due to the movement of rolling stock. This happens due to the fact that a greater portion of the wheel load is transferred to the ballast under the rail seat. If the ballast is not packed properly under the rail seats, in that case sleeper is better supported at the centre than at ends. Such sleepers are known as *centre bound* sleepers and become a source of discomfort to the passengers.

16.9.1. Remedial measures

Centre bound defect may be eliminated by the following measures:

1. Breaking the consolidation of ballast at centre during packing operation.
2. Provision of central drain under the sleeper

In this case not only one sleeper but two or three neighbouring sleepers should be attended.

16.9.2. Boxing of ballast section

Filling of ballast between the sleepers is called boxing of ballast section.

16.9.3. Dressing the section

Keeping the section in its original shape is called the dressing operation.

16.10. SYSTEMATIC OVER HAULING OF TRACK

Well maintrained track is the foremost requirement from the point view of safety and economy of the rail journey. Better the maintenance of the track, safer and more economical is the journey. Thus for standard maintenance, periodical over hauling of track is essential. Systematic over hauling of the track normally should commence after the completion of one cycle of through packing, Systematic over hauling consists of the following operations:

1. Proper drainage of the ballast
2. Making up the shortage of ballast
3. Replacement of damaged fastenings
4. All items included in through packing
5. Making up the cess

The periodicity of over hauling depends upon the following factors:

(*a*) Type and age of track structure

(*b*) Maximum permissible speed and volume of traffic

(*c*) Mode of traction and rate of track deterioration

(*d*) Rain fall in the area etc.

Depending upon the above factors, the length of the track to be over hauled is decided in such a way that systematic over hauling is completed in a section in about 3 to 4 years duration. The over hauling work under taken during a year should be in continuation of the work completed during the pervious year. Preferably surrey and adjustment of gaps including joint gaps should be under taken prier to systematic over hauling.

16.10.1. Joint gap surreys and adjustment of gaps

1. The gaps should be measured every year by the end of February, when the rail temperature varies between 15°C and 50°C for each rail by taper gauge.

2. For a standard rail length of 13 m for B-G track the recommended value and its range is shown in Table 16.1.

3. The average value of observed gaps is calculated and compared with the recommended range of gaps. The following three situations may arise.

(*a*) The individual as well as the average values of gaps lie out side the permissible values. In this situation the joint gaps should be adjusted from one end to the other end systematically of the sub section. The recommended values of the adjusted gaps should be as shown in Table 16.1.

(*b*) The average values lie with in the permissible range, but some individual measured values fall out side the rage. In this case the corrections should be limited to correct the individual gaps which fall out sides of the recommended range. Rectification should be done by pulling minimum number of rails. In no case cutting of rails or introducing a long or short rail should be resorted.

(*c*) The average as well as individual values lie with in the permissible range. In such a situation no action is required to be taken.

Table 16.1. Recommended and range of gaps

S. No.	*Rail temperature at the time of gap measurement*	*Recommended value of gap in mm*	*Recommended range of gap values in mm*
1.	0 to 10°C	10	12 to 8
2.	10°C to 25°C	8	10 to 6
3.	25°C to 40°C	6	8 to 4
4.	40°C to 55°C	4	6 to 2
5.	55°C to 70°C	2	4 to 0
6.	Above 70°C	0	0

16.11. DRAINAGE OF BALLAST

To provide a good drainage to the track, it is necessary that the ballast be screened on a planned basis regularly. Screening of ballast may be deep screening or shallow screening. Deep ballast screening is more effective for good drainage of the track as it is done to the full depth of the ballast including cores under sleepers, but it requires long blocks. This method is very costly and its recovery time also is more. Thus due to these factors deep screening should be undertaken once in 10 to 12 years. In case of shallow over hauling or screening, the ballast is opened upto 5 cm to 7.5 cm below the bottom edge of the sleeper in sleeper cribs and shoulders. Thus shallow screening is cheaper than deep screening. Hence to get good drainage shallow screening or over hauling is the best.

16.11.1. Procedure of Shallow screening

1. The ballast is opened out to the full depth in shoulders and between sleepers called crib to a depth of 5 cm to 7.5 cm below the bottom edge of the sleepers sloping from the centre towards sleeper ends in case of wooden, steel trough and CST9 sleepers and for a depth of 7.5 cm 10 cm for PRC sleepers. In PRC sleepers, bottom of sleepers is not opened out. The ballast shoulder opposite to the crib and sleeper and for 5 cm beyond its end is cut at a slope of 1:1. The dirty ballast is screened

and reused. Fresh ballast also is used if required.

2. Work in two continuous spaces of sleepers should not be under taken simultaneously. It should be progressed in alternate panels of one rail length each.
3. The stretch, where the drains across the track exist, the drains should also be cleaned and filled with ballast or boulders so that packing may not get loose and form slacks.
4. Shallow screening should never be done in hot season.
5. The normal output of shallow screening per gangmen should be about 6.4 m for B.G, 9.4 m for M.G.

16.11.2. Special points to be kept in mind while doing shallow screening

1. After over hauling, the work should be started in such a way that no ballast is destroyed in sufficient quantity.
2. While opening out the crib and shoulder ballast, the core under the sleepier should not be disturbed.
3. After over hauling, clean ballast should be filled in cribs near the rail seat to support the sleeper core and at sleeper ends to provide lateral strength. No deficiency of ballast should be allowed in the central portion of the sleeper, it should be made up at the earliest.
4. Through packing should follow the overhauling.
5. On L.W.R./C.W.R. over hauling should be undertaken only in winter season when the rail temperature does not exceed $t_d + 10°C$.
6. Overhauling should not be under taken in sand and earth packed tracks.
7. Over hauling work should be taken up in alternate panels only. This will help in maintaining the geometry of the track.
8. Between two sleeper cribs, where over hauling work is in progress, atleast two adjoining cribs should not be disturbed at the same time.
9. *Replacement of damaged fittings.* Defective, broken, or fractured rails, fittings and fastenings etc. should be replaced where ever required.
10. *Through packing.* Along with shallow screening all work associated with through packing should be done.
11. *Making up the cess.* High cess should be cut and low cess should be made up along with the over hauling. Higher cess hampers the drainage and low cess results in loss of ballast. Thus a template should be used to keep the proper height and slopes of cess i.e. the cess should be dressed to the correct height as per template with a slope upto the edge of the bank. It enables the ballast to remain in position, while water is capable to flow out from the track towards the cess down the slope of the bank.
12. *Disposal of muck.* Muck released during the over hauling operation should be disposed off in such a way that it may not obstruct the drainage. In cuttings it should be disposed off out side.

16.12. LIFTING OF TRACK

Lifting of track is essential in the following situations:

1. For remodeling of yard and construction of bridge.
2. To eliminate sags developed in approaches of level crossings and bridges.
3. In vulnerable locations developed due to defective maintenance.
4. In yielding soil formations.

16.12.1. Points to be kept in view while lifting the track

While lifting the track following points should be given special attention:

1. At a time, maximum lifting should not be done more than 7.5 cm. In case lifting is required more than 7.5 cm, then it should be done in more than one stage, each time maximum lifting should not

be done more than 7.5 cm. Before starting lifting of track, level pegs should be fixed at suitable intervals. After each operation of lifting, track should be consolidated properly. After attaining the desired level of track, the track should be ballasted fully and the cess is made up to proper level. The easement gradient should not be steeper than 1 in 520 (2.5 cm per 13 m length of rail).

2. In a single line track, the lifting should be under taken from the lower end and should be carried out in the direction of rising gradient.
3. In case of double line track, it should be started from the higher end and carried out in the decreasing gradient *i.e.* the operation should be carried out opposite to single line track. Care should be taken that easement gradient does not exceed.
4. Lifting operation should be under taken under the supervision of P.W.I. with suitable speed restrictions.

16.13. LOWERING OF TRACK

Track lowering should not be under taken unless it is unavoidable, as this creates unstability to the track and is quite difficult, time consuming and costly. Generally lowering of track is resorted under the following situations.

1. For remodeling of yard
2. For providing level crossing

16.13.1. Procedure of track lowering

For lowering of track, normally following procedure is adopted:

(*a*) Lowering of track should be done in the direction of falling grade.

(*b*) Lowering of track should not be done more than 7.5 cm at a time as in the case of track lifting. The easement grade should not exceed more than 1 in 520.

(*c*) For lowering the track, trenches should be dug across the track at every 30 m interval of the final level. Ballast should not be allowed to mix in the excavated material.

(*d*) While doing actual lowering of track, the spaces between the sleepers are cleared, the track is slightly lifted and packing under the sleepers is broken, and leveled in the space between sleepers. The material is then removed and operation is repeated till the final level is reached. After this, the track is ballasted, through packed, boxed and cess cut to the proper level.

(*e*) The lifting work should be done under the supervision of P.W.I. with suitable speed restrictions.

16.14. DEEP SCREENING OF BALLAST

Removal of ballast upto formation level, screening it, and refilling is called deep screening. One of the essential requirement of a good track is it's good drainage ability. Thus to provide proper drainage and desired elasticity to the track, it is essential to provide a clean ballast cushion of required depth below the bottom of the sleepers. In the absence of the required depth of clean ballast cushion, drainage will not be proper and the geometry of the track will be distorted, which will affect the safe running of the trains. Hence deep screening is essential.

16.14.1. Draw backs of deep screening

Deep screening has following draw backs:

(*a*) It requires long duration blocks.

(*b*) It is very costly.

(*c*) Its recovery time is also more.

Thus due to these draw backs deep screening should be done at a interval of 10 to 12 years.

16.14.2. Procedure of deep screening of ballast

Normally deep screening of ballast is carried out under speed restriction with out resorting to traffic block. It is desirable that deep screening work should proceed in opposite direction of the traffic. Before starting the deep screening work, sufficient quantity of ballast, necessary tools and equipment and required labour should be arranged well in advance on the site of work. Deep screening work should not be done in rainy season. The sequence of work should be as follows:

1. The work of deep screening should be started in such a way that four sleepers are tackled in a sequence. As shown in Fig. 16.5, the sleepers are numbered as 1, 2, 3, 4 and the spaces between sleepers denoted by the letters, P, Q, R, S, T etc. Out of the four sleepers mentioned above, only one sleeper is tackled at a time.

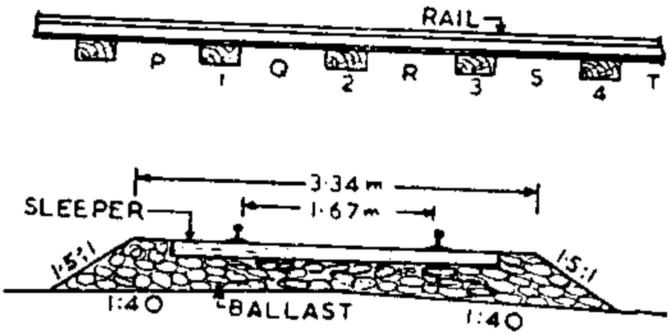


Fig. 16.5. Deep screening of ballast

2. After selecting the sleeper, the ballast is removed from spaces P and Q upto the formation level and the sleepers are supported on wooden blocks. It should be ensured that consolidated top of formation is not dug.
3. Remove the ballast from the bottom of the sleeper No. 1, screen the ballast and place the screened ballast under the same sleeper and pack the sleeper.
4. Remove the wooden block from space P.
5. Remove the ballast from space R and screen it, after screening, place the screened ballast in space P. If additional ballast is required, it may be taken from the extra ballast already stacked on the cess.
6. Now place the wooden block released from space P in space R. In this way sleeper No. 2 gets supports on its both sides to support the track.
7. Remove ballast from the bottom of sleeper No. 2, screen it and provide screened ballast under sleeper 2 and pack the sleeper.
8. Remove the ballast from space S, screen it and place it in space Q. Use extra ballast if necessary from the stack on the cess.
9. Remove wooden block from space Q and put it in space S to support the track.
10. Repeat the process till the work is completed.

16.15. OVER HAULING

Every year overhauling should be done at least for one third length of the gang beat along with through packing. For overhauling, the ballast should be opened out to the full depth in shoulders and to a depth of 5 to 7.5 cm below the bottom surface in between the sleepers. Two continuous spaces between the sleepers should not be tackled at the same time, but the work should be progressed in alternate panels of one rail length each. Ballast should be filled in the screened portions simultaneously, so that full quantity of ballast is always available in the track.

16.15.1. Picking up of slacks

Slacks are the points in the track which are not running good. Slacks occur in the following situations:

(*a*) Track portions in yielding formations.

(*b*) In poorly maintained sections, such as loose packing, improper alignment, incorrect or faulty levels etc.

(*c*) Curves are not aligned properly.

(*d*) Approaches to girder bridges, level crossings etc. are specially in sag.

(*e*) Sections of track having poor drainage.

(*f*) Sections with inadequate cleaned ballast cushion or sections not running smooth due to any other reason.

16.15.2. Works to be done during picking up of slacks

Generally following works are to be attended during picking up of slacks:

(*a*) Joint sleepers and two sleepers on either side of the joint and second shoulder sleeper.

(*b*) A few sleepers in the approaches of bridges and level crossings.

(*c*) Intermediate sleepers.

(*d*) Rough running stretches of the track. Attention to points and crossings should be given through out the year.

16.16. MAINTENANCE OF LEVEL CROSSING AND THEIR APPROACHES

At the crossing where a road crosses a railway track, the surface of the road is kept at rail level and grooves are left in the road surface along the inner edges of the rail for the wheel flanges.

These grooves are provided with the help of guard rails. These guard rails usually are spiked to wooden sleepers.

The level crossing being a rigid structure, it can not be packed, unless the whole structure is disturbed. Hence special care is needed in packing the level crossing. Thus each level crossing must be over hauled at least once a year. It needs special attention due to change of track structure. At the time of over hauling, the level crossing should be fully opened out and rails, fittings and sleepers etc. are inspected properly by the competent authority. As the rails and fittings are liable to be corroded, they should be thoroughly cleaned with wire brush and kerosene oil and painted with coaltar to avoid corrosion. A badly packed crossing is easily noticed as the road metal adjoining to the rail gets loose.

16.16.1. Approaches

The approaches to level crossings are very important. As the level crossing is a rigid structure, its approaches are liable to sink causing severe lurtch to the fast moving trains. Thus to ensure that there is no sagging, they should be attended at suitable interval by lifting it. At places of heavy traffic, bitumen or wooden surface is provided. In order to obtain better riding qualities of the track, provision of wooden sleepers for one or two rail length in the approaches has been found very satisfactory.

The clearances between the check rails or guard rails and the depth of check blocks should be properly checked and the flanges of the check rails should be kept free of dust and muck. The clearance at level crossings should be as shown in Table 16.2.

Table 16.2. Clearance at level crossing

Clearance	*B.G.*	*M.G.*	*N.G*
(*a*) Minimum clearance of check rails	5.0 cm	5.0 cm	5.0 cm
(*b*) Maximum clearance of check rails	5.625 cm	5.625 cm	5.625 cm
(*c*) Minimum depth for flanges from rail level	4.0 cm	3.44 cm	3.125 cm

Thus the road surface at level crossing as well as its approaches should be levelled, watered and rammed. In short they should be well maintained.

16.17. MAINTENANCE OF TRACK ON BRIDES AND APPROACHES OF GIRDER BRIDGES

At the junction of a girder bridge with a bank, the resilience of the track changes considerably. The track on the bank or approach yields more than the track on the girders directly. Thus the level of the track on girder bridge does not vary whilst that on the approach is liable to change. Hence in order to avoid bumps, special care of the approaches has to be taken. Usually the bumps are due to the sinking of track on approaches, but in black cotton soil area in rainy season bumps may occur due to the swelling of the soil. Sleepers on bridges should be so spaced that a derailed wheel could fall through. In case of large bridges, sleepers should be prevented from being pushed out of position by special guards.

16.18. LUBRICATION OF RAIL JOINTS

Lubrication of rail joints is also called oiling and greasing of fish plates etc. It is very important item in the maintenance of the track.

16.18.1. Purpose of lubrication

Lubrication of joints is done for the following purposes:

(*a*) To allow free expansion of rails.

(*b*) To reduce wear and tear of rails and fish plates.

Lubrication of joints should be done atleast once a year. Lubrication should not be done in extreme temperatures or when the rails are in tension due to creep. Thus it is advisable to carry out the lubrication operation in winter. Before doing actual lubrication, the surfaces should be cleaned properly, preferably with wire brush and jute. Lubricant used is a paste of workable consistency made of plumbago, kerosene and black oil or axle oil mixed in the proportion of 4:1.

16.18.2. Materials used as a lubricant

Following materials may be used as a lubricant:

1. Dry graphite (plumbago)	5 kg
2. Kerosene oil	3.5 lit.
3. Black or reclaimed oil	2.75 lit.

This quantity is sufficient for 100 joints of 52 kg rail or 90 R, rail or 125 joints of 75 R rail.

During lubrication operation not more than one joint should be opened at a time and one fish plate should be tackled at a time. Some times for lubrication of fish plates only plumbago and kerosene oil is used in the ratio of 3:2. Black oil is used for oiling fish bolts and nuts.

16.19. MAINTENANCE OF SURFACE DEFECTS

16.19.1. Hogged joints

In due course of time rail ends get hogged (depressed) due to poor maintenance of rail joints, loose and worn out fittings and faulty fastenings etc. This defect causes deterioration of the running quality of the track. This defect can be rectified as follows:

(*a*) The very small hogging can be rectified by over packing of the joint sleeper and tightening the fittings.

(*b*) It can also be rectified by shovel packing.

(*c*) It can be rectified by cutting off abut 4.5 m length of the hogged portion of the rail and reusing it after necessary drilling of holes.

(*d*) By removing the vertical bends of the rail, it can be dehogged and reused.

16.19.2. High joints

A rail joint higher than the rail level is known as high joint or riding joint. It gives a very uncomfortable riding of the track. It is developed generally due to the following reasons.

(*a*) Over packing of sleepers near the rail joint or over packing of joint sleepers.

(*b*) Sinking of intermediate sleepers.

(*c*) Change in track structure. If in a metal sleeper track wooden sleepers are provided and maintained better than metal sleepers, then joints tend to be high. This results camel riding track. This defect can be rectified by proper packing of the intermediate sleepers with out packing of joint sleepers.

16.19.3. Blowing joints

A rail joint which blows out fine dust during the passage of train is called a blowing joint. It is always surrounded by fine dust. This defect is developed due to the poor maintenance of the joint, particularly the packing of the joint sleepers and uncleaned ballast etc. Battered rail ends, week sleepers and wide expansion gaps accelerate the process of formation of blowing joint. As the moving loads or the vehicles pass over the joint, the joint sleepers constantly get depressed and lifted up during the passage of loads. The dust get sucked up and spread in the vicinity of the joint.

16.19.3.1. Remedial measures

Following remedial measures may be taken to rectify this defect:

(*a*) Through packing of joint and shoulder sleepers.

(*b*) Deep screening of ballast below the joint and shoulder sleepers.

(*c*) Tightening the loose fittings and reducing the expansion gaps etc.

(*d*) Cleaning of the ballast.

16.19.4. Pumping joint

A blowing joint becomes a pumping joint during rainy season. The water seeps into the joint forming slurry of mud under the joint. When moving loads pass over this joint, mud slurry comes out of the joint in place of dust. This defect is caused primarily due to the poor drainage of the track.

16.19.4.1. Remedial measures

This defect can be rectified by the following measures:

(*a*) By providing proper drainage of the joint.

(*b*) By adopting deep screening of the ballast below the joint and shoulder sleepers.

(*c*) Some times slightly away from the ends of the sleepers ballast is dug right upto the bottom of the section and water removed. Actually it is a temporary measure and is known as *bleeding of sleepers.*

16.19.5. Longitudinal sag in the track

The track between two rigid structures such as level crossings and bridges etc. usually settles down due to the passage of moving loads. The settlement of the track also takes place on the yielding formations due to weak formation, and the ballast gets punctured into the formation. Some times this longitudinal unevenness may not be noticeable in the shape of a vertical curve but it may cause riding quite uncomfortable. In such cases proper surveys should be carridout and the track should be lifted up at the proper place. The lifting should not be more than 7.5 cm at a time. For this purpose enough quantity of ballast should be collected at site.

16.19.6. Heaved track

Railway track has to cross the different type of soil formations. Certain soils as that of black cotton soil swells when comes in contact with moisture and shrinks on withdrawing of moisture. Thus railway track in such soil formations experiences trouble due to this property of black cotton soil in rainy season. The expansion of soil causes heaving up of the formation. This problem is more serious in areas which are prone to frost. In the frozen condition, the track can not be packed. The low places are raised by inserting wooden packing between the rails and sleepers. When it rains, this packing is removed and the track is packed in normal way.

16.19.6.1. Remedial measures

The effect of heaving of track can be reduced by providing a layer or blanket of sufficient thickness of more permeable material such as moorum between the ballast and the top of formation. It will check the penetration of rain water into the top layer of formation and check its bulging.

16.19.7. Centre bound sleepers

Under the rolling loads, ballast is packed down more under the rail seats than at the centre of the sleeper due to load being greater under the rail seats resulting in voids or depressions there and periodically these depressions need to be rectified. Thus sleepers instead of being better supported under rail seats are found to be better supported at the centre. This causes rocking of trains and the sleepers are said to be centre bound.

16.19.7.1. Remedial measures

This defect can be rectified by loosening the ballast at the centre of the sleepers.

16.20. TRACK DRAINAGE

Water is the enemy of the track. Thus proper drainage of the track is the most important factor. Water gets percolated into the sub grade by seepage, percolation, gravity and hydroscopic action from the atmosphere etc., which affects the track drainage. Thus the track drainage may be defined as the interception, collection and disposal of water from upon and under the track. Proper drainage is accomplished by proper surface and sub surface drainage system. It has been discussed in chapter 15.

16.20.1. How to ensure good drainage

Proper drainage may be ensured by the following measures:

1. On embankments proper drainage may be obtained by maintaining proper cess level and the clean ballast. However in situations as in cuttings and in yards where free and quick flow of water from the track is not possible, proper drainage system should be provided:
2. Growth of vegetation in the track, indicates clogging of ballast and lack of good drainage of the track. In such stretches of track, deep screening of ballast or over hauling should be done. If the ballast is clean, rain water will flow out of the track easily.
3. To avoid corrosion and failure of track circuit, rail foot should be kept clear of the ballast, cinder or earth upto about 2.5 cm to 5.0 cm depth below on all lines, inside and out side the yard, and good surface flow should be maintained.
4. All drains should be cleaned and repaired as a part of annual through packing on all lines.

16.20.2. Yard drainage

While planning the drainage of a yard, following points should be kept in mind:

1. Surface drains in yards should be open for ease in cleaning and inspection. The velocity of water in the drains should range from 0.5 m/s to 1.0 m/s for Katcha drains and 1.0 to 2.0 m/s for pucca drains. For different discharges the shape and size of the drains is given in the following Table 16.3.

Table 16.3. Size and section of drains

Discharge in cunees	*Slope*	*Size of drain in mm*			
		Depth of (D)	*Bottom width of drain (B)*	*Bottom width of concrete base (C)*	*Top width of drain (W)*
0.0028	1 in 400	300	80	210	305
0.0080	1 in 500	300	160	460	460
0.015	1 in 600	300	160	345	610
0.04	1 in 700	400	210	460	610
0.056	1 in 800	500	210	460	710
0.101	1 in 900	700	210	460	910
0.165	1 in 1000	915	210	460	1125

2. Longitudinal drains between two tracks should be saucer shaped. However vertical side drains may be provided where ever saucer shaped drains are not practicable.
3. Where ever an proper out fall is available at either end of the yard, longitudinal drains should be

provided with slope in opposite direction from the middle of the yard. This will result in minimum depth and size of the drain.

4. For effective drainage of the ballast, normally the top of the drain should not be above the cess level. However if to retain ballast a drain with higher top level has to be provided, then weep holes in the drain should be provided at the assumed cess level and the drain should be so designed as not to flow above bottom level of the weep holes.
5. Formation with in 3.5 m of track centre line should be maintained at least 20 cm below the sleeper bottom for run through lines and 15 cm for other lines.

16.20.3. Drainage in mid section

1. Where the cess level is not above the ground level, side drains should be provided in cutting and Zero fill locations along the tack. All drains should be given adequate slopes to enable free flow of the collected water.
2. Side drains should be lined except in rocky strata.
3. Adequate opening should be provided under the level crossing to take full discharge or flow of the drains.
4. Where ever possible water drains should be provided in cuttings. Their size may be adopted according to volume of the water catered for.
5. Surplus ballast in the shoulders retards the drainage and encourages growth of vegetation. Thus extra ballast should be removed from the track and stacked in small heaps along side.

16.20.4. Drainage in station yards

1. Ballast section in station yards must be the same as that on main lines.
2. Every station yard should have a net work of cross and longitudinal drains such that the storm water is taken away in the least possible time. Arrangements for surface drainage at water columns and carriage washing points, washing hydrants should be efficiently maintained. The waste water must be adequately trapped and led away either through pipes or lined drains.

16.21. MAINTENANCE OF BRIDGES

There are about 100364 bridges on Indian railways. Out of these bridges there are 8052 major bridges and the rest small bridges. Track inspectors are responsible for the maintenance of small bridges and culverts, while bridge inspectors are responsible for the maintenance of major bridges. For the proper functioning of the bridges, following works should be under taken carefully.

1. The depth of scour near the abutments and piers should be checked and effective measures taken. The depth of scour may be determined by taking soundings in the bed of the river.
2. The embankments near the bridge should be pitched suitably to protect it from wave action etc.
3. Flood control measures should be taken in rivers near the bridge if need be.
4. The super structures of steel girder bridges should be painted with lead paint at least once in five years.
5. All riveted joints should be inspected periodically and defective rivets replaced.
6. The bearings of the girders should be inspected regularly and lubricated. If the bearings are not kept properly lubricated, it may lead the bridge to failure.
7. The bed blocks should be inspected regularly and necessary repairs carried out.
8. All masonry works should be inspected regularly and any defect observed such as cracks development, damage to masonry by flood water or any other damage should be attended immediately.

16.22. MAINTENANCE OF ROLLING STOCK

Rolling stock includes locomotives, coaches and wagons.

In order to obtain proper efficiency of the traffic, the rolling stock has to be maintained in perfect running condition. To achieve this objective, following points need special attention.

1. All bearings and reciprocating parts of the rolling stock should be properly lubricated regularly.
2. The worn out parts of the rolling stock should be replaced as soon as they are noticed or as per departmental instructions.
3. Daily cleaning of all parts of the rolling stock is essential.
4. All axles which have run 32200 km should be replaced with new ones.
5. Generally the useful life of a passenger vehicle is 30 years. At the end of this period, it should be dismantled and re assembled even if the vehicle has not worn-out.

16.23. GRAPHITING OF FISH PLATES

Fish plates are graphited for the following purposes:

1. To allow the expansion and contraction of rails.
2. To enhance the life of fish plate and bolts.
3. To protect the fish plates from corrosion etc.

16.24. MAINTENANCE OF POINTS AND CROSSINGS

Points and crossings or switches are considered to be the weakest points of the track and most of the derailments occur at these points and crossings. Thus it is essential that points and crossings are thoroughly examined periodically and well maintained. They should be inspected while the moving loads are passing over them due to the fact that defects that can not be noticed otherwise can be detected under moving loads. Thus following measures may be adopted to keep the point and crossings in good condition:

1. The gauge should be maintained correctly at all points except at the toe where it can be slightly slack.
2. The badly damaged, worn out and burred stock and tongue rails should be replaced as a complete set. The bent tongue rail should be straightened.
3. If creep occurs, it should be rectified as discussed latter.
4. The leads and radii of the turn out should be checked and if any variation is found, it should be corrected.
5. Clearance between the check rail, wing rail and tongue rails should be properly maintained.
6. Bolts should be tightened properly daily.
7. The displacement of sleepers should be checked periodically and corrected if found otherwise.
8. Ballast should be screened periodically and repacked.
9. Interlocking connections should be cleaned of ballast and all connections should be fitted fully tight.
10. Proper drainage must be maintained near the points.
11. Fouling marks should be cleaned and painted periodically.

16.25. TRACK MAINTENANCE IN DESERT AREAS

The desert and semi desert areas pose a serious problem of track maintenance due to scanty rainfall, excessive temperature variation and drifting of sand dunes. This problem is acute, particularly in Bikaner and Jodhpur, Jaipur, Ajmer and Kota divisions of North Western Railways in Rajasthan. Some of the features which create problems in the maintenance of track are as follows:

(*a*) Scanty rainfall and poor availability of drinking water.

(*b*) Poor vegetation.

(*c*) Sand dunes and their drifting particularly in summer season.

(*d*) Extreme temperature variations.

(*e*) Sand storms of high velocity and long duration particularly in summer season.

(*f*) Corrosion of rails and fittings due to salinity in water and soil.

(*g*) Cyclonic rains which cause serious wash ways in sandy embankments.

16.26. PROBLEMS OF TRACK MAINTENANCE IN DIFFERENT SEASONS

16.26.1. In summer season

In summer season generally following problems are encountered:

1. **Collection of sand on track.** Due to sand drift, the track is completely covered with sand, which causes obstruction in the movement of traffic.
2. **Problem of overhauling.** Due to earth packed track, no over hauling of track is possible. The foot of rail and other fastenings get corroded due to remaining constantly in contact with sand and earth.
3. **Loss of resilience of track.** Though the track is well ballasted but it gets mixed up with sand which reduces the resilience quality of the track and the track becomes of poor riding qualities.
4. **Poor inspection of sleepers and fittings.** Sand fills in between rails and sides covering all sleepers and fittings. Generally only the top of rail head is visible. Thus the inspection of sleepers and fittings etc. is impossible.
5. **Reduced out put of gangmen.** Due to intense heat, lack of shelters and shortage of water, the out put of gangmen is reduced.
6. **Turffing becomes difficult.** Plantation of vegetation (turffing) becomes difficult in the absence of water.
7. **Griding action of sand.** Due to the griding action of sand, the wear and tear of track components as rails, points and crossings etc. is more.

16.26.2. Winter season

1. **Increase in fractures.** In some parts of Rajasthan, the night temperature dips upto freezing or below freezing point. This excessive variation in temperature causes very high compressive stresses in the rail sections, resulting increase in rail fractures.
2. **Heavy corrosion.** Due to salt petre action of soil and water heavy corrosion to rail and track fittings is caused, which reduces the riding qualities of rail journey and makes the journey quite uncomfortable.

16.26.3. Rainy season

1. **Washing away of sand from the track.** Due to heavy rains, the sand is swept away from under neath the track along with the running water under the track, leaving the track suspended in air. This problem is acute during the cyclonic rains.
2. **Early rusting of rails.** As the wet sand/earth remains in contact of rails and fittings, it causes its early rusting due to salt petre action.
3. **Unsatisfactory drainage.** Generally drains are filled up with sand due to continuous sand blowing. Thus the drainage of track in cuttings and yards becomes more difficult.
4. **Longitunal levels get affected.** The longitudinal levels of the track get adversely affected. The middle portion of rails tends to be higher than the ends due to bulking of sand during rainy season. The joins get depressed due to passage of loads where as rest of the rails continue to be high.

16.26.4. Remedial measures

For the eradication of above problems following remedial measures are suggested:

1. Stabilization of sand dunes by forestry. This can be done by providing mechanical obstacles on wind ward side in the free sweep of sand and stop the advancement of sand dunes towards the track by planting suitable type of trees and bushes at reasonable distance from the track. Thus the sand dunes are stabilized by the leaves and roots of the bushes and trees grown in the area. In desert areas following species are recommended for plantation as suggested by Arid zone Research Institute (Jodhpur).

(*a*) Israseli babul known as Acacia Tortils.

(*b*) Vilayti babul known as proscopis Juliflora.

(*c*) Grasses as Leasarus cirdicus (SEVAN) and pormicum torgirun (Murth) (*d*) Creepers-citrulas colisynihes (Tumba).

2. Stabilization of sand dunes by chemical treatment. The sand dunes may also be stabilized in a limited way by spraying a solution of calcium silicate on a strip of 2 to 3 m of land on either side of the track. The 2 to 4% mixture of calcium silicate is found quite effective.

3. Use of sand removing machines. Now high capacity sand removing machines are available, which can be used on track where sand accumulates due to sand drifts. This machine is capable of removing sand at the rate of 500 cubic meter per hour.

4. Use of bulldozers. Ridges formed on both sides of track can be dressed up with the help of bulldozers. Small sand dunes also can be levelled up by bulldozers.

5. Clearance of excess sand. Uptc 3.5 m from the centre of track on both sides excess sand should be cleared. The side drains should also be kept clear of sand.

6. Cutting out channels. At suitable distance from the track on wind ward side a channel of about 1 m depth and 1 m width should be cut so that before advancing towards the track, the sand first will be collected in these channels.

This method has been found quite effective in checking advancement of sand dunes. The channels should be cleared at regular intervals.

7. Removing obstructions on lee ward side. In order to check the movement of sand back wards towards the track, cross gullies should be cut in the longitudinal mounds on the lee ward side, which will help the sand to blow away.

8. Cleaning of ballast mixed with sand. The sand mixed with the ballast should be removed by screening it through the inclined screen as in the case of overhauling. The clean ballast then should be put back in the track.

9. Stabilization on wind ward side. In worst affected areas, a row of mulch bushes and trees should be provided on the wind ward side on a large scale to break the momentum of the sand blowing into the track.

10. frequent deep screening. In desert areas deep screening should be done after 6 to 8 years instead of 12 to 15 years as normally done. Recoupment of ballast also should be done more frequently alongwith deep screening.

11. Coal taring of S.T. sleepers and fittings. Frequent of coal taring of S.T. sleepers, steel fittings and under side of rails should be done where there is heavy corrosion.

12. Plantation of trees. In sand affected areas, large scale plantation of trees should be resorted. For nursing these trees reasonable quantity of water should be supplied.

13. Soil treatment. Soil treatment of top layers of high banks should be done where ever there is erosion of banks due to sand storm.

14. Pitching of banks and cuttings. Sections where track is on embankment and are more prone to sand drifts should be given special treatment. Pitching of banks and cuttings can be done in selected reaches which are more prone and pucca masonry side drains/cross drains should also be provided.

16.27. TOOLS REQUIRED FOR MANUAL MAINTENANCE

During the maintenance operations following tools are required:

Table 16.4. Showings tools and their use in track maintenance

S. No.	*Name of tool*	*Use of the tool*
1.	Beater cum picaxe	To pack the ballast under sleeper
2.	Rail gauge	To check the distance between the inner faces of rails
3.	Cant board	To check the super elevation or cant
4.	Shovel	To handle the ballast

S. No.	*Name of tool*	*Use of the tool*
5.	Spanner	To loose or tighten the fish bolts
6.	Phaorah	To handle the ballast
7.	Ballast screen	To screen the ballast
8.	Wire claw or ballast fork	To clean the ballast
9.	Jim crow	To bend the rails
10.	Augur	To drill holes in spikes
11.	Chisel	To cut rails, bolts etc.
12.	Lifting Jacks	To lift the track
13.	Rail Jacks	To lift the rail
14.	Spirit level	To verify cross levels
15.	Crow bars	To correct the track alignment for slight variation
16.	Sleeper tongs	To lift the sleepers
17.	Square	To square the sleepers
18.	Claw bar	To square the sleepers
19.	Sledge hammer	To cut rails etc. with the help of chisel
20.	Adzed	To do adging to the wooden sleepers
21.	Mallot	To sound the sleepers for packing
22.	Slice rail	To indicate the levels of rails on curves
23.	Track liner	To correct the variation of alignment, if variation is large
24.	Electric tie tamper	To pack the ballast under sleepers more effectively and efficiently.

Note. Some of these tools are shown in the figures below

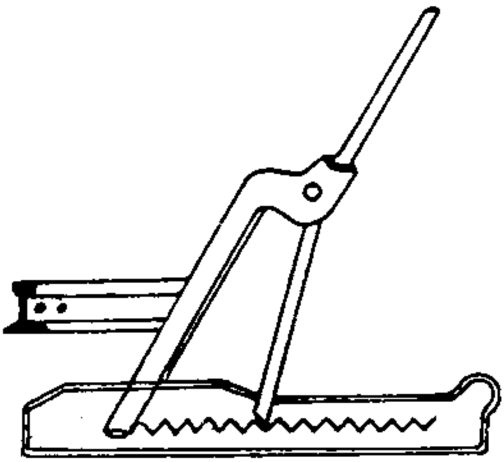


Fig. 16.6. Track liner

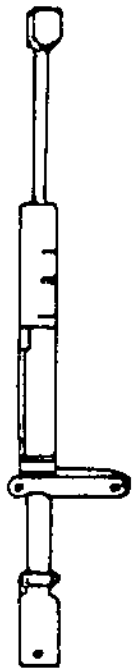


Fig. 16.7. Electric tie tamper

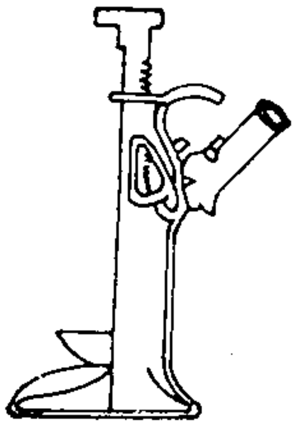


Fig. 16.8. Jack

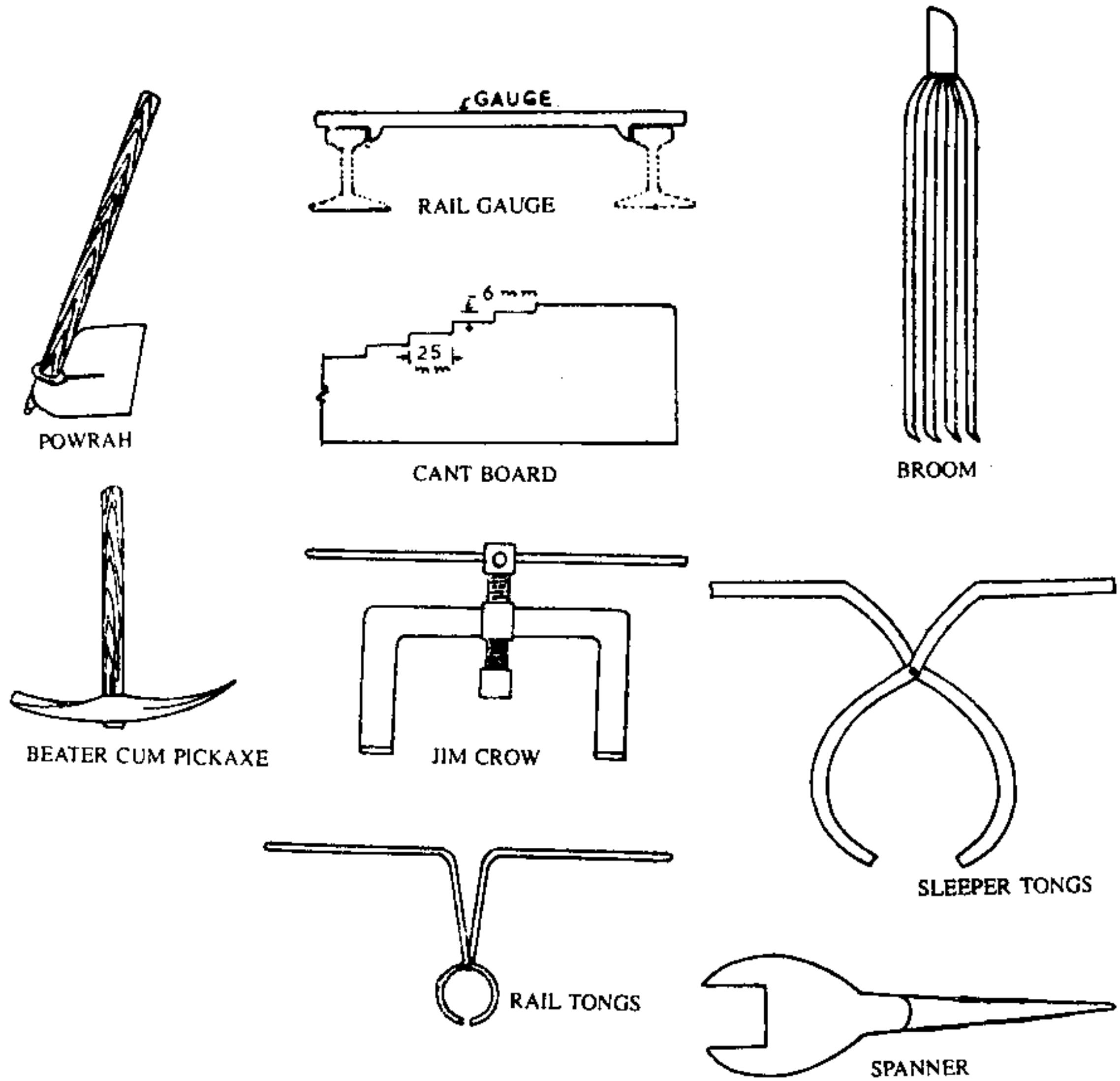


Fig. 16.9. Track maintenance tools

16.28. TRACK MAINTENANCE ORGANISATION

A track maintenance organisation is as follows:

1. Chief engineer
2. Deputy chief engineer one or two
3. Divisional engineer
3. Assistant engineer or resident engineer
5. Permanent way inspector (P.W.I.)
6. Inspector of works
7. Assistant permanent way inspector
8. Gang mate or Ganger
9. Gangmen.

The basic unit of track maintenance organisation is the gang strength under the charge of a gangmate or ganger. In India about 5 to 6 km length of track is kept under the charge of one gang. The number of gangmen in a gang depends upon the following factors:

(*a*) Type of soil of the formation

(*b*) No of trains passing per day on the track

(*c*) Condition and age of permanent way
(*d*) Type and speed of traffic
(*e*) Type of sleepers used on the track
(*f*) No. of crossings, turn outs and length of siding etc.
(*g*) No. of curves and grades etc.

The number of man in a gang can be ascertained as follows:

If on a B.G. track less than 10 trains pass daily, then it is said as light traffic track. In such cases 2 gangmen per 1.6 km length of track are sufficient. In case more than 30 trains pass daily over a B.G. track then it is called a heavy traffic section. In this case 3 gangmen per 1.6 km length of track are considered sufficient. For M.G. and N.G. tracks 3/4 and 1/2 of the above number of gangmen can be taken. The number of turn out, sidings, crossings, can be changed in terms of track kilometrage as follows:

10 turn out	= 1 track km
5 cross overs	= 1 track km
2.5 diamond crossings with double slip	= 1 track km
1½ scissors crossing	= 1 track km
40 single trap points	= 1 track km
1.4 km important track in yards	= 1 track km
2 km of other track in yards	= 1 track km

Thus based on the above calculations from 8 to 10 gagman, one key men, and one gangmate form a maintenance gang. This gang is responsible for the maintenance of 5 to 6 km rail track.

The work done by track gangs may be divided into the following two groups:

1. Maintenance work
2. Other works

1. Maintenance works. Track maintenance works further may be divided into the two groups as

(*a*) Routine works
(*b*) Special works. Heavy lifting of track by 5 cm or more is classified as special works.

2. Other works. Under this head following works are classified:

(*a*) Cleaning weeds from yards
(*b*) Loading and unloading of wagons etc.

16.28.1. Task per man per day

Normally work suggested in the following table should be done per man daily on a B.G. track and proportionally more work is expected on M.G. and N.G. tracks.

Table 16.5. Showing progress of one man per day

(*a*)	Spot packing and dressing	15 to 20 sleepers
(*b*)	Through packing	About one rail length (13.0 m)
(*c*)	Screening of ballast for drainage	Half rail length (6.6 m length)
(*d*)	Lubrication of fish plates and bolts	20 to 30 joints
(*e*)	Adging and boring holes in wooden sleepers	40 to 50 per carpenter and one helper provided relaying of sleepers is done by other labourers
(*f*)	Stocking sleepers with a little lead	About 2000 No.
(*g*)	Putting dates on wooden sleepers	70 to 100 per carpenter and one helper

16.29. DUTIES OF A GANG MATE OR GANGER

1. The gangmate or ganger is the incharge of the gang and is personally responsible for the safety and up keep of the track of his section.

2. He should arrange for tools, equipment etc. required for his gang. While these articles are not in use, he should ensure their safety.
3. He should keep his section in good running condition at all times.
4. He should ensure safety of his gangmen while working on the line and in emergency should slow down or stop the train by using temporary signals.
5. He should check and examine the points and crossings periodically at an regular interval.
6. He should maintain the correct gauge of the track.
7. He is responsible for maintaining the track of his section in correct alignment and level.
8. In case of an accident, he should look after the broken track components and rolling stock and should ensure that they are not disturbed unless they are inspected by the competent authority.
9. He should be fully conversant with the details of his section such as location and number of points and crossings and level crossings etc.
10. He should check the tress pass by persons or cattle in the railway limits under his charge and report to his seniors any unauthorized construction etc. in his section.
11. Often he is asked to perform some miscellaneous duties such as cutting of tree branches obstructing the vision of signals, noting of high flood levels of small bridges, repairing of fencing, cleaning of water ways etc.
12. He should maintain complete record of work, report of key man, and instructions issued by the P.W.I. and A.P.W.I.

16.29.1. Duties of Key man

1. He is No. 2 in rank of his gang. In the absence of the ganger, he performs his duties. He is called key man, because he attends to the bolts and keys for maintaining the gauge and rest of the work is carried out by the gangmen.
2. He is responsible for the up keep and inspection of the fastenings and points of his section. He should move along the track daily and personally inspect all fastenings and points of his section. He should carry with him one hammer, one wrench, two red flags, one green flag, 8 detonators and other necessary tools.
3. During his routine inspection, if he comes across any serious defect in the track as a broken rail, or washing away of ballast, he should arrange to protect the line immediately and should report to his superiors.
4. If during his routine inspection, he finds materials as engine tools, passenger's luggage, dynamo, belt etc., he should collect them and hand over to the nearest railway station master.
5. He should grease fish plates and oil fish bolts etc. to protect them from freezing.
6. He should open and refill all the joints at least once a year.

16.29.2. Duties of P.W.I.

1. P.W.I. is personally responsible for maintaining the track in good condition for the passage of trains. For this purpose he travels over the track by push trolley and watches the defects of the track and arranges the repair of the defective track by his gang.
2. He is responsible to carry out the renewals of rails and sleepers.
3. He should maintain the record of wear of rails in his section. He should chalk out programme for lubrication of rail joints in such a way that all rail joints are lubricated once a year during winter season.
4. He is responsible to maintain the correct gauge, super elevation on curves, and removal of creep etc.
5. He should see the welfare of his gangmen.
6. He should supervise the work of his gang regularly.

7. Level crossings under his charge must be maintained in perfect condition. During his visit to level crossings, he should check the working of gatemen also. If necessary he should issue instructions to the gate man.
8. At the time of accident, his is responsible to restore the traffic in the shortest possible time. He should also find out the causes of accident.
9. He should prepare estimates of the maintenance work and should report to his seniors.

16.30. ANNUAL PROGRAMME OF SYSTEMATIC MAINTENANCE OF TRACK

The twelve monthly cycle of systematic track maintenance routine adopted on Indian Railways is shown in Table 16.6 below.

Table 16.6. Annual programme of systematic maintenance

S. No.	*Period*	*Type of work to be done*
1.	Post monsoon period from 15th October to 15th December.	(*a*) Through packing from one end to the other should be done systematically for 4 to 5 days in a week. (*b*) Picking up of slacks, attention to bridge approaches, level crossings and scattered renewals etc. should be attended on the remaining days of the week.
2.	Working season from 15th December to 15th April	(*a*) Through packing and screening of ballast for one third (1/3) portion of the track and only through packing for the remaining (2/3rd) portion of the track for 4 to 5 days per week. (*b*) Picking up of slacks, attention to bridge approaches, level crossings, and scattered renewals for the remaining days of the week. (*c*) Greasing and oiling of fish plates and bolts should be completed between 15th Dec. to 15th March. Additional gangs may be deployed for this work. (*d*) Realignment of curves, ballasting of track etc. also should be done during this period.
3.	Pre monsoon period from 15th April to 15th June:	
	(*a*) In areas having rain fall less than 75 cm	(*a*) Through packing for about four days depending on the discretion of the divisional engineer.
	(*b*) Areas having rainfall more than 75 cm	(*b*) Cleaning of side and catch water drains, picking up of slacks, and repairs to cess during the remaining days of the week.
4.	Monsoon period extending from 15th June to 15th October:	(*a*) Through packing or other types of maintenance as per instruction of D.E.N. for 3 to 4 days per week.
	(*a*) Areas having rainfall less than 75 cm	(*b*) Picking up of slacks for remaining days.
	(*b*) Areas having rainfall more than 75 cm	(*c*) Picking up of slacks for all the days.

Note Attention to points and crossings should be given round the year. In sections where no points and crossing exist, this time should be utilized to adjust the creep. Separate charts for main line and yards etc. should be maintained by each gang and kept in the personal custody of the gangmate.

16.31. MAINTENANCE OF RAILWAY TUNNEL

Though a permanent way inspector is personally responsible for the maintenance of track through the tunnel and its up keep to maintain it in perfect running condition. Usually he also inspects every tunnel in his section at least once a year after the monsoon season. Following points should be noted in connection with the maintenance of railway tunnels.

1. At the ends of the tunnel, portals should be inspected periodically and any defect as bulging or cracking of masonry, percolation of catch water drains into the tunnel, signs of slip above top, and bulging etc. noticed, should be rectified at the earliest.
2. The track should be kept free from dampness by maintaining proper drainage.
3. Rails, sleepers and fastenings etc. should be checked periodically and it should be ensured that metallic parts are not affected by corrosion.
4. Track through the tunnel should be in line and level.
5. The dimension of the tunnel should not be allowed to deform. The tunnel section should confirm to the original dimensions.
6. To keep the healthy atmosphere in the tunnel, all foul gases etc. should be removed.
7. All ventilation shafts should be kept clear of any obstruction and vegetation.
8. Tunnel should be kept properly lighted. For this purpose lighting arrangements should be checked periodically and defective elements should be replaced or rectified as the case may be.
9. The reference marks and level pillars should also be checked periodically.
10. Side drains and weep holes should be kept clear. The tunnel floor should be maintained dry. In no case water should remain standing on the tunnel floor.
11. Lining of the tunnel should be kept in good condition and it should not be allowed to be damaged due to any reason. Periodic maintenance of lining should be carried out.
12. In case track renewal is required, in that case track in the tunnel should be given top most priority.
13. Tunnel maintenance should be carried out under the protection of signals.
14. P.W.I. is responsible for the safety of tunnel and the labour employed during the tunnel maintenance.

16.32. SIGNALING DURING THE MAINTENANCE WORK

During the maintenance of the track, it becomes essential to inform or warn the railway driver about the condition of the track ahead. This objective is achieved by providing proper signals at appropriate distances and locations.

In case the duration of the maintenance is not long, say less than three days, in that case flags are used as temporary signals. In case the maintenance work is heavy and likely to last for a long time, then temporary fixed signals of semaphore type are provided at suitable locations. For night working proper arrangements of lighting are also done.

Some times as an additional precaution a suitable explosive contained in a flat circular container is put on the top of the rail, so that when a rolling load passes over the rail, there is an explosion with a loud sound. This arrangement is known as fog signal or audible signal or detonator. When explosives are to be used as signals, all railways have established their own rules for the safety of labour and material.

For temporary signals, following points should be kept in mind:

1. The caution signals should be placed or installed at an adequate distance, so that driver may get sufficient time to bring his train to halt. Normally a distance of 400 m is adopted.
2. The signals should be placed and removed at specified hours of time and speed restriction caution board should also be notified.
3. The position of signals should be changed as the work progresses.
4. Lighting arrangements at night should be made for the temporary signals.
5. The signal man should also be provided with detometers, Kerosene oil, match boxes, flags and hand signal lamps.
6. To convey the correct massage of signals, universal convention of hand signals should be followed.

16.32.1. Speed restriction during maintenance work

During track maintenance work usually speed restrictions have to be imposed. It should be remembered that speed restriction affects the efficiency of the railways. Hence as far as possible, speed restrictions should be avoided. If the total avoidance of speed restrictions is not possible duration of speed restriction should be minimised. Regarding speed restrictions following points should be observed:

1. During daily maintenance no speed restriction should be imposed.
2. In case of periodic maintenance, speed indicator and termination posts should be installed at proper locations.
3. The speed restrictions should be gradually lifted with the progress of track maintenance and it should ue completely removed when the track has been fully attended.
4. Some times permanent speed restrictions are imposed on curves, bridges and if the track is of light type.
5. Every effort should be made to avoid speed restrictions, but not at the cost of safety.

QUESTIONS

1. Why is the maintenance of railway track necessary? List out the item of maintenance.
2. Why packing of sleepers is done? Describe the process of through packing of sleepers.
3. On curves what extra items must be paid attention in comparison of a straight track.
   (*a*) Degree of curve (*b*) Super elevation
   (*c*) Surface defect (*d*) Extra allowance in gauge
4. For through packing, operation/operations carried out are:
   (*a*) Opening of road (*b*) Examination of rails, sleepers and fastenings
   (*c*) Squaring of sleepers (*d*) Alignment of track
   (*e*) All the above
5. Packing of sleepers can be done by
   (*a*) Beater method (*b*) Scisser method
   (*c*) Shovel method (*d*) By all the above methods
6. The periodicity and systematic over hauling of the track depends on
   (*a*) Type and age of the track structure
   (*b*) Maximum permissible speed of vehicles and volume of traffic
   (*c*) Method of traction and rate of deterioration
   (*d*) Rain fall in the area
   (*e*) All the above
7. Identify the incorrect statement/statements
   (*a*) Hogged joints in rails are developed due to poor maintenance of rail joints, loose and worn out fittings and faulty fastening
   (*b*) This defect is not serious and un removable
   (*c*) Joints higher than rail levels are called high joints
   (*d*) High joints are developed due to over packing of joint sleepers, and sinking of intermediate sleepers
   (*e*) It is not possible to rectify high joints
   (*f*) High joints provide smooth and comfortable journey
8. Identify the in correct statement/statements
   (*a*) A rail joint blowing out fine dust during the passage of train over it is called blowing joint
   (*b*) During rainy season a rail joint blowing out mud slurry during the passage of train over it is called a pumping joint
   (*c*) A blowing joint can not be changed to a pumping joint
   (*d*) Good drainage of the track is most essential for good performance
   (*e*) Good drainage is not essential at all for good performance of the track
9. Tool used for bending rail during track maintenance is
   (*a*) Jacks (*b*) Crow bar

(*c*) Jim crow (*d*) Rail tongs

10. Ballast is packed under sleepers by
    (*a*) Forks (*b*) Shovels
    (*c*) Crow bars (*d*) Phaorah
11. Blowing joints are caused in rail track due to
    (*a*) Poor maintenance of the joint (*b*) Insufficient width of ballast section
    (*c*) Over packing of ballast under sleeper (*d*) Over packing of ballast under rail seat
12. Pumping joints are developed due to
    (*a*) Poor drainage of the track (*b*) Non squaring of sleepers
    (*c*) Wide expansion joints (*d*) Poor stabilization of formation
13. The stability of formation of permanent track depends on
    (*a*) Side slopes of earth work (*b*) Intensity of traffic
    (*c*) Thickness of ballast (*d*) Width of formation
14. Explain the followings with reason
    (*a*) Rail track should be under constant watch of an experienced ganger
    (*b*) Ballast under rail seat is depressed more than at the centre of the sleeper during passage of a vehicle on the track
    (*c*) The construction of speed breakers on the approaches near the level crossings help in reducing the accidents
    (*d*) The ballast under the sleepers should be packed regularly
    (*e*) At important points along a track, wagons full of rubble and ashes should be kept ready at all times
    (*f*) Proper maintenance of points and crossings should be insisted upon

ANSWERS

3. (*b*)	6. (*e*)	9. (*c*)	12. (*a*)
4. (*e*)	7. (*b, e, f*)	10. (*b*)	13. (*a*)
5. (*d*)	8. (*c, e*)	11. (*a*)	

17

Defects and Failure of Rails

17.1. DEFINITION

Rails are steel girders and placed end to end to provide a level and continuous surface for the movement of trains.

17.2. FUNCTIONS OF RAILS

Followings are the functions of rails:

1. The rails provide a level and continuous surface for the movement of trains.
2. The rails provide a pathway to trains. This pathway has a very low friction. The friction between the wheels of trains and steel of rails is about 20% of the friction between pneumatic tyres and metalled roads.
3. The rails serve as a lateral guide for the running of wheels.
4. The rails bear the stresses developed due to vertical loads transmitted to them through axles and wheels of the rolling stock, due to thermal stresses and bracking forces etc.
5. The rails transmit the heavy load of the rolling stack etc. to the large area of the formation through sleepers and ballast.

17.3. LENGTH OF RAILS

Theoretically longer the rail length, lesser the number of joints and fittings in the track, resulting saving in cost of construction and the maintenance of the track. Longer rails are not only economical, but also give a smoother and comfortable riding to the passengers. As the train moves, passengers experience the jerks at joints. With longer rails, the number of joints will be lesser and the passengers will experience lesser jerks and feel comfortable. However the length of rails is restricted due to the following factors:

(*a*) The cost of production

(*b*) Difficulties in handling of longer rails

(*c*) Lack of facilities for transporting longer rails, specially on curves

(*d*) Difficulties in handling a bigger expansion joint for long rails

(*e*) Heavy internal thermal stresses in long rails.

Rail length used in some counters are as follows:

Table 17.1. Rail length used in some counters

S. No.	*Name of country*	*Rail length in metres*
1.	Germany	30 m (99 feet)
2.	France	23 m (79 feet)
3.	U.K.	18 m (60 feet)
4.	U.S.A.	12 m (39 feet)
5.	India	13 m (42 feet)

Now in U.K. also 27 m and 36 m rail lengths have been used. Recently in 2005-2006 Indian steel plant Bhilai has rolled out welded rails of 273 m length to facilitate the gauge conversion work.

17.3.1. Minimum rail length

Though no restrictions have been laid for the minimum length of a rail piece to be used on a through track, but it should not be less than the distance between two adjacent axcles, which has been kept 3.6 m in India. Hence a piece of rail less than 3.6 m in length should not be used on through tracks.

17.4. GRADE AND CHEMICAL COMPOSITION OF RAIL STEEL

The rail steel has been classified into two categories, namely steel grade 710 and steel grade 880. The chemical composition of these grades of steel and medium manganese steel is shown in the Table 17.2 given below.

Table 17.2. Showing chemical composition of rail steel

S. No.	*Elements*	*% in grade 710 steel*	*% in grade 880 steel*	*% in medium manganese steel*	*Remark*
1.	Carbon	0.45 to 0.60	0.60 to 0.80	0.45 to 0.60	(*a*) The combined contents of carbon and manganese for 710 grade steel in no case should be less than 1.45%
2.	Manganese	0.95 to 1.40	0.80 to 1.30	0.95 to 1.40	(*b*) Where carbon content is less than 0.45%, the combined amount should not be less than 1.55%.
3.	Sulphur	0.04 to 0.5	0.10 to 0.5	0.05 to 0.3	
4.	Phosphorous	0.05 (max)	0.05 (max)	0.06 (max)	(*c*) Max. limit of these elements will be 1.95%.
5.	Silicon	0.05 (max)	0.05 (max)	0.06 (max)	

17.5. DEFECTS IN RAILS

Due to the passage of number of wheels of the rolling stock during the service life of the rail and friction between the wheels and rail, the head of the rail gets worn out in course of time. The wear and tear on the vertical and lateral planes of rail head develops due to forces caused by bracking, acceleration, deceleration, impact of moving loads and atmospheric effect etc. Depending upon the position, the wear of the rail can be classified as follows:

1. Rail wear on head
2. Wear at the end of the rail or rail end batter
3. Wear on the side of the rail

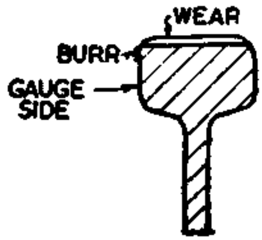


Fig. 17.1. Rail burr

17.5.1. Rail wear on head or top

Due to the impact of different forces discussed above, the metal from the top of a rail flows and assumes the shape as shown in Fig. 17.1 forming projections on sides. These projections beyond the original section of the rail are called as burr.

17.5.2. Causes of development of wear at top

Following are the causes for the development of wear on the top of a rail:

1. The head of the rail worns out due to the abrasion of rolling wheels over the top of the rail.
2. The head of the rail worns out due to the concentration of heavy loads of wheels on a small area. This causes development of high stresses in the rail exceeding its elastic limit. Due to these high stresses metal from the top of the rail flows down. This factor is more significant than other wear producing factors in rails.

3. The grinding action of sand particles between wheels and rail also helps to produce wear in rails.
4. Corrosion also contributes to development of wear in the top of a rail.

17.5.3. Measurement of the wear

The wear of rail tops can be measured as follows:

(*a*) By weighing the rail.

(*b*) By profiling the rail section either with the help of lead strips or with the help of needles.

(*c*) By special methods designed for this purpose.

17.5.4. Rail end batter or wear at the end of a rail

The hammering action of moving loads at the rail joints cause the rail ends batter in due course of time. As shown in Fig. 17.2 it is more pronounced than the wear on the top. The wear at the ends of the rail is also called *end batter.*

The rail end batter is the measure of difference of the vertical heights at the end of the rail and at a point 30 cm from the end. Fig. 17.2. If the batter is upto 2 mm, it is classified as average and tolerated. If the batter is between 2 and 3 mm, it is classified as 'severe' and the rail end needs correction. If the batter is excessive and the rail otherwise is alright, then the rail ends may be cut off and the rail is reused.

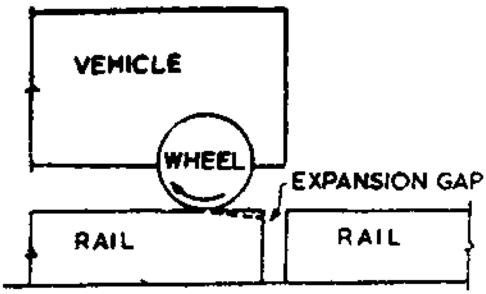


Fig. 17.2. Rail end batter

17.5.5. Effects of end wear or battering of a rail

Due to the hammering action of moving loads at the rail joints following side effects are produced:

(*a*) The contact surfaces between the rails and sleepers get worn out.

(*b*) The fish bolts and fish plates become loose.

(*c*) Due to vibrations at the joints, the settlement of ballast takes place, resulting in depression of sleepers. These factors further worsen the situation by increasing the rail end batter. Rail end batter increases due to the following factors:

(*i*) Due to poor maintenance of joints.

(*ii*) Due to heavy loads and large joint openings.

(*iii*) Due to bad condition of vehicle springs.

17.5.6. Wear on the sides of a rail

This wear occurs in the track on curves. This is the most destructive type of wear. This is caused due to the following factors:

(*a*) On curved portion of the track, the centrifugal force causes thrust of the wheel flanges against side of the outer rail head, which results in the grinding of the rail flanges producing side wear on the outer rail.

(*b*) On the curved portion of the track, the vehicles do not bend to the shape of the curvature, resulting in biting of the inner side of the outer rail head by wheel flanges due to rigidity of wheel base.

(*c*) Wear on inner side of head of the inner rail also occur. It takes place mainly due to siipping and skidding action of wheels on curves.

17.5.7. Measures to minimise wear of rails

Wear of rails can be minimised by the following measures:

(*a*) By conning of wheels.

(*b*) By providing super elevation on the tracks.

(*c*) By the use of special alloy steel for the rails.
(*d*) By adopting good maintenance of the track.
(*e*) By reducing the number of joints and expansion gaps.
(*f*) When the wear exceeds 5% of the total weight of the section, rail must be replaced.
(*g*) Regular tightening of the fish bolts and packing of ballast will reduce the wear.
(*h*) By lubricating the gauge face of the outer rails.
(*i*) By adopting exchange of inner and outer rails
(*j*) By introducing check rails on curves.

The introduction of check rails on curves has been found very effective in reducing the wear to a great extent. The check rail holds back the flange of the inner wheel, preventing the outer wheel to damage the rail. The gap between the inner rail and check rail should be equal to the thickness of the flange and required side plays. In India for B.G track this gap is kept as 44 mm. They are connected with suitable fastenings as shown in Fig. 17.3.

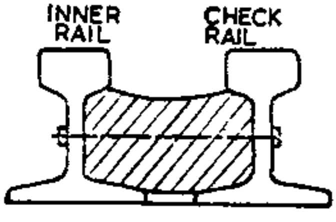


Fig. 17.3. Check rail

Check rails are used on curves of 8 degrees and above for B.G., 14 degrees and above for M.G. Generally worn-out rails are used as check rails.

(*k*) Use of wearing plates are also found useful in reducing wear of rails.
(*l*) Welding or dehogging battered rail ends at proper time will also reduce wear of rails.

17.5.8. Use of worn out rails

Worn out rails should not be used under the following conditions:

(*a*) If the wear exceeds the prescribed limit of 5%, at the most upto 8% of its total weight, then the rail should be replaced.
(*b*) If the top of the head is worn by 10 mm, it should be replaced.
(*c*) If the gauge side is worn by 3 mm it should be replaced.
(*d*) If the web or head split has developed, it should be replaced.
(*f*) If the fish plates are cut by flanges, they should be replaced.
(*h*) If the gauge side of the head is worn to the slope of the wheel flange, it should be replaced, other wise wheels may mount on the top.

17.5.9. Rail lubricator

Rail lubricators are provided on sharp curves to reduce the friction on the running face of the outer rail, where lateral wear is considerable. It has been observed that by applying lubrication, the wear is reduced considerably, some times upto 50%. To provide lubrication many mechanical devices can be attached to the rails.

17.5.10. Reconditioning of worn out rails

From economical considerations, the worn out rails can be reconditioned by the following methods:

(*a*) The battered ends may be cut off and rails can be welded.
(*b*) Rails worn out at top or side may be re rolled in lighter sections and can be used.
(*c*) The bent or hogged ends are cut or cropped off and holes are redrilled in rails. These rails can be reused using stiffer fish plates.

17.5.11. Wheel burns

Wheel burns are caused by the slipping of driving wheels of the locomotives on the surface of the rail. In this process extra heat is generated and the metal of the top of the rail burns, causing depressions on the rail table. Wheel burns are generally noticed at the steep gradients or near water columns or where there are heavy incidence of braking to stop train.

17.5.12. Scabbing of rails

Scabbing of rails is due to the falling off patches of metal from rail table or top. Generally it has been observed in the form of elliptical depressions, whose surface reveals progressive fracture with numerous cracks around it.

17.5.13. Hogging of rails

Rails bent vertically at the ends are known as hogged rails. The hogging of rails is one of the serious defects which develops due to poor maintenance of rails joints, yielding formation, loose and faulty fastenings etc. This defect can be rectified by the following measures.

(*a*) By replacing the hogged rails.

(*b*) If the hogging is small, it can be rectified by measured shovel packing as discussed in chapter 19.

(*c*) The end of the rail is cut abut 1 m in length and fresh holes are drilled for fish plates.

(*d*) The hogged rails can be improved by welding the worn out ends

(*e*) The vertical bent of the rail is removed by dehogging it in the opposite direction with the help of dehogging machine.

17.5.14. Shelling

The progressive horizontal separation of metal occurring on the gauge side is known as shelling. Generally it occurs at the upper gauge corner. These are caused primarily by heavy bearing pressure coming on a small area of contact, which causes heavy internal shear stresses. These points are also called *black spots*.

17.6. CORRUGATION OR ROARING OF RAILS

Corrugation consists of minute depressions on the surface of rails varying in shape and size occurring at irregular intervals. In other words in due course of time the upper surface of the rail becomes wavy.

The corrugation of rails is an undesirable feature. When a train passes over a wavy rails, a roaring sound is produced, which is very unpleasant to the ears. This unpleasant sound is produced possibly due to the blocking of air in the corrugations. This unpleasant and excessive noise not only causes inconvenience to the passengers, but also results in producing rapid oscillations in rails, which in turn looses the keys. Loosening of keys results in excessive wear of fittings and disturbs the packing.

17.6.1. Cause of Corrugation

Actually exact cause of the corrugation is not yet known. Different researches have put forth their theories. How ever following factors have been found contributing to the development of rail corrugation.

1. Metallurgy and age of rail. Under this head following two factors are grouped.

(*a*) High contents of nitrogen in the steel of the rail

(*b*) Effect of oscillations at the time of rolling and straightening of rails

2. Physical and environmental conditions of the track. Under this head following four factors are grouped:

(*a*) Yielding formation (*b*) Steep gradients

(*c*) Electrified sections (*d*) Long tunnels

3. Train operation. Under this head following factors are grouped:

(*a*) High speed and high axle loads.

(*b*) Points of starting and stopping of trains.

4. Atmospheric effects. Following factors are grouped under this head:

(*a*) Presence of sand particles.

(*b*) High moisture content in the air, particularly in coastal area.

17.6.2. Remedial measures

The problem of corrugation may be eliminated by grinding the rail head by fraction of a mm. However on Indian Railways no method of grinding has been standardised as yet, where as on German Railways corrugation problem has been tackled successfully by using different types of equipments.

17.7. KINKS IN RAILS

Kinks or shoulders are formed in rails, when the ends of adjoining rails move slightly out of their positions. Following causes have been found responsible for the development of kinks:

(*a*) Loose packing at joints

(*b*) Defective gauge and alignment

(*c*) Defects in level crossing at joints

(*d*) Formation of uneven wear at rail head

17.7.1. Ill effects of kinks

Followings are the ill effects of kinks:

(*a*) Kinks produce undesirable jerks in the vehicle passing over them.

(*b*) Kinks obstruct the smooth running of trains.

(*c*) Kinks at curves may cause defects in the alignment and camber of the track which may result risk in running operations of the trains.

17.7.2. Remedial measures of kinks

The defects due to kinks may be rectified by the following measures:

(*a*) By having the correct alignment of the track at curves and joints.

(*b*) By providing proper packing at joints.

(*c*) By keeping proper gauge and providing proper maintenance to the track. Worn out rails should be welded and cross levels should also be properly attended periodically.

17.8. BUCKLING OF RAILS

The displacement of the track from its original position is known as *buckling of rails*. Buckling takes place due to the development of excessive compressive forces in the track due to insufficient expansion gaps in the track.

17.8.1. Causes of buckling

Following are the causes of rail buckling:

(*i*) *Due to excessive creep.* Development of excessive creep throws the track out of its original position.

(*ii*) *Due to insufficient expansion gap.* The insufficient expansion gap does not allow the rails to expand fully, resulting in the development of compressive forces in the rails, which throw the rails out of their positions.

(*iii*) Leaving rail closures in rails, particularly when laid in summer season, when the temperature is very high.

(*iv*) Failure to lubricate switch expansion junctions in time.

(*v*) Due to loose fittings.

(*vi*) Due to inadequate ballast.

(*vii*) Due to use of welded rails on weak track.

17.8.2. Location of rail buckling

Following locations are more susceptible for buckling:

(*i*) Wooden sleeper track in the vicinity of turn outs, insulation joints and switch expansion joints.
(*ii*) Short stretches of wooden sleepers track on a road.
(*iii*) Junctions of two tracks one laid with anti creep fastening on metal sleeper and the other laid on wooden sleepers with out anti creep fastenings.
(*iv*) Wooden sleeper track between metal sleeper on one side and level crossing on the other side.

17.8.3. Remedial measures of buckling

Following measure may be adopted for the removal of buckling:
(*i*) The ballast section, sleeper density and rail section should be redesigned, and suitably increased.
(*ii*) Anti creep fastenings should be used.
(*iii*) Number of welded rails should not be very large.
(*iv*) Provision of steel sleepers or welded rails anchoring should be made.
(*v*) Proper lubrication of contact surfaces of fish plate and fish bolts should be done at regular interval at least once a year.
(*vi*) Sufficient expansion gaps between rail joints should be provided.
(*vii*) The fish bolts should not be tighten too much, so that expansion or contraction may take freely.

17.9. FAILURE OF RAILS

A rail is said to have failed if it is considered necessary to replace it immediately due to the defects noticed on it. Majority of rail failures originate from the fatigue cracks developed due to alternating stresses induced in the rail section on account of moving loads.

17.9.1. Causes of rail failures

Following are the main causes of the rail failure:

1. **Indirect defects in the rail.** This is a manufacturing defect. It may be due to incorrect chemical composition of steel, harmful segregation, piping, seams, laps and guide marks etc.
2. **Defects due to rolling stock and abnormal traffic effects.** These failures occur due to flat spots in tyres, engine burns, skidding of wheels and severe braking etc.
3. **Excessive corrosion of rails.** Excessive corrosion of rails takes place generally due to atmospheric conditions, sub soil containing corrosive salts such as chlorides etc. If the rails are exposed constantly to moisture and humidity in the locations such as near water columns, ashpits, and tunnel etc. corrosion of rails takes place. Corrosion leads to the development of cracks in the region of high stress concentration. Hence rails should not be allowed to be constantly exposed to moisture and humidity.
4. **Poor maintenance of joints.** Poor maintenance of joints such as improper packing of joint sleepers and loose fittings lead to rail failure. Such failures occur in the rail ends in the form of horizontal or longitudinal splits through head web, foot web, Junctions, diagonal cracks through bolt holes and shelling fractures at the rail ends etc.
5. **Defects in welding joints.** These failures occur due to the defects in the welding of joints. These defects develop either due to improper composition of thermit weld metal or defective welding technique.
6. **Improper maintenance of track.** These failure develop due to ineffective or care less maintenance of track or due to delayed track renewal.
7. **De-railments.** Derailment of train causes failure of rails.

17.9.2. Types of rail failures

Following are the common failures of rails:

1. **Crushed head.** In this case of rail failure, the head of the rail gets crushed and the metal flows on

the head. In other words head gets flattened or sagged. This type of failure occurs due to inherent defects, due to faults of rolling stocks as slipping of wheels, development of flat spots due to sliding, week supports at rail ends due to loose fish bolts etc. Fig. 17.4 (*a*).

2. **Angular or square cracks.** When the rail is completely broken either in a vertical or inclined plane, it is known as angular or square break. Fig. 17.4 (*b*).

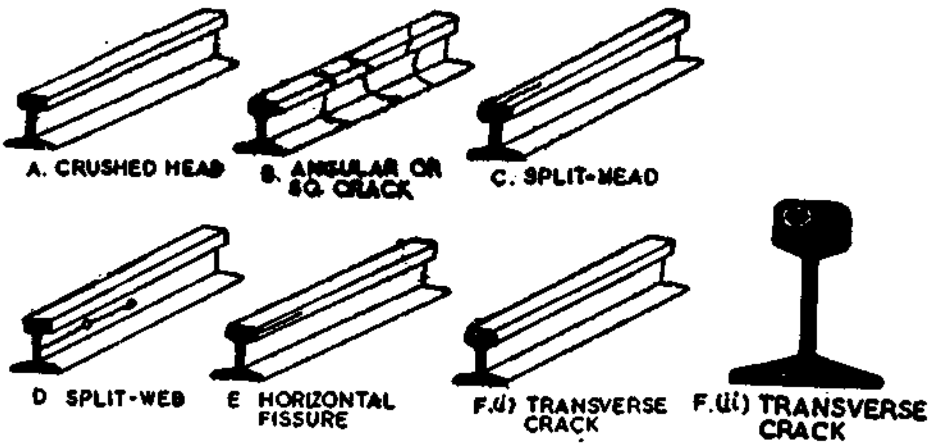


Fig. 17.4. Types of Rail Failure

3. **Split head.** When the cracks develop in the middle of the head or from the side to the end of the head, the failure is called as split head failure. Fig. 17.4 (*c*).
4. **Piping of the rail.** Piping of rail failure occurs due to the formation of cavity during its manufacture or due to shrinkage of metal, if it has not been welded closely. If the opened surfaces of the cracks appear dark and smooth then the rail is known as piped rail.
5. **Split web.** When a through crack develops in the web of the rail, necessarily through the bolt holes, then this failure is called as split web failure. Fig. 17.4 (*d*).
6. **Horizontal fissures.** If in the rail head fissures develop gradually, then this failure is known as horizontal fissure failure. Fig. 17.4 (*e*).
7. **Transverse fissures.** Transverse fissure develop in the form of a hole or fissure in the head of the rail. It starts from a point inside of the head and spreads gradually in the shape of a contour. The broken surface has a smooth round or oval shaped bright spot. This defect develops due to faulty manufacture or due to the fatigue of the metal by the over passing vehicles. This defect is more common in American Railways. Fig. 174 (*f*) (*i*) and (*ii*)
8. **Flowing metal.** In this case the metal of the head is forced to move to sides, resulting in widening and depressing of head of the rail.
9. **Horizontal cracks.** In this case, cracks develop at rail ends between head and web. These cracks develop due to insufficient ballast packing under joint sleepers or due to the use of worn out fish plates or due to fatigue. This defect also is very common on American Railways.
10. **Development of elbows in rails.** Elbows in rails develop at the joints on curves having curvature greater than 3°. This happens due to the fact that at curves greater than 3° in curvature, the joints are less flexible in horizontal direction than the remaining portion. Curve less than 3° is called Flat curve. In case of curves less than 3°, rails can be laid with out bending the rails. On such curves

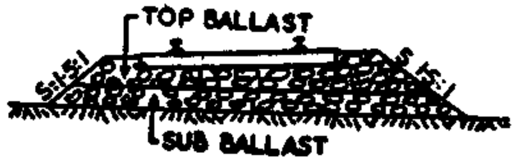


Fig. 17.5. Bending of Rail

rail is retained in curved position by sleepers. These sleepers are held in position by ballast heaped up at their ends upto their top. The heaping of ballast upto the top of sleepers is known as *boxing* shown in Fig. 17.5.

In case the curve is greater than 3°, it is desirable to bend the rail with correct curvature, before fixing them with sleepers. If it is not done, elbows will develop at joints which will disturb the alignment of the track.

17.10. JOINTS IN RAILS

In straight tracks usually joints are provided in two parallel rails exactly opposite to each other. On curves, the outer rail has to traverse a larger circumference than the inner rail. Due to this difference in distance the outer rail gradually falls behind the inner rail. When the deference between the two rails comes about 11.5 cm, a length of about 23 cm from one of the inner rails is cut. In this way after some rail lengths the joints come exactly opposite to each other. Now a days the joints are staggered by the half rail length.

17.10.1. Advantages of staggered joints

Following advantages have been observed of staggered joints:

(*a*) Staggered joints provide better smooth running of trains.

(*b*) Staggered joints reduce the centrifugal force on curves.

(*c*) Staggered joints provide a more uniform vertical continuity of the track.

17.11. CONNING OF WHEELS AND ITS EFFECTS ON RAILS

To enable the vehicles of railway track to move smoothly on curves as well as on straight tracks their rim or tread are sloped at about 1 in 20. Generally the wheels remain central on a straight and level surface with uniform gauge and the circumference of the treads of both wheels remain the same *i.e.* the treads remain equal as can be seen from Fig. 17.6.

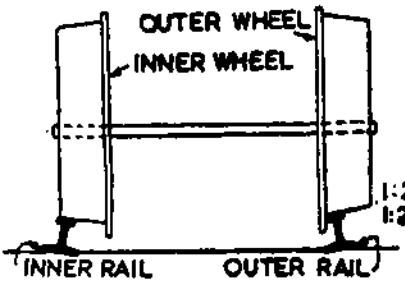


Fig. 17.6. Conning of wheels

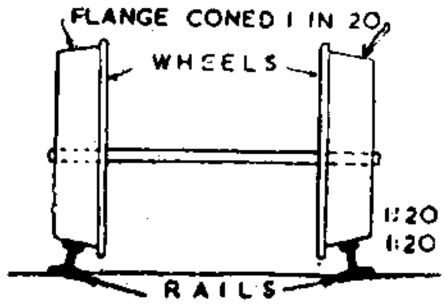


Fig. 17.7. Conning of wheels

In case on a curve when the outer wheel has to travel more distance in comparison of the inner wheel, the vehicle tends to move out due to centrifugal force on the curve. Thus the circumference of the tread of outer wheel becomes greater than that of the inner wheel. This helps the outer wheel to travel longer distance than the inner wheel. Fig. 17.7.

Due to conning of wheels, the side movement of wheels results in the increase in the tread circumference of one wheel than the other. As both the wheels have to traverse the same distance, one wheel slides instead of moving. Due to the resistance to sliding, further side movement is stopped. If the conning of wheel was not there, the side movement would have continued till the flange of the wheel would have come in contact with the side of the rails, causing shocks and jerks, resulting in uncomfortable riding. Thus to avoid the lateral movement of wheels and development of shocks in rails, conning of wheels is done.

17.11.1. Advantages and disadvantages of conning of wheels

It has been shown in tabular form in the Table 17.3.

Table 17.3. Showing advantages and disadvantages of conning of wheels

S. No.	*Advantages*	*Disadvantages*
1.	It gives smooth riding	The pressure of the horizontal component near the inner edge of the rail wears out the rail quickly.
2.	It helps a vehicle to negotiate a curve smoothly	The pressure of the horizontal component tends to turn the rail outwardly.
3.	It reduces the wear and tear of wheel flanges	Lateral bending stresses develop in the rails
		Sleepers are crushed due to non uniformly distributed load.

17.12. TILTING OF RAILS

In order to minimise the disadvantages caused by conning of wheels the rails are tilted inwards at an angle of 1 in 20. The tilting of rails reduces the wear and tear of the rail as well as the tread of the wheel. This practice is followed on Indian and U.K. Railways and not on American Railway.

17.12.1. Advantages of tilting of rails

Following advantages have been found of tilting the rails:

(*a*) It maintains gauges properly

(*b*) The wear of rail head is uniform

(*c*) The life of sleepers is increased.

17.13. CREEP OF RAILS

It is defined as the longitudinal movement of the rail in a track in the direction of motion of the locomotives. Though it is common in all railway tracks, but varies considerably in magnitude. At some places it is negligible, where as at other places it may be as high as 15.5 cm per month.

17.13.1. Indications of creep

Creep occurrence may be detected by:

(*a*) Closing of successive expansion spaces of rail joints in the direction of creep and opening out of joints at the point from where creep starts.

(*b*) Marks on rail flanges and webs made by spike heads due to scratching as the rails slide.

17.13.2. Cause of creep

Following are the main causes of development of creep:

(*a*) *Development of wavy motion in the rails by the moving train.* Due to the load of the wheel the portion of the rail under loads is depressed slightly. As the wheels move, the depression also moves with them and the previous depressed portions regain their original position. Thus under the wheels of a train wavy motion is developed. This wavy motion tends the rail to move forward. Fig. 17.8.

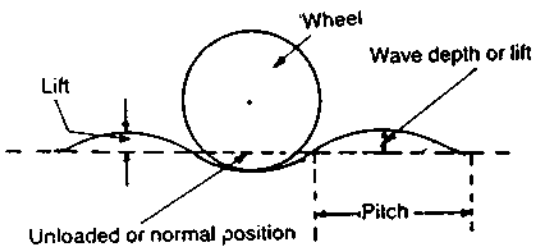


Fig. 17.8. Wave theory of creep

(*b*) Forces acting at the time of starting, accelerating, slowing down or stopping the train cause creep. As shown in Fig. 17.9 during the starting operation the wheels push the rails backward,

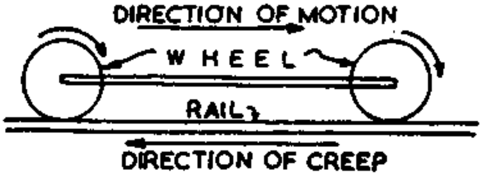


Fig. 17.9. Creep during starting

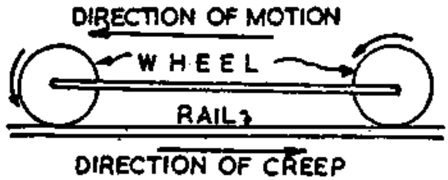


Fig. 17.10. Creep during stopping

while during the stopping operation rails are pushed in forward direction. Fig. 17.10.

(*c*) Creep may also develop due to unequal expansion and contraction of rails due to variation in temperature.

(*d*) *Percussion theory.* According to this theory, the creep is developed due to the impact of wheels at the rail end ahead of joint. The horizontal component P of reaction R tends to creep and the vertical component tends to bend the rail end vertically *i.e.* to batter the rail end. Thus as and when wheels leave the trailing rail and strike the facing rail end at each joint, it pushes the rail forward, resulting in creep. Fig. 17.11.

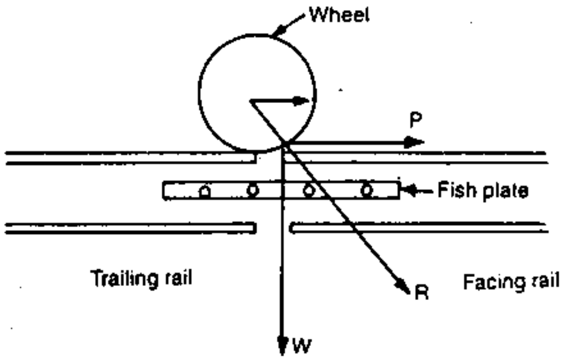


Fig. 17.11. Percussion theory

In addition to the above main causes for the development of creep, following minor causes also help in the development of creep in rails.

(*a*) Rails not properly fixed with sleepers.
(*b*) Good quality sleepers are not used.
(*c*) Inadequate consolidation of formation of the track.
(*d*) Insufficient drainage of the track.
(*e*) Track is not maintained properly.
(*f*) Gauge maintained either too tight or too slack.
(*g*) Rail joints are not properly maintained.
(*h*) Uneven spacing of sleepers.
(*i*) Defective packing of sleepers.
(*j*) Insufficient ballast cushion etc.

17.13.3. Factors affecting the pitch and depth of the wave

Pitch and depths of the wave formed on rails depend upon the following factors:

1. Stiffness of the track
2. Weight of rails
3. Spacing of sleepers
4. Wheel base of vehicles
5. Quantity and quality of ballast
6. Maintenance of track
7. Condition of drainage etc.

17.13.4. Magnitude and direction of creep

The magnitude and direction of creep is governed by the following factors:

1. **Alignment of the track.** Creep on curves is found greater than the straight part of the track.
2. **Gradient of the track.** Generally creep develops in the down gradient. However development of creep on up gradient also is not impossible. It changes direction frequently.
3. **Direction of motion of train.** Greater creep develops in the direction, in which more numbers of

trains move.

4. **Load of the vehicle.** The direction in which trains carry heavier loads, greater creep develops in that direction. Thus load of the vehicle also influence the development of creep.

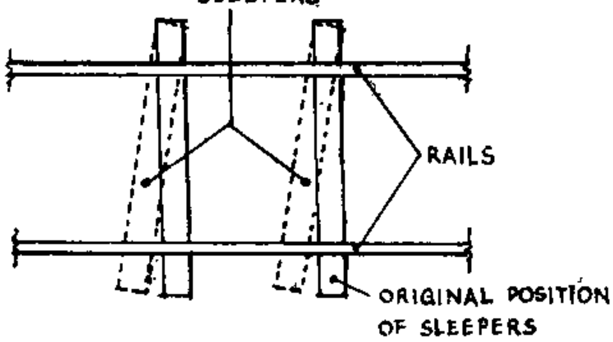


Fig. 17.12. Result of creep

17.13.5. Effects of creep development

Following are the main effects of creep development:

1. **Disturbance in gauge and alignment.** Moving out of sleepers from their original positions, disturb the gauge and alignment of the track. Due to sleepers movement, rail level is also disturbed, resulting in bad running of trains. Fig. 17.12.
2. **Widening of gaps.** At some places the rail joints open out beyond their limits and develop considerable stresses in fish bolts and plates. Some times the bolts break. Due to excessive gaps, the rails at the joints are battered badly. At some places joints get jammed preventing expansion which may cause buckling of rails.
3. **Disturbance at points and crossings.** The positions of points and crossings get disturbed due to the creep. It becomes difficult to maintain correct gauge and alignment. The movement of switches also becomes difficult due to the creep.
4. **Disturbance in interlocking mechanism of signals.** The inter locking mechanism of signals is also disturbed and thrown out of gear due to creep.
5. **Buckling of track.** In extreme cases buckling of track takes place due to creep.
6. **Joints disturbed.** The suspended joints become supported joints due to battering of rail ends.
7. **Use of creeped rail.** If a creeped rail is removed from the track it becomes difficult to refix it as it is found either too short or too long due to creep.

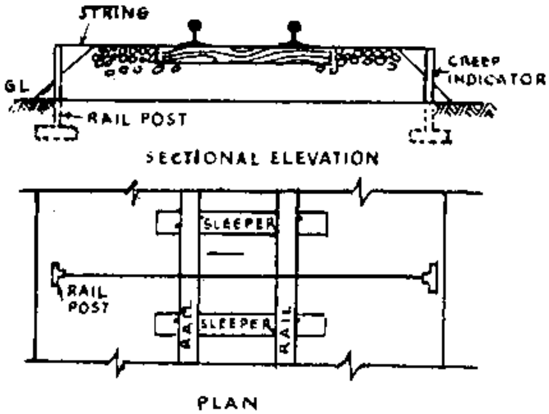


Fig. 17.13. Measurement of creep

17.13.6. Measurement of creep

To measure the creep of rails, creep indicators are used. A chisel mark is made at the side of the bottom flange of the rail and two rail posts are fixed to the formation with their top levels at the top of sleepers. A fishing string is stretched below the rails on the marks on the top of posts. The difference between chisel mark and the string is the amount of the creep. Fig. 17.13.

17.13.7. Methods of correcting creep

Following methods can be used to correct the creep:

1. Pulling back of rails
2. Use of creep anchors
3. Use of steel sleepers
4. Increase in sleepers density

1. Pulling back of rails

When the creep becomes more than 15 mm, it is known as excessive creep. It causes difficulties in carrying out maintenance operations. In su^h situations the creep is corrected by pulling back the rails.

Before carrying out the actual operations, a careful survey of expansion joints should be carried out and the position of rail joints is noted. The total creep to be adjusted, expansion gap to be provided and the length of the track to be tackled in one operation, is decided in advance. The point from where the work is to be started also decided. Generally the work is started from the widely opened rail joint.

Operation. Before starting the work, fish plates at one end of rail are loosened and those at other end are removed. Sleeper fittings whether spikes or keys are also loosened. The rails are then pulled back one by one with the help of a rope attached to the hook or inserting crow bar between adjacent ends of the rail.

Pulling back should be regulated in such a way that the rail joints remain central over the joint sleepers. It is not enough to obtain only the necessary expansion gaps, but the position of joints relative to sleepers and the position of one rail joint relative to the joint on the opposite rail must also be maintained. Pulling back rail by rail is a slow process and only useful for isolated lengths. About 40 to 50 persons are needed per km of rail length.

When creep adjustment is needed for longer lengths, five rails are tackled at a time. The procedure is same as described above. The only difference is that instead of pulling by rope, blows are given with the help of a rail piece about 5 m long.

When the work involved is of greater magnitude, a creep adjuster is used. The creep adjuster is fixed at the centre of the length to be tackled at a time, keeping wide joint behind and the tight joint ahead of it. Now expansion liners of correct size are put in all expansion joints and all keys on this side of adjuster removed and fish bolts loosened. Now the creep adjuster is operated to close up gaps to the required dimensions. The corrected rails are then keyed. While carrying out the pull back operations, following points should be observed for efficient use.

(*a*) After pulling or pushing operations, the track should be properly packed below the sleepers.

(*b*) To allow a train to pass, small pieces of rails should be kept ready during the progress of work. The cut pieces are inserted into the gaps and the train is allowed to pass with restricted speed.

(*c*) All the fish plates should be removed, cleaned, oiled and then refixed in their proper positions after pulling the rail.

2. Use of anchors

(*a*) To prevent creep, anti creep bearing plates are used for wooden sleepers.

(*b*) To prevent creep, Indian Railways have tried anchors of many types.

Out of all anchors, a V shaped anchor as shown in Fig. 17.14 has been found very effective to check the creep. To be fully effective, the anchor should be tight against sleepers. For efficient use of anchors, following points should be observed carefully.

(*a*) The anchors should butt against the sleepers properly, otherwise they will not function.

(*b*) Anchors should be uniformly distributed in each panel of rails.

(*c*) There must be sufficient ballast in the sleeper cribs to prevent the dragging of sleepers with rails.

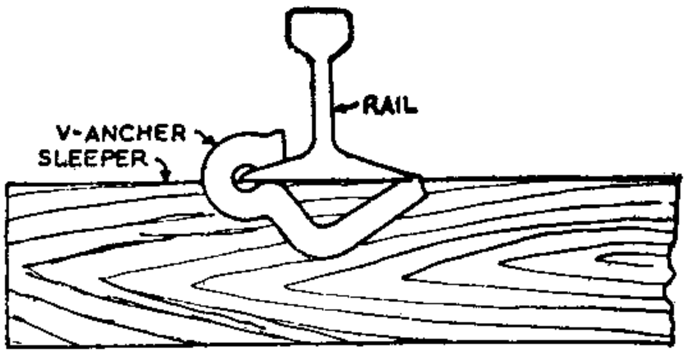


Fig. 17.14. Creep ancnor

(*d*) Anchors should be fixed to good sleepers and defective anchors should be replaced.

(*e*) Fish plates must allow the free expansion and contraction in rails.

(*f*) Number of anchors should be increased at approaches to yards and in yards themselves.

3. Use of steel sleepers. Use of steel sleepers has been found creep resistant as they have good grip with the ballast, which resists their movement in the ballast. Secondly their type and fittings also help to resist the creep in rails.

4. Increased density of sleepers also has been found useful in checking creep of rails.

17.13.8. Measures to reduce creep

Following measures have been found useful in reducing the creep:

1. It should be ensured that rails are held firmly to the sleepers and adequate ballast resistance is available. All spikes, keys, screws should be driven tight. Toe load of fastening should be always slightly more than the ballast resistance.
2. The sleepers should be properly packed, crib and shoulder ballast well compacted that is track should be well maintained.
3. For a series of jammed joints, careful watch should be kept. In case of fish plated track, not more than six continuously jammed joints should be permitted. In case of short welded rails, not more than two consecutive jammed joints should be permitted at rail temperature lower than 't_m' (Refer short welded rails)
4. Anti creep bearing plates should be provided on wooden sleepers to check creep, but joint sleepers should be provided with standard canted bearing plates with rail screws.
5. Creep anchors are provided at the rate of 8 anchors per panel.

QUESTIONS

1. Discuss the functions of rails.
2. Discuss the defects in rails and their remedial measures.
3. The wear on rail top develops due to
   (*a*) Abrasion of rolling wheels on the top of rail
   (*b*) Concentration of heavy wheel load on small area.
   (*c*) Grinding action of sand particles between wheel and rail top
   (*d*) Corrosion of rails
   (*e*) All the above
4. The rail end batter causes the
   (*a*) The contact surfaces between rails and sleepers get worn out
   (*b*) Fish bolts and fish plates become loose
   (*c*) Due to vibrations at ends, settlement of ballast takes place
   (*d*) All are correct
   (*e*) None of the above is correct
5. Wear of rails can be minimised by
   (*a*) Conning of wheels
   (*b*) Providing proper super elevation on the track
   (*c*) Adopting good maintenance
   (*d*) Introducing check rails on curves
   (*e*) Using special alloy steel for rails
   (*f*) All the above
6. Identify the correct statement/statements
   (*a*) Rail lubricators are provided on sharp curves where lateral wear is considerable
   (*b*) The process of falling of metal patches from the rail top is called scabbing of rails
   (*c*) The process of progressive horizontal separation of metal occurring on gauge side is known as shelling of rail
   (*d*) The process of extra heat generation due to slippage of driving wheels of the locomotives on the surface of rail is called wheel burns
   (*e*) Rails bent vertically at the ends are known as hogged rails
   (*f*) All are correct
   (*g*) None of the above is correct

7. Roaring of rails develops due to the following factors:
   (*a*) Due to metallurgy of the rail
   (*b*) Physical and environmental conditions of track
   (*c*) Train operations
   (*d*) Atmospheric effects
   (*e*) All are correct
8. Identify the wrong statement/statements
   (*a*) When the ends of adjoining rails slightly move out of their positions kinks in rails develop
   (*b*)Undesirable jerks are produced in the vehicle passing over the kinks
   (*c*) Kinks hinder the smooth running of train and cause defects in the alignment at curves
   (*d*) Displacement of the track from its original position is called buckling of the rails
   (*e*) All the above
   (*f*) None of the above
9. Identify the correct statement/statements
   (*a*) When the immediate replacement of rail is called for then it is said to have failed
   (*b*) Buckling of rail can not be rectified by using anti creep fastenings and redesigning the sleepers density and ballast section etc.
   (*c*) Failure to lubricate switch expansion junction in time has no effect on rail buckling
   (*d*) Poor maintenance of joints has no effect on rail failure
10. Identify the incorrect statement
   (*a*) Staggered joints provide better smooth running of trains and also reduce centrifugal force on curves
   (*b*) Conning of wheels provides smooth riding
   (*c*) Tilting of rails maintain gauge properly
   (*d*) Tilting of rails causes non uniform wear of rail head
   (*e*) Conning of wheel hinder the vehicles to negotiate a curve smoothly
11. What additional attention is to be paid in checking the alignment of a railway track on a curve in comparison to straight portion
   (*a*) Degree of curve
   (*b*) Super elevation
   (*c*) Extra allowance in gauge
   (*d*) All the above
12. The creep in rails develops due to
   (*a*) Development of a wavy motion under the wheels
   (*b*) Use of week or brick ballast
   (*c*) As and when wheel leave the trailing rail and strike the facing rail end at each joint
   (*d*) Due to curvature in the track
   (*e*) Due to unequal expansion and contraction of rails due to variation in temperature
13. Identify the current statement/statements
   (*a*) Creep is greater on curves than straight track
   (*b*) Generally creeps develops on down gradients
   (*c*) Greater creep develops in direction, in which more trains move
   (*d*) Heavier the load moved, greater the creep
   (*e*) All are correct
   (*f*) None is correct

ANSWERS

3. (*e*)	6. (*f*)	9. (*a*)	12. (*a, c, e*)
4. (*d*)	7. (*e*)	10. (*d, e*)	13. (*e*)
5. (*f*)	8. (*f*)	11. (*b*)	

18

Maintenance of Welded rails

18.1. INTRODUCTION

Usually the rail length on B.G. track is 13 m, which needs 77 joints per km length of the track. For joining these joints a large number of fish plates and bolts are required. This involves high expenditure. Along with huge expenditure, more expansion gaps at joints are required due to rise in temperature. Further rails batters (bent) at joints. Thus to minimise the above problems welded rails are used in the railway track.

18.2. CLASSIFICATION OF WELDED RAILS

Welded rails can be classified as follows:

1. **Long welded rail (L.W.R.).** The welded rail whose central part does not under go any longitudinal movement due to temperature variation is called a long welded rail. For B.G. track usually 250 m length of the rail is assumed as long welded rail. Now in the year 2005 Bhilai steel plant of India has rolled out 273 m long rail and has been sent to site for trial to assess its performance.
2. **Short welded rail.** The welded rail whose entire length under goes expansion and contraction is called short welded rail (S.W.R.). On Indian railways for B.G. track the length of short welded rail is taken as 39 m (*i.e.* 3 rail length of 13 m).
3. **Continuous welded rail (C.W.R.).** The long welded rail whose distressing is carried out in parts is known as continuous welded rail. In Indian Conditions the length of C.W.R. is restricted to one block section.
4. **Buffer rails.** A set of rails provided at the ends of long welded rails to allow expansion and contraction of the breathing lengths due to temperature variation is called buffer rails. Usually its length varies from 6.0 to 6.5 m. They are laid on wooden sleepers.
5. **Breathing length.** At each end of long welded rail, the length of rail which undergoes expansion and contraction due to temperature variation is known as breathing length.
6. **Anchor length.** The length of the track which is capable to resist the full pull exerted by the rail tensor on rail is called *anchor length*. For 52 kg rail its value may be taken as 2.5 m per degree centigrade of ($t_0 - t_p$).

where

t_0 = is temperature at which rail is free from thermal stresses.

t_p = is known as prevailing temperature at which any operation of de stressing is carried out.

t_m = Mean rail temperature.

t_d = Average temperature during the period of fastening of rails to sleepers.

18.3. DEFECTS DEVELOPED IN WELDED RAILS

Usually following major defects are developed in welded rails:

1. Development of stresses in the welded long rails due to temperature variation.
2. Development of rail fractures.
3. Buckling of rails.

18.4. DEVELOPMENT OF STRESSES AND THEIR REMOVAL

The stresses developed in welded rails are removed by destressing the rails. The operation of removing stress from long welded rails at a specified temperature is known as de stressing.

18.4.1. Situation when de stressing is necessary

Destressing becomes necessary under the following situations:

1. **Gaps at switch expansion joints.** When the gaps at switch expansion joints, stock or tongue rail crosses the mean position or gap observed at stwich expansion joint exceeds the maximum designed gap for the SEJ, de stressing becomes necessary.
2. **After special maintenance operations.** After special maintenance operations such as deep screening, lowering/lifting of track, major realignment of curves, sleeper renewals other than causal renewals and rehabilitation of bridges and formations causing disturbance to the track, de stressing becomes necessary.
3. **Temporary repairs.** If the location of temporary repair per km length exceed three, then destressing should be done.
4. **Unusual occurrence.** After replacement of defective rail or glued joint or rail fracture or damage to switch expansion joint of buffer rails or buckling of track or accident and breaches etc. have occurred, de stressing should be done.

18.5. METHODS OF DESTRESSING

Destresing can be done by the following methods:

1. Without rail tensors
2. With rail tensors

18.5.1. Destressing without rail tenser

In this method following steps are involved:

(*a*) A traffic block of about 3 hours duration is taken at such a time when the rail temperature is expected between t_m + 5°C to t_m + 10°C, where t_m is the mean rail temperature for 60 kg/52kg rail or t_m to t_m + 5°C for lighter rail sections. Before taking the block, the speed restriction of 30 km ph should be imposed and fastenings on alternate sleepers loosened.

(*b*) During the traffic block, the closure rails are disconnected and switch expansion joints are adjusted to be in mean position.

(*c*) Starting from the switch expansion joint to the centre of the long welded rail (L.W.R.) the sleeper fastenings on both the rails are loosened.

(*d*) The rails are lifted and placed on rollers at about every 15th sleeper. To permit free expansion, the rails are also struck with wooden hammers to help in destressing.

(*e*) After this, the rollers are removed and fastenings tightened, starting from the centre of the L.W.R. towards switch expansion joint. The tightening of the fastenings must be completed in the defined temperature range of the destressing.

(*f*) A cut rail is provided between the switch expansion joint and L.W.R., keeping adequate provision for thermit welding.

(*g*) Thermit welding is done after completing all operations of destressing.

The Destresing of both rails should be done simultaneously. While destresing on curves, rails should be provided lateral support at an interval of 10 sleepers on the inside curve and at an interval of 30 sleepers on the out side curve. At the time of de stressing a gap of 7 to 8 mm should also be provided at each of the fish plated joints of the buffer rail assembly.

18.5.1.1. Short Comings of destressing with out tensor

Usually following two short comings are noticed in this method:

1. The destressing operations have to be done between a specified range of temperature only.
2. For carrying out destressing, a long traffic block of 3 hours has to be arranged.

18.5.2. Destressing with the help of tensors

1. **Tensors may be mechanical type or hydraulic type.** A mechanical type tensor is shown in Fig. 18.1. With the help of a tensor normally panel of welded rails of 500 m length can be destressed at a time. In case of mechanical tensor, the force is applied mechanically by longitudinal jacks. By these jacks the rail can be pulled or pushed to the desired length. In case of pushing, the force exerted should not be more than 30 tonnes. If this force is more than 30 tonnes, the buckling of the track will take place. Normally rails are pulled during destressing operations only. The rail tensor is capable of destressing a rail panel at any time when the prevailing rail temperature is less than the destressing temperature. This method also gives better results, but needs trained workers to carry out the operations of destressing.

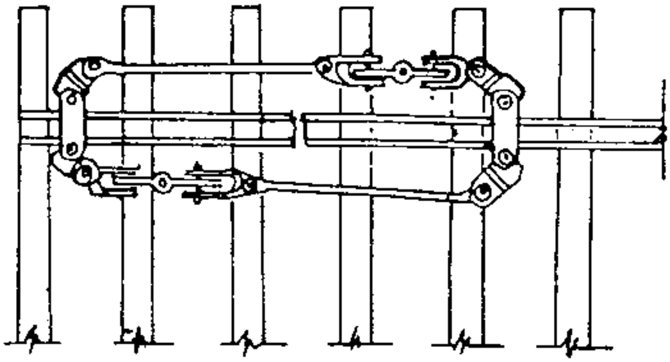


Fig. 18.1. Mechanical rail tensor

18.6. RAIL FRACTURES

A rail is said to be fractured if it breaks in two or more pieces. Usually rail fracture occurs at the joint through the bolt holes. Rail, fracture is very dangerous and risky for the safety of passengers as well as rolling stock.

18.6.1. Causes of fracture

A rail develops fracture mainly due to the following reasons:

1. Inherent defect of rail. Under this head defect as unsatisfactory chemical composition of rail metal, harmful segregation, piping, seams, laps etc. can be grouped.
2. Use of faulty rolling stock. A flat tyred locomotive exerts extra pressure on the rail, which develops excessive stresses than permissible stress of rail, causing fracture in the rails.

18.6.2. Remedial measures for the fracture of rails

For removing a fracture from the rails following equipment is required:

(*a*) Screw clamps
(*b*) Slotted fish plates
(*c*) Joggled fish plates and one metre long fish plates
(*d*) Thermit welding set
(*e*) Destressing equipment
(*f*) Sawing machine, steel tape capable to read upto one mm, punch, hammer etc.
(*g*) 6.5 mm sawn rail piece of same sectional rail and a 30 mm long closure. The rail piece should be ultra sonically tested.

(*h*) Equipment for protection of track and for night working as lighting arrangement etc.

18.6.2.1. Emergency repair

As soon as the fracture is brought to the notice, the traffic should be suspended immediately and the track protected by Engineering signals and the emergency repairs carried out by the keyman or mate by binding the two fractured rail ends with the help of joggled fish plates and screw clamps. In case the gap is more than 30 mm, a rail closure of 30 mm thickness is placed in the gap before clamping the rails. The traffic is allowed to pass at a restricted speed of stop dead and 10 km ph for the first train and 20 km ph for the subsequent trains.

18.6.2.2. Temporary repairs

After emergency repair, the fractured portion of the track is further attended by the P.W.I. or P.W.M. of the section under block protection as under:

(*a*) A traffic block of about 2 hours duration is taken. The time of traffic block should be so choosen that the day temperature falls with in the recommended range of temperature for destressing t_d. Destressing temperature range for 52 kg and heavier rails sections is t_m + 5°C to t_m + 10°C and for lighter rail sections it is t_m + 5°C.

(*b*) Two points on either side of the fracture are punched on the rail at a distance equal to available cut rail, but not less than 4.051 m, 4 m clear gap and 51 mm for saw cuts. If any gap is created after the fracture, it should also be added to this length. The principle applied in this case is metal taken out should be equal to metal put in

(*c*) Rail is cut at these locations by saw and clamped with the Joggled fish plates and screw clamps after adjusting the gap. The cut rail piece is then inserted and clamped after removing the existing fractured rail.

(*d*) The traffic is allowed to pass at a speed of 30 km ph.

18.6.2.3. Permanent simplified method

This method is based on the principle "Replace the old rail by new rail of the same length. In his method of repair of rails tensors are used.

18.6.2.4. Procedure

1. After the emergency repair, the traffic block is arranged as soon as welding party is available.
2. On the other side of the fracture, two points are punched on the rail at a distance equal to the length of the available cut rail, but under no circumstances it should be less than 5.5 m plus gap at the time of repair and two gaps required for welding minus 1 mm for each saw cut. The two cuts then are made and cut rail is inserted in the track.
3. After this, the rail joint at one end of the cut rail should be welded and the other joint should be welded after pulling the rails by tensor.
4. After welding the both joints, the fastenings on each side are opened for a distance of 100 m and rails tapped to allow free movement for equalisation of stresses.

18.7. SPEED RESTRICTIONS

Under different conditions of the track following speed restrictions should be applied as shown in Table 18.1.

18.8. BUCKLING OF TRACK

When compressive stresses (forces) in the track exceed the longitudinal or lateral resistance of the track, the distortion developed in the track is called buckling of the track. Buckling of track is quite serious as it may cause derailment and fatal accidents. This phenomenon occurs usually in summer season.

Table 18.1.

S. No.	*Condition of track*	*Speed restriction in km/ph*	
		Ist train	*Subsequent trains*
1.	At fracture after emergency repairs completed	Stop, dead and 10 kmph	20
2.	At temporary rail joint, if other than specified screw clamps are used.	20	20
3.	At temperary joint if specified screw clamps are used and there is provision of 24 hours watch	30	30
4.	After temparary repairs of the rail fracture and before permanent repairs completed	30	30
5.	Aftre emergency repairs of the track after buckling	Stop dead and 10 kmph	20
6.	Before destressing when sleeper fastenings on alternate sleepers are loosend	30	30
7.	After regular track maintenance, track being consolidated if temperature exceeds $t_d + 20°C$:		
	(*a*) When crib and shoulder consolidation has been done.	BG – 50 MG – 40	BG – 50 MG – 40
	(*b*) When crib and shoulder consolidation has not been done	BG – 30 MG – 20	BG – 30 MG – 20

18.8.1. Causes of buckling

Usually buckling is caused by the following factors:

(*a*) Inadequate resistance of the track due to deficiency of the ballast.

(*b*) Ineffective or missing fastening.

(*c*) Failure to lubricate switch expansion joints in time.

(*d*) Due to excessive creep, jammed joints and sun kinks in welded tracks.

(*e*) Carrying out of laying work, destressing, maintenance or raising the track out side the specified rail temperature range specially in hot weather.

18.8.2. Buckling prone locations

Following locations are considered as buckling prone locations:

1. Approaches of level crossings, bridges and yards.
2. Locations where wooden sleepers with rail free fastenings exist in short isolated reaches in a metal sleepers track.
3. An old track laid with worn out or loose fastening butting against a newly laid track.
4. Locations with deficient ballast sections specially on shoulders.
5. Junction points of fish plated track and L.W.R./S.W.R. track.

18.8.3. Symptoms of buckling

Following are the symptoms of buckling

(*a*) Sun kinks in the track

(*b*) High percentage of hollow sleepers

(*c*) Absence of gaps in the S.W.R. portion of the track during the morning hours of the hot weather.

(*d*) Observed contraction or expansion at switch expansion joints is more than 20 mm.

18.8.4. Precautions to avoid buckling

Following precautions may be taken to avoid buckling:

1. Proper gap should be provided in the short welded rail portion of the track as per specifications.
2. Buckling is likely to occur between 11 to 17 hours of the day. Hence proper patrolling should be maintained of the L.W.R. portions where temperature exceed $t_m + 20°C$.
3. No work of track maintenance including aligning, laying, packing, screening of ballast should be done out side the specified range of temperature.
4. Where ever the track is weak and likely to buckle, it should be immediately strengthen by providing extra ballasts, increase in sleepers density, provision of anti creep fastening, replacement and tightening of missing and loose fastenings etc.

18.8.5. Action to be taken after buckling

As soon as the tendency of buckling is detected, the traffic should be suspended and the track fully protected. The ballast from the inter sleeper faces between rails is collected and heaped on the shoulders upto the bottom of rail head to stabilize the track. After actual buckling, traffic should be suspended and its rectification should be done under the supervision of P.W.I. as follows:

1. The temperature of rails is brought down to the extent possible by pouring water on them.
2. Destressing and emergency repairs or permanent repairs should be carried out as per L.W.R. manual.
3. In case of S.W.R. track or fish plated track, to ease out the stresses a gentle reverse curve may be given in the rear of the buckled track. The buckled rail then should be cut at two places more than 4 m apart. After that, the track should be slewed to the correct alignment and the gap is closed by inserting rail of required length.

18.9. MAINTENANCE OF LONG WELDED RAILS/CONTINUOUS WELDED RAILS

For the proper functioning of L.W.R./C.W.R. an important pre requisite is that initial laying of track is of high standard and its subsequent maintenance is done by competent trained personnels.

18.9.1. Classification of L.W.R. maintenance

The maintenance of L.W.R./C.W.R. may be classified into the following two categories:

1. Regular maintenance
2. Special maintenance

18.9.1. Regular maintenance

Under this head of maintenance following works are carried out:

(*a*) Packing/tamping, lifting, aligning including minor realignment of curves.

(*b*) Shallow screening/shoulder cleaning.

(*c*) Causal renewal of sleepers.

(*d*) Renewals of fastenings

(*e*) Maintenance of switch expansion joints/buffer rails.

(*a*) **Working hours.** The regular maintenance of L.W.R./C.W.R. should be confined to the period when the rail temperature is in between the $t_d + 10°C$ and $t_d - 30°C$. It should be completed well before the on set of summer. If after maintenance operation, the rail temperature exceeds $t_d + 20°C$. then during the period of consolidation, a speed restriction of 50 km ph for B.G. and 40 kmph for M.G. should be imposed after completing the crib and shoulder compaction. In case crib and shoulder compaction has not been done, then speed restriction of 30 kmph for B.G. and M.G. be imposed. In addition to this, a mobile watch man should also be posted.

(*b*) **Ballast section.** Ballast section should be properly maintained, specially on curves, approaches to level crossings, and bridges, pedestrian and cattle crossings. To prevent loss of ballast at pedestrian and cattle crossings, dwarf walls may be provided. Cess level also should be correctly maintained.

Replenishment of ballast should be completed before the on set of summer. At isolated places the shortage of ballast in shoulders should be made up by gangmate by taking out minimum quantity of ballast from the centre of the track between th two rails over a width not more than 60 cm and 35 cm and a depth not more than 10 cm for B.G. and 7.5 cm for M.G. respectively.

(*c*) **Fastenings.** In case of L.W.R./C.W.R., special attention should be paid to the fastenings, especially on concrete sleepers. All fastenings should be complete and well secured.

(*d*) **Special attention.** In case of L.W.R./C.W.R. special attention should be paid to the maintenance of switch expansion joints, breathing lengths, points and crossings, approaches of level crossings horizontal and vertical curves and un ballasted deck bridges should be given.

18.9.2. Mechanised maintenance of L.W.R./C.W.R.

In this maintenance following works are done:

(*a*) **Tamping.** In L.W.R./C.W.R. tamping with general lift not more than 5 cm in case of concrete sleepers and 2.5 cm in other types of sleepers including alignment correction should be carried out during the prevailing rail temperature range of t_d + 10°C and t_d – 30°C.

(*b*) **Lifting of track.** If lifting is required more than 5 cm in case of concrete sleepers and 2.5 cm in other types of sleepers, it should be carried out in stages with sufficient gap in between the successive stages such that full consolidation of the previous stage is achieved before taking up the next lift.

(*c*) **Cleaning of shoulder ballast.** Mechanised cleaning or shoulder ballast cleaning should be done between prescribed limits of prevailing rail temperature.

18.9.3. Manual maintenance

Under this head following works are carried out:

(*a*) **Opening of track.** For manual maintenance or shallow screening at no time should be opened more than 30 sleepers space in continuous stretch. At least 30 fully boxed sleepers spaces left in between adjacent openings. The maintenance of in between lengths should not be under taken till the passage of traffic for 24 hours on B.G. tracks carrying more than 10 GMT or 48 hours in case of other B.G. and M.G. routes.

(*b*) **Alignment.** For correction in alignment, the shoulder ballast should be opened out to the minimum extent necessary, and that too just opposite the sleeper ends. Before opening out crib ballast for packing, the ballast in shoulders should be put back.

18.9.4. Causal renewal of sleepers

Not more than one sleeper in 30 consecutive sleepers should be replaced at a time. If it becomes necessary to replace two or more consecutive sleepers in the same length, then they should be replaced one at a time after packing the sleepers renewed earlier. The temperature limits specified should be adhered strictly.

18.9.5. RENEWAL OF FASTENING

The renewal of fastening work should be under taken with in the specified temperature limits (t_d – 15°C to t_d + 15°C

(*a*) **Renewal of fastening not requiring lifting.** Fastenings not requiring lifting of rails should not be renewed on more than one sleeper at a time. In case fastening of more than one sleepers is required to be renewed at a time, in such a case at least 15 sleepers in between should be left intact. The work should be done under the supervision of keyman.

(*b*) **Renewal of fastening requiring lifting.** Fastening requiring lifting of rails then grooved rubber pads etc. should not be renewed on more than one sleeper at a time. In case fastenings of more than one sleeper are required to be renewed at a time, then at least 30 sleepers in between should be left intact. The work should be carried out under the supervision of gangmate.

18.9.6. Maintenance of switch expansion joints

(a) All switch expansion joints should be checked, packed and aligned if necessary once in a fort night. Oiling and greasing of tongue and stock rails of the switch expansion joints and tightening of fastenings should be done simultaneously. Movements of switch expansion joints, should be checked and destressing is done if necessary.

(b) The keyman during his daily patrolling should keep a special watch on switch expansion joints falling in his beat.

18.9.7. Special track maintenance

This maintenance includes followings works.

(a) Deep screening/mechanised cleaning of ballast.

(b) Lifting/lowering of track

(c) Major realignment of curves

(d) Sleeper renewal other than casual renewals

(e) Rehabilitation of bridges

(f) Formation causing disturbance to track

18.9.8. Deep screening/Mechanised cleaning of ballast

(a) If the range of temperature falls with in t_d + 10°C to t_d – 20°C, then deep screening may be done with out cutting or temporary destressing. In case the temperature range falls out side the above range, then temporary destressing should be done at 10°C below the maximum rail temperature likely to be attained during the period of work. The continuous welded rail should be cut into long welded rail of about 1 km length with the two temporary buffer rails of 6.5 m length duly clamped. When ever rail renewals is under taken L.W.R./C.W.R. may be converted into three rail panels and deep screening is done.

(b) **Monitoring.** During the progress of work, constant monitoring of rail temperature should be done. if the temperature rises more than 10°C above temporary destressing temperature t_d, then adequate precautions should be taken. If necessary, a second round of destressing may be carried out.

(c) **Sequence of operations.** Deep screening of L.W.R. may be done from one end to the other end. After deep screening and consolidation, destressing of L.W.R. should be carried out.

18.10. MAINTENANCE OF SHORT WELDED RAILS

The maintenance of short welded rails may be divided into the following two parts:

18.10.1. General maintenance

Under this maintenance following operations are carried out:

(a) At the appropriate rail temperature, ensure the correct gaps in joints at the fish plated joints.

(b) Ensure the availability of sufficient and well compacted ballast at all times.

(c) As far as possible, maintenance work should be undertaken close to the mean annual rail temperature.

(d) Prompt action should be taken to check and arrest of the creep.

(e) To safe guard against bending or shearing of bolts in winter and buckling of track in summer proper watch on abnormal variations should be kept.

(f) Special attention should be paid to short stretches of wooden sleepers track in between short welded rail track which are vulnerable to buckling.

18.10.2. Regular maintenance

Under this maintenance following works are included:

(*a*) All regular maintenance of track including all operations of packing, lifting, aligning, local adjustments of curves, screening of ballast other than deep screening and scattered renewals of sleepers may be carried out with out restriction at the temperature below t_m + 25°C in zone I and II only. However on yielding formations and curves of radii less than 875 m on B.G. and 600 m on M.G., the limit of above temperature should be restricted to t_m + 15°C for zone I and II only.

(*b*) If the maintenance work has to be done at temperature higher than t_m + 25°C in normal cases and at t_m + 15°C in specified cases of yielding formations and curved tracks as indicated above, not more than 30 sleeper spaces in one continuous stretch should be opened. Between two adjacent lengths which are opened up, at least 30 fully boxed sleepers spaces should be left out. Before the close of the days work the ballast should be boxed up.

(*c*) The gang should have sufficient number of joggled fish plates with special clamps for use in case any welded joint or rail fails.

(*d*) In the event of any fracture in the weld or rail, the fractured portion of the rail is cut and the rail length not less than 4 m is removed and rewelded after introducing new equivalent rail length. It should also be ensured that no welded joint lies closer than 4 m from the fish plated joint.

(*e*) In case of deep screening and removal of sleepers in continuous lengths, major realignment of track or major lifting of track is to be done, then each of these operations should be carried out with suitable precautions. These precautions generally be observed when the rail temperature is below t_m + 15°C in zone I and II and t_m + 10° in zone III and IV. In case it is essential to carry out such works at rail temperature out side the above temperature range, then suitable speed restrictions should be imposed.

(*f*) The M.S.P. (Measured shovel packing) of short welded rails should be undertaken when the rail temperature is below t_m + 15°C for zone I and II and t_m + 10°C for zones III and IV, provided the rails are not butting and also not likely to butt during the course of work. However for wooden sleepers M.S.P. at joints may be under taken at higher temperature than t_m + 15°C, provided the gaps are not closed and temperature is expected normal in the afternoon.

(*g*) Where ever maintenance problems can not be solved by the known measures, it will be better to convert 10 rail panels into 2.5 rail panels.

18.11. TEMPERATURE ZONES

S. No.	*Zone No.*	*Temperature range*
1.	Zone I	40 to 50°C
2.	Zone II	51 to 60°C
3.	Zone III	61 to 70°C
4.	Zone IV	71 to 80°C

QUESTIONS

1. Define the following terms
   (*a*) Long welded rail (*b*) Continuous welded rails
   (*c*) Buffer rails (*d*) Breathing length of rail
2. Discuss the process of destressing of welded rails.
3. Define buckling of rails and measures for its removal.
4. Discuss briefly maintenance of short welded rails.
5. Usually the length of buffer rail is about

(*a*) 6.5 m (*b*) 9.5 m
(*c*) 12.5 m (*d*) 1.5 m

6. Buffer rail is provided
   (*a*) To remove thermal stresses
   (*b*) To allow expansion or contraction at the end of welded rail
   (*c*) To maintain the gauge of the track
   (*d*) To maintain the longitudinal level of the track
7. For laying the buffer rails, the most suitable sleeper is
   (*a*) Concrete sleeper (*b*) Steel trough sleeper
   (*c*) Wooden sleeper (*d*) Any of the above
8. Breathing rail length is
   (*a*) It is a special type of rail
   (*b*) It is ordinary steel rail
   (*c*) The short portion of long welded rail at each end is called breathing rail length
   (*d*) Any of the above rails
9. Destressing of long welded rail is the process to
   (*a*) Remove thermal stresses from rails (*b*) Check expansion or contraction of rails
   (*c*) Maintain correct gauge of the track (*d*) Maintain correct longitudinal level
10. Destressing of long welded rails becomes necessary when
    (*a*) After deep screening and major realignment of curves
    (*b*) When gaps at switch expansion joints cross the mean position
    (*c*) In case the locations of temporary repairs per km length exceeds three
    (*d*) Replacement of defective rail is carried out
    (*e*) All the above
    (*f*) None of the above
11. A rail is said to be fractured when
    (*a*) It breaks in two or more pieces (*b*) It bends down wards at the ends of the rails
    (*c*) When rail buckles at the centre (*d*) None of the above
12. For rectifying the fracture, the minimum rail length cut is
    (*a*) 4.0 m (*b*) 6.0 m
    (*c*) 7.5 m (*d*) 9.0 m
13. Bucking of track is said when
    (*a*) Distortion of the track when compressive forces exceed lateral resistance of the track
    (*b*) When linear expansion of the rails exceed the permissible limits of expansion
    (*c*) When gauge variation becomes more than the permissible limits
    (*d*) All are correct
14. Buckling of track takes place due to
    (*a*) Deficiency of ballast (*b*) Ineffective fastenings
    (*c*) Excessive creep and jammed joints (*d*) Inefficient lubrication of switch expansion joints
    (*e*) All the above
15. Buckling prone situations are
    (*a*) Approaches of level crossings, bridges and yards
    (*b*) An old track laid with loose fastening butting against a newly laid track
    (*c*) Deficient ballast sections specially on shoulders
    (*d*) Junction points of fish plated track and welded track
    (*e*) All the above
    (*d*) None of the above

ANSWERS

5. (*a*)	8. (*c*)	11. (*a*)	14. (*e*)
6. (*b*)	9. (*a*)	12. (*a*)	15. (*e*)
7. (*c*)	10. (*e*)	13. (*a*)	

19

Measured Shovel Packing Maintenance

19.1. MEASURED SHOVEL PACKING

It is a scientific technique of manual maintenance of track with out the use of any sophisticated machine or equipment. Essentially it consists of accurate measurements of track defects, specially the voids and unevenness developed in due course of time of service and attending the same by placement of measured quantity of small sized stone chips under the sleepers to bring the track to the predetermined levels. The compaction of chips is achieved by the passage of the rolling stock. The extent by which the track is to be lifted is calculated by measuring the longitudinal unevenness in the track after applying corrections for cross levels and voids under the sleepers.

The longitudinal levels are measured by an optical instrument known as *viseur and mire*. The voids in the ballast under the sleeper bed are measured by the instrument called *canne-a-boule*. It is a bull ended rod. The packing voids are checked with the help of a mechanical device known as *Densometer.*

19.2. METHOD OF PACKING OF SLEEPERS

To assess the extent of packing voids under the bed of sleepers, the canne-a-boule is dropped from a height of 40 cm at both ends of the sleeper and the height of its rebound and the sound emitted by it is heard and noted as shril or dull. If the rebound height is good and the sound emitted by it is shril, or as that of a metal then the sleeper is sound and healthy. In case the rebound height is less or zero and the sound also is dull, then the sleeper is not healthy and needs packing. Lesser the height of rebound and dull sound, higher will be the packing. In other works there are more voids.

After determining the extent of packing, the track is lifted up more than 40 mm by special non infringing jacks and a measured quantity of stone chips is placed under the sleeper bed with the help of special type of packing shovels.

The jacks are then tripped off and the alignment is finally corrected. The chips are consolidated by the movement of rolling stock or traffic.

19.2.1. Pre requisites of M.S.P.

There are following two pre requisites of measured shovel packing:

1. The ballast cushion under the bed of the sleeper should be well settled.
2. The formation of the track should be stable.

19.2.2. Conditions under which M.S.P. should not be attended

M.S.P. should not be attended under the following conditions:

1. Immediately after track renewal and deep screening.
2. Just after renewal of large number of sleepers.

3. If the track lift required is more than 80 mm.

19.2.3. Use of M.S.P. technique on Indian Railways

On Indian Railways now a days the M.S.P. technique is used for the following works.

1. The rough packing of flat bottom sleepers as that of wooden and concrete sleepers.
2. Packing of joint wooden sleepers in metal sleeper track.
3. Through packing of points and crossings with wooden and steel sleepers.

19.3. ADVANTAGES AND DISADVANTAGES OF M.S.P.

Following are the advantages and disadvantages of M.S.P. maintenance.

Table 19.1. Advantages and Disadvantages of M.S.P.

Advantages	*Disadvantages*
1. For maintenance by M.S.P. technique, no traffic block is required. This is the greatest advantage of this technique.	1. M.S.P. technique can only be used for flat bottom sleepers. This puts a limit on its scope.
2. Per gangman this technique gives higher out put. Thus economical.	2. Special sized stone chips are needed which may not be available easily. About 50% stone chips should pass through 13 mm mesh and retained on 10 mm mesh, while rest 50% should be retained on 6.5 mm mesh.
3. For high speed tracks, track maintenance is closer to required tolerances as finer adjustments are possible by this technique.	3. This technique is not effective for maintaining the newly screened track or consolidated bed.
4. Packing retentivity, specially for joint sleepers is more by M.S.P. in comparison with other methods of maintenance.	4. Delicate devices are needed for the maintenance work.
5. It is more economical as condition of minimum clean ballast cushion is not applicable to be adopted.	5. Skilled and trained labour is needed.
6. It does not damage the under side of wooden sleepers as in the case of manual maintenance.	
7. It is less strenuous.	
8. The consolidated ballast under sleepers is not disturbed by M.S.P.	
9. It is easy to perform and very little training and experience is needed for supervisory staff and gangman to pick up the maintenance techniques.	

19.4. EQUIPMENT NEEDED

For M.S.P. operations following equipment is needed.

1. Canne-a-Boule. It is a very simple device used for measuring the extent of packing voids under the sleeper. For wooden sleepers, it is made of an iron ball of 100 mm diameter, having a mild steel rod handle of 20 mm diameter and 120 cm length. For steel trough sleepers an wooden ball, 120 cm long is used with a cylindrical wooden block of 100 mm diameter and 155 mm long. The canne-a-boule is dropped from a height of 40 cm at both ends of the sleepers and the height of rebound and the sound emitted determines the extent of packing voids. Zero packing value is given to the sleeper which gives

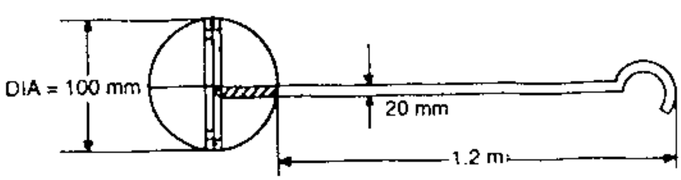


Fig. 19.1. Canne-A-Boule

good or high value of rebound and shril metallic sound. The value of packing increases with dull sound and decreasing rebound.

2. Densometer. This instrument is used for measuring the packing of voids under three sleeper ends. The three tripod legs are fixed in the ballast bed with the dancing rod on the sleeper. The extent by which the friction sleeve shifts from its original position determines the extent of voids under the sleeper ends under dynamic conditions.

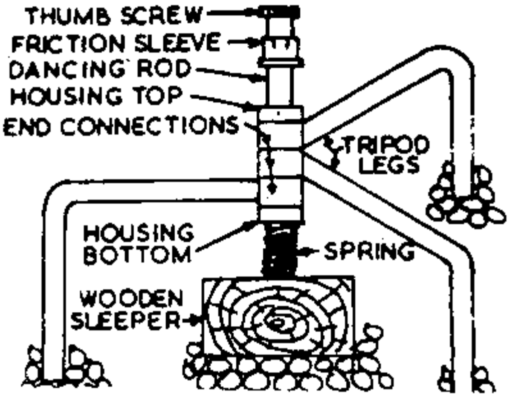


Fig. 19.2. Densometer

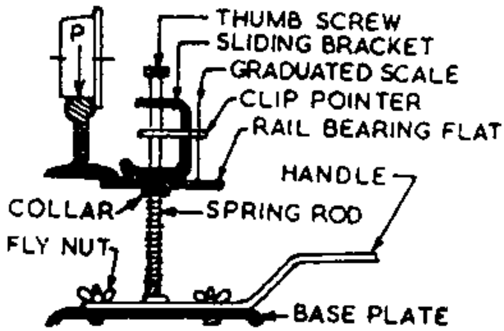


Fig. 19.3. Flaximeter

3. Flaximeter. This instrument is used to determine the depression of rail under traffic and gives the amount of packing voids together with the play in the fastening *i.e.* the gap between the rail foot and the sleeper. Flaximeter is used along with Densometer to check the tightness of the fastenings. The difference between the flaximeter and Densometer reading gives the extent of looseness of fittings between the rail and fastenings.

4. Viseur and Mire. These are used for measurement of the unevenness of rail top and rectification of alignment defects. Viseur is a type of telescope, having a magnifying power of about 12. It is supported on

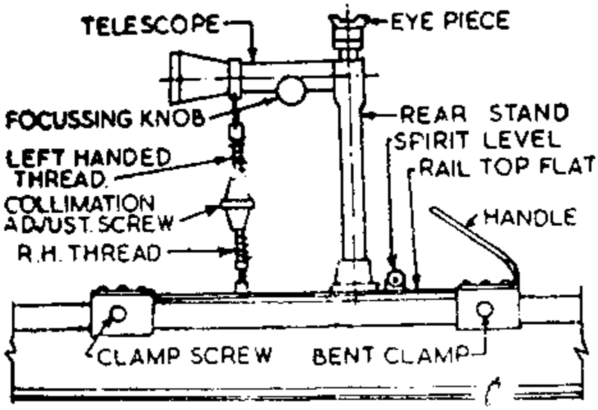


Fig. 19.4. Viseur

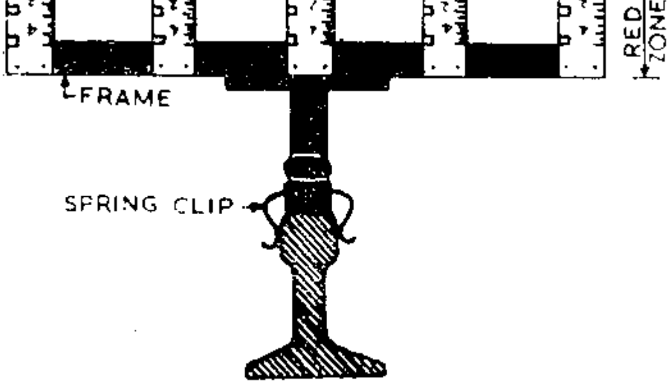
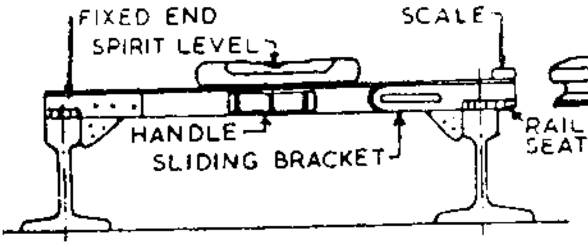


Fig. 19.5. Mire

a stand, which can be fixed to the rail head with the help of two clamps. Fig. 19.4 shows a viseur.

Mire. It is a staff having five graduated scales as shown in Fig. 19.5 painted in mm. It has a supporting frame which can be fitted to the rail head with the help of bent clamps.

Gauge cum level. It is used for measuring the gauge of the track and cross levels. The level is measured with the help of sensitive sprit level about 20 cm long and having a sensitivity of 2 minutes 30 seconds. The cross levels can be measured to an accuracy of 1 mm with the help of this gauge cum level instrument. Fig. 19.6.



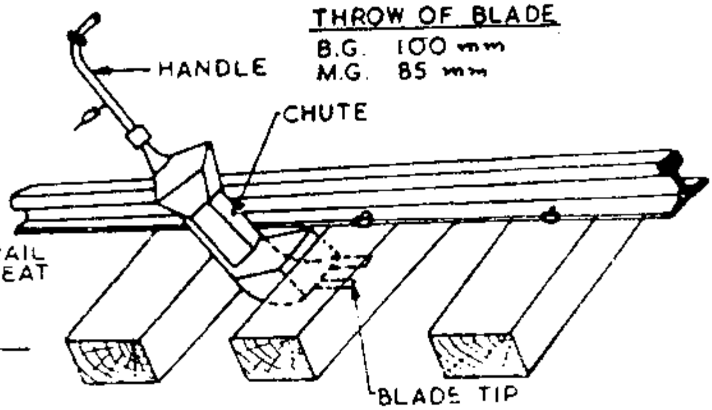


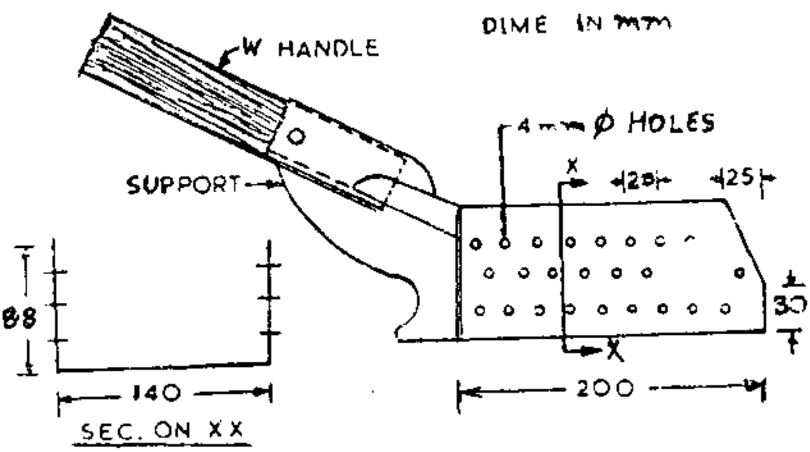
Fig. 19.6. Gauge cum level

Fig. 19.7. Packing shovel

Packing shovel. It is used for placing the stone chips under the rail seat over the full width of the sleeper. It is about one meter long having special blade for collection and spreading the chips under the sleeper bed. The throw of blades is 100 mm for B.G. and 85 mm for M.G. Fig. 19.7.

Dosing shovel. It is used for packing up a measured quantity of stone chips for packing. It has a series of holes at different levels as shown in Fig. 19.8. These levels give an idea of the quantity of chips picked up in the shovel depending upon the height to which the chips are collected in the shovel.

Measuring can. It is used to check the accuracy of dosing shovel. It is a cylindrical container having a height of 150 mm for B.G., and 120 mm for M.G. with perforated holes at calibrated intervals. Fig. 19.9.



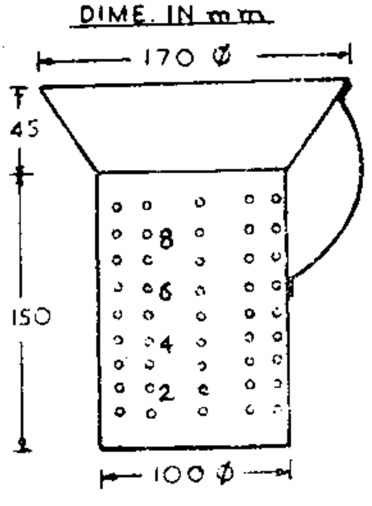


Fig. 19.8. Dosing shovel

Fig. 19.9. Measuring can

Plain shovel. It is used for placing stone chips under the bed of sleepers. It's size for B.G. is 18 × 23 cms, and 18 × 18 cm for M.G. Fig. 19.10.

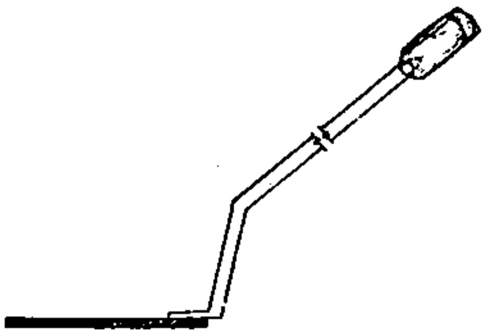


Fig. 19.10. Plain shovel

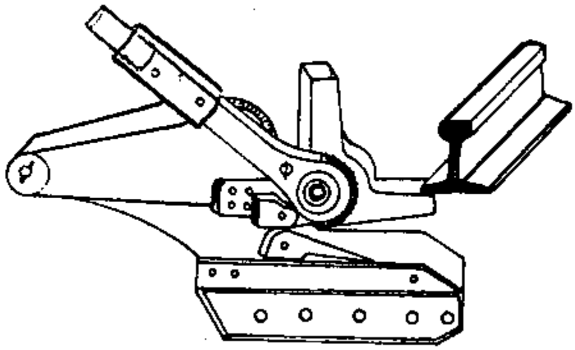


Fig. 19.11. Non infringing jack

Non infringing track Jack. These jacks are used for lifting the rails to a desired height. The non infringing feature of this jack is that it can be easily brought to its normal position in the event of an approaching train and can be left on the track as none of its parts projects above rail level and interferes with the moving parts of the train. The safe designed load of these jacks is 5 tonnes. Their maximum lift for B.G. is 200 mm and for M.G. 160 mm. Fig. 19.11.

19.5. THROUGH MEASURED SHOVEL PACKING OF TRACK WITH FLAT BOTTOM SLEEPERS

As stated above, M.S.P. has been found most suitable for flat bottom sleepers, specially wooden sleepers. As Indian Railways have very little track on wooden sleepers, so its scope also is limited. How ever it has been tried for concrete sleepers.

19.5.1. Operations carried out in M.S.P. Maintenance

In M.S.P. maintenance, following operations are carried out:

1. Determination of voids. The extent of packing voids is ascertained with the help of canne-a-boule as discussed on page 343. The amount of packing voids so determined is marked on the ends of the sleeper. A cross check of the packing voids is done with the help of densometer fixed on few sleepers of high value voids. The measurements of looseness of fittings are also taken with the help of flaximeter.

2. Fixation of high points. The high points are fixed on each rail by sighting with naked eye. The cross levels are also taken with the help of gauge cum level instrument at these high points with a accuracy of 1 mm. These high points are then corrected for cross level errors.

At curves the cross levels are taken at every fifth sleeper and general pattern of super elevation is observed. In case there is deficiency in the superelevation, then the high points should be marked on the inner rail otherwise on the outer rail.

In case of transition curves, the obligatory high points are the points where the transition curve meets the simple curve or the straight track. Normally these points are not spaced more than 25 m apart. In French technology these high points are known as 'pH' points.

3. Transfer of high points to good points. To obtain effective packing under the sleeper normally a general lift of 10 mm in the 1st round and 5 mm in the second round of M.S.P. is given to the track. The lifted points are known as good points and marked on both the rails. These good points are also called PB points. The PB value for the higher rail will be equal to general lift of 10 mm for the 1st round of M.S.P. The PB value for the lower rail will be equal to general lift of 10 mm plus cross level difference.

In case of curves, where the actual cant is less than the theoretical cant, the values of good points are obtained as follows:

(*a*) For inner rail, the value of PB is equal to general lift of 10 mm.

(*b*) For outer rail, the value of PB is equal to the general lift of 10 mm plus the amount of deficiency in superelevation. These values of PB are written on the sleepers on the out side of the gauge face.

4. Longitudinal levelling. The longitudinal levels are taken on two high points on every alternate sleeper with the help of *Viseur and Mire*. The readings on the intermediate sleeper are obtained by interpolation.

5. Total lift. The total lift is calculated by adding packing voids as determined in (1) above to the amount of lift determined as per requirement of longitudinals levels as in 4 above, Thus total lift = packing voids + longitudinal lift.

The total lift is called "Mark definitive" and marked on the in side of the food of rail.

6. Opening out of ballast. As shown in Fig. 19.12 the ballast is opened out with the help of ballast rakes and special type of beaters. The ballast is opened out 25 cm on either side of the rail for a width of 15 cm to 20 cm in all cases. The opening of ballast is done only on one side of sleeper in the direction of the approaching train as shown in Fig. 19.12. In case of double line, the opening is done on one side of the sleeper as explained above. In case of single line section where traffic is in both the directions, the opening is done in one side of the sleeper, but direction of opening is changed at every 25 m interval.

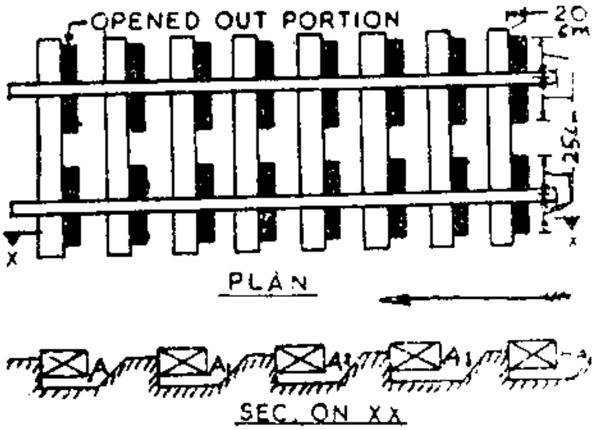


Fig. 19.12. Opened track lifted by jack

7. Lifting and Packing of track. The lifting of track is done with the help of non infringing jacks. The jacks are placed 9 sleeper apart on evenly made up ballast bed. To avoid rolling of bigger pieces of ballast under the sleeper bed, the track should not be lifted more than 4 cm at a time by the jack.

The packing of the track is done with the help of a special packing shovel. Depending upon the amount of lifting of the track and amount of voids, the required quantity of small sized chips is inserted below the sleeper bed by the dozing shovel. The accuracy of the dozing shovel is checked occasionally with the help of a measuring can. Generally a party of 9 gangmen is required for lifting and packing operation.

8. Provision of ramps. In order to ease off gradually, the difference in the longitudinal levels of the track between the portion already attended and the one to be attended, ramps are provided. The provision of such ramps is essential in the following two conditions.

(*a*) In the face of approaching train. In this case a provisional ramp of 3 mm per sleeper is provided.

(*b*) At the end of the day's work. In this case a provisional ramp of 1 mm per sleeper is provided.

Note. As far as possible such provisional ramps should not be provided at rail joints or sags.

9. Alignment. After correcting the longitudinal and cross levels of the track, the alignment is checked with the help of *Viseur and Mire* using rear side as vertical line of the Mire as the target. For alignment the use of guide is very important as these will not allow the viseur and mire to be disturbed while slewing.

19.5.2. Procedure

(*a*) The alignment of the sighting rail is checked by the eye judgment and points of good alignment *i.e.* where the track is fully or deed straight are choosen and marked.

(*b*) The viseur is placed at such a good point and the mire is placed at about 100 m apart on the next good point of the alignment in such a way that its (mire) rear side (vertical line) face the viseur.

(*c*) The viseur and mire are levelled and adjusted. The line of vertical cross hair of viseur is made to coincide with the central vertical line of mire. The mire is then shifted and brought towards the viseur in stages of 5 to 6 sleepers each time, assessing the line of perfect alignment and points of kinks.

(*d*) The kinks in the alignment if any are then corrected by proper slew at each location with the help of crow bars.

10. Boxing and dressing of ballast. After attending the track for surfacing and alignment, the open out of ballast is put back in the track by ballast rakes and the ballast section properly boxed and dressed. Normally before putting back the ballast one train should be allowed to pass on the attended portion of the track.

11. Majoration of joints. The next day the joints should be checked second time and if some low points are found, they should be attended. The joints and shoulder sleepers are shovel packed to the required extent. This second attention to the joints technically is known as *majoration of joints.*

12. Quality and size of chips. Stone chips used should be of hard variety as that of granite so that it may not be crushed under the load. It should not be flaky. The size of stone chips used for different types of works should be as shown in Table 19.2.

Table 19.2. Showing the size of chips used for different works

S. No.	*Type of work*	*Size of chips*
1.	First round of M.S.P. after screening of ballast and one round of beater packing.	16 to 30 mm
2.	First round of M.S.P. on consolidated track.	10 to 20 mm
3.	Subsequent round of M.S.P. or M.S.P. of wooden sleepers at joints.	8 to 15 mm
4.	Chips used for Majoration of joints. No direct supply of size of chips is to be taken. Only left over of 8 to 15 mm sized chips are to be used.	6 to 8 mm

13. Quantity of chips required.

(*a*) For first round of M.S.P. having a general lift of 10 mm for B.G. and M.G. tracks about 3 m^3 chips are required for 250 to 300 sleepers.

(*b*) For second or subsequent round of M.S.P. having a general lift of 5 mm or less about 3 m^3 chips are required for 1000 to 1200 sleepers.

(*c*) For carrying out of M.S.P. on one turn out about 2.0, 1.5 and 1.0 m^3 chips are required for 1 in 16, 1 in 12 and 1 in 8½ turn out respectively.

14. Checking of works. The longitudinal and cross levels of the attended portion of the track should be checked after passing two trains over it. At any sleeper the variation in cross level should not exceed more than 3 mm and variation from sleeper to sleeper should not exceed 1 mm in any case.

19.6. SPECIAL INSTRUCTIONS REGARDING LIFTING BY JACKS AND LENGTH OF SHOVEL PACKING

1. Lifting of track by jacks should not exceed 40 mm.
2. Length of packing between straight track and a curved track of radius more than 800 m should not be more than 150 m. For curves of radius less than 800 m, the length should not exceed 100.
3. Lifting of track by M.S.P. should be limited according to the speed of the train as follows:
   (*a*) For speeds of train upto 100 km per hour. The total lift by shovel packing should not exceed 30 mm subject to a maximum lift of 20 mm in one operation of shovel packing. The second operation of shovel packing for remaining lift of 10 mm should be carried out after the passage of at least one train.
   (*b*) For speeds of trains more than 100 km ph and upto 130 kmph. The total lift by shovel packing should not exceed 20 mm and it can be lifted in one operation.
5. In case the total feed value required is more than the maximum permissible limit on both rails, the lowest point should be raised by the maximum limit only. Lowest point be treated as an obligatory

additional high point and the PB value at the point will be equal to maximum permissible lift or feed minus the packing voids on that particular sleeper. Fresh readings should be taken by viseur and mire with the required packing plates.

19.7. M.S.P. OF JOINT WOODEN SLEEPERS ON METAL SLEEPERD TRACK

We known that a joint is the weakest link in the track, hence it needs special attention for maintenance. The maintenance of joint sleeper has not been found very effective with conventional beater packing method due to closer spacing of sleepers at the joint. The packing remains loose at the joints and a number of problems of maintenance arise due to this account. As in M.S.P., packing is required to be done from one side of the sleeper, M.S.P. method of joint sleeper has been found ideal.

1. Procedure of M.S.P. maintenance. In the maintenance of joint wooden sleepers with through packing of metal sleeper track, only the joint wooden sleepers are attended by M.S.P. and the intermediate sleepers are packed by conventional beater packing method as usual. The surface of the track is brought to the correct longitudinal and cross levels consistent with the metal sleeper track.

2. Calculation of total lift. The total lift required is determined by finding out the voids at joints under the sleepers by the use of canne-a-boule and adding to it the longitudinal lift required due to general sag of the track. The voids of joint sleepers found should be checked occasionally with the help of densometer.

The longitudinal lift is calculated by flaximeter fixed under the sighting rail in a compressed position. The intermediate sleepers are packed by conventional beater packing as usual and the track is lifted to the extent required to achieve perfect longitudinal levels. The joint sleeper is lifted by the judgment of the eye at the level of intermediate sleepers and the readings of flaximeter under the sighting rail recorded, which give the amount of longitudinal lift of the rail.

Thus the total lift for two rails is determined as follows:

(*a*) Total lift for sighting rail = Longitudinal lift plus voids under sighting rail

(*b*) Total lift for second rail = Flaximeter reading on sighting rail plus voids under the second rail plus cross level difference at the joint

Note. Cross levels should be determined correctly with the help of an accurate gauge cum level instrument.

3. Lifting and packing of joint sleepers. After the above operations, the joint sleepers are lifted with the help of non infringing jacks to the required level, but not more than 40 mm. The required quantity of small sized stone chips are then taken by dozing shovel and placed under the joint sleepers with the help of packing shovels. The jacks are then released from the lifted position and sleepers are tamped with the help of blunt ended crow bars so that they are seated evenly on the layers of the chips.

4. Alignment corrections. General alignment corrections are made while attending the intermediate sleepers with conventional beater packing method. The distortions to alignment caused during M.S.P. operations are corrected subsequently.

19.8. M.S.P. OF JOINT SLEEPERS WHERE THROUGH PACKING ALREADY DONE

This operation aims to eliminate the low joints by M.S.P. of joint sleepers and beater packing of adjacent shoulder sleepers.

Procedure. Following operations are carried out in this case:

1. Measurement of voids. Voids at the joint sleepers are measured by canne-a-boule and few values of voids are crossed checked with the help of densometer.

2. Measurement of cross levels. Cross levels are measured at the following points:

(*a*) At the rail joints.

(*b*) At a distance of 3.6 metres on either side of rail joint for B.G. and at 2.74 m on M.G. From these readings the proposed cross levels at the joint is taken as the mean value of cross levels at two points on either side of the joint.

(*c*) *Measurement of lowness of joints.* The lowness of joints is measured by stretching a string over a 3.6/2.74 m chord length on B.G. and M.G. on the rail and the depression is measured at a point 5 cm from the edge of the rail.

(*d*) *Measurement of total feed.* Feed for sighting rail = Depression of sighting rail + dance or clearance between the bottom of joint sleeper and ballast
Feed for second rail = Depression of second rail + dance or clearance.

(*e*) *Lifting and packing.* The joint sleepers are lifted by non infringing jacks and the required quantity of stone chips is placed below the joint sleepers by packing shovels. The jacks are then released and the track lowered. The joint sleepers are tamped by the blunt end of the crow bars, so that joint sleeper may rest evenly on the chips. After the passage of one train, three shoulder sleepers on either side of the joint are also tamped with blunt ended crow bars. While tamping the shoulder sleepers, care should be taken that joint does not get lifted up.

(*f*) *Alignment corrections.* Due to lifting and packing of joint sleepers, if any disturbance in the alignment of the track is noticed, it should be corrected immediately. After the alignments of the track, the ballast section is boxed and dressed properly.

19.9. M.S.P. OF TURN OUTS

The M.S.P. of turn outs laid on wooden sleepers has been found quite effective. The work is carried out under block protection. Normally for carrying out M.S.P. of a turn out, a guide line is marked. The guide line helps to place the gratting shovel correctly both on main line track and turn out track. At the same time it guides the shoveling man to place the shovel over the additional width for switch and crossing portions.

19.9.1. Procedure

1. Measurement of voids. For measuring voids, the turn out assembly is divided into three parts or zones:

(*a*) Switch portion (*b*) Central portion

(*c*) Crossing portion

The number of sleepers coming under various zones for different type of crossings are shown in Table 19.3.

Table 19.3.

Gauge	*No. of crossing*	*Numbers of sleepers*		*Cross portion*
		Switch portion	*Central portion*	
B.G.	1 in 16	1 – 33	34 – 61	62 – 83
B.G.	1 in 12	1 – 27	28 – 53	54 – 70
B.G.	1 in 8½	1 – 20	21 – 38	39 – 51
M.G.	1 in 12	1 – 22	23 – 29	30 – 45
M.G.	1 in 8½	1 – 18	19 – 23	24 – 34

2. Location of high points. Same as for through packing, except that high points should be located on stock rails for switch portion.

3. Transfer of high points to good points for cross level corrections. Same as for through packing except for switch portion, where transfer of high points to good points is carried out on stock rail.

4. Longitudinal levelling. Same as for through M.S.P. except that longitudinal levels are taken on the stock rail upto four or five or six sleepers for 1 in 8½. 1 in 12 and 1 in 16 turn out behind the bed.

5. Mark definitive (M.D.). The total lift or feed is the algebraic sum of longitudinal levels and packing voids.

6. Shovel packing. For this operation the ballast between the sleepers is completely removed and the track is lifted by track jacks of 5 or 15 tonnes capacity. For M.S.P. four grating shovels are used, two for out side rails and two for inside rails. The inner side shovels are used for giving additional lift to a point where rails are 40 cm apart. The grating shovel has suitable marking at 0.25, 0-5 and 0.75 of its capacity, so that correct quantity of chips may be used at the area to be shoveled.

7. Putting back the ballast. After packing, the ballast is put back and the joints are attended once again if needed.

8. Alignment corrections. The main line is aligned with the help of viseur and mire.

9. Attention to approaches. To adjust the longitudinal levels, the approaches of the turn out are attended by M.S.P. or beater packing.

19.10. SPECIAL PRECAUTIONS FOR M.S.P. ON TURN OUTS WITH STEEL SLEEPERS

The steel sleepers have a flat bottom for about 150 mm. Thus this depth of steel sleepers has been considered quite suitable for M.S.P. To get good results, initially M.S.P. has to be repeated 2 to 3 times, so that a hard ballast core is obtained. Some of the usefull precautions are as follows:

1. For measuring voids, a wooden canne-a-boule should be used.
2. For the first M.S.P. the rise over the high points should be limited to 4 mm while for subsequent M.S.P. the rise should be 2 mm or less.
3. 15 tonnes jacks are required for turn outs with steel sleepers due to heaviour weight and greater lifts. The work has to be carried out under block protection of 1 to 1½ hour duration.
4. The total quantity of chips can be shoveled under sleepers upto a height of 15 mm subject to a maximum height of 10 mm at a time. If at a particular point, the chips are to be fed for more than 15 mm height, then the lowest point is raised by 15 mm and adjustments made accordingly.
5. The M.S.P. of turn outs on steel sleepers should not be done on hot days.
6. The M.S.P. is carried out either by plain or grating shovels. Using plain shovels, the chips should be placed under sleepers carefully.

19.11. DE-HOGGING OF RAIL ENDS BY M.S.P.

The hogged rail ends as shown in Fig. 19.13 can be de hogged with the help of M.S.P. as follows:

1. The dip at joint sleepers (a) is measured with the help of a 1.5 m straight edge and a feeler gauge at a distance of 50 mm from the rail ends as shown in Fig. 19.13.

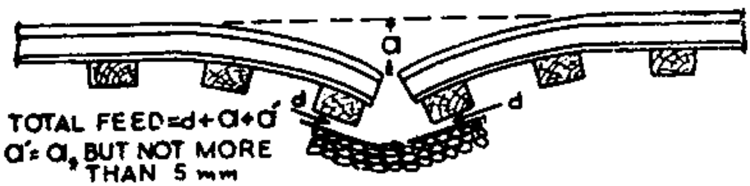


Fig. 19.13. Dehegging of rail ends

2. The clearance *i.e.* gap between the bed of sleeper and top of ballast bed at the joint sleepers 'd' is measured by canne-a-boule or densometer.
3. The joint sleepers are lifted up and packed to a value = $d + a + a'$.

where,

d is the dance value (clearance between the bottom of joint sleeper and top of ballast bed)

a is the amount of dip of rail ends

a' is also equal to 'a' subject to a maximum value of 5 mm.

After allowing traffic for two days, the adjoining sleepers are beater packed or shovel packed depending upon the type of sleepers as metal or wooden. While packing, it should be ensured that no lifting is done on these sleepers.

If the complete de hogging is not achieved, the process should be repeated.

QUESTIONS

1. Define measured shovel packing. Explain the method of operation of M.S.P.
2. Discuss the merits and demerits of M.S.P.
3. What are the basic requirements of M.S.P.? What works can be attended by M.S.P.?
4. What is a canne-a-boule? For what purpose it is used? Explain with sketch.
5. Explain the working process for the maintenance of
   (*a*) Flat bottomed sleepers (*b*) Turn outs
6. Explain the following terms:
   (*a*) Shovel packing (*b*) Alignment of track
   (*c*) Open out ballast (*d*) Transferring of high points to good points
7. Explain in brief the use of the following equipment
   (*a*) Flaximeter (*b*) Densometer
   (*c*) Viseur and mire (*d*) Canne-a-boule
8. Explain the process of de-hogging of rail ends with a neat sketch.
9. Identify the incorrect statement/statements
   (*a*) Measured shovel packing does not need very sophisticated machines
   (*b*) M.S.P. needs very sophisticated machines.
   (*c*) M.S.P. is a scientific manual method of maintenance
   (*d*) No traffic block is required for M.S.P. maintenance
   (*e*) M.S.P. maintenance gives higher out put per gagman.
10. Identify the correct statement/statements
    (*a*) M.S.P. maintenance is easy to perform
    (*b*) Packing retentivity specially for joint sleepers is more by M.S.P. technique than other methods
    (*c*) M.S.P. method is more economical as condition of minimum clean ballast cushion is not applicable to it.
    (*d*) Consolidated ballast under sleeper is not disturbed by M.S.P. method
    (*e*) All are correct
11. Identify the correct statement/statements
    (*a*) M.S.P. method of maintenance is ideal for wooden sleepers
    (*b*) M.S.P. is quite effective in maintaining newly screened track
    (*c*) Any size of aggregate chips can be used for M.S.P. techniques
    (*d*) Same canne-a-boule can be used for all types of sleepers

ANSWERS

9. (*b*) 10. (*e*) 11. (*a*)

20

Modern Methods of Track Maintenance

20.1. INTRODUCTION

For the last more than one century, the maintenance of railway tracks on Indian Railways has been maintained manually. This method of maintenance is suitable for traffic speeds upto 130 kmp. In recent past technological advancement has taken place at a very fast rate and railway traffic speed has gone upto more than 500 kmph. In India the speed has gone upto 250 km per hour on certain tracks. To suit the requirement of highly efficient track for high speeds and heavier axle loads traffic, use of modern methods of track maintenance will prove more economical, and efficient.

20.2. MODERN METHODS OF TRACK MAINTENANCE

Following are the modern methods of track maintenance:

1. Mechanical tamping or mechanised maintenance.
2. Measured shovel packing (M.S.P.)
3. Directed track maintenance (D.T.M.)

20.3. NEED FOR MACHNISED MAINTENANCE

The need for mechanised maintenance is felt due to the following reasons:

1. The manual (beater packing) method of maintenance is very hard and strenuous job and the labour has started shirking to carry out such jobs.
2. Due to the varying physical strength of labour, it is very difficult to get uniform packing under sleepers by manual maintenance. Weather conditions and interest of the labour in the work also affect quality of work to a great extent.
3. Some times the intensity of pressure and shocks imparted to the ballast by the beater exceeds the limit of crushing strength of the stone ballast. This results in further fragmentation of stone ballast and clogging the ballast section, which finally leads to poor drainage of the track.
4. In recent years on Indian Railways, the traffic densities, axle loads, and speeds have increased considerably. Thus it has become difficult to maintain the geometry of the track with in the close tolerance limits by manual maintenance.
5. The retentivity of packing with manual maintenance is not very good and the geometry of the track gets disturbed in very short time due to heavy and fast moving traffic.
6. For modern tracks of long welded rails and heavy concrete sleepers, the manual maintenance has not been proved to be useful.
7. Due to higher density of traffic and higher speed of trains, the time gap available between trains is becoming progressively shorter and the maintenance by manual method is becoming increasingly difficult and inadequate.

8. By manual maintenance, it takes considerable time to consolidate the track fully. Hence long duration speed restriction period is required after track removed by manual maintenance.

20.4. REQUIREMENTS OF MECHANICAL TAMPING

Some of the important requirements of mechanised maintenance are as follows:

1. Before the use of tampers, it should be ensured that the track structure is elastic and free from surface defects. This can be achieved in the following manner.
   (*a*) Hogged rails either replaced or dehogged.
   (*b*) Creep if any is adjusted.
   (*c*) Lifting of saged portions, destressing of short welded rails, correction of expansion joints is done in advance.
2. For proper working of the tampers, ballast cushion under the bottom of the sleepers should not be less than 20 cm thick. The ballast should be of proper size and good quality.
3. The tamping tool should be allowed to penetrate vertically well into the ballast.
4. To achieve uniform tamping, the tamping tool should have sufficient pressure or vibration for penetration.
5. The ballast surrounding the tool should be in constant motion.
6. The operator should have control over the tamping pressure.
7. The tamping should be moderate, neither too hard nor too soft.
8. The formation of the track should be strong having uniform strength characteristics.
9. The vibratory action of tamper should compact the ballast uniformly.
10. The suitability of tamping with different kinds of sleepers is as follows:
    (*a*) *Wooden and concrete sleepers.* The tamping machines are best suited for flat bottom sleepers as wooden and concrete sleepers.
    (*b*) *Steel trough sleepers.* For steel trough sleepers, though the packing is quite effective, but ballast tends to move towards the centre, causing center binding. This tendency can be checked by providing recess under centre of the track.
    (*c*) *CST 9 sleepers.* These sleepers are not fully compacted by the tampers.

20.5. TYPES OF TAMPERS

Basically mechanical tampers are of the following two types:

1. OFF track tampers
2. ON track tampers

20.6. CLASSIFICATION OF OFF TRACK TAMPERS

They can be classified into two classes as follows:

1. Self contained
2. Worked from a common power unit

20.6.1. Self contained tampers

These tamper are further classified into the following two groups:

(*a*) **Percussion type.** In this case, the tamping of sleepers is done by the blows imparted by striking mechanism.

(*b*) **Vibratory type.** In this case, the tamping of the sleepers is done by the vibrations and self weight of the tamper.

20.6.2. Worked from a common power unit

These tampers also can be classified in the two groups as follows:

(*a*) Electric vibratory tampers

(*b*) Pneumatic percussion type tampers.

20.6.3. OFF track tampers used on Indian Railways

Details of OFF track tampers used on Indian Railways are shown in the following Table 20.1.

Table 20.1. Different tampers used on Indian Railways

S. No.	*Name of tamper with manufacturer*	*Details of tamper*	*Length of tamper*	*Weight of tamper*	*Remark*
1.	Cobra tampers, manufactured by M/s Atlas Corporation Stockholm (Swedden)	Self contained percussion type. Powered by single cylinder 2 stroke air cooled petrol engine.	0.61 m	13 kg	It imparts about 2000 blows/min. Though the quality of tamping is good but causes excessive fatigue to the operator.
2.	Jackson tampers manufactured by Jackson vibrators, Illinois (U.S.A.)	It is self contained vibratory type tamper. It contains 4 units.	—	Weight of each unit is 25 kg	It is a portable electric generator set giving three phases A.C. power of 110 volts. It imparts 4000 vibrations/min. It is not found suitable for Indian railways specially for steel trough and CST 9 sleepers. where bed is hard.
3.	Shibaura tampers	It is manufactured by M/s Shibaura Engg. Ltd. Japan, It is a vibratory type tamper	—	—	It comprises of 4 units of tampers connected by flexible wire and portable generator. 220 volts generator is powered by an air cooled petrol engine. It is not found suitable for Indian railways.
4.	Kango hammers	Manufactured by M/s Kango Elect. hammers Ltd. It is a combination of percussion and vibratory type tampers. It consists of 4 tampers and one portable electric generator.	1.11 m	13 kg	It is electromechanical high frequency vibratory tampers. It gives about 2000 blows/min. They are found satisfactory for Indian Railways specially for CST-9 sleepers.

20.6.4. Working principle of OFF track tamper

In order to get maximum consolidation of ballast, OFF track tampers are worked in pairs from opposite side of the sleepers diagonally under the rail seat. This is achieved by the following operations.

1. First the ballast around the rail seat in the crib is loosened with the help of beaters for a distance of 45 cm on either side of the rail foot.
2. After loosening the ballast, the tamper is inserted vertically in such a way that the tamping tool blades remain away by a distance of 7.5 cm to 10 cm from the sleepers so that enough ballast is available between the sleeper and the tamping tool blade as shown in Fig. 20.1.
3. For compacting the ballast well, the head of tamper should move circumferencially back wards and forwards during working.
4. The tamper should not be pressed by the operator as it works automatically either by vibratory or percussion system.

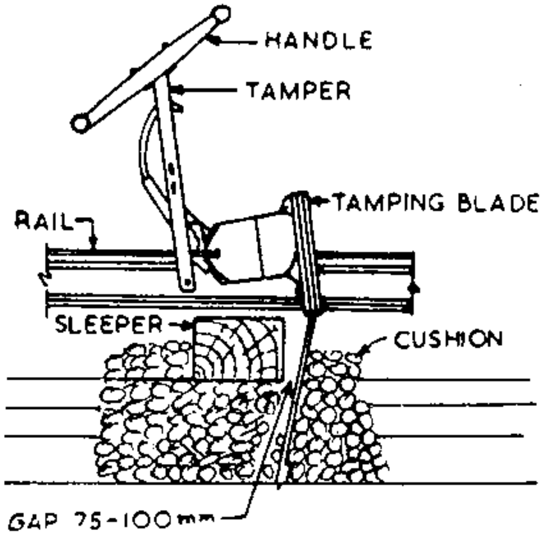


Fig. 20.1. Off track tamper

20.6.5. Use of OFF track tampers

These are portable tampers and can be taken off from the track with in a very short time and can be driven by petrol or electricity. They are used when the train is not on the traffic block.

20.6.6. Merits and demerits of OFF track tampers

The merits and demerits of OFF track tampers are shown in the following Table 20.2.

Table 20.2. Merits and demerits of OFF track tampers

S. No.	*Merits*	*Demerits*
1.	It requires no traffic blocks.	Maintenance of these tampers (OFF track tampers) is very difficult and costly as their spare parts have to be imported.
2.	It can be used on high speed and heavy traffic density track with advantage.	Transportation of these tampers with power to the site of work in the mid section is very difficult.
3.	Short periods between the trains can be utilised gain fully.	Working with these tampers is strenuous. A worker gets fatigued after working for 30 to 40 minutes only. Due to tireness of workers, quality of work also deteriorates.
4.	They have been found useful for packing points and crossings where manual packing is difficult due to limited space.	To get desired results, intensive supervision is required.
5.	These tampers have been found very useful for packing newly re aligned curves where track needs immediate consolidation to restore speed at the earliest.	Quality of maintenance by these tampers is inferior than manual maintenance.
6.	These are also found very useful for packing concrete sleepers on isolated lengths laid with concrete sleepers where manual packing is prohibited.	The use of these tampers has not been found useful after deep screening and relaying the track.

20.6.7. Progress of work of OFF track tampers

With an effective working period of 5 hours per day, the yearly progress of one set of OFF track tamper is about 40 km of track, taking into account repair, over hauling time of the tamper.

20.7. ON TRACK TAMPERS

This class of tampers are self propelled automatic vehicles. The tamping of sleepers is done automatically through the control provided in the cabin of the operator.

Heavy type ON track tampers are superior to the OFF track tampers in respect of quality of work, retention, and control of tamping and efficiency. Besides these qualities, automatic lifting, aligning, longitudinal and cross levelling and packing etc. are simultaneously possible by modern ON track tampers.

20.7.1. Classification of ON track tampers

The ON track tampers can be classified into the following two categories:

20.7.1.1. Light ON track tampers

These tampers primarily consist of two tamping units working in parallel and mounted on a common motorised trolly. Each tamping unit is consisted of four tamping tools fixed on a vibrating chassis and arranged in opposite pairs on either side of the rail. This chassis slides in a fixed chassis. The tamping tools forming a pair are inter connected by a tie bar and a hydraulic cylinder, which ensures their symmetrical opening and closing. This arrangement ensures perfect compaction.

The total weight of a unit of ON track light tamper is about 1200 kg. These tampers being light can be taken off the track easily with suitable arrangements. The travelling speed of this tamper is 10 km per hour on level track and can work upto 30% gradient. These tampers can work with out traffic blocks. The average out put of these tempers is 150 sleepers per effective tamping hour. These tampers can only be used for tamping or packing. Other works like aligning, have to be done separately. On Indian railways ON track tampers are used under the following conditions:

(*a*) Packing of ballast for new railway lines.

(*b*) Packing ballast under concrete sleepers laid in short stretches in different locations, where the use of heavy ON track tampers may not be economical.

(*c*) Picking up of slacks and packing of ballast in busy lines, where taking of traffic blocks is very difficult.

20.7.1.2. Heavy ON track tampers

Heavy ON track tampers are superior to the light ON track tampers and can do automatically and simultaneously lifting, aligning, levelling and tamping. These are heavier machines weighing 20,000 to 30,000 kg. They can not be easily removed form the track. Hence work has to be done necessarily under the traffic blocks.

20.7.2. Principle of working of ON track tampers

Principle of working of on track tampers is described as follows:

1. Tamping. It is the most important or main job of a tie tamping machine. Tamping is the process of packing the ballast under the sleeper. This is achieved by vibrating the ballast. Vibrations make the ballast to move like a fluid and then compressing it under the sleeper as shown in Fig. 20.2 by squeezing it with tamping tool.

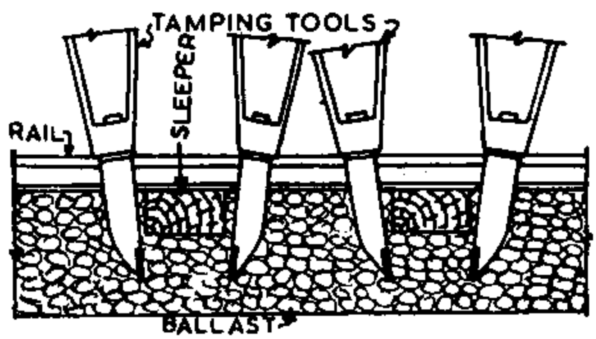


Fig. 20.2. Squeezing of ballast

Each tamping unit may have from 16 to 32 tamping tools depending upon whether single or double sleepers are to be packed at a time. Recently quadromatic tamping machines are also available in the marked which can pack four sleepers at a time.

The tamping is done either by synchronous or non synchronous system of vibrations.

In the synchronous system, the movement of two tamping tools is equal and simultaneous, synchronizing with each other. While in the case of non synchronizing system the two tamping tools are independent and work independly. Both systems are equally good and have their own merits and demerits. Their comparative merits and demerits are shown in the following Table 20.3.

Table 20.3.

S. No.	*Item*	*Synchronous*	*Non synchronous*
1.	Working mechanism	Mechanical end can with stand sufficient wear and tear.	Hydraulic end can not with stand much wear and tear. How ever better lubrication reduces wear.
2.	Movement of two tamping arms	The movement of two tamping arms is equal and simultaneous on the ballast core, giving better quality of packing.	The movement of two tamping tools is independent and equal. No harmful effects have been experienced.
3.	In the event of an obstruction like boulder etc.	Both the tamping tools stop and no tamping is done.	Only one tamping tools stops, when an obstruction is met and the other tool remains working. Thus some tamping is done.
4.	Forces on bearings.	Forces balance each other causing less wear and tear.	Forces do not balance and normal wear is experienced.
5.	Effect of tamping when sleepers are out of square	Tamping is not satisfactory due to limited space. How ever machine helps in squaring the sleepers.	Tamping is satisfactory as tools work independly. Machine does not help in squaring the sleepers.

20.8. LINING

The alignment defect of the track is known as lining. The alignment defect is corrected by two chord system machine manufactured by M/s Plasser & Theurer. In this method two chords, one long chord 24 m length and the other short chord 12 m length are stretched parallel to the track between the two rails at a certain distance apart as shown in Fig. 20.3. The ordinate H at quarter point of long chord and the versine h of central point of short chord are measured by the measuring bogie of the equipment. In a circular curve the ratio of $H/h = 3/1$. If the dimensions measured by the measuring bogie at the same point and the ratio of H/h is found as 3:1, then the curve is correct and alignment is in order. If this ratio is not maintained then the track is to be slewed at the location of central bogie by means of special rollers attached to the rails till the correct ratio is obtained. By this method the alignment defect can be corrected to a value of 1/6th of the original defect due to the relative positions of measuring bogie and central bogie as shown in Fig. 20.3.

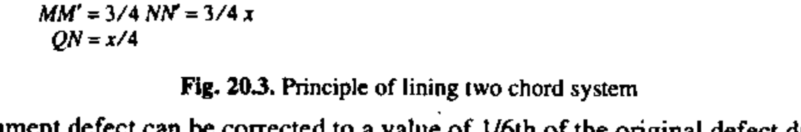


Fig. 20.3. Principle of lining two chord system

20.8.1. Equipment

The lining equipment consists of rollers which are operated hydraucally. These rollers are mounted between two axles. The slewing force to align the track is transmitted to the track at two points to the rollers through the double acting hydraulic cylinders. This equipment is consisted of the following parts:

(*a*) The front bogie, which surveys the defect ahead.

(*b*) The central bogie, lies mid way where the defects are corrected.

(*c*) The measuring bogie lies where the defect is measured and relayed to the galvanometer.

(*d*) The rear tightening bogie, which holds the chords in position.

(*e*) In addition to above four components an idle bogie is also provided between the rear and measuring bogie just to cover the long chord.

20.8.2. Working

The measuring system of the machine is shown in Fig. 20.4. It uses two mobile bases. The first resting entirely on the correct path of the track and the second on the path of track to be corrected. When the machine moves on the track, the irregularities in the alignment are picked up by the gauge rollers of the front bogie and the long chord gets shifted from its natural position and the ratio of 3:1 explained above is disturbed. The change in the ratio of H/h as 3:1 changes the resistance equilibrium of the galvanometer mounted on the measuring bogie and the same is relayed to the galvanometer kept in the control cabin. The alignment is corrected automatically through the servo valve which operates the rollers to slew the track hydraulically. When the track comes to its correct position, the needle of the galvanometer returns to its zero position. The alignment of the track can be corrected upto 1/6 of the original defect as stated above.

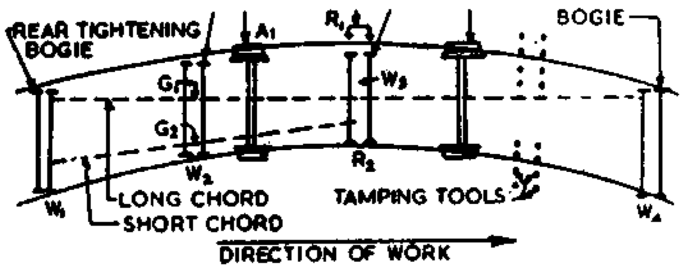


Fig. 20.4. Lining equipment

20.9. LEVELLING

The longitudinal levels of the track are corrected by the tampers on the principle of proportional levelling with the help of infra red transmitter, shadow board and photo cell as shown in Fig. 20.5. The distance between these three units is fixed and arranged in such a way that error in longitudinal level is reduced to one fifth of its value.

20.9.1. Equipment

As shown in Fig. 20.5 it consists of the following components:

(*a*) A front tower or bogie consisting of two infra red beam transmitters for each rail. The transmitters receive power from the machine through coaxial cables. The front tower moves infront of the machine at a fixed distance.

(*b*) Two receivers one for each transmitter consists of photo electric cells. These receivers are mounted on the machine. These receivers remain in touch with the rail top with the help of feeler roller equipment.

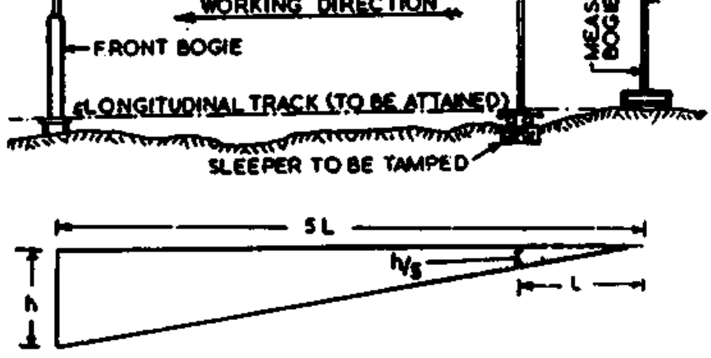


Fig. 20.5. Principle of levelling

(*c*) Two shadow boards mounted on the machine are placed in between the transmitters and receivers. These shadow boards touch the rails with the help of feelers and control the lifting of the sleeper to be tamped. The distance between the transmitter, photo cells and the shadow boards is kept approximately as follows:

(*i*) Distance between transmitter and photo cells = 17.5 m

(*ii*) Distance between shadow boards and photo cells = 3.5 m

20.9.2. Procedure

The infra red rays are transmitted from the transmitters towards the machine. These infra red rays are received by the photo electric cells in the receiver. The impulses generate a small electric current which is amplified to actuate a hydraulic distribution valve, which controls the lifting of the track. The lifting of track continues till the shadow board reaches the level of infra red beams. At this level the infra beams are intercepted by the shadow boards and lifting of track is stopped automatically. Thus the track is lifted to a height which is in line with the position of transmitter receiver. Once the track lifted, it remains in this position till the tamping is completed on a particular sleeper. When machine moves forward, the shadow boards drop, depending upon the level of the track. The infra red beams act again on the photo cells and the levelling continues. The error is reduced to 1/5th of the original value based on the principle of proportional levelling.

The cross levels are also corrected in the above process to an accuracy of 1/10th of the original value. Its accuracy can be checked with the help of a precision electric device mounted on the front feelers.

20.10. SWITCH TAMPING MACHINE

This is a specially designed machine for tamping switches (points and crossings). The tamping units are mounted on guide columns laterally and can be adjusted suiting to the requirements of the particular location. The machine is automatically centered in each forward block and gives progress of about 400 sleepers per hour.

20.10.1. Special features of the machine

Some of the special features are as follows:

(*a*) The machine has only eight (8) tamping tools.

(*b*) The depth of the tamping tool can be adjusted.

(*c*) If required, only one tool can operate and tamp at a time.

(*d*) To suit the local conditions, the tamping tool can tilt 15° inside and 85° out side.

(*e*) Tamping units can slide sideways. Similarly tools can also be made to slide about 15 cms.

20.10.2. Preparation for working of the tamping machine

Following preparatory works are carried out before the use of tamping machine:

1. Track

(*a*) For effective packing, the ballast should be heaped up on the cess.

(*b*) All loose fittings should be tightened.

(*c*) All worn out fittings and sleepers should be replaced.

(*d*) Proper squaring of sleepers should be done. Also proper spacing of sleepers should be ensured.

(*e*) The gauge should be checked and kinks, if any should be removed.

(*f*) Any sag in the track should be lifted up by manual labour before the use of the tie tamping machine.

(*g*) While working on curves, super elevation should be written on sleepers.

20.10.3. Tie tamping machine

(*a*) The depth of the tamping tools should be adjusted depending upon the type of sleepers.

(*b*) The squeezing pressure should be adjusted depending upon the type of sleepers and the condition of the ballast.

(*c*) The lift to the track which varies from 5 to 7 mm should be given depending upon the site conditions.

(*d*) The number of insertions whether single or double should be decided depending upon the type and condition of packing.

(*e*) To attain the entire required lift, a ramp of about 1 in 1000 should be given.

20.10.4. Works to be done after working with the machine

1. **Ballast.** The ballast must be spread and levelled to the correct profile. For providing better retention to the packing, shoulders and cribs should be properly rammed.
2. **Joints.** Fish plates should be checked and tightened if required.
3. **Fastenings.** Fittings should be checked and tightened if required.
4. After working with the machine a record of cross levels, alignment, unevenness, and packing conditions should be maintained.

20.11. TOLERANCE FOR MACHANISED MAINTENANCE

For mechanised maintenance following tolerances have been laid down by Northern Railways.

(*a*) Unevenness measured on 3.6 m base	± 2 mm
(*b*) Variation in cross levels	± 2 mm
(*c*) Variation in alignment measured on 7.2 m base	± 2 mm

Note. Above measurements should be taken under no load condition.

20.12. DIRECTED TRACK MAINTENANCE

It is a method of maintaining the track as directed every day or per need. It is not as pre prescribed routine method. Essentially directed track maintenance is a need based maintenance rather than routine and conventional periodical maintenance. Under this system of track maintenance the defects in the track geometry are properly identified and these defects are rectified under the close supervision at these isolated locations only and the track is maintained to the pre determined standards.

20.12.1. Features of directed track maintenance

Following are some of the important features of D.T.M.

1. Systematic identification and recording of the geometry of the track from one end of the maintenance unit to the other end including inspection of track to record the visually noticeable defects.
2. Analysis of these records.
3. Identification of stretches which need immediate attention and others which can be taken up during periodic maintenance.
4. Rectification of defects and checking of quality of work done.

20.12.2. Use of D.T.M.

The use of D.T.M. system should be limited preferably to the following situations:

(*a*) Track maintained by machines.

(*b*) Tracks on double or multiple lines.

(*c*) Tracks monitored by special recording devices systematically and continuously at fairly frequent intervals.

20.12.3. Pre Requisites of D.T.M.

Following are the pre requisites of D.T.M.:

1. Reasonably adequate ballast resistance.

2. Stable formation in major portion of the track length.
3. Effective track components.
4. Reasonable good track geometry.
5. Adequate retentivity of the packing.

20.12.4. Scope of work under D.T.M.

As per revised manual of 1985, under D.T.M. the maintenance operations can be classified in the three categories:

(*a*) Systematic maintenance.

(*b*) Periodical inspection and need based maintenance.

(*c*) Occasional maintenance.

20.12.5. Systematic maintenance

Under systematic maintenance by D.T.M. following works are classified:

1. **Systematic through packing.** In order to ensure that the entire track is opened out regularly and fittings, fastenings, etc. are examined properly at a regular periodicity. Normally through packing of entire track should be done once a year. Depending on the retentivity of the packing and the prevailing geometry of the track, Chief Engineer may decide, whether one round of through packing should be done in the entire beat or in selected portion of the beat to be done every year.
2. **Systematic over hauling.** Same as discussed under manual maintenance.
3. **Lubrication of rail joints and oiling of switch expansion joints.** The lubrication of rail joints and oiling of switch expansion joints should be done regularly in order to have a free and smooth movement of these fittings.

20.13. PERIODICAL INSPECTION AND NEED BASED MAINTENANCE

The items of work to be maintained are classified, based on the periodical inspection at prescribed frequency. How ever the maintenance is carried out based on actual need. Mostly this will consist of rectification of geometry of track after identification of defects. Operations involved are as follows:

20.13.1. Identification of defects

Defects in track are identified as follows:

(*a*) By manual inspection either by foot plate/brake van of a fast moving train or by trolly.

(*b*) By track recording with the help of portable accelerometer.

(*c*) Detailed ground maintenance during the inspection on foot by a permanent way inspector.

20.13.2. Analysis of track recordings

To decide the action to be taken for track maintenance an analysis of various defects is done, based on inspection of the track recordings. Based on this analysis following actions are planned:

(*a*) To select stretches of track which need immediate attention in order of priority.

(*b*) Stretches which require regular attention.

(*c*) Stretches which need no attention.

20.13.3. Record of observations in the field

According to 1986 track maintenance manual guide lines, the permanent way man will carry out inspection on foot and check the defective portions of the track systematically given in the programme of work in order of priority. Following defects should be noticed and recorded.

(*a*) Alignment — (*b*) Unevenness

(*c*) Cross level — (*d*) Loose packing of sleepers

(*e*) Gauge — (*f*) Loose, broken or missing fittings

These defects should be recorded in the prescribed performa of the department.

20.13.4. Ancillary items of track maintenance work

Following other ancillary item of track maintenance should be attended where ever required:

(*a*) Adjustment of creep

(*b*) Realignment of curves

(*c*) Destressing of low welded rails

(*d*) Gap surveys and their adjustment

(*e*) Cleaning of side drains, catch water drains and water ways etc.

20.13.5. Rectification of Defects

Next day the gang should rectify the defects marked by P.W.M.

20.13.6. Verification after rectification defects

Prior to boxing of ballast, the P.W.M. should check the defects rectified by the gang and ensure that all defects have been rectified satisfactorily.

20.14. OCCASIONAL INSPECTION WORKS

Following items are maintained occasionaly:

1. Repairs of formation and cess.
2. Scattered renewals of rails, sleepers, and other track components.
3. Restoration of correct spacing of sleepers.
4. Reconditioning of switches and crossings.
5. Making good of the deficiency in ballast.
6. Cleaning of yards and removing of weeds.
7. Improvement in the drainage system of yards.
8. Building of damaged rail ends.

20.15. QUALITY CONTROL

Quality control on the gang's work can be exercised as follows:

1. At the end of the work, P.W.M. should check the quality and progress of the work.
2. Other senior officials as APWI/PWI/A.E.N. should also check the work to ensure that the work parameters are with in permissible limits.
3. Track recording should be done periodically and track records are analysed carefully to ensure that the track is maintained to the required standard. The PWI/A.E.N. should travel with the track recording car and give a list of big defects (unevenness more than 15 mm, misalignment more than 10 mm, Twist of B.G. track more than 10 mm) to the P.W.M. for rectification with in next 48 hours.

20.16. Track tools and instruments etc.

Following tools and instruments are provided to each D.T.M. maintenance unit:

1. Stepped fealer gauge correct upto 1 mm = 1
2. 25 m long nylon chord with marking at 3.6 m and 7.2 m for checking the alignment and un even ness of the track = 1
3. One canne-a-boule with rubber cap for concrete sleepers and iron cap with wooden sleepers = 1
4. Gauge cum level = 1
5. 15 cms long steel scale = 1
6. 1 m long steel straight edge = 1

7. Complete set of tools for maintenances as per adopted maintenance practice = 1
8. If available one track recording cum corrector to record track geometry = 1

20.17. COMPARATIVE STUDY OF DIRECTED TRACK MAINTENANCE AND ROUTINE MAINTENANCE

It is given in tabular form in Table 20.4.

Table 20.4.

S. No.	*Directed track maintenance D.T.M.*	*Routine manual maintenance*
1.	It is a scientific and need based maintenance method.	It is the prescribed routine manual maintenance method. It is called systematic through packing.
2.	It provides maintenance of higher standard.	This method is based on the calendar system of maintenance.
3.	It is more rational and more economical in man power and material.	In this method entire track has to be through packed at a fixed cycle of time after opening each sleeper irrespective of the fact whether the whole length of track needs such maintenance or not.
4.	It gives better out put.	In this system prior to through packing no examination and measurements of track are taken.
5.	No extra work has to be done.	Extra work has to be done by the gangmen.
6.	Wear and tear of rolling stock and track components is less.	Due to repeated opening and repacking, the quality of track also deteriotes due to the disturbed stability of sleepers.
7.	This method is more scientific, rational, and economical method of maintenance.	It is not a scientific method.

QUESTIONS

1. Discuss the need for mechanised maintenance of railway track.
2. What are the requirements of mechanised maintenance.
3. Differentiate between ON track and OFF track tampers.
4. Explain the working principle of OFF track tampers.
5. State the preparations for working of tie tamping machine.
6. What works are to be done after working with the tie tamping machine.
7. Identify the incorrect statement/statements:
   (*a*) Manual track maintenance done by beater packing is useful for speeds upto 130 kmph.
   (*b*) Retentivity of packing with manual maintenance is not very good and the geometry of the track gets disturbed easily.
   (*c*) For high densities of traffic and high axle load and high speed trains manual maintenance is very good.
   (*d*) Manual maintenance is not tiresome.
   (*e*) Mechanised maintenance needs sophisticated machines.
8. Identify the correct statement/statements:
   (*a*) For mechanised maintenance the track should be elastic and free from surface defects
   (*b*) The ballast cushion under the bottom of the sleeper should not be less than 20 cm thickness
   (*c*) The tamping machine should be allowed to penetrate vertically into the ballast
   (*d*) The operator should have control over the tamping pressure
   (*e*) The suitability of tamper varies with the kind of sleepers
   (*f*) All are correct

9. Identify the correct statement/statements
   (*a*) OFF track tampers require no traffic blocks
   (*b*) They have been found very useful for packing points and crossings
   (*c*) They have been found very useful for packing newly realigned curves
   (*d*) The have been found useful for attending isolated tracks with concrete sleepers
   (*e*) All are correct
10. Identify the incorrect statement/statements:
   (*a*) The maintenance of OFF track tampers is very difficult
   (*b*) Transportation of OFF track tampers to the site is very difficult
   (*c*) The quality of maintenance by these tampers is not very good.
   (*d*) After deep screening and relaying the track the use of these tampers has not been found useful
   (*e*) None of the above

ANSWERS

7. (*c*, *d*) 8. (*f*) 9. (*e*) 10. (*e*)

21

Maintenance of Timber works

21.1. INTRODUCTION

The wood used for building construction and other Engineering works is called *timber*. It is a natural product. In the past it was available in abundance in India, but it is becoming scarce day by day.

21.2. ADVANTAGES OF TIMBER AS CONSTRUCTIONAL MATERIAL

The advantages of timber over other constructional materials are as follows:

(*a*) It is comparatively stronger than other construction materials keeping their weight in mind.
(*b*) It can be converted easily in any shape and size.
(*c*) Its different components may be joined to gether easily.
(*d*) It provides decorative surface to the structure.
(*e*) It is non conductor to heat and electricity.
(*f*) Its life may be increased by properly seasoning and preserving the surface
(*g*) It is economical as wastage is found very little.
(*h*) Its scrap value is also high.

21.3. CLASSIFICATION OF TREES

The trees available on the surface of the earth may be classified into the following two categories:

1. **Exogenous or out ward growing trees.** The trees which grow out wards and increase in bulk by forming concentric rings from the centre, are called exogenous trees. All commercial timbers (trees) used for Engineering purposes are included in this class as Deodar, Sal, Teak, Kail, Shishem etc.
2. **Endogeneous threes.** The trees which grow inwards by depositing each fresh layer of longitudinal fibrous mass, are called as Endogeneous trees, as palms, bamboo etc.

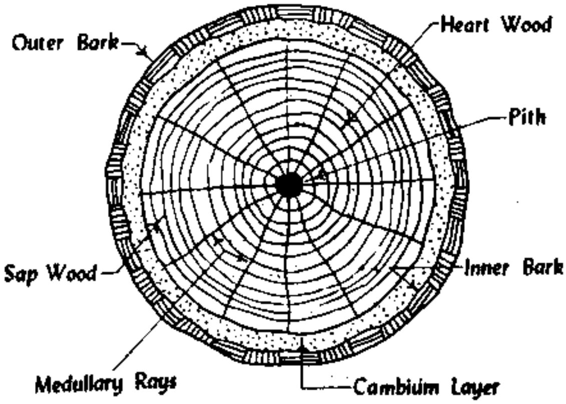


Fig. 21.1. Cross-section of an exogenous tree

21.4. STRUCTURE OF A TIMBER TREE

By cutting the trunk of a fully developed tree, following parts may be seen as shown in Fig. 21.1.

1. Pith. The inner most part of the timber log near about its centre, consisting mainly of soft tissues is called pith. Its size and shape depends on the age and type of the tree. It is found to vary from 1.5 mm to 10 mm in diameter.

2. Heart wood. The inner part of the timber log surrounding the pith or wood between sap wood and pith is called heart wood. This portion does not contribute to the growth of a tree. It simply forms a firm core which gives support to the tree trunk during storms. Heart wood is darker in colour and is compact, durable and very strong. This part of the log provides best type of timber for engineering purposes. Usually sap wood gets converted into heart wood in course of time varying from 10 to 30 years.

Sap wood. The portion of a trunk of a tree which carries sap from the roots to leaves and provides food material is known as sap wood. It is comparatively young in age. Usually it is of light colour and light weight. It exists inside the bark with living cells. It is unsuitable for engineering works as it is likely to be attacked by insects easily.

Cambium layer. The active layer between the sap wood and the inner bark is called cambium layer. In this zone, the growth of the tree takes place and wood is build up. It is an immatured sap wood.

Inner bark. The layer which covers the cambium layer of the log of a timber tree is called *inner bark* or Bast or *Pholeum*. It is always moist and soft. It is responsible for the transportation of food manufactured in leaves upto the root through branches and trunk.

Outer bark. The outer most covering of the log of a tree is called as outer bark. It is a dry and dead layer. This layer protects the tree from external weathering effects.

Annual rings. The nearly concentric rings in the log of a tree are called annual rings. These rings indicate the growth of the tree. The number of rings indicate the age of the tree in years as one ring is formed every year.

Medullary rays. The horizontal thin fibrous tissues extending radially from pith to wards cambium layer are called medullary rays. These rays hold to gether the annual rings of sap wood and heart wood. These rays also store the food of the tree and distribute to different parts as per need.

21.5. FELLING OF TREE

Trees used for building and engineering purposes should be felled at the earliest after the attainment of maturity. The attainment period of maturity may range from 40 to 100 years depending upon the species of the tree. If a tree is felled prematurely, the timber obtained will not be durable having excessive sap wood. On the other hand if the tree is felled after its maturity, the timber produced will be brittle. The central portion of the log may decay. In short the timber will not be suitable for engineering purposes.

21.5.1. Season of felling

In plains felling of trees has been found good in mid winter and in hilly areas in mid summer when the sap is at rest. Thus the trees should be felled when the sap is at rest. How ever trees may be felled in Autumn just before the fall of leaves when sap is still thin.

To get good yield from a tree, it should be cut from a place a little below the top soil but above the roots as shown in Fig. 21.2.

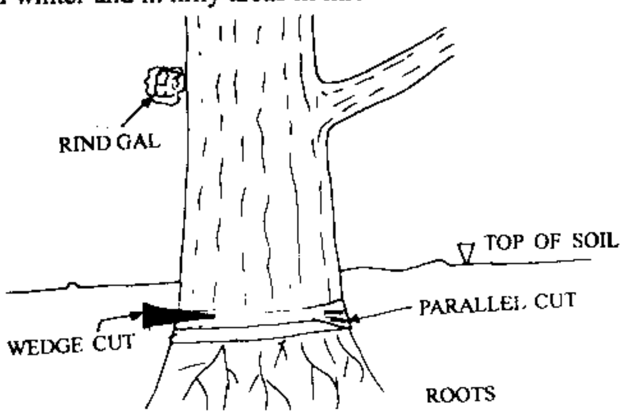


Fig. 21.2. Felling of a tree

21.5.2. Process of felling

A deep cut is made at the lowest possible point of the trunk with an axe. This cut should be made on the side opposite to that on which it is intended to be felled. The trunk then may be sawn to the point beyond the centre of gravity. Then a cut is also made on the opposite side of the first cut.

The top of the tree is tied on all the four diametrically opposite sides. The rope of the side, tree to be felled is pulled and its opposite rope is loosened slowly, so that tree may fall gently. The tree would break at the cut level and fall. It should not be damaged during felling process.

21.6. SEASONING OF TIMBER (IS 1141-1993)

A newly felled tree contains considerable quantity of moisture. In many cases this quantity of moisture may be even 100% based on oven dry weight of the wood, where as a well seasoned timber on an average should contain only 10 to 12% moisture. The process of reducing this natural moisture in timber to the required limit is known as seasoning of the timber. The control of moisture content is essential to ensure durability and satisfactory service of the timber. The limit of moisture content of seasoned timber depends on the surrounding humidity of the area. The degree of seasoning is necessary for proper retention of shape and size of the component parts of high class furniture as cabinet and furniture etc.

During the process of drying, usually timber develops some defects, which may be avoided by providing adequate protection against unduly rapid drying conditions and taking due care in stacking and top weighting the stacked timber. Further during drying timber shrinks.

21.6.1. Objectives of seasoning of timber

Following are the objectives of seasoning of timber:

1. The main objective of seasoning of timber is to eliminate the shrinkage of timber and its related defects before use.
2. Increase in the strength and electrical resistance of timber.
3. Improvement in wood working qualities, gluing, painting and polishing.
4. Reduction in weight.
5. Protection from the attack of insects and fungi depending upon the moisture content.

21.6.2. Permissible moisture content in seasoned timber (IS 287-1993)

The moisture content of a fully seasoned timber depends mainly upon the prevailing atmospheric conditions in the locality in which it has been seasoned. The moisture content of seasoned timber changes from season to season depending mainly upon the fluctuations in the atmospheric humidity of the area. For specifying the limit of moisture content in the timber, India has been divided into four climatic zones as follows: (See Appendix 21.1)

Zone 1. Average annual relative humidity less than 40%.

Zone 2. Average annual relative humidity between 40 to 50%.

Zone 3. Average annual relative humidity between 50 to 67%.

Zone 4. Average annual relative humidity greater than 67%.

The maximum permissible limit of moisture content of timber for different uses is shown in Table 21.1. below.

Table 21.1. Showing maximum limit of moisture in seasoned timber

S. No.	*Use*	*Max. Moisture content %*			
		Zone I	*Zone II*	*Zone III*	*Zone IV*
1.	Beams, Rafters and posts	12	14	17	20
2.	Doors and windows				
	(*a*) 50 mm and thicker	10	12	14	16
	(*b*) Less than 50mm thick	8	10	12	14
3.	Flooring strips	8	10	10	12
4.	Furniture and cabinet making timber	10	12	14	15

21.6.3. Determination of moisture (IS 11215-1991)

As per above I.S. the moisture content should be determined with in a depth of 12 mm from the surface leaving 30 cm from each end with the help of a moisture meter. The average moisture content for all the samples from a lot should be with in + 3% and moisture content of individual sample with in + 5% of the maximum value specified in the above Table 21.1.

21.7 METHODS OF SEASONING OF TIMBER

The methods of timber seasoning may be classified as

1. Natural seasoning
2. Artificial seasoning

21.7.1. Natural seasoning.

Natural seasoning is also called as air seasoning. The natural seasoning of a log of a freshly felled tree takes about 3 to 4 years. To reduce the seasoning period, the logs of freshly felled trees are sawn in the form of batten and planks and are stacked on a well drained place in shade a few cm above the ground. While stacking the sawn pieces, it should be ensured that there is free circulation of fresh air all round the each piece of timber. A gap of about 2.5 cms should be left between two adjoining pieces. The freshly sawn timber should not be exposed to strong winds and direct sun rays. The sawn timber should be stacked in a covered shed. It may be covered either on all the four sides or three sides, leaving the north side open. If it is not possible, the shed at lest should be covered at top. The floor level of the shed should be at least 50 cm higher than the surrounding ground level.

Air seasoning is a slow process. The actual period of seasoning depends on the species, size of timber and seasonal variation of climatic conditions. Ordinarily for fully air seasoning takes 6 months. 25 mm thick planks of hard wood may take 3 to 4 months for fully seasoning in a moderate climate. Scantling used for doors, window frames may take from 6 month to one year for fully seasoning.

This method of timber seasoning is simple, cheap and requires little supervision. However the rate of drying is slow and it is difficult to exercise control over temperature and humidity. Hence desired quality of seasoning is difficult to attain.

21.7.2. Artificial methods of seasoning

Following are the artificial methods of timber seasoning:

1. Kiln or hot air seasoning
2. Water seasoning
3. Steam or boiling seasoning
4. Salt or chemical seasoning
5. Electric seasoning
6. Smoke drying
7. Charring

27.7.2.1. Kiln seasoning (IS-7315-1974)

In order to reduce the seasoning time of timber and getting better quality of seasoned timber, kiln seasoning of timber is adopted. In this method timber can be seasoned to any desired moisture content, hence this method is commonly adopted for rapid seasoning of timber on a large scale. This process of drying timber can be carried out either in stationary kilns by stacking timber in kiln or in progressive kilns *i.e.* by moving the timber from one end of the kiln to the other end. Usually second method is preferred. This chamber is equipped for heating and humidifying the air to the desired conditions of relative humidity and temperature and for circulation of air across the timber stacked in the chamber.

In kiln seasoning of timber, usually steam is used for heating and humidifying the air in the kiln. The seasoning of timber is started at a comparatively lower temperature and high humidity. As the timber dries the conditions are altered gradually till at the end of the seasoning cycle, the temperature of the air in side the chamber is fairly high and the humidity is low. The kiln charge is allowed to cool in side the chamber before removal. Kiln seasoning of timber takes about 5 to 10 days for proper seasoning depending upon the species and size of the timber section.

Though this method of timber seasoning gives a well seasoned timber as it controls all the three important factors namely circulation of air, relative humidity and temperature of the air. How ever this method is costly and can be used for timber sawn to small pieces and needs skilled supervision.

21.7.2.2. Water seasoning

In this method the freshly felled log of suitable size is totally immersed in running water with the thicker end of the log pointing up stream. The sap of the timber is washed by water. After a period of 3 to 4 weeks, the logs are removed from the water and kept in open air to dry out. Some authors have suggested that this method of seasoning takes 3 to 4 years. Some authors have suggested that this method renders timber less liable to wrap and crack, but it reduces the elasticity and durability of the timber considerably making it weak and brittle.

21.7.2.3. Steam seasoning

In this method, first timber is immersed in water and then water is boiled for 3 to 4 hours. In this method the timber is exposed to steam sprays. The timber dries out slowly and seasoned. Though this method is very quick and reduces the shrinkage to a great extent, but it is expensive and affects the strength and elasticity of timber.

21.7.2.4. Chemical seasoning

In this method the timber is immersed in a solution of suitable salts, which absorbs the inside moisture content of the timber. After this, the timber is taken out and dried in air. In this case the interior surface dries before the exterior surface, hence there are less chances of developing cracks on exterior surface.

21.7.2.5. Electric seasoning

It is a well known fact, that green timber offers less resistance to the flow of electric current in comparison to dry timber. The resistance is inversely proportional to the moisture content present in the timber. Thus in this method a high frequency alternating current is used to dry the timber. The current produces heat, which dries out the timber. This is the quickest method of timber seasoning, but very costly. Hence this method is not feasible to season timber on commercial basis.

21.7.2.6. Smoke drying

In this case, timber is dried over a mild heat such as of straw and twig etc. The heat should be applied gradually and it should be ensured that splitting of timber does not take place. This method of seasoning makes the timber hardened, more durable, and worm attack proof. Generally this method is used for bending planks for boat building.

21.8. DEFECTS OF TIMBER

Generally defects in timber can be classified as:

1. Natural defects
2. Those developed after felling the tree

21.8.1. Natural defects developed during the growth of the tree

Following are natural defects, which occur in all kinds of trees depending upon the soil on which they grow and the climatic conditions of the area. As far as possible these defects should be removed during conversion for use.

(*a*) **Heart shakes.** These cracks occur in the centre starting from the pith and extending in the direction of medullary rays. It may also occur towards sap wood. Such defects are found in over matured trees. Some times they may also be caused by quick drying of the central part of the log, if a tree nearing maturity is felled and left un barked for a long time. Thus this defects is caused due to shrinkage of heart wood. Fig. 21.3. This defect renders conversion difficult and uneconomical.

(*b*) **Star shakes.** These cracks extend from bark towards sap wood. This defect develops if the tree is subjected to severe heat or frost during its growth. The width of these cracks is more at the outer ends and reduces towards centre. Fig. 21.4.

(*c*) **Cup shakes and ring shakes.** These cracks develop between two adjacent annual rings. When the rupture extends a part round, it is called a cup shake and when the whole way round, it is called a ring shake. This defect is caused either due to unequal growth or due to sudden contraction of timber under atmospheric changes assisted by twisting action due to wind. It is also caused by sap freezing during ascent of sap in spring. This defect interferes with conversion of timber, resulting in much wastage.

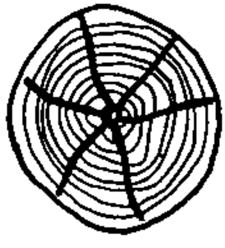


Fig. 21.3. Heart Shake

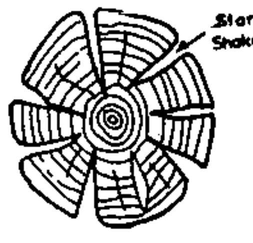


Fig. 21.4. Star Shake

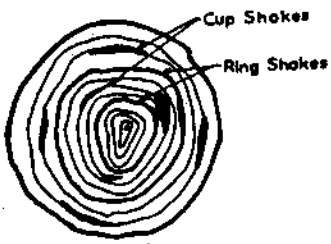


Fig. 21.5. Cup Shake

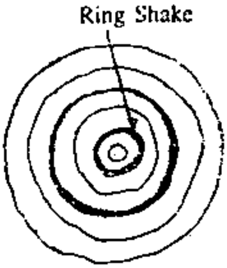


Fig. 21.6. Ring Shake

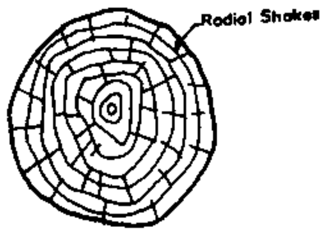


Fig. 21.7. Radial Shake

(*d*) **Radial shakes.** These shakes are similar to star shakes but occur due to exposure of timber to sun when felled timber is placed for seasoning. These cracks are fine, irregular and large in number. Many cracks run for a short distance from bark to wards centre and then follow the path of an annual ring and in the end go towards the centre radially. Fig. 21.7.

(*e*) **Rindgalls.** The peculiar curved swellings found on living or dead trees are called *Rindgalls*. Generally these are caused by the growth of layers forced over the wounds left due to imperfectly cut off branches. The sap from the trunk or branch log gets deposit at the point of removing branch imperfectly and forms the irregular curved swelling. Fig. 21.8.

Remedial measures. The branch should be cut carefully flush with the trunk and a coat of hot coaltar or ash and some other suitable paint will check the flow of sap.

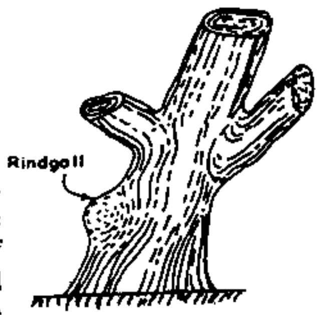


Fig. 21.8. Rind Gall

(*f*) **Knots.** These are the roots of small branches of the tree. They may be live or dead, but they break the continuity of the fibres. In the beginning, the root portion *i.e.* knots get food from stem, but finally becomes hard of black coloured rings. This portion of roots is known as knot. Small, hard and round knots are not harmful and the timber with such knots can be used for all works except tie bars and beams. Fig. 21.9.

Classification of knots. Knots are classified on the basis of their diameter as follows:

(*i*) **Nail knot.** If the diameter of the knot is less than 6 mm then it is called a *Nail knot.*

(*ii*) **Small knot.** If the diameter of the knot ranges between 6.5 mm and 20 mm then it is called *small knot.*

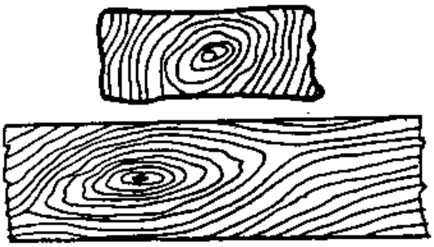


Fig. 21.9. Knots

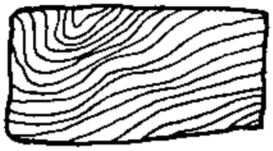


Fig. 21.10. Upset

(*iii*) **Medium knot.** If the diameter of knot ranges between 20 and 40 mm then it is called *medium knot.*

(*iv*) **Large knot.** If the diameter of the knot is more than 40 mm, then it is known as *large knot.*

Timber containing large or loose knots should not be used as they are un sightly and readily get removed. Timber containing large number of knots is difficult to work *i.e.* hard to plane and a source of weakness. The aggregate area of all kinds of knots is permissible upto 1.5%.

(*g*) **Up set or Ruptures.** The ruptures of fibers are caused due to injury, pressure or impact due to violent effect of wind or un skillfull felling of the tree. Fig. 21.10.

(*h*) **Twisted fibres or Wandering hearts.** This defect is developed due to the tree being twisted constantly in one direction by the force of prevalent wind. This timber can be used as poles or posts as it is un suitable for sawing. Fig. 21.11.

Fig. 21.11. Twisted Fibres

Fig. 21.12. Wind Cracks

Wind cracks. The cracks on the out side the bark of timber due to shrinkage of the exterior surface exposed to atmospheric effect as sun or wind etc. are called wind cracks.

End split. Cracks extending from one face to another is called *end split.*

Dead wood. Timber obtained from a tree felled after its maturity is called *dead wood.* It is light weight, and weak *i.e.* its strength is less and it is radish in colour.

Druxiness. The early decay of an healthy timber is called Druxiness. Whitish spots on the timber are indication of druxiness. It is caused by fungi.

21.8.2. Defects Developed after felling of a tree

Following defects are developed after felling of a tree.

Dry rot, wet rot, shrinking, swelling, warping, wane etc.

Dry rot and wet rot are also called as diseases of timber. It has been observed that timber obtained from a sound and matured tree and perfectly seasoned and placed in a well ventilated dry place or immersed in water lasts for several years. On the other hand if the timber is placed in such a place where it is likely to be subjected to alternate drying and wetting, wet rot develop in the timber. There are two common diseases of the timber.

1. Dry rot

It develops due to the lack of proper ventilation. In such situations the growth of fungus takes place in side the timber cells which eats the fibers of the timber and reduces them to dry powder. The fungus develops due to the decomposition of sap in the timber. The decomposed sap is a favourite food of fungus responsible for the dry rot. As the growth rate of fungus increases, the damage by dry rot also increases.

This disease is highly infectious and causes massive destruction of the timber. The powder of dry rot is yellowish.

This desease may develop in seasoned or unseasoned timber treated with preservatives. This desease is commonly observed in un ventilated wooden floors, warm cellers, basements, ends of timber built into walls with out protection, timber piles etc. This desease can be detected by tapping the timber and hearing its sound. The dull and heavy sound is the indication of decay of the timber by dry rot. Timber infected by dry rot has very little strength.

Remedial measures of dry rot

To prevent or eradicate the dry rot, following measures may be adopted:

(*a*) By providing free circulation of air.

(*b*) The infected portion with dry rot may be cut off and the remaining portion any be painted with copper sulphate.

(*c*) By exposing the infected portion to sun and sweeping off the fungus.

2. Wet rot

This disease is caused by alternate wetting and drying of timber. The cells of the timber are decomposed by damp and moisture. The affected portion of the timber is reduced to grayish brown powder. In this case the timber is decomposed first while wet and then scales off on drying. All types of timber used in un sheltered situations are liable to be attacked by wet rot.

Remedial measures

1. Providing proper shelter to the timber.
2. By avoiding alternate wetting and drying conditions of the timber.
3. By removing sap completely by seasoning timber well and then treating it with preservaties.

Circumferential shrinkage. On drying, the timber shrinks causing circumferential cracks radiating towards the centre as in the case of star shakes. These cracks decrease in width from the out side and usually are limited to the sap wood. It is caused due to shrinkage during seasoning.

Warp. It is the distortion or twisting out of shape. This is developed during drying and shrinkage. If the plank is slightly curved in the length direction then it is called bowing or simply bow In case timber is curved in cross section, then it is called cup or cupping.

Wane. It is the original rounded or splayed surface of the tree which remains at the edge of a piece of timber after conversion. It is not considered a defect if used where appearance of the object is not of importance such as in shoring, pilling etc.

21.9. DECAY OF TIMBER

When the timber is decayed or deteriorated to such an extent that it is no longer useful for Engineering works then such a timber is called *decayed timber.* Generally timber deteriorates in strength when subjected to excessive defects or diseases (discussed above) or attacked by certain insects. Insects in search of their food and sheltre damage the appearance and reduce strength of the timber. Generally timber is attacked by the following insects:

21.9.1. Pin hole borers

These insects attack the standing or recently felled trees. These insects are also called borer beetles. These are very small insects and bring out the decay of timber at a very fast rate. These insects attack sap wood of all species of hard wood.

These insects make pin holes and tunnels in the timber with out affecting the outer shell or cover. Timber attacked by this insect may look sound till it suddenly collapse.

21.9.2. Powder post beetles

These instects attack timber while it is stacked for air seasoning, or awaiting for use or used many years ago.

21.9.3. Marine borers

There borers generally are found in hot salty sea waters. These borers do not eat wood, but make hole or tunnel in timber to take shelter there. The body of these borers vary from few centimeters to as much as 3 metres.

Continuous immersion of timber or its product in a sea water also induces the danger of marine borer attack. No untreated wood is immune to the attack of marine borers. For boats, normal antifouling paints have been found to provide efficient protection against marine borers attack but in area where marine borer is particular problem, regular inspection should be carried out to ensure that un protected timber is not exposed by abrasion. Hence for marine work, naturally durable or adequately preserved timber should be used. Most of the available preservaties may reduce the rate of attack, but can not entirely prevent it.

21.9.4. White ant or termite

It has been discussed fully in chapter 3.

The magnitude of damage depends upon the following situations favourable to decay.

(*a*) Alternate wetting and drying conditions.

(*b*) Improper storage or stacking of timber.

(*c*) Improper or no seasoning of timber.

(*d*) Use of unseasoned timber with out treating with preservaties.

(*e*) Use of seasoned timber with out treating it with preservaties.

(*f*) Presence of sap and moisture and different type of insects.

(*g*) Development of defects during growth, conversion and improper use etc.

(*h*) Development of timber diseases.

(*i*) Effect of natural agencies.

(*j*) Improper positioning of structural members of timber.

Remedial measures

Damage due to insect attack can be minimised by providing adequate ventilation, preventing dampness, and impregnation of proper preservatives in properly seasoned timber.

21.10. MOULDS AND STAINS IN TIMBER

In the early stage of growth of trees, wood destroying fungi develop in them. These fungi are called mould or stain. These fungi are not particularly injurious provided the timber does not remain in damp conditions. Moulds cause discoloration of the timber to some extent which can be easily surfaced off.

21.10.1. Classification of timber stains

Timber stains may be divided into the following categories:

1. Stains developed by mould fungus and sap fungus. These fungi are troublesome.
2. Stains developed by fungus which can cause decay of timber. The effect caused by such fungi is called dote. (The strength decreases with age).
3. Stains developed during the growth of the tree. These stains develop due to soil and frost action.
4. Stains developed due to chemical contamination.

5. Stains developed due to the oxidation of the wooden cells. Due to the exposure to the direct sun, these stains become dark.

21.10.2. Brief description of different types of stains

1. **Mould fungi.** These fungi are minute microscopic plant organism. They attack the timber only under the following conditions when they are satisfied simultaneously.
   (*a*) The moisture content in the timber is more than 20%. and
   (*b*) Availability of sufficient air and warmth is there for the growth of the fungi.
   Mould fungi thrives or lives on the tree food *i.e.* sap. These stains or fungi neither attack wooden cells nor break them. Thus these stains do not affect the strength characteristics of the timber. Generally these stains are brown, green and some times they are found of while colour. These spots can be rubbed off by sand paper or brushing or by planning.
2. **Sap stain fungi.** Sap stains develop on those timbers which contain moisture content 27 to 30%. On soft woods the sap stain fungi develops spots of blue colour while on hard woods the colour of spots is found as grey. This fungi also do not attack the timber.
3. **Dote.** This fungi can cause decay of timber. If these spots are developed due to the presence of excessive moisture content and lack of ventilation, the strength of the timber is affected very badly.
4. **Mineral stains.** Mostly mineral stains are found to develop on hard timbers. The colour of mineral stains may be grey or brown. They also do not affect the strength of the timber. These stains can be removed by bleaching action.
5. **Chemical contamination stains.** These stains are developed on wooden surfaces as experimental tables used in chemical laboratories. Chemical action of acids cause red or rose coloured spots while alkaline chemical action develops blue or green coloured spots or stains.
6. **Iron stains.** These stains develop by a special type of chemical contamination. These spots are developed by a special alkanine substance called *Tannin*. However very few timbers have this substance in sufficient quantity to cause iron stains.

21.11. PRESERVATION OF TIMBER

Preservation is the process of protecting the timber structure from the attack of different destroying agencies such as moisture, fungi, insects, dry rot, internal decay etc. It also ensures increased life of timber and its durability.

The basic principle used for preservation of timber is to poison the food of fungi in the form of preservaties. The success of preservative treatment depends to a great extent on the proper choice of proper preservative and the method of its application. Thus before using a timber for structural purposes, it should be well seasoned and treated with a suitable preservative.

21.11.1. Requirement of a good preservative

Following should be the characteristics of a good preservative:

1. The preservative should be cheap and easily available.
2. It should be capable of being used by unskilled or semi skilled person.
3. It should be quite effective in destroying the fungi and insects, but should be safe and harm less for the persons and animals.
4. It should be highly resistant to moisture, fire and dampness.
5. It should be colour less and odorless, but it should give pleasant look after application.
6. Its covering capacity should be more *i.e.* a smaller quantity should be capable to cover more area.
7. It should have high stability, durability and penetrating power.
8. It should not be liable to be affected by heat, light etc.
9. It should not be washed away by water and should not react with building materials which come in contact with timber.

21.11.2. Types of preservatives

Following preservaties are commonly used:

21.11.2.1. Oil preservatives

These preservatives are generally used for out door and wet exposure con- ditions. Though they possess high toxicity and non corrosive qualities, but they are difficult to paint, Oil paints, creosote oil, solignum paints and coal tar etc. are classified under this category. They are used for members as poles, posts, piles, etc. as they give unpleasant odour and are difficult to handle.

21.11.2.2. Water soluble preservatives

These preservatives are commonly adopted for interior wood work as they can be washed away by rain water. They are odour less, colourless, and involve very little fire hazzard. Timber preserved by such preservatives can be varnished or painted easily. These preservatives contain organic or inorganic salts as zinc chloride, boric acid, and sodium fluoride etc.

21.12. METHODS OF PRESERVATION

Following methods can be used for preserving the timbers:

21.12.1. Charrying, Tarrying and creosoting

(*a*) **Charrying.** In this method no preservative is used. In this method, timber to be preserved is kept wet for about 30 minutes and then burnt to charcoal over wood fire. Finally it is quenched with water. This method is used where timber is to be used under ground as piles, posts etc.

(*b*) **Tarrying.** In this method the timber is coated with coal tar while it is in liquid state. Members of wood built into walls and ground are generally treated by this method. Door and wooden frames, piles etc. are treated by this method.

(*c*) **Creosoting.** In this method the creosote is applied under pressure to the timber stacked in a vertical air tight cylindrical vacuum chamber.

21.12.2. Surface treatment

In this method the preservative solution like tar, oil, paints, creosote etc. are applied by any of the following methods.

(*a*) **Brushing.** In this method, hot preservatic solution is applied to the timber by brush liberally, usually in two coats.

(*b*) **Spraying.** In this method, the preservative solution is sprayed under pressure by the spraying guns on the timber. This method is more effective and superior than brushing method.

(*c*) **Dipping method.** In this method, the timber is dipped in the preservative solution for a short period. This gives better penetration of preservative in the timber than brushing or spraying. Depth of penetration depends upon the type of timber.

21.12.3. Soaking treatment

In this method timber is submerged in the preservative solution for a long time till the required absorption of the preservative is achieved.

21.12.4. Hot and cold process

This method is recommended for treating sap wood and easily treatable heart wood. This process is considered to be the most efficient non pressure treatment. In this process the timber is stacked in a tank and the cold preservative, usually creosote is filled in the tank, till the timber is completely submerged. Then the preservative is heated upto a temperature of 85°C to 95°C and maintained at this temperature for a short period. Now the source of heating is withdrawn and the tank is allowed to cool gradually, while the timber is still submerged in the tank.

During this process of alternate heating and cooling, air in the timber first expands during heating and contracts during cooling, which creates a partial vacuum. Due to this partial vacuum the preservative is sucked into the timber.

21.12.5. Vacuum process

This is the most effective method of treating timber with preservative. In this process the preservative is injected into the timber under pressure. The preservative can be injected in two ways as follows:

(a) **Full cell or Bathed process.** In this process, the timber is placed in a airtight impregnating chamber. The air is sucked out by pumps from this chamber and the preservative, usually creosote oil (Dark brown coloured thick oil) under a pressure varying from 7 to 12.5 kg/cm^2, usually at 9.0 kg/cm^2 and at a temperature of 48°C 50°C is forced into the chamber. This pressure is maintained till the desired absorption is achieved. Under this pressure the preservative is injected into the timber.

Finally the pressure is released and vacuum again created to withdraw the excess preservative. This treatment protects the timber from dry rot and white ants and doubles the life of the timber. This process usually is applied for Railway wooden sleepers, piles and poles etc.

(b) **Empty cell or Rueping Process.** This process needs much less preservative to give the desired absorption, hence comparatively cheaper than the full cell or Bathed process. The timber is stacked in a strong steel cylindrical tank and its door closed tightly. In the tank, the timber is subjected to the air pressure of 1.75 kg/cm^2 to 5.0 kg/cm^2. This pressure is maintained during the filling of the preservative in the tank. When the tank is fully filled, air pressure of 5.0 kg/cm^2 to 12.75 kg/cm^2 is applied till the desired absorption is achieved. This pressure is then released which expels excess preservative from the cells of the timber. This method is recommended for preserving timber of mixed species.

21.12.6. ASCU treatment

This preservative has been developed by FOREST RESEARCH INSTITUTE DEHRADUN (FIR) to protect the timber from the attack of white ants. This preservative consist of 1 part (by weight) of hydrated arsenic pentoxide ($AS_2O_2.2H_2O$), 3 parts (by weight) of copper sulphate ($CuSO_4.5H_2O$) and 4 parts (by weight) of potassium dichromate ($K_2Cr_2O_7$). This preservative is available in powder form. To prepare the solution of this preservative 6 parts of the ASCU are mixed in 100 parts of water (by weight). This solution is applied or sprayed on the surface of timber to be preserved. The surface treated with ASCU can be polished, painted, and varnished or waxed.

21.13. COMMONLY USED TIMBER IN BUILDING WORKS AND THEIR WEIGHTS (IS-12896-1990)

1. **Babul.** Its functions and uses are same as those of Khair.
2. **Benteak.** Its strength is very close to teak and is suitable for all construction purposes and not prone to fungus attack. It is finished to a fine smooth surface and takes good polish. It is used for furniture, carriage, and house building and general carpentry.
3. **Chir.** It is not very durable. Its weight is 580 kg/m^3 and fit for rough work as for wooden boxes.
4. **Deader.** It is the strongest of Indian confiners. Its weight and strength is 20% less than teak. It has oil, hence not suitable for polish or paint. It weighs about 550 kg/m^3. It is used for furniture, house building and other construction work.
5. **Haldu.** It is a fairly hard and strong wood. It is about 10% harder than teak but slightly weaker in transverse strain, elasticity and compression. It breaks easily. It is easy to saw. It takes good polish. It is used for furniture, carving, turning, door and window frames and house hold fitments.
6. **Hollock.** It is not a durable timber un less properly treated. It can be readily treated and finished to

fairly good surface. It is used for house building in the form of beams, rafters, planking and scantling, furniture etc.

7. **Kail wood.** It is of pale brown colour timber. It is not very durable. It is easy to saw and work. It can be finished to a fine surface. It is more suitable for paint and enamel finishes than for polish work. It is useful for joinery, construction work, light furniture and house fitments.
8. **Khair.** The heart timber is very durable and is seldom attacked by white ants and fungii. It is extremely strong and very hard and rough timber. It is difficult to saw and machine, especially when the timber is old and dry. It finishes and polishes well. It is used for posts in house building, tool handles and tool bodies.
9. **Mango.** It is very sturdy when seasoned and is as good as teak, but not very durable in exposed position. It is attacked very easily by white ant. Its weight is 650 kg/m^3.
10. **Mahogany.** It is reddish brown in colour. It is moderately hard and durable. It takes good polish. As it contains resinous oil, it is not attacked by insects. It is used for cabinet making, furniture and building work. It weights about 690 kg/m^3.
11. **Mulberry**. Its colour is brown. It seasons well. It is strong, elastic and tough. It is easily turned, carved and finished. It is easy to work and gives a good finish. It is mostly used for sports goods like tennis and badminton rackets, hockey sticks, and cricket bats. It is good substitute for imported ash timber. It weighs about 670 kg/m^3.
12. **Sal wood.** It is pale brown in colour, darkening on exposure. It is a closed grained, hard and heavy timber. It is about 30% heavier, 50% harder and about 20 to 30% stronger than teak. It can absorb about 45% more shocks than teak *i.e.* it is 45% more resistant to shocks than teak.

    The heart wood is quite durable and immune to the attack of white ants and fungi, while sap wood is perishable. Well dried sal is difficult to saw and work. It does not give good finish. Hence it is a rough constructional timber. It is used as beams, rafters, piles, chokats for doors etc.
13. **Shishem.** It is dark brown in colour. It is closed grained, tough, hard and durable. It seasons well and takes good polish. It weighs about 880 kg/m^3. It is a very valuable timber for building construction. It is used for high class furniture and important building works.
14. **Teak wood.** It is a out standing timber in retaining shape and durability. The heart wood is one of the most naturally durable wood of the world.

Usually it remains immune to white ant and insect attack for a fairly long time. However it is not always immune to fungus attack (rot). It weighs about 770 kg/m^3. It can be finished to a very fine surface and it takes very good polish. Good quality teak wood is used for making furniture and important building works.

21.14. PERMISSIBLE SIZE OF KNOTS AND AGGREGATE AREAS OF KNOTS

Table 21.2. Permissible size and area of knots

Name of wood	Size of individual hard and sound knot not exceeding	Aggregate area of all knots not exceeding
1. **Deoder:**		
(*a*) First class	25 mm	1.0%
(*b*) Second class	40 mm	1.5%
2. **Teak wood:**		
(*a*) Superior	12 mm	0.5%
(*b*) First class	25 mm	1.0%
(*c*) Second class	40 mm	1.5%
3. Sal	25 mm	1.0%

21.15. PAINTING OF NEW WOOD WORK

While painting a new wooden surface, following operation are carried in order.

21.15.1. Surface preparation

The new wood work to be painted should be well seasoned, dry and it should not contain more than 15% moisture. Projecting fibers and irregularities should be smoothened off with the abrasive paper along the grains before painting, otherwise marks of abrasive paper may be seen if grains are rubbed across the grain. All un evenness is rubbed smooth with sand paper and the surface is thoroughly cleaned.

Before fixing to frames, wooden door and window shutters should be made smooth by rubbing them with sand paper of grade 60 and 80. Special attention should be paid to tops of shutters and surfaces in similar hidden locations, which can not be easily approached after they are fixed either in door or window frame. The nails should be punched to a depth of 3 mm below the surface. Grease or oil if present on the surface, should be removed by sand paper. For a new wooden work usually the sequence is, that it is knotted, primed, stopped and painted.

21.15.2. Knotting

A careful treatment of knots is essential as the resin coming out of the knot damages the paint film by cracking, peeling or brown decolouration. Thus knotting in wood work is the process of covering knot with a substance through which resin may not come out.

21.15.3. Methods of knottings

Following methods may be applied for wood knotting:

1. **Size or ordinary knotting.** In this method two coats of red lead solution in water and oil respectively are applied on the knot. The first coat consists of red lead ground in water and mixed with strong glue size as Fevicol is applied in hot condition on the knot. After drying the first coat after about 10 minutes, second coat consisting of red lead ground in lin seed oil and thinned with boiled lin seed oil and turpentine oil, is applied. This treatment is extended about 25 mm beyond the actual area required treatment.
2. **Patent knotting.** In this method two coats of varnish are applied on the knot. This varnish is prepared by dissolving shallac in methylated sprit or Neptha.
3. **Lime knotting.** In this method knot is covered with hot lime for about 24 hours. After this period the lime is scrapped from the surface and the knot is treated with ordinary method of knotting.
4. Loose, dead knots and specially those knots which are resinous should be cut off and replaced. For filling the knots, cracks, holes etc., following method may be adopted.

On a piece of wood about 20 × 15 cm face, and on the side where cross grains appear, a small quantity of fevicol is poured and the surface is scrapped with the edge of fine chisel to get fine powder of the wood. On this face very fine wood powder (saw dust) is mixed with the fevicol. The stiff paste so formed is used for filling the knot, hole etc. Whiting (chalk) should never be used as knot filling.

The filling, when dry is rubbed with carpenter's file. After this, the entire face is made perfectly smooth with medium grained and fine sand paper. The treated surface is then cleared with a piece of dry cloth to get a uniform appearance. The surface treated for knotting should be perfectly dry before painting.

21.15.4. Priming or 1st coat

After knotting, priming is applied to fill the pores of the wood. It also prepares a smooth base for the subsequent coats of paint and accelerates their drying. Selection of primer depends upon the nature and type of surface, nature of materials, degree of exposure and number of coats etc. Generally the ingredients of the priming is kept same as for the subsequent coats, but with varying proportions. On wooden work priming coat should be applied before fixing it in position. Priming coat should not only be applied on the surface which will be visible after fixing but those surfaces also should be given priming which will be in contact with masonry work, so that wood work may not absorb moisture from the masonry. It would be desirable to give an additional coat of priming to such surfaces before fixing them. Surface should be made smooth with sand paper No. 180 along the direction of grains and loose dust removed with brush before applying priming coat.

21.15.5. Stopping and filling

Stopping consists of rubbing the primed dry surface with either pumice stone or glass paper or both. Stopping and filling is done after the priming. If the surface is not primed first, the filler may shrink and fall away as wood would absorb oil from the filling, and the filling is liable to crack and fall. Filling is done to fill any nail holes or indentations or cracks in the wood surface. The function of filler is to fill the opened cells of the wood in the surface layer and level up small irregularities of the surface. Ordinary putty may be used for ordinary works.

Usually the filler is applied with a putty knife and the excess filler is removed immediately after application. After drying for 6 to 8 hours, the filler coat is rubbed again to get a smooth surface with emery paper No. 320. The filler coat should be of optimum thickness. It should be allowed to fully harden and flatten over night before the application of subsequent coat.

For high class interior works, hard stopping consisting of a mixture of 1/3 part of white lead and 2/3 part of ordinary putty is used for filling cracks and other such defects.

21.15.6. Application of Paint

Normally paint is done in three coats, two under coats and one finishing coat for the new wood work so that painted surface presents a uniform appearance and glossy finish free from streaks and blisters etc.

Under coats

Priming is taken as the first under coat. After drying of the priming coat, second coat of desired colour is applied exactly in the same way as the first coat. On drying the surface of the second coat, the surface is rubbed with pumice stone or glass paper. These under coats provide an even, smooth and hard foundation to the finishing coat.

Finishing coat

After completely drying of the under coat, finishing coat is applied very carefully in a thin coat so that the painted surface present a perfectly smooth and even surface with out any brush mark on it.

21.16. REPAINTING OF OLD WOOD WORKS

In case, the old paint is firm and in sound condition, then its removal may not be necessary. The surface should be rubbed with sand paper of No. 120 and lower. For removing, smoke, grease and oily substances the surface should be cleaned by washing with lime water and rinsing with clear water and dried. All dust and loose paint etc. should be completely removed. The surface should be washed with soap and water. Holes etc. if any be filled with wood putty as per IS 419-1967. Then it should be painted as discussed for painting new surfaces.

In case the old painted surface is blistered or flaked badly, old paint should be removed completely and the painting is done as for a new surface.

21.16.1. Removal of old paint

The old paint may be removed by the following methods:

21.16.1.1. Removal of old paint with caustic soda solution

A solution of caustic soda is prepared by dissolving 1 kg of caustic soda in 5 litres of water or the volume of water may be taken as 48 times that of caustic soda. After leaving the solution for few hours to cool down, it is applied on old painted surface either with a long stick, at one end of which a piece of cloth is tied or with brush. When the paint film lifts and wrinkles, it should be completely scrapped with painter's steel plate. If the film is not completely removed, the above solution is applied again on the patches remained and removed as above.

After removing the paint film completely, the surface is rinsed several times with clean water to remove all traces of alkali, which if allowed to remain, may spoil the new paint applied on the surface. At the time of final rinsing with water a little vinegar or accetic acid may be added to water to neutralize any residual alkali.

21.16.1.2. Use of soft soap and potash solution

In this case, a solution of 1 part of soft soap and 2 parts of potash is prepared by dessolving them in boiling water. After they mix together 1 part of quick lime is added to it. This solution may be of thick consistency. This whole mixture (1 part of soft soap, 2 parts of potash and 1 part of quick lime) is applied on the painted surface with a brush and left for about 24 hours. After this, the paint is removed by washing the surface with hot water.

21.16.1.3. By quick lime and washing soda solution

A mixture of creamy consistency is prepared by adding 2 parts of quick lime and 1 part of washing soda by adding required quantity of water. The mixture is spread over the painted surface and left for 1 hour. The surface is then washed with water fully.

21.16.1.4. Use of paint removers

These paint removers consist of a volatile organic liquid, thickened with waxes and other ingredients to retard the evaporation of organic liquid and to increase its volume so that it may be applied to a substantial surface. The paint remover is applied liberally with a brush and allowed to remain on the surface for few minutes. When the paint film starts to lift and wrinkles due to the paint remover action, it should be scrapped with painter's steel plate. In case film is not completely removed, a second coat of remover may be applied over such patches and the film thoroughly scraped.

After stripping the surface completely, it is washed with turpentine oil to remove all traces of paraffin wax, which is one of the ingredient of paint remover. If it is left in place, it will prevent the paint to dry.

21.16.1.5. Removal with blow lamps

The lamp flame is applied on the painted surface which softens the paint enough without either charring the paint or wood. The softened paint is then removed with a stripping knife. The flame is moved from place to place of the painted surface to soften the paint and it is removed by the knife when still is quite soften. Burning off should start from the bottom of vertical surface and should be taken up wards.

After the surface is fully cleared of the old paint, it is prepared as above and repainted as new wood surface.

21.17. PROTECTION OF TIMBER

Timber products of any type such as door and windows, furniture, piles etc. need protection against the damage by white ants (termite) and weather action, rot or insect attack etc. For durability and longer life all timber works need proper ventilation and protection from atmospheric action as direct sun, rain etc. Thus care should be taken that timber works are protected from direct rains, sun rays and should be kept in well ventilated conditions.

21.18. CRACKS IN WOOD WORK

Cracks in wood work mainly develop due to moisture movement. Thus a timber to be used in a good work should not have moisture content more than 12 to 15% of its weight *i.e.* it should be fully seasoned before use.

21.18.1. Cracks in door and window joinery

Cracks in door and window frames develop basically due to initial drying. They could be quite unslightly if un seasoned timber is used in their construction. The shrinkage in wood work is quite substantial in a direction normal to the length of the grain. There is no satisfactory remedial measure to check this shrinkage and warping of wood work if un seasoned timber is used. Thus to avoid cracks in timber work planks wider than 25 cm should not be used. In unavoidable circumstances ply wood panels may be used for internal works where it may not be subjected to wetting. Cracks in wood work or door panels etc. could be filled by filling them with some glue (Fabicol) and saw dust paste after cleaning the crack carefully. Cracks in wood work may also be filled with good quality putty made by mixing paint and whiting. One or two coats of paint may be applied. After this treatment moisture movement should be checked. These repairs should be carried out during dry weather and periodical renewal coats should be applied as and when needed.

The repair of cracks of wood work generally has not been proved effective. Hence the use of unseasoned wood should be avoided to check cracking. Suitable type of wood should be selected for a proective job and protected coats of paint etc. should be applied to it to check moisture movement.

21.18.2. Cracks around door and window frames

These cracks develop due to the following reasons:

1. **Shrinkage of wooden frames.** These cracks are easily noticeable if the wood used in frames is not properly seasoned.
2. **The frames are fitted flush with the wall.**
3. **Slack fitting between the frames and hold fasts.** When hold fasts are not fixed properly to the frames, heavy vibrations are transferred to the masonry due to repeated opening and closing of the door causing cracks.

As far as possible door and window frames should not be fitted flush with the plaster surface on either side. If it is not possible, the frame of the shape and design as shown in Fig. 21.12 should be used.

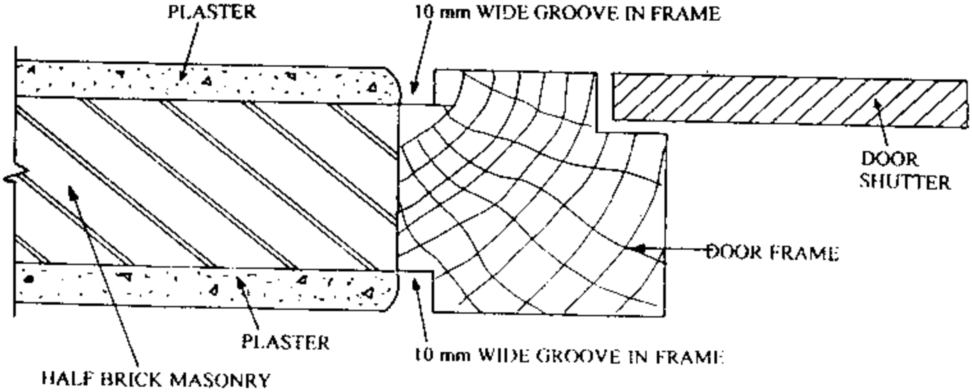


Fig. 21.12. Fixing of frames flush with plastered surface

The remedy for slack fitting is to dismantle the masonry and remove the frame. Refix it after securely fixing the hold fasts to the frame. In case doors are to be provided in half brick masonry walls then hold fasts should be at least 25 cm in length and should be embedded in 1:2:4 concrete, 2 brick courses in height and 1½ brick length.

QUESTIONS

1. Discuss the advantages of timber as building material.
2. Give the structure of a fully mature tree.

3. Discuss with neat sketch natural defects of timber.
4. Discuss decay of timber fully and also suggest their remedial measures.
5. Write a note on the stains of timber.
6. Name different types of preservatives and discuss one of them in detail.
7. Discuss important timbers used for engineering works.
8. Discuss in detail the procedure of painting a new wooden surface and an old wooden surface
9. Discuss the process of treating the knots.
10. The best season of felling trees is:
    (*a*) Mid winter (*b*) Mid rainy season
    (*c*) Autumn (*d*) All the above
11. A newly felled tree contains moisture upto.... of its oven dry weight.
    (*a*) 15% (*b*) 25%
    (*c*) 45% (*d*) upto 100%
12. A well seasoned timber less than 50 mm thick should contain moisture
    (*a*) 10 to 12% (*b*) 15 to 18%
    (*c*) 20 to 25% (*d*) 35 to 45%
13. Moisture content of a seasoned timber mainly is affected by
    (*a*) Relative humidity of the area (*b*) Soil on which the tree has grown
    (*c*) Age of the timber (*d*) Weight of the timber
14. The objectives of seasoning of timber are
    (*a*) To eliminate the shrinkage of timber
    (*b*) To increase its strength and electrical resistance
    (*c*) To improve its working qualities
    (*d*) Reduction in weight and protection from attackes of insects and rots
    (*e*) All the above
15. The best method of seasoning of timber is
    (*a*) Natural seasoning (*b*) Kiln seasoning
    (*c*) Smoke seasoning (*d*) Electrical seasoning
16. The average area of knots in a engineering timber should not be more than
    (*a*) 3.5% (*b*) 1.5%
    (*c*) 2.5% (*d*) 4.5%
17. Knots in timber are classified on the basis of
    (*a*) Weight of the timber (*b*) Diameter of the knot
    (*c*) Age of timber (*d*) Specie of timber
18. According to diameter knots may be classified as
    (*a*) Nail knot (*b*) Small knot
    (*c*) Medium knot (*d*) Large knot
    (*e*) Al the above
19. Defects developed after felling the tree are
    (*a*) Dry rot (*b*) Wet rot
    (*c*) Warping (*d*) Circumferential shrinkage
    (*e*) All the above
20. Preservation of timber is the process of protection of timber from the damage due to
    (*a*) Moisture (*b*) Fungi
    (*c*) Insects (*d*) Dry rot or internal decay
    (*e*) All the above

ANSWERS

10. (*a*)	13. (*a*)	16. (*b*)	19. (*e*)
11. (*d*)	14. (*e*)	17. (*b*)	20. (*e*)
12. (*a*)	15. (*b*)	18. (*e*)	

22

Inspection of Culverts and Bridges

22.1. INTRODUCTION

Bridges are the key elements of the transportation net work due to their strategic locations and the dangerous consequences of their failure or reduction in their capacity. A bridge is a quite massive structure and requires substantial quantity of material and huge amount of money for its construction. Though the life expentency of sub structure and super structure of a bridge is 100 years and 70 years respectively, but if not maintained properly, their lives may reduce drastically, hence the importance of their maintenance. But before carrying out maintenance operations, it is essential to carryout proper and timely inspection to assess the quantum of damage and their locations of occurrence. The fundamental justification of bridge inspection programme lies in the assurance of the safety. Timely and economic planning and programming of remedial and preventive maintenance and repair work of the bridge with minimum interruption to traffic are dependent upon detailed inspection of the bridges. Thus in this chapter inspection of bridges will be discussed before maintenance.

22.2. AIM OF INSPECTION

The aim of inspection is to identify and quantify the deterioration caused by applied loads and other factors such as live and dead loads, wind loads, physical and chemical influence of environment. Apart from inspection of bridges, damaged caused by unpredictable natural phenomenon or collision of vehicles etc. should be identified. Inspection is also necessary to identify the effect of any built in imperfection. Inspection may also help to increase the life of older bridges. There are some types of deteriorations which appear in the early life of the bridges, which if not repaired promptly, can reduce their service life considerably.

22.3. SPECIFIC PURPOSE OF BRIDGE INSPECTION

Following are the specific purpose of bridge inspection:

(*a*) To determine the soundness of the bridge structure and to decide the action to be taken to make it safe.

(*b*) To identify the actual potential sources of trouble.

(*c*) To record the condition of the structure systematically and periodically.

(*d*) To impose speed restriction on bridge if required, till the necessary repairs of the bridge are carried out.

(*e*) To determine whether major rehabilitation of the bridge is necessary to cope with the natural environment and traffic passing over it.

22.4. PLANNING OF BRIDGE INSPECTION

For a well organised, efficient and complete inspection careful planning is essential. Bridges over water are inspected at times of low water after the monsoon. Bridges requiring high climbing are inspected when high velocity winds or extreme temperatures are not prevalent. Bridges having troubles due to thermal movements should not be inspected during extreme temperatures. The bridge inspection should start from foundation and end with supper structure.

22.5. SCHEDULE OF INSPECTION

As per way and works manual of Indian Railways, the schedule of inspection of various officials is as follows:

(*a*) All the bridges are to be inspected by P.W.I./I.O.W. once a year before monsoon.

(*b*) All the bridges are to be inspected by A.E.N. once a year after monsoon.

(*c*) All the important bridges are to be inspected by divisional engineer once a year after monsoon.

(*d*) All steel structures are to be inspected by bridge inspector once in 5 years and selected bridges by bridge engineer/deputy chief engineer (B & F) as and when found necessary.

(*e*) Along with bridge inspection, track on bridge should also be inspected thoroughly.

22.6. PRELIMINARY STUDY

While going for bridge inspection, one should be familiar with the following features of the bridge:

(*a*) Completion plans of bridge, if available.

(*b*) Foundation details, piles or well foundation.

(*c*) Earlier inspection reports.

(*d*) Report of earlier repairs/strengthening carried out in the past.

(*e*) Traffic data as no of trains passing, type of locomotive, rolling stock etc. running in the section should be noted on the cover sheet of the bridge register.

(*f*) For major girder bridges stress sheets have proved useful.

22.7. EQUIPMENT REQUIRED AT THE TIME OF INSPECTION

For thorough inspection of the various elements of bridges, following equipments are required:

1. Pocket tape
2. Chipping hammer
3. Plumb bob
4. Straight edge
5. 30 m steel tape
6. Feeler gauge
7. Long line with weights
8. Wire brush
9. Thermometer
10. Elcometer
11. Mirror
12. Magnifying glass
13. Centre punch
14. Calipers
15. Torch
16. Screw drivers
17. Paint and brush
18. Gauge cum level
19. Nylon cord
20. 15 cm steel scale
21. Inspection hammer
22. Rivet testing hammer

Following additional equipment also may become necessary depending upon the site condition of the bridge at the time of inspection:

(*a*) Scaffolding

(*b*) Ladders

(*c*) Boats or barges

(*d*) Echo sounders

(*e*) Levelling equipment

(*f*) Binocular and camera

(*g*) Dye penetrants to detect cracks in welds

22.8. CLASSIFICATION OF INSPECTION

Bridge inspection may be divided into the following two groups:

22.8.1. Routine inspection

Routine inspection aims to look after the general examination of structures at regular intervals and the spots having outward physical defects repaired immediately. Routine inspection generally is applicable to short span brides. It is carried out before the on set of monsoon and the details are recorded on a performa. In order to check deterioration, the post monsoon inspection also is carried out and both datas are compared and deterioration detected.

22.8.2. Detailed inspection

The detailed inspection involves the visual examination of all super structure and sub structure elements. It is sub divided into the following two categories.

(*a*) **General.** In this category the items of the check list are inspected either visually or with the help of standard instruments. Generally this inspection is carried out once in two years.

(*b*) **Major inspection.** In this case close examination of elements with the help of standard instruments and access facilities is carried out. Generally it is conducted at about 5 years intervals depending upon the design of the structure. It is started from the foundation and carried out right upto super structure including track.

22.9. SPOTS TO BE CHECKED DURING DETAILED INSPECTION

During detailed inspection, following spots are checked:

(*a*) Foundation settlement and movement and material disintegration

(*b*) Abutment and priers

(*c*) Cracks in metal works

(*d*) Damaged structural members

(*e*) Excessive vibrations

(*f*) Behaviour of expansion joints

(*g*) Deterioration and cracks in concrete

(*h*) Loose connections

(*i*) Indiscriminate past maintenance

(*j*) In operative expansion bearings

(*k*) Approaches of bridges etc.

22.9.1. Foundation

As stated above at foundation level following points should be examined carefully:

(*i*) Any abrubt change in the bridge alignment and settlement.

(*ii*) Movement of foundation and depth of scouring.

(*iii*) Bed levels of river and cracks in masonry if any.

In majority of the cases the visual inspection of bridge foundation is very difficult and the behaviour of the foundation has to be judged based on observations of exposed elements of the bridge structure. The movements of foundation often may be detected by the deviation from the geometry of the bridge.

Any abrupt change or kink in the alignment of the bridge indicates the lateral movement of the pier as indicated in Fig. 22.1.

Inadequate or abnormal clearance between the ballast wall and end girders indicate the movement of the abutments such as bulging and leaning etc. of the abutment. At the time of inspection following defects should be attended.

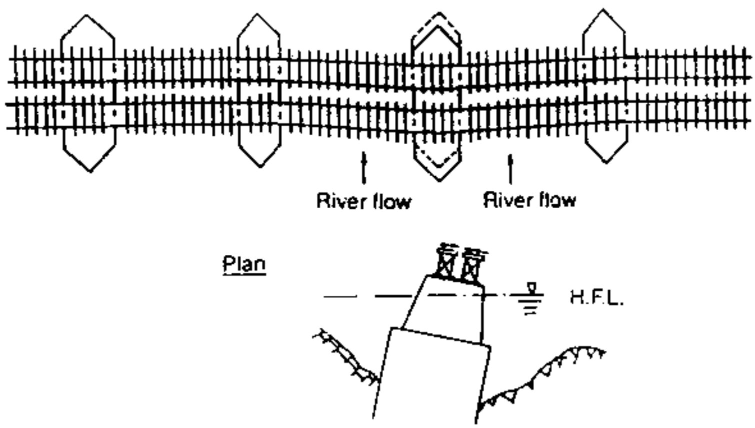


Fig. 22.1. Effect of scour on deep foundation

22.9.1. Disintegration of foundation material

(*a*) **Open or shallow foundations.** In case of open foundations in many bridges, during dry season, some portions of foundations under priers may be visible. Such portions may be probed easily to ascertain the deterioration of the construction material. The deterioration may be due to weathering of construction materials or leaching out of mortar etc. If the foundation so examined indicates signs of deterioration, then other foundations of piers should also be examined by excavating the soil around these foundations. The excavation around the foundations of piers and abutments should be done very carefully, tackling small portion of the foundation at a time, especially in the case of arch bridge. The excavation around foundation results in the removal of over burden in the vicinity of the foundation, resulting loss in bearing capacity and longitudinal resistance. As far as possible such excavations should be avoided in situations where water table is high. In such situations excavations should be done when the water table is at the lowest level. It is the ideal situation for such excavations.

(*b*) **Deep foundations.** In case of deep foundations in rivers or creeks having perennial presence of water, a portion of foundation exposed to dry weather conditions can be easily examined and assessed any deterioration. In case any deterioration observed, then it is advisable to carry out inspection of under water portion with the help of divers, using diving equipment and under water cameras.

22.9.2. Abutments and piers

22.9.2.1. Heavy localised scour in the vicinity of piers and abutments observed

A serious problem frequently encountered around piers and abutments is that of scour. The erosive action of running water results in loosening and carrying away bed material from the bed and banks of the river causing scouring of bed and banks. Local scouring mostly occurs around the following locations.

(*i*) Nose of the pier
(*ii*) Head of the guide bund
(*iii*) Down stream side of drop walls
(*iv*) Down stream side of skew bridge
(*v*) Where hard strata is met surrounded by comparatively softer erodable material
(*vi*) Out side of the curve in a bend in the course of river/stream etc.

During floods, the scour will be maximum, but during the period water level subsides, the scoured portion of the river bed partially or fully would be silted up. Thus the inspection carried out during dry season at the best can indicate only the possible locations of the excessive scour occurred during flood season, but it will not be possible to assess the magnitude of such scour. After identifying the locations of heavy scour, the measurements should be carried out in rainy season during medium floods. Such measurements can be used to ascertain the grip length of deep foundations available during floods.

The most effective and least expensive method of inspection of scour determination is taking soundings with long line. This is the most commonly used method. Echo sounder method is the sophisticated method of measuring scour as well as bed levels of the river.

If the shallow foundations are not protected from scour, it may lead to removal of material from beneath the foundation, resulting

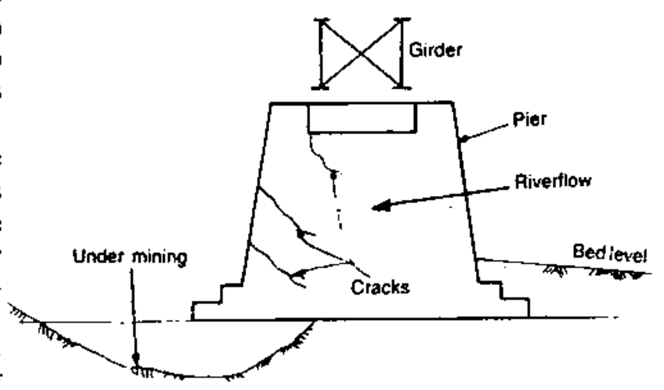


Fig. 22.2. Effect of scour on shallow foundation

development of cracks on the portion of abutment or pier above water as shown in Fig. 22.2. Undermining of deep foundations lead to tilting or sinking of a pier.

This is indicated by a slight change in the cross level of the track over the bridge. Fig. 22.1. In case the longitudinal level of the track gets disturbed, it is an indication of sinking of pier as shown in Fig. 22.3. All

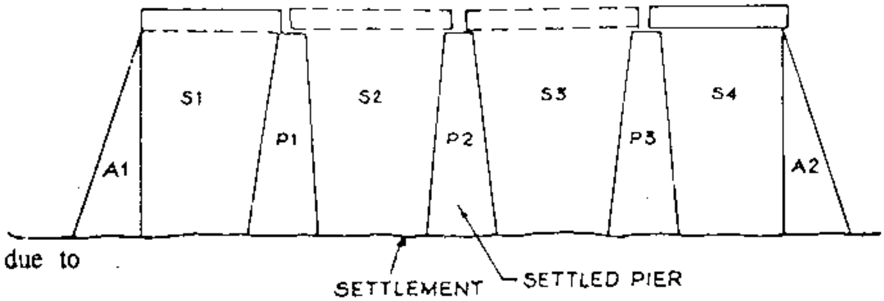


Fig. 22.3. Sinking of pier

these defects should be recorded in the bridge register immediately. These notes will be helpful for proper analysis and execution of suitable corrective measures to prevent total failure at a later date.

22.9.2.2. Settlement

The settlement may occur due to the following factors:

1. Scour
2. Increased loads
3. Consolidation of the under lying material
4. Failure or yielding of under lying soil layer.

Uneven settlement

The uneven settlement of the foundation may occur due to the following factors:

1. Difference in loading pattern in different parts of pier or abutment.
2. Due to different soil strata below the foundation.
3. Due to varying pattern of scour in different parts of foundation.

The presence of uneven settlement may be detected from the observations of cracks pattern on the pier/abutment/wing walls etc. some times uneven settlement may lead to tilting of abutment or pier. It is difficult to measure the tilt of pier/abutment.

22.9.3. Cracks in abutments and piers

During the inspection of abutments and piers following aspects should be noted:

(*a*) Cracking and crushing of masonry

(*b*) Weathering

(*c*) Failure of mortar

(*d*) Bulging

(*e*) Transverse cracks in piers

22.9.3.1. Cracking and crushing of masonry

This type of defect usually is noticed around the bed blocks. It occurs mainly due to the following reasons:

(*i*) Due to excessive dynamic impact.

(*ii*) Due to reduction in strength of construction materials with aging.

22.9.3.2. Weathering

This defect develops due to the exposure of materials of construction in the bridge to the severe environmental conditions over long periods of time. Bridge structures which undergo alternate wetting and drying are prone to develop weathering defects. This defect can easily be identified by tapping the masonry with the help of a chipping hammer. The spalling off the layers of the material on hammering, the masonry indicates surface deterioration, where as dull or hollow sound indicates the deterioration of stone/brick /concrete masonry as the case may be.

22.9.4. Failure of mortar.

Lime and cement mortars with free lime contents are subject to leaching due to rain or running water action. As a result of leaching out, the binding power of mortar gradually decreases. Some times this defect can be covered up by pointing the masonry from time to time. This defect can be identified by removing the mortar from a few places by raking out the joint with sharp tool. If the material, taken out from the joint is powdery with complete separation of lime and sand particles, is a definite sign of loss of mortar strength. The leaching of mortar also leads to loose or missing bricks or stones.

22.9.5. Bulging of piers

Essentially it occurs due to excessive back pressure in abutments, wing walls and parapet walls. The excessive back pressure develops due to the following reasons:

(*i*) Due to excessive surcharge with increased axle loads.
(*ii*) Due to chocking up of weep holes.
(*iii*) Due to improper back fill material.
(*iv*) Due to raising of wing walls and abutments over the years for the track.
(*v*) Due to failure of backfill material on account of clogging of material. Proper corrective measures should be taken immediately.

22.9.6. Transverse cracks in piers.

The transverse cracks may develop due to the following reasons:

(*i*) Due to increase in longitudinal forces coming over the pier, resulting in increased tensile stresses in portions of prier and correspondingly redistributing higher compressive forces in the compressive zone.
(*ii*) The increase in longitudinal forces may also develop by freezing and zamming of bearings due to improper maintenance.

In case such transverse cracks are observed on tall masonry piers of bridges in the vicinity of stopping places such as signals, the condition of bearings must be examined. To ascertain the reason of such cracks detailed investigations must be carried out and remedial measures undertaken on priority basis. How ever such cracks are observed very rarely. Many a times such cracks are observed on plain concrete or R.C.C. piers of recent origion. The reason for the development of these cracks is attributed to the long gap between two successive concrete lifts due to the intervention of rainy season. In such situations when the work is recommenced, following precautions should be taken:

(*i*) Clean the old concrete surface of all loose matter by rubbing it with wire brush.
(*ii*) Clean this rubbed surface by water jet.
(*iii*) Spread a layer of neat cement slurry over this surface before laying a new lift or layer.

A good measure will be the provision of dowel bars at the interface.

22.10. ARCH BRIDGES

Almost all arch bridges are of old origion, but still they are quite strong to carry the present day traffic with increased axle loads and longitudinal forces with out much signs of distress.

For proper inspection of any structure, it is necessary to have the under standing of the load transfer mechanism in that structure. In case of an arch structure, the loads coming on the arch are transferred as vertical reaction and horizontal thrust on the sub structure *i.e.* pier or abutment as shown in Fig. 22.4 Thus in case of arch structures the soundness of foundation is extremely important.

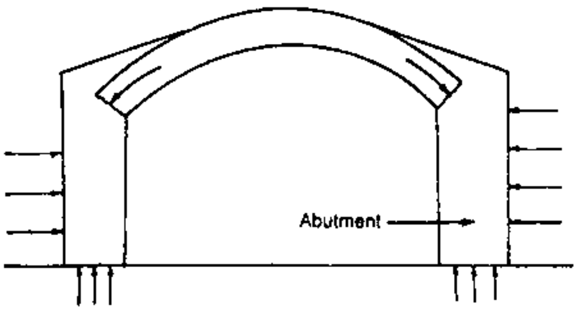


Fig. 22.4. Load transfer mechanism

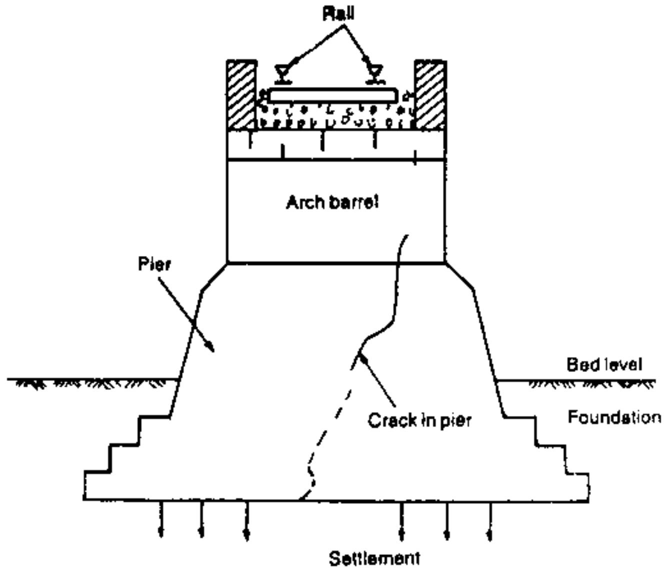


Fig. 22.5. Cracks due to unequal settlement of foundation

22.10.1. Cracks in abutment and piers in arch bridges

This type of cracks indicate the differential or uneven settlement of foundations. These cracks are of serious nature. In the worst conditions such cracks extend through the arch barrel and are seen as longitudinal cracks *i.e.* parallel to the direction of traffic in the arch barrel as shown in Fig. 22.5.

22.10.2. Cracks associated with spandrel wall

In case of brick masonry bridges where spandrel walls are constructed monolithically with the arch barrel, some times longitudinal cracks are developed under the inside edge of spandrel wall on the intrados.

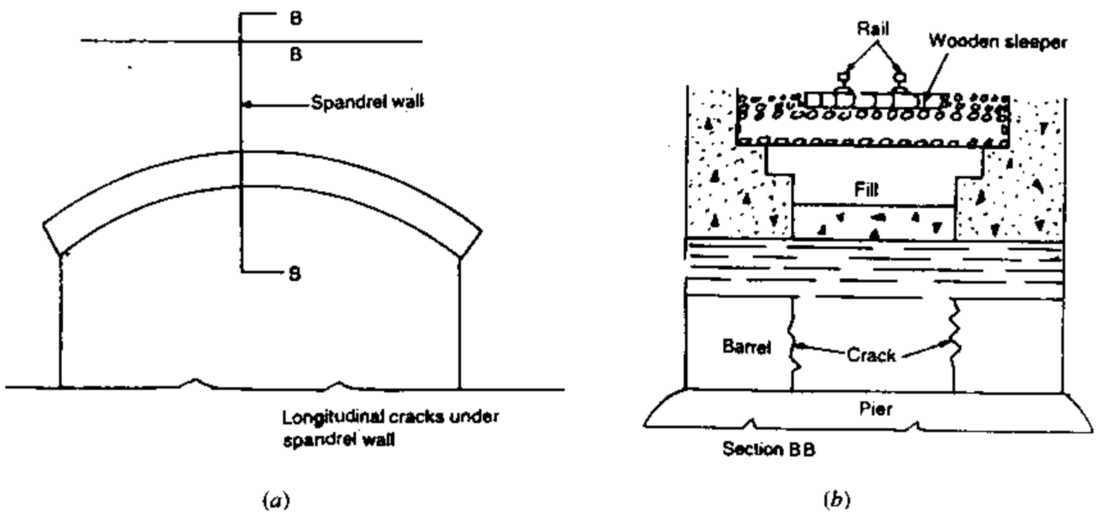


Fig. 22.6. Longitudinal cracks under spandrel wall

If these cracks are fine and do not widen with time, then they are not considered serious, but they should be kept under observation Fig. 22.6.

In case these cracks show tendency to widen with time, then the problem may be due to excessive back pressure on the spandrel wall due to ineffective drainage or excessive surcharge load from the track. Drainage blockage and excessive surcharge many also lead to sliding forward of the spandrel wall, particularly where spandrel wall and the arch barrel are not monolithically connected Fig. 22.7.

The excessive back pressure on spandrel walls may also lead to bulging/tilting of the spandrel walls.

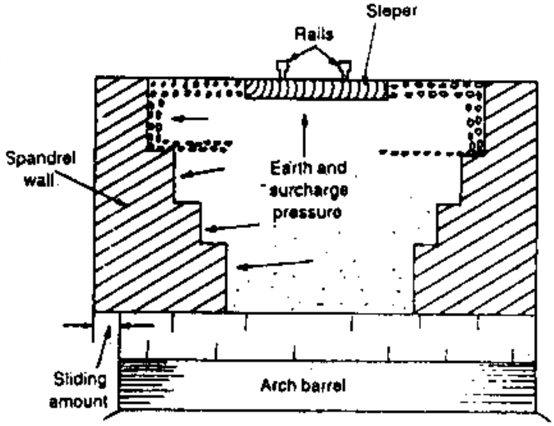


Fig. 22.7. Sliding forward under spandrel wall

22.10.2.1. Remedial measures of this defect

Following measures may be adopted to check this defect:

(*a*) This defect can be checked by improving the drainage of the spandrel walls by clearing the weep holes in the spandrel walls and providing suitable backfill material over a strip of about 45 cm immediately behind the spandrel wall.

(*b*) The improvement of drainage of the arch should never be attempted by drilling holes through the arch barrel as it may lead to shaking of barrel masonry and widening of arch bridge.

22.10.3. Cracks on the face of arch bridge

Some times cracks develop at the junction of spandrel wall extrados of the arch in the vicinity of the crown of the arch as shown in Fig. 22.8. The cause of these cracks may be as follows:

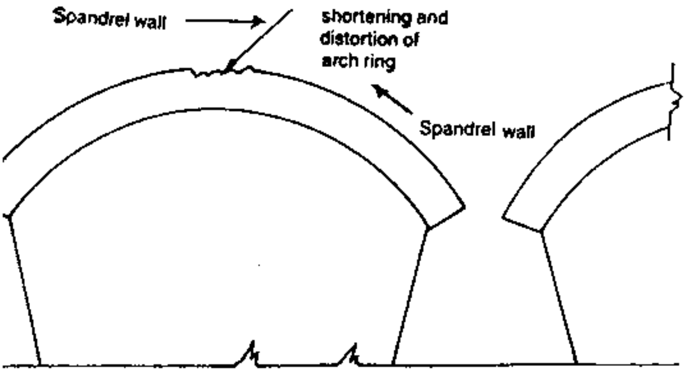


Fig. 22.8. Cracks in spandrel wall

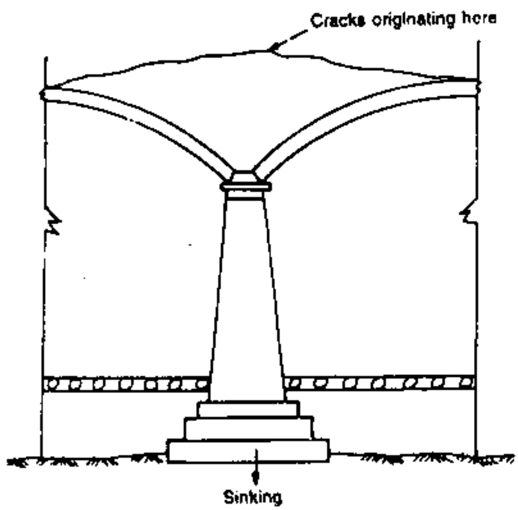


Fig. 22.9. Cracks in spandrel wall due to sinking of pier

(*a*) Excessive back pressure on the spandrel wall.

(*b*) Excessive rib shortening or distortion of the arch barrel due to excessive loads.

These cracks are serious in nature and indicate the inherent weakness in the arch. If these cracks breath under traffic, then they are due to rib shortening and distortion of arch barrel.

Cracks originating in spandrel walls above the piers may be due to the sinking of piers. This is a serious defect and needs immediate strengthening of foundation.

22.10.4. Cracking and crushing of masonry

Some times these type of defects are seen in the vicinity of the crown of the arch. These defects may be due to the following reasons:

(*a*) Excessive loading

(*b*) Inadequate cushion over the crown

(*c*) Weathering of stones/bricks

As per Indian Railways Arch Bridge code, a minimum cushion of 90 cm should be provided over the crown of the arch. Cushion is the vertical distance between the bottom of the sleeper and the top of the arch. Lesser cushion results in transfer of heavier impact on the crown which results in the cracking and crushing of the masonry in the vicinity of the crown.

22.10.5. Leaching out of mortar in the barrel

Many a times mortar leaching in the barrel has been noticed. This defect is attributed due to poor drainage. Water trapped in the fill above the arch seeps through the joints.

22.10.5.1. Remedial measures

This defect can be rectified by the following measures:

(*a*) Seepage through joints may be checked by grouting the joints.

(*b*) By improving drainage through weep holes.

22.10.6. Loosening of key stone and voussoirs

This defect can happen due to the following reasons:

(*a*) Tilting of abutment or pier due to excessive thrust.

(*b*) Transfer of more dynamic forces due to lesser cushion.

22.10.7. Transverse cracks in the arch intrados

These cracks are serious in nature. They indicate the presence of tensile stresses at the intrados of the arch. In the initial stage these cracks are seen in the vicinity of the crown of the arch. These cracks have a tendency to develop in diagonal or zig- zag direction in the stone masonry arches. This pattern is exhibited due to the fact that cracks always progress or develop along the weakest plane in the structure. In case of stone masonry, the weakest plane is along the mortar joints. These cracks indicate serious weakness in the arch and need proper investigation and adoption of appropriate strengthening measures.

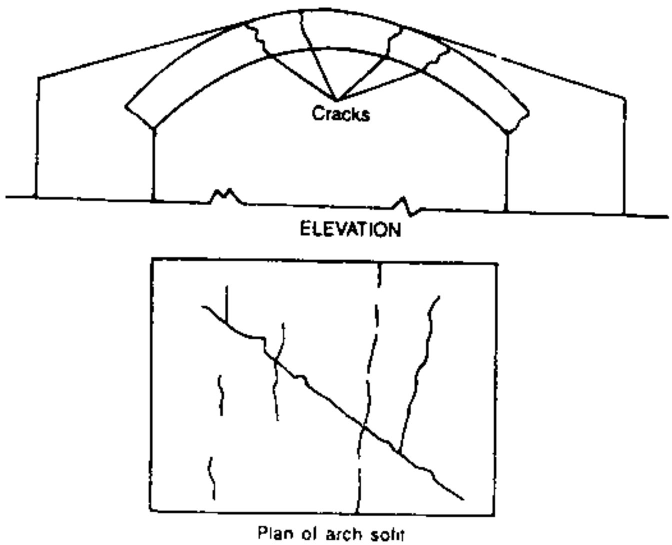


Fig. 22.10. Diagonal and transvers cracks at intrados

22.11. BEARINGS

Bearing is one of the most important part of a bridge, which transfers the forces from super structure to the sub structure. It also allows necessary movements in the super structure caused by the temperature variations with out over stressing.

Bearings used on Indian Railway bridges

Generally following types of bearings are used on Indian Railway bridges:

(*a*) Elastomeric bearings (*b*) P.T.E.F. bearings

(*c*) Sliding bearings (*d*) Rocker and roller bearings

Here only first two types of bearings have been discussed in brief.

22.11.1. Elastomeric bearings

The material of this type of bearings which does not conform to the specifications, develops defects like cracking, splitting, bulging, or tearing etc. The first sign of distress in this type of bearings is the development of horizontal cracks near the junction of rubber pad and steel laminate. These bearings should also be examined for excessive rotation which is indicated by the difference in thickness between the back and the front of the bearing. These bearings need replacement every 15 or 20 years. For the replacement of bearings, the girder will have to be lifted up at pre designed and predetermined locations.

22.11.2. P.T.F.E. Bearings

For the proper functioning of this type of bearings, the surface between the stainless steel plate and P.T.F.E. elements should be dust free. If it is not kept dust free, excessive frictional forces will be transferred to the sub structure. The surface should be lubricated by silicone grease which reduces the coefficient of friction to a great extent.

22.11.3. Inspection of bearings

Following elements of bearings should be inspected in detail:

1. The rockers, pins, and rollers should be free to move. There should be no corrosion and accumulation of dust and debris etc. at these locations. The excessive corrosion may lead the bearing to lock or freeze and it becomes incapable to move. When the movement of expansion bearings is checked, the temperature stresses can reach enormous values. In such conditions, the sub structure will be subjected to higher longitudinal forces.
2. To ensure the proper functioning of plain bearings, their oiling and greasing should be done once in 3 years.
3. In case, where phosphor bronze sliding bearings are used, only periodical cleaning of the area surrounding the bearing is required.
4. Many a times a uniform contact between bottom face of the bed plate and top surface of the bed block is not ensured, which results in gaps at certain locations. This leads to transfer of excessive impact forces to the bed block under live loads. This may cause cracking and crushing of bed block and masonry underneath.
5. Excessive longitudinal movements of the super structure result in shearing of location strips as well as anchor bolts connecting the base plates.
6. The tilt of segmental rollers should be measured with respect to reference line and the temperature at the time of measurement should also be noted.
7. In case of roller bearings with oil baths, dust covers invariably should be provided to keep the oil free from dust and dirt.

22.12. BED BLOCKS

Generally cracks in bed blocks develop due to the following reasons:

(*a*) Improper sealing of bearing as shown in Fig. 22.11 and 22.12.

(*b*) Cracking and crushing of masonry under the bed block.

The bed blocks can start loosening if they are isolated type. In such cases normally a gap develops between the surface of the bed blocks and the surrounding masonry. The falling of mortar from the pointing

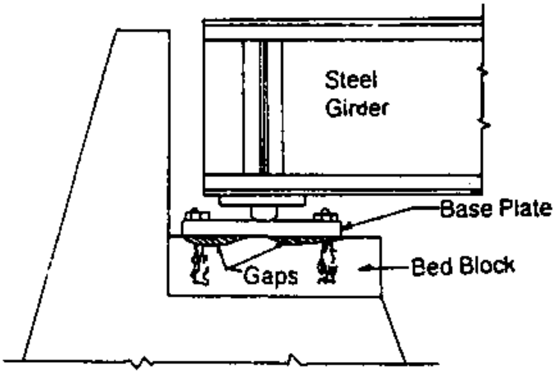


Fig. 22.11. Cracks in bed block due to improper sealing

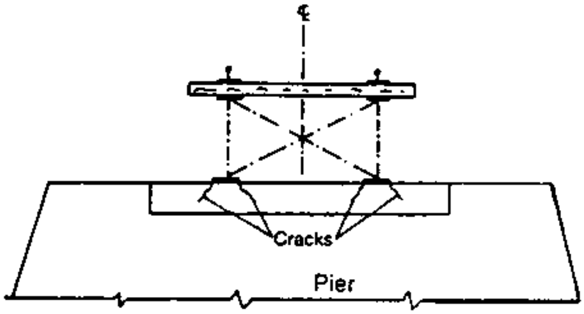
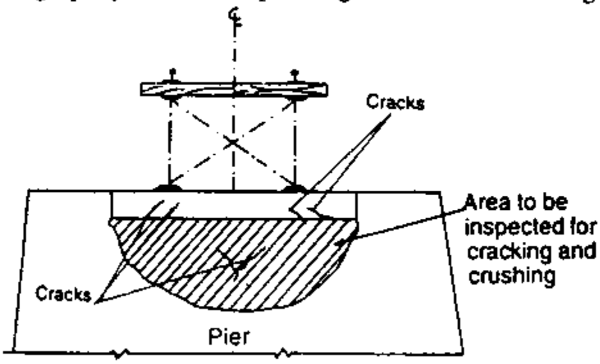
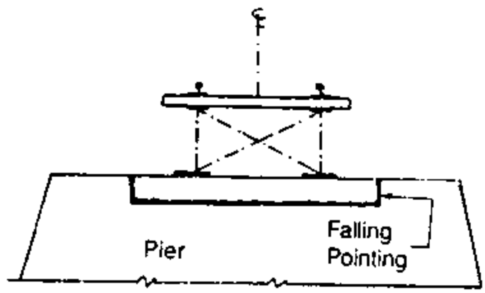


Fig. 22.12. Improper sealing of bearings

at joints between the bed blocks and the adjoining masonry is known as shaken bed block. This defect develops due to insufficient curing and improper setting of cement pointing. This defect can be avoided by using epoxy mortar for pointing stone bed blocks Fig. 22.13 and 22.14.





Falling of mortar from pointing at joints

Fig. 22.13. Fig. 22.14.

22.13. INSPECTION OF STEEL BRIDGES

Steel bridges can be classified into the following categories:

(*a*) Pate girder/RSJ bridges

(*b*) Open web girder bridges

(*c*) Composite bridges

While inspecting steel girder bridges following points should be noted:

22.13.1. Loss of camber

Plate girders and open web girders bridges more than 36 m spans are provided with camber to compensate for deflection under load. The camber is provided during fabrication or erection. For no distress condition the camber should be retained during the service life of the girder. The camber may be checked either by dumpy level or precision level on all intermediate panel points. The original camber of a girder is indicated in the stress sheet. Camber observations should be taken at the same ambient temperature as adopted for the original camber mentioned in the stress sheet. The camber is observed during annual inspection and compared with the designed camber. If a variation in camber is observed, then the bridge girder should be inspected thoroughly to identify the cause of it. Loss in camber may be due to the following reasons.

(*a*) Space left (Play) between rivet holes and rivet shanks.

(*b*) Over stressing of joint rivets at a splice in the plate girder or at the gusset plate in case of open web girder.

(*c*) Heavy overstressing of girder members.

22.13.2. Distortion

Distortion develops in the girders when the longitudinal movement of girders due to temperature variation is restrained by improper maintenance of bearings. This can be checked by piano wire by taking readings at every panel point. Distortion is likely to develop in the following members of the girder.

(*a*) Top flanges of plate girders

(*b*) Diagonal web members

(*c*) Tension members made up of flats due to mishandling during erection

(*d*) Top chords members due to insufficient restraint by bracings

22.13.3. Loose rivets

Rivets get loose under following conditions:

(*a*) Rivets driven at site

(*b*) Rivets subjected to heavy vibrations

(*c*) Corrosion around rivets

22.13.4. Critical areas for loose rivets

Following areas are critical for loose rivets:

(*a*) Top flanges of plate girders

(*b*) Gusset plates at panel points of open web girders

(*c*) Connection between rail bearer and cross girders in open web girders

(*d*) Connections between cross girders and bottom or top boom in open web girder.

22.13.5. Corrosion

Steel structures are sensitive to the atmospheric conditions and splashing of salty water. The presence of moisture aggravates the corrosion. Corrosion eats up the steel section and reduces its structural strength. If the corrosion is not checked in time, the necessity of replacing the girder will arise. In a steel structure at certain locations moisture is likely to be retained for a long time. These places are prone to severe corrosion.

22.13.5.1. Corrosion prone locations

These locations are as follows:

(*a*) Places where dust can accumulate.

(*b*) Places where water pockets are formed due to constructional features

(*c*) Places where wood and steel come in contact with each other.

22.13.6. Places needing special attention

Following places need special attention:

(*a*) Sleeper seats

(*b*) Top laterals of through girders

(*c*) Inside fabricated boxes of bottom booms

(*d*) Areas in the vicinity of bearings

(*e*) Troughing of ballasted decks

(*f*) Under side of road over bridges

(*g*) Seating of wooden floors on FOBS

(*h*) Interface between steel and concrete in composite girder

(*i*) Parts of bridge girders exposed to sea breeze and salt water spray.

22.13.7. Fatigue cracks

Fatigue is the tendency of the metal to fail at lower stress when subjected to cyclic loading than static loading. Fatigue is becoming important due to growing volume of traffic, greater speed and higher axle load.

22.14. CAUSES OF FAILURE OF STEEL STRUCTURES

One of the major causes of potential failure in steel structures is the development of cracks due to repeated stresses. In case of steel trusses cracks usually start developing in an diagonal steel member from a rivet or bolt nearest to the edge of the member. Fatigue cracking is observed at locations of higher local stresses such as at connections or at the change of geometry. Fatigue cracks should be investigated in old steel structures and where the intensity of traffic is heavy.

The usual inspection and detection of fatigue cracking is done with the help of a magnifying glass.

22.15. SOPHISTICATED TECHNIQUE TO DETECT FATIGUE CRACKING

Following technique for fatigue cracking inspection may be adopted:

1. **Radiographic Examination**. In this examination an *x*-ray is passed through the weld. Any void in the weld will reduce the thickness of the steel to be penetrated by *x*-ray and allow more radiation to pass through that point than through the sound metal. The void will form a dark spot on the *x*-ray plate on development of the film. Normally this test is conducted in workship only.
2. **Magnetic particle method.** In this test a magnetic field is set up electrically with in the piece to be tested. If there is a surface defect, the magnetic lines of force will form a small north south pole area at the location of surface defect. The iron powder used in the test forms a cluster around the surface defect. This test can also indicate sub surface defect if close to the surface. This method can be used for inspection at site.
3. **Liquid dye penetrants method.** This test can be conducted at bridge site. This test is widely used for the detection of surface discontinuity such as cracks and porosities etc. in the welds, especially of non magnetic metals such as stainless steel. The dye penetrant can be applied by spraying, brushing, or dipping, or swabbing etc. After the penetration duration, the excess penetrant on the specimen surfaces is removed. When penetrant starts to bleed out of the discontinuity following the removal of excess penetrant, a developer as talcum powder with high absorbent property is used. After some time an indication of discontinuity will be visible on the developer.
4. **Ultra sonic test.** This method can be used on almost all solid materials that can transmit vibrational sound energy. Ultrasonic test can be used to inspect box metal or weld for voids, cracks and laminations. By this method surface and sub surface discontinuities can be detected. Their size, location, and orientation can be closely delineated. Access to any one side of the work is required. This test can be used for testing welded girders at bridge site.

22.16. INSPECTION OF CONCRETE GIRDERS

Concrete is affected by the following factors:

(*a*) Poor design details

(*b*) Chemical attack

(*c*) Over stress

(*d*) Moisture absorption

(*e*) Movement in foundation

(*f*) Damage by collision

(*g*) Construction deficiencies as insufficient compaction and curing, inadequate cover etc.

(*h*) Temperature variation between inside and out side of box girder etc.

(*i*) High alkali cement and reactive aggregate.

(*j*) Corrosion of reinforcement.

22.16.1. Defects observed in Concrete girders

Following defects can be observed in concrete girders:

22.16.1.1. Cracks

Location of cracks, their width and nature can be used to establish the cause of their development. Minor hair cracks generally occur due to shrinkage of concrete. They are not of much structural significance.

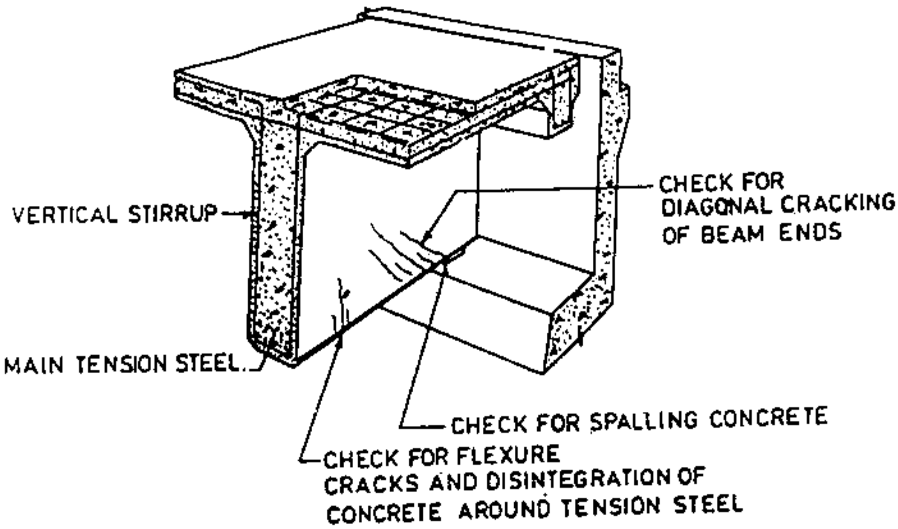


Fig. 22.15. Cracks in concrete girder

Normally transverse cracks develop at the bottom of R.C.C. beams. If such cracks are very thin and spaced at some distance, then they are not harmful. However if the transverse cracks are wide and open out during passage of live load, then they are serious and proper analysis and testing should be carried out to assess the strength of the beam.

Diagonal cracks in the web near the support indicate excessive shear stress and are of serious nature. Cracks near the bearings may develop due to the seizure or jamming of bearings or improper seating of bearings.

Longitudinal cracks at sofit of slabs or beams running parallel to reinforcement bars indicate corrosion of reinforcement. These cracks occur mainly due to honeycombing of concrete *i.e.* in sufficient compaction of concrete and inadequate cover to reinforcement. These defects lead to ingress of moisture which corrodes the reinforcement. The corroded metal increases in volume. Thus the corroded reinforcement exerts pressure on the concrete leading to cracking and spalling of concrete around the reinforcement specially towards the cover side of the concrete.

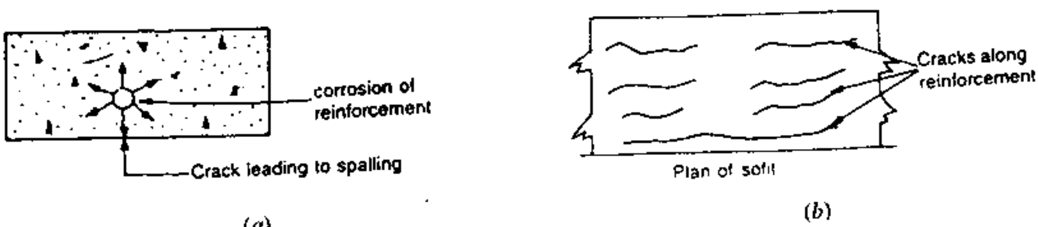


Fig. 22.16. Cross section of sofit showing cracks

22.16.1.2. Spalling

Spalling usually occur with the transfer of excessive dynamic forcess in the vicinity of bearings or with unchecked corrosion of reinforcement. Spalling can be identified by tapping the area with a small chipping hammer. The dull or hollow sound indicates the spalling. Spalling reduces the cross sectional area of concrete and exposes the reinforcement steel. Spalling may also occur at locations of bad compaction or bad quality of concr:te etc.

22.16.1.3. Reinforcement Corrosion

Corrosion of reinforcement may develop due to the following factors:

1. Improper storage of reinforcement before use in the concrete structure, *i.e.* girder.
2. Improper concreting.
3. Improper drainage of deck slab.

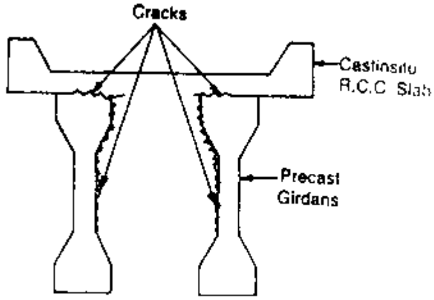


Fig. 22.17. Cracks at interface

The corrosion of reinforcement leads to cracking and spalling of concrete. It is indicated by staining of concrete (spot of brown or red colour on concrete structure). The problem of reinforcement corrosion basically develops due to the seepage of water through concrete decks. The reason for seepage again is improper drainage arrangements during construction and mucked up ballast on concrete deck. Fig. 22.17 shows cracks at the interfaces of pre cast and cast in place concrete elements.

22.17. TRACK ON GIRDER BRIDGES

1. Approaches. Generally track on approaches of girder bridges has a tendency to settle down with respect to the level of track on the bridge proper. It is preferable to continue the same level of the bridge on the approaches for some distance. The track on the approaches should be in correct alignment with the track on the bridge. The gauge, cross level, and packing under the sleepers should be checked. Rail joints should be avoided with in 3 m of a bridge abutment. The condition of ballast wall should be checked and repaired where ever necessary. Full ballast section should be maintained for at least 50 metres on the approaches. This portion of the track should be well anchored.

22.18. TRACK ON BRIDGE PROPER

Track on bridge proper should be central on the rail bearer and the main girders. Also track should be in good line and level.

(*a*) **Departure from line.** Departure from line is caused by the following factors:

(*i*) Incorrect seating of girders

(*ii*) Incorrect seating of sleepers on girders

(*iii*) Shifting of girder laterally and length wise

(*iv*) Creep or varying gauge

(*b*) **Departure from level.** Departure from level is caused by the errors in the levels of bed blocks or care less timbering. There should be adequate clearance between the running rails and ballast walls or ballast girders at the abutments.

(*i*) *Level of rails.* The rails should follow the camber of the girders. Open web girders of span more than 30.5 m are provided with camber.

(*ii*) *Rail cant.* The rail should be laid with an inward cant of 1 in 20.

(*iii*) *Rail joints.* Rail joints should be avoided on the approaches of the bridges with in 3 m of abutments and on short single span of 6.1 m and below. For other spans, the joints preferably should be provided at 1/3rd of the span from either end. Where ever it is not possible to reduce B.M. and S.F. effects, joints should be provided far away from ends and centre of the girders. Where switch expansion joints are provided, the free movements of the switch should be ensured.

22.19. SLEEPERS

22.19.1. Laying of bridge timber

The depth and spacing of sleepers should be as shown in the Table 22.1 below.

Table 22.1. Showing dimensions of sleepers

Gauge	*Clear distance between consecutive sleepers not to exceed in (mm)*	*Depth of sleepers exclusive of notching not less than (mm)*	*Length of sleepers*
B.G.	500	150	Out side to out side of girder flanges plus 305 mm but not less than 2440 mm (2.4 m)
M.G.	300	125	Out side to out side girder flanges plus 305 mm but not less than 1676 mm (1.676 m)
N.G.	250	120	As above, but not less than 1525 mm (1.525 m)

The clear distance between joint sleepers should not exceed 200 mm (20 cm) for both B.G. and M.G.

22.19.2. Depth of bridge sleepers

The depth of sleepers on bridges should be about 25 mm extra to plane and notching. For special situations like bridge on curves, thicker sleepers should be used or M.S. packing plates should be used for making up the thickness. For such situations the thickness of sleepers should be as:

B.G. = 175 mm
M.G. and N.G. = 150 mm

22.19.3. At fish plated joints

At fish plated joints the clear spacing should not exceed 180 mm. Creep should be checked and rails should be pulled back where ever possible. To avoid the transfer of longitudinal forces to the bridge, rail free fastenings should be used on all unballasted deck bridges. The rail fastenings should be tight.

22.19.4. On Girder bridges

On all girder bridges which do not have ballasted deck, guard rails should be provided. On all flat top arch and pre stressed concrete girder bridges with deck slab, where guard rails have not been provided, the whole width of the bridge between the parapet walls should be filled with ballast upto the sleeper level.

22.19.5. Top of guard rails

The top table of guard rails should not be lower than that of the running rails by more than 25 mm. At the extremities of the guard rails out side the bridge, the guard rails should converge and their ends should be bent upwards vertically and burried. A timber block is fixed at the end to prevent entanglement of hanging loose couplings.

To ensure that guard rails are effective, they should be spiked down systematically to every sleeper with two spikes towards the centre of the track and one spike on the out side. To accommodate the spikes, notching of the rail foot should be done on every alternate sleeper.

22.20. POSTING OF BRIDGES

The term posting of a bridge is used to indicate the restriction imposed on the use of the bridge so that its safe load carrying capacity is not disturbed. The posting of bridge can be classified into the following two categories.

1. Load limit posting 2. Speed posting

1. Load limit posting. The load restrictions may either be in the form of maximum axle loads or maximum gross loads of the vehicles. The posting signs are in the form of advance warning signs and the load restriction signs. They are placed as under:

(*a*) The advance warning signs indicating the load limit on the bridge ahead are placed about 200 m from the abutment on either side.

(*b*) The load restriction signs, indicating the load limit are placed about 60 m from the abutment on either side.

2. Speed postings. Restriction on the speed of the vehicle on the bridge is imposed. The speed posting reduces the impact effect and thus bridge can be allowed to carry heavier loads by reducing the speeds of vehicles.

In general speed restrictions are not imposed. These should only be imposed in exceptional circumstances.

22.21. RATINGS OF EXISTING BRIDGES

The process of assessing the safe load carrying capacity of a bridge is known as *rating of the bridge.* It has to be carried out systematically for most of the old existing bridges, which have not been designed for the present day heavy high way loadings.

22.21.1. Purpose of rating of existing bridges

Following are the purposes of rating of existing bridges:

1. To provide safety to the traffic and public.
2. To avoid immediate reconstruction of the existing bridges, resulting in substantial saving of money and material of construction.
3. To ensure flow of traffic on the existing old bridges with out imposing unnecessary restrictions.
4. To suggest measures for the safe use of existing bridges during the remaining period of their life.

During the rating process, the bridge should be thoroughly inspected to determine its physical condition. The inspecting engineer must be well conversant with the design aspect as well as construction features of the bridge structures. The field inspections and investigations should be properly recorded in the form with detailed sketches and self explanatory notes. The findings are then correctly interpreted and suitable measures recommended to remove the structural deficiency of the bridge.

The collection of field data after thorough inspection of the existing bridges is the most difficult part of rating. Thus it should be entrusted to the experts only. In advanced countries the data processing and laborious calculations required for rating are made with the help of computers. For giving in depth information of a damaged member of the structure, modern non destructive testing equipments are used.

22.22. EQUIPMENTS USED FOR TESTING

Commonly following three equipments are used for testing of a bridge:

1. **Magnetic particle detector**. It is a portable magnetic equipment available for insitu inspection. Its use is limited for the detection of surface or sub surface defects. The area of the metal structure to be inspected is magnatised and a fine magnetic powder is sprinkled on the surface under inspection. The layout of the powder formed is anyalised to detect the defect.
2. **Radio graphic equipment.** To detect defect in steel bridge structure *x*-rays or gamma rays are used. In addition to *x*-ray tube and film, it requires a source of power and cooling system. This equipment is capable to detect surface and sub surface defects. It provides a permanent record.
3. **Ultra sonic testing equipment.** This is a simple portable equipment. It requires a skilled operator for its operation. It is capable of locating both surface as well as sub surface defects in the metals such as cracks, laminations, weld fusion etc. It can also be used for measuring the thickness of the plate. It is well suited for analysing the possible defects in the steel bridge elements and joints.

22.23. REBUILDING OF BRIDGES

An existing bridge may be required to be re built partly or fully due to one or more factors:

22.23.1. Factors leading to rebuilding a bridge

Usually following factors or reasons lead to rebuilt a bridge:

1. Damage to the bridge. An existing bridge may have severely damaged or collapsed due to unprecedented heavy floods in the river where it is built. The causes of this heavy flood may be as follows:

(*a*) Breach of reservoir on up stream of the bridge.

(*b*) Increased precipitation in the catchment.

(*c*) Changed pattern of flow of the river.

2. Excessive cost of maintenance. The maintenance cost of a bridge increases as it approaches to the end of its useful or service life. Due to increase in material cost or labour cost, the maintenance cost may become so excessive that its maintenance may prove un economical in comparison of the reconstruction of a new bridge even before the useful life of the existing bridge.

3. Obsolescence. The existing bridge may have become functionally obsolete due to any of the following reasons:

(*a*) Due to change in the pattern of the traffic.

(*b*) Due to navigational requirements.

(*c*) Due to the introduction of heavy and large locomotives or vehicles.

(*d*) Due to grade separation etc.

4. Weathering. Due to the atmospheric effects such as presence of fumes, saline vapours etc. the bridge structure might have deteriorated even though it is well maintained. The structural members can also be subjected to failure due to fatigue. In practice it is extremely difficult to predict the actual service life of the structure.

Hence some parts of the structure may be subjected to more number of load cycles than expected and they fail far inadvance than their intended service life. Thus the bridge structure as a whole fails before its useful service life.

The replacement of a bridge structure may be undertaken partly or fully depending upon the circumstances. In case of railway bridges whose sub structure is of masonry and super structure that of steel girders, partial replacement is quite common. Normally the life of steel girders is less. Thus the partial replacement is carried out using temporary arrangements and keeping the traffic movement continuous with restricted speed.

22.24. CONDITIONS FOR FULL REPLACEMENT OF THE BRIDGE

Under the following conditions full replacement of an bridge is undertaken:

1. The bridge has become too weak to take the present day heavy loads or heavy traffic.
2. The bridge has been considerably damaged due to weathering or ageing.
3. The bridge has not been found suitable for being raised due to change in gradient.

QUESTIONS

1. Enumerate the aims and objectives of bridge inspection.
2. Discuss the safety measures taken while inspecting a bridge.
3. What points or parts should be seen during a detailed inspection of a bridge?
4. What defects should be seen in foundation during the inspection of a bridge?
5. Discuss the likely defects of an arch bridge?
6. Where heavy scour is expected in case of piers and abutments?
7. The inspection of a bridge should be done starting from:

   (*a*) Super structure to sub structure *i.e.* from top to bottom.

   (*b*) Sub structure to super structure *i.e.* from bottom to top.

   (*c*) Can it be started from any position of the structure.

   (*d*) All are correct.

8. Uneven settlements of bridge foundation takes place due to:
   (*a*) Increased loads (*b*) Scour of foundation
   (*c*) Consolidation of underlying materials (*d*) Yielding of under lying soil
   (*e*) All the above
9. During the inspection of abutments and piers aspects to be noted are/is:
   (*a*) Bulging (*b*) Transverse cracks
   (*c*) Failure of mortar (*d*) cracking and crushing of masonry
   (*e*) Weathering (*f*) All the above
10. Bulging of abutments and piers occurs mainly due to
    (*a*) Material of construction used (*b*) Excessive back pressure
    (*c*) Faulty construction (*d*) Inadequate inspection
11. The development of transverse cracks in tall masonry piers of bridges in the vicinity of stopping places are due to
    (*a*) Distance between the pier and stopping place
    (*b*) Condition of bearings
    (*c*) Height of pier
    (*d*) Load coming on the pier
12. Excessive back pressure may cause
    (*a*) Longitudinal cracks in the arch bridge
    (*b*) Cracks on the face of arch bridge
    (*c*) Bulging and tilting of abutment and piers
    (*d*) All the above
13. Locations prone to severe corrosion are
    (*a*) Places where water pockets are formed due to constructional features
    (*b*) Places where dust can accumulate
    (*c*) Places where wood and steel come in contact with each other
    (*d*) None of the above
    (*e*) All the above
14. In case of concrete bridges, diagonal cracks in the web near the supports are due to
    (*a*) Excessive bending stresses (*b*) Excessive shear stresses
    (*c*) Excessive volume of steel (*d*) Excessive volume of concrete
15. Longitudinal cracks at the sofit of beams or slab are due to
    (*a*) Excessive shear force (*b*) Excessive bending moment
    (*c*) Corrosion of reinforcement (*d*) Deficiency of reinforcement
16. Posting of a bridge means
    (*a*) Registering its number in central government register
    (*b*) Registering its number in state Government register
    (*c*) Restriction imposed on the use of bridge
    (*d*) All are correct
    (*e*) None of the above is correct

ANSWERS

7. (*b*)	9. (*f*)	11. (*b*)	13. (*e*)	15. (*c*)
8. (*e*)	10. (*b*)	12. (*d*)	14. (*b*)	16. (*c*)

23
Maintenance of Bridges

23.1. INTRODUCTION

After the construction of a bridge, it is absolutely necessary to inspect it at regular intervals and maintained in such a condition that it functions properly for the intended purpose. The damage to a bridge structure may occur due to any of the following reasons:

(*a*) Due to faulty design
(*b*) Dut to faulty construction
(*c*) Due to aging of the materials
(*d*) Due to floods and storms
(*e*) Due to accidents etc.

Though the expectancy lives of sub structures and super structures are 100 years and 70 years respectively, but the over all utility of a bridge can reduce drastically due to faulty and poor maintenance. Thus the maintenance of a bridge structure is very important.

23.2. WORKS OF MAINTENANCE OF A BRIDGE

For major bridges, generally following elements should be maintained well:

1. The bearings of girders should be oiled/greased periodically to keep them in perfect movable condition.
2. Embankments near the bridges should be stone or brick pitched to avoid erosion.
3. The river training works near the bridges should be properly built and maintained.
4. In brick or stone masonry works any sign of movement of brick/stone should watched carefully.
5. The bed blocks should be inspected periodically and necessary repairs should be carried out immediately.
6. The floor system of bridges and approaches should be maintained properly.
7. The movements of foundations if any should be inspected carefully and attempts should be made to check them.
8. The rivets should be inspected regularly and defective rivets should be punched off and replaced.
9. The scour depth near the foundation of abutments and piers should be detected by sounding during rainy season, specially after floods.
10. Deterioration, and cracking etc. of masonry work should be checked from time to time. If the masonry has developed cracks, then it should be ensured whether these cracks are superficial or due to structural failure.
11. In steel structures development of cracks due to fatigue, buckling or over loading etc. should be noted carefully and attended as per programme.
12. Normally concrete girders need very little maintenance. However they should be kept clean. The bearing area should be left free of dirt and oiled. Any crack of structural significance should be sealed by pressure grouting or otherwise.

13. The weep holes should be inspected regularly and must be kept clean and in working condition otherwise poor drainage would cause serious defects as bulging, tilting etc. in abutments and piers.
14. In case of high way bridges, the condition of kerbs, parapet walls and foot path etc. should be examined in all respects.
15. The entire drainage system should be inspected and examined for any blockage, damage or deterioration etc. It should be maintained in proper functioning condition.
16. It should also be ensured whether the masonry work has washed away during floods, cracked or deteriorated.

23.3. SYMPTOMS AND REMEDIAL MEASURES OF DEFECTS

Some of the common problems or defects and their remedial measures are shown in Table 23.1.

Table 23.1. Common problems and their remedial measures

S. No.	*Nature of problem or defect*	*Remedial measures*
1.	Foundation settlement:	
	(*a*) Moderate	Packing under super structure may be sufficient
	(*b*) Severe	Stabilization by piles around the foundation, root piling or rebuilding may be resorted
2.	Scour:	
	(*a*) Moderate	Boulders may be dumped around the piers in the scoured portion
	(*b*) Severe	Sheet piles around the foundation may be driven
3.	Weathering of masonry:	
	(*a*) Joints superficial	Painting of joints may be adopted
	(*b*) Joints deep	Cement or Epoxy grouting may be adopted
4.	Leaching of lime mortar through:	
	(*a*) Masonry units	Guniting may be adopted
	(*b*) Cracks	Grouting with cement or Epoxy may be adopted. Jacketing may also be adopted
5.	Leaning or bulging:	(*a*) Drainage of back fill
		(*b*) Soil or rock anchoring
		(*c*) Jacketing or rebuilding
6.	Cracked or shaken bed blocks	Bed blocks should be recast either cast in situ or precast and bonded
7.	Hollows left in masonry due to defective workmanship	Cement grouting may be adopted.
8.	Arches:	
	(*a*) Weathering	(*a*) Painting, (*b*) Guniting, (*c*) Grouting with cement or Epoxy
	(*b*) Cracks in arch	Grouting with cement or epoxy or rebuilding.
9.	Cracks or bulging in parapet/ spandral wall.	(*a*) Drainage of back fill
		(*b*) Provision of ties
		(*c*) Rebuilding
10.	R.C.C. or prestressed concrete girders and slabs:	
	(*a*) Cracks	Grouting with Epoxy
	(*b*) Spalling	Grouting
11.	Steel girders:	
	(*a*) Defective material	Replace
	(*b*) Corrosion moderate	Painting or metallising

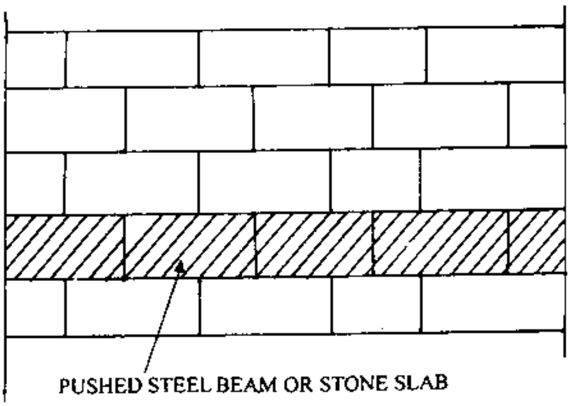
S. No.	*Nature of problem or defect*	*Remedial measures*
	(*c*) Corrosion severe	Strengthening and painting or metallising
	(*d*) Cracks	Strengthening
	(*e*) Loose rivets	Replacement of rivets
	(*f*) Loss of camber	Strengthening

Note. Epoxy grouting has been found suitable in situations where dynamic loads are encountered.

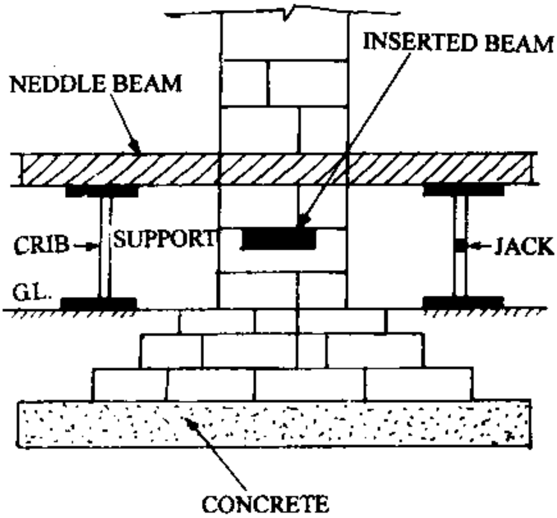
23.4. REMEDIAL MEASURES OF BRIDGE DEFECTS

23.4.1. Foundation settlement

1. Settlement is moderate. In this case the packing of super structure will be sufficient. Packing can be done with the help of under pinning. Packing of superstructure will be easy in case of brick or stone masonry. The structure is divided into sections of about 1 to 2 m length. Holes are drilled in the masonry at a suitable height from the ground and needle beam of steel is inserted on both sides of the working section to support the structure. These needle beams are supported on hydraulic jacks placed on cribs on



(*a*) Front view



(*b*) End view

Fig. 23.1.

sound ground. The joint of the masonry is opened and a section of steel of desired thickness is inserted in the joint. If need be one layer of bricks or stones may be removed and the concrete blocks of desired dimensions may be inserted.

In case of concrete structures, it would be easy to strengthen the foundation underneath.

23.4.2. UNDER PINNING PIT METHOD

In this case the pier is divided into the sections not longer than 1.2 m to 1.5 m. A hole is drilled through the pier and a needle beam placed across this hole. Bearing plates are placed over the needle beam below the pier surface as shown in the Fig. 23.2. The needle beam is supported on the crib supports (wooden blocks) and screw jacks sufficiently away from the proposed excavation on the firm ground. After the pier has been properly supported, the pit is made exposing the old foundation. The new foundation of the desired dimensions is laid in concrete after removing the old foundation. After completing work in one section, work in the next sections is taken. The work should be taken in the alternate section. Fig. 23.2

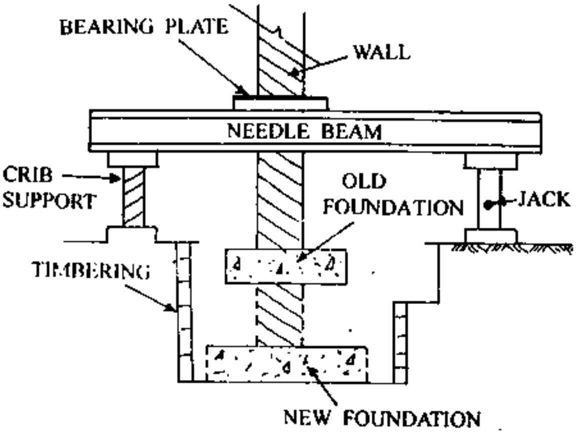


Fig. 23.2. Under pinning pit method

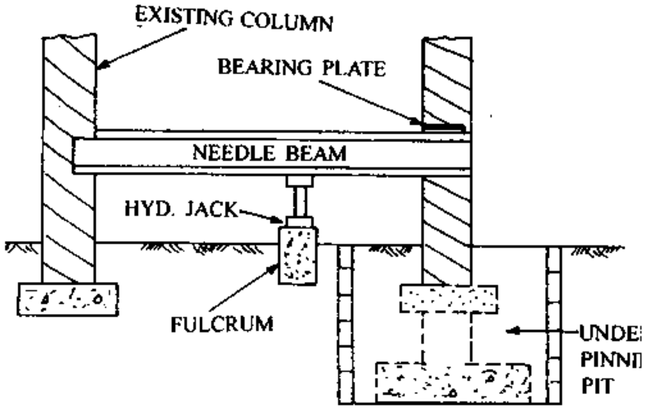


Fig. 23.3. Under pinning with cantilever needle

shows under pinning pit method and Fig. 23.3 shows under pinning pit method with cantilever needles.

23.4.3. Settlement is severe (Pile method)

In this case, generally steel or under reamed piles are driven along both sides of the structure at regular intervals. On the top of a pair of piles, steel or concrete needle beams are placed which serve as needle beams as well as pile cap. The pier is supported on these needle beams and the necessary work below the foundation as removing the old foundation and laying new foundation is carried out. This method is very useful in clayey soils and water logged areas, but it should be adopted where no other method of under pinning can be adopted. Fig. 23.4 shows pile method.

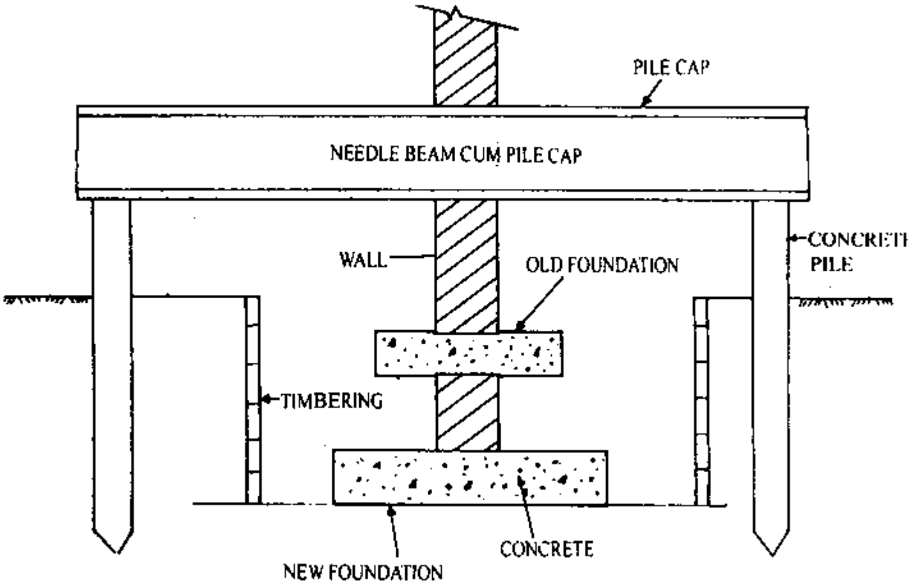


Fig. 23.4. Under pinning by pile method

23.5. SCOUR OF FOUNDATION

23.5.1. Scour is moderate

In this case, usually boulders are placed in the scoured portion and around it in sufficient quantity to check the further eroding of foundation.

23.5.2. Scour is severe

(*a*) In this case to provide sufficient weight on the scoured area, concrete filled bags may be deposited in and around the scoured foundation. In this method old empty cement bags are filled 2/3rd with concrete and the remaining one third part is turned down and tied securely. The bags are tied in such a way that they can be placed readily in any profile of the surface on which they are to be placed. The properly filled bags are lowered into the water and placed properly in header and stretcher courses by the help of divers. They will check the scouring of the bed.

(*b*) *Prepacked concreting method.* In this case a series of round cages of 50 mm mesh of 6 mm diameter steel bars are made and extended upto the height concreting is required. These cages are placed over the full area to be concreted at an interval of about 1 m centre to centre. Now aggregate not less than 50 mm and not greater than 200 mm is deposited on the out side of these cages. The stone aggregate should be wetted before depositing. While depositing the aggregate it should be ensured that no cage is disturbed from its position.

After depositing the aggregate, the cement sand grout of 1:2 proportion and water cement ratio not less than 0.6 and not greater than 0.9 is prepared in a mechanical mixer and sent through a 38 mm to 50 mm diameter pipe into the steel cages. The pressure of the grout may vary from 2 kg/cm^2 to 3.0 k/cm^2. As the grout proceeds, the pipe may be raised gradually upto a height of not more than 60 cm above the starting level. After this level, the pipe may be withdrawn from the cage and the procedure is repeated till all the cages are grouted. The grout should be sufficient to fill all the voids which may be taken as 55% of the volume of the concrete to be used.

(*c*) *Sheet piling.* The most effective method of preventing severe scour is to drive sheet piles around the pier or structure to be protected. The sheets piles should be driven sufficiently deeper than maximum depth of scour. These piles will prevent the water current from scour the bed. However this method has not been found effective where the river bed is rockey and full of big boulders.

23.6. WEATHERING OF MASONRY

Following remedial measures may be adopted.

23.6.1. Cement grouting

In this case cement slurry grout 1:1 cement and water is used:

23.6.1.1. Equipment used

Usually following equipment is used for cement grouting:

(*i*) **Air compressor.** For this purpose usually air compressors of 3 m^3 per minute capacity are used. It exerts an pressure of 3.5 kg/cm^2.

(*ii*) **Grout injecting machine.** This machine has an inlet, out let, valves, pressure gauge and one air tight pressure chamber for filling the grout.

(*iii*) **Flexible hose pipe.** These pipes are used for transmitting the grout from the pressure chamber to the parts embedded in the masonry.

23.6.1.2. Procedure

1. 25 mm diameter holes are drilled upto a depth of 200 mm in staggered manner in the area in which pressure grout is to be done especially along the cracks and hollow joints.
2. G.I. pipes of 25 mm diameter and 200 mm long with threaded ends are inserted into the masonry and fixed with rich cement mortar. These pipes are called ports.
3. The annular space around G.I. pipes and cracks if any are sealed with rich cement mortar.
4. To saturate the masonry, the grout holes should be sluiced with water one day earlier the grouting is to be done.

Filling of water and its circulation through the holes is known is as sluicing. This is carried out by using the same equipment as for grouting. All holes are plugged with wooden plugs. Bottom most plug in holes 1, 2 and 9 as shown in Fig. 23.5 are removed. Water is injected in hole no 1 under pressure. When the water comes out through holes 2 and 9, injection of water is stopped. Plugs in holes 1 and 9 are restored. The process is repeated in all the holes. After 24 hours, all plugs are removed to drain out excess water. After draining the water from the holes, the plugs are restored.

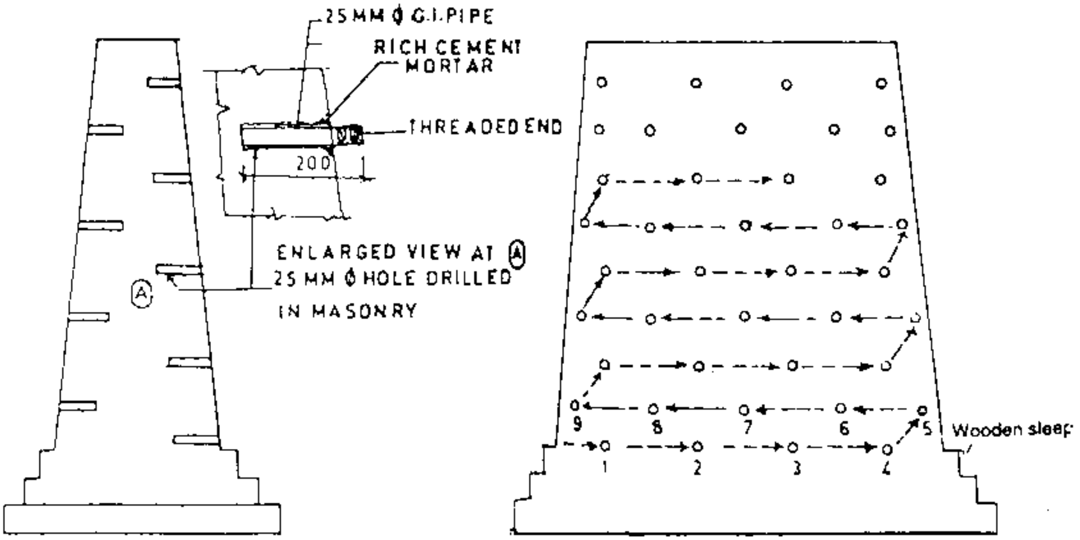


Fig. 23.5. Cement pressure grouting

5. Cement grout of 1:1 cement and water is sent from bottom to top and left to right with the help o injecting machine. The cement grout prepared should be fully used with in 15 minute of it: preparation. The procedure of injecting cement grout is similar to sluicing in terms of sequencin; and of removal and refixing of plugs.
6. Water curing for 14 days should be done of the grouted portion.
7. If holes are provided in every third layer of masonry or at intervals at 1.2 to 1.5 m in staggere position, then for effective grouting, hand operated grouting machines should be used.
8. The grouting machines should be properly cleaned of any grout immediately after its use.

23.6.2. Epoxy Grouting

All structures built of stone, brick or concrete get affected by prolonged weathering action. The ingres of moisture associated with chemicals such as nitrates, chlorides, and sulphates accelerate the deterioratio of the structure. If the structures are built in the proximity of sea or on aggressive ground soils, then th process of deterioration further accelerates. Stone masonry built with inferior stones such as sand stones o laterites etc. suffers spalling by the ingress of moisture. Similarly brick masonry built with porous brick suffers spalling action. Leaching of cement and lime due to poor drainage further deteriorates structure leading to their failure.

It is a well known fact that adhesion between old damaged masonry or concrete and newly masonry o concrete is very poor. Besides this, cement does not get enough time for setting and hardening before traffi is allowed over the newly repaired structures. This leads to frequent repairs at the same spot. To over com this draw back Epoxy grouting may be adopted.

Epoxy resins consist of condensation products of Epichlorohydrain and bisphenol-A. They are therm setting with high adhesive strength. Practically they have no shrinkage and possess good resistance to wea and to most of the chemicals. The resin and hardener have to be mixed for starting the chemical reactio for hardening. The pot life of the mixture varies between 30 to 120 minutes depending upon the ambier temperature and the type of hardener. For preparing mortars, silica flour is added. The recommendations c manufactures should be followed for the best application procedure, temperatures and pot life etc. Fc mixing Epoxy components plastic vessels should be used.

23.6.2.1. Surface Preparation

The surface over which Epoxy is to be applied must have following characteristics:

1. The surface should be sound and strong
2. It should be dry and clean
3. It should be free from oil, grease and loose materials
4. It should be dust and debris free
5. It should be laitence free

All dust and other materials should be removed from the surface. If required, compressed air may be used for this purpose. For thin cracks low viscosity resins may be used. To ensure complete filling of vertical cracks, the grouting should be done from bottom to top.

Before grouting, a V shaped groove is made all along the crack and all loose pieces of concrete are removed by using a jet of air. Nails are driven into the cracks at intervals of 15 to 30 cm. Copper or Aluminium pipes or M.S. sheaths 40 to 50 mm long and 6 to 9 mm diameter are inserted around the nails and allowed to rest on them. Now all the cracks are sealed along the groove with Epoxy putty. The tubes provide an unobstructed passage for the Epoxy resin into the cracks and also an out let for the entrapped air.

23.6.2.2. Procedure

Epoxy of suitable formation is injected from the bottom most pipe. keeping all pipes blocked with wooden plugs except the adjacent to the injecting pipe. Suitable nozzles are used for injecting the epoxy. These nozzles are connected to air compressor or other such machine and a pressure of 3.5 kg/cm^2 to 7.0 kg/cm^2 usually is applied. As soon as Epoxy starts coming out from the adjacent open pipe it is plugged and the pressure is increased to the desired level and maintained for 2 to 3 minutes. This operation is continued for the other pipes also. Any surplus resin from copper pipes is scrapped off with a metal spatula and the surface is cleaned with a rag socked in non inflammable solvent. The worker doing this work should wear rubber gloves. The equipment used should be washed with acetone immediately after completion of work. Grouting operations are shown in Fig. 23.6.

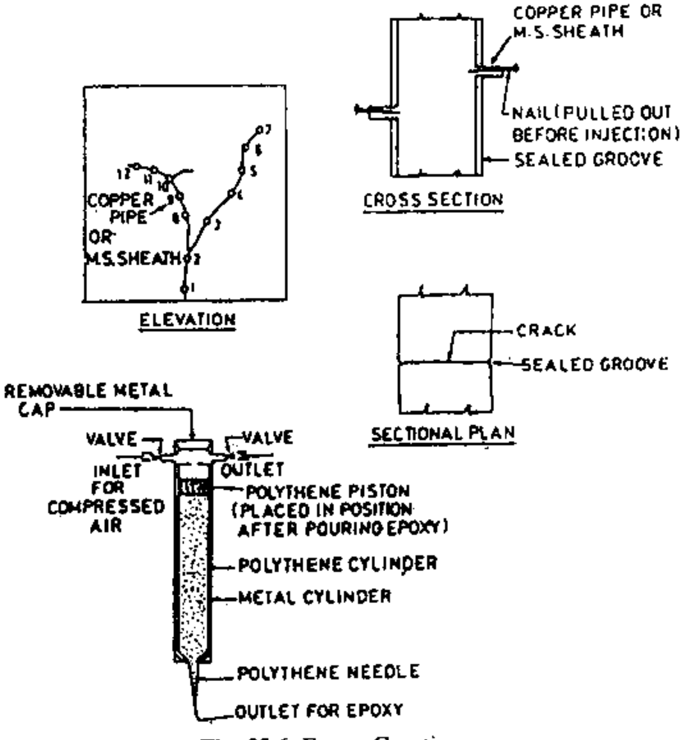


Fig. 23.6. Epoxy Grouting

For superficial net work of fine cracks which does not endanger the stability of the structure, 300 to 400 micron thick coating of solvent free Epoxy is sufficient. In case of wider cracks, which are not expected to endanger the stability of structure can be partially filled with Epoxy putty, which is a mixture of Epoxy, hardener and China clay. Epoxy being a costly material, its use should be restricted to areas below and around the bed block, cracks in R.C.C. or plain cement concrete, where the dynamic forces are likely to be transmitted.

23.6.2.3. Advantages of Epoxy resins

Epoxy resins have following advantages over cement as bonding materials:

1. Epoxy resins are quick setting
2. Have low shrinkage

3. Low viscosity to fill hair cracks
4. High adhesion to all materials
5. Stable at all temperatures

23.7. STRENGTHENING WORK BY JACKETING

Often railways have to under take the strengthening work of existing bridge sub structures connected with the work of the following type:

(*a*) Connected with the railway track.

(*b*) Introduction of heavier type of locomotives and other rolling stock producing higher longitudinal forces.

(*c*) Increase in vertical clearance as per provision of the code.

By raising the formation level, the existing sub structures are subjected to higher loading due to higher earth pressure and increased moments. To strengthening the sub structure, its cross sectional areas is required to be increased. For increasing the cross-sectional area of the existing sub structure *Jacketing* is adopted.

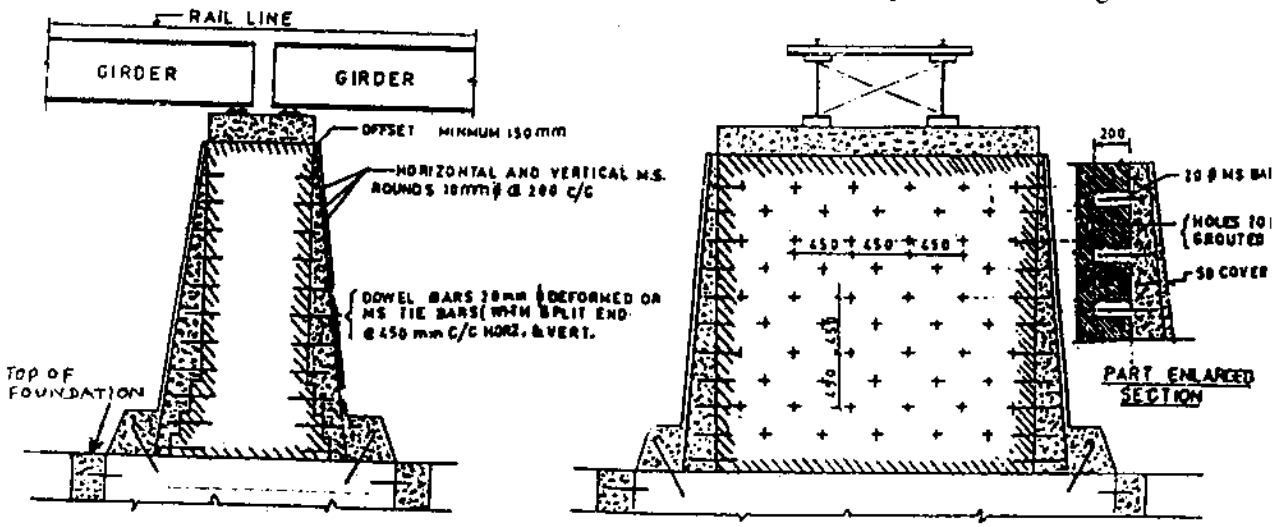
Jacketing should be adopted when the existing structure is fairly sound and does not show sign of distress. Before starting Jacketing all cracks should be thoroughly grouted. For effective functioning, the Jacketing should be taken right upto the foundation and at this level, it should be integrated with the existing foundation.

To avoid the endangering of safety of the structure, the foundation should be exposed for only a limited width at a time and for the shortest time necessary for strengthening. For deciding the width of foundation to be exposed at a time, site and soil condition including water table should be kept in mind.

The minimum thickness of jacketing should be kept at least 150 mm. The speed restriction of 8 kmph should be imposed during the period of strengthening and may be relaxed in stages in proportion of gain in strength.

23.7.1. Procedure

The face of existing concrete or masonry structure should be thoroughly cleaned of all dirt etc. Before laying new concrete, neat cement slurry should be applied uniformly over the face of the old masonry. The dowel bars of M.S rods of 20 mm diameter and hooked at exposed end are fixed in the old masonry. M.S. tie bar flats with split ends can also be similarly fixed into the old masonry. These dowels should be taken upto a depth of not less than 200 mm in side the masonry as shown in Fig. 23.7. For driving these dowels



SECTIONAL ELEVATION SIDE ELEVATION

Fig. 23.7. Strengthening of substructure by Jacketting

some times holes are required to be drilled in the masonry. The vertical and horizontal spacing of the dowels should not be more than 450 mm. The dowels should be staggered. The 28 days cube strength of the new concrete should not be less than 150 kg/cm^2. A mat of steel reinforcement with maximum diameter of 10 mm, spaced at 200 mm horizontally and vertically may be provided as distribution reinforcement.

23.8. PAINTING OF GIRDER BRIDGES

Girder painting essentially is an application of surface coating of the steel work to check corrosion. The basic principle under lying the maintenance painting is not to allow the deterioration of existing paint film to reach such a stage that rusting starts underneath the paint film.

23.8.1. Surface preparation

To ensure the good performance of painting, applied to steel works, the most important factor is the correct preparation of the surface. Paint on a well prepared surface lasts many times more than the badly prepared surface. To ensure the good adhesion of paint film to the surface, it is necessary to remove the rust, oil, grease and dust etc. from the surface. The surface preparation in the maintenance of painting depends upon the existing conditions of the paint film.

1. Situations where surface has sign of deterioration. In such situations the only finishing coat of the paint is unable to hide the signs of deterioration. The surface should be washed with luke warm water containing 1 to 2% detergent to remove salts and dust deposits. After washing the surface, it is dried and lightly wire bushed and sand papered. On this prepared surface, the finishing coat of paint is applied.

2. Situations where there is corrosion on surface. In situations where the girders are affected by corrosion and parent metal surface is exposed, the surface should be prepared as follows:

(*a*) To clear the rust and scales etc. from the surface, sand blasting is one of the best method of surface preparation. The colour of a properly sand blasted steel surface appears silvery gray.

(*b*) *Scrapping, chipping and wire brushing.* To remove rust and scale etc. the surface can be scrapped and chipped and wire brushed either manually or by machines. Finally the surface is sand papered and dusted. Surface so prepared is of inferior standard than prepared by sand blasting.

(*c*) *Flame cleaning.* In this method oxyacetylene flame is directed on the surface to soften the old paint. After the old paint has soften then the surface is wire brushed. This method also is inferior to sand blasted method of surface preparation for painting where the surface is excessively rusted.

Flame cleaning should not be adopted on plates whose thickness is 10 mm or less as it may lead to permanent distortion of plates. The surface to be cleaned by flame should not be exposed to flames for a longer period. After the passage of the flame, the surface should be cleaned with wire bush, sand papered and dusted.

23.9. PAINTING AS PER INDIAN RAILWAYS CODE

This code is applicable to the following two conditions:

23.9.1. Situations where corrosion is not severe

In such situations painting can be done as follows:

(*a*) **Priming coat.** One heavy coat of ready mixed red lead paint may be applied as per IS-102.

OR

One coat of ready mixed zinc chromate paint followed by one coat of red oxide zinc chromate paint may be applied.

OR

Two coats of zinc chromate red oxide may be applied.

(*b*) **Finishing coat.** Two coats of red oxide paint or any other approved paint may be applied as per IS 123.

23.9.2. Situations where the corrosion is severe

In such situations the girders should be painted as follows:

(*a*) **Priming.** For Priming two coats of ready mixed red lead paint may be applied as pr IS-102.
OR
One coat of ready mixed zinc chromate paint followed by one coat of zinc chromated red oxide priming may be applied as per IS-104 and 2074.

(*b*) **Finishing coat.** Two coats of aluminum paint may be applied as IS 2339.

23.9.3. Precautions to be adopted while painting

To get the satisfactory results of bridge painting, following precautions should be adopted:

1. The surface should be fully cleared of all rust and dirt etc.
2. Only good quality materials should be used.
3. The paint should be applied on dry and warm surface when the humidity is low. Shortly after a shower or on winter morning when dew might have condensed, painting should not be done.
4. Special care should be taken to shift the sleepers on girders or rail bearers to clean the seating thoroughly before applying the paint.
5. In case of red lead paint only small quantity should be mixed, which may be consumed with in one hour and in case of red iron oxide paint the mixed quantity should be consumed with in 72 hours.
6. Scaffolding for painting should be so fixed as not to interfere in the movement of rolling stock. If this is not possible, the work should be done under block protection.
7. In case of through bridges or road over bridges in electrified sections, work near the conductors should be done after obtaining traffic and power blocks and under responsible supervision.

23.10. LOSS OF CAMBER

To compensate the deflection of girders under load, steel girders are provided with camber. The total designed camber consist of two parts as:

23.10.1. Dead load camber

Deflection corresponding to dead load is called dead load camber.

23.10.2. Live load camber

The balance part of camber is called live load camber. The live load camber should be visible and measurable in the girder, when there is no load on the girder. The loss of camber of girders may be due to the following factors:

(*a*) Heavy over stressing of members beyond elastic limit.

(*b*) Over stressing of joint rivets.

(*c*) Play between rivets holes and rivet shanks due to faulty riveting.

Out of the above causes, cause no. (*a*) may be ruled out unless heavier loads than the designed loads come over the bridge. If this happens then the girder should be replaced immediately.

Cause No. (*b*) may be checked from design. In this case the panel points on trestles should be lifted and jacked upto full designed camber or till the bearings start floating. The existing rivets should be replaced with bigger diameter rivets or with bigger gussets and more number of rivets.

For cause No. (*c*) if the number and diameter of rivets are insufficient, then the existing rivets can be replaced by sound rivets.

23.11. OILING AND GREASING OF BEARINGS

Generally all bearings of all girder bridges should be cleaned and greased or oiled once in three years. In case of flat bearings, the girder is lifted a little more than 6 mm, the bearing surface cleaned with kerosene oil and a mixture of black oil and graphite is mixed in a definite proportion and applied between the flat bearings and the lower portion of the girder. For spans over 12.2 metres special jacking beams have to be inserted and jack applied. The roller and rockers are lifted from their positions by adequate slinging and the bearings are scraped, polished with zero grade sand paper and grease sulphite applied evenly over the bearings, rockers and rollers before lowering the bearings. The quantity of grease sulphite applied should be sufficient to keep the surfaces smooth. The knuckle pins of both free and fixed end should also be greased. While lifting ends, the space between the girders (in case of piers) or between the girder and ballast wall (in case of abutment) at free ends should be jammed with wedges to prevent longitudinal movement of the span.

Phosphor bronze bearings need not be greased as they are corrosion resistant and retain smooth surface and consequently they limit the initial coefficient of friction to 0.15.

The segmental rollers should be placed vertically at mean temperature. It will be better to indicate in the completion drawing of the bridges or stress sheets, the maximum expansion with range of temperature to which it is designed, so that the slant at the time of greasing can be decided depending on the temperature recorded at the time of greasing.

23.12. REPLACING LOOSE RIVETS

Rivets become loose more frequently at locations where dynamic stresses, reversal of stresses and vibrations take place maximum. Similarly insitu rivets connections, carried out under less ideal conditions than in case of shop rivets, rivets become loose early. Thus the incidence of loose rivets takes place in joints carried out in the field.

Generally loose rivets are replaced using the pneumatic equipment. In pneumatic riveting, the driving of rivets, filling the hole and formation of head is done by snap mounted pneumatic hammer by giving quick hard blows on the white hot rivet. The rivet head is held tightly against the member by pneumatically or hand pressed dolly or wooden shaft. The rivet shank should be about 1.5 mm less than the diameter of the hole. The normal working pneumatic pressure should be kept between 5.6 to 7.0 kg/cm^2. The length of the rivet shank for every 4 mm grip or part there of for snap head rivet may be calculated by the following relation.

$$L = G + 1.5\,D + 1.0\text{ mm}$$

where,

L = Length of rivet shank

G = Length of grip in mm

D = Diameter of rivet in mm.

At the time of riveting a loose joint, more than 10% rivets should be cut at a time. Each rivet should be replaced immediately after cutting with a turned bolt of adequate diameter and length, then only the next rivet should be cut. Parallel drifts may be used in place of 50% of turned bolts. It is preferable to drill a rivet out than to use a rivet bruster as it cut the rivet head in shear which transmits heavy shocks to the adjoining groups of rivets.

In a joint where only a few rivets are loose, adjoining rivets are also rendered loose while brusting the loose rivets. It is very necessary to recheck the tightness of the the rivets in the assembly after the replacement of loose rivets in a joint.

23.13. SHOT CREATE OR GUNITING

The process of applying cement mortar or concrete through a hose pipe and projected pneumatically at high velocity on the backup surface is known as shot-creating or Guniting and the material, mortar or concrete is known as shot crete or gunite. The force of the jet impacting on the surface compacts the material such that it can support itself without sagging or sloughing even on a vertical face or over head. In general terms it may be called sprayed concrete. The shot crete has no different properties than that of conventionally placed concrete of similar proportions. It is the method of placing that imparts some significant advantages to it in some of its applications. How ever considerable skill and experience is required in the application of shot crete. Thus the quality of shot crate depends to a large extent on the performance of the operator.

23.13.1. Mix proportion

For shot crete generally one part of cement and 4 to 4.5 parts of moist sand by weight are found quite satisfactory. In general, richer mixes shrink more. The high shrinkage may destroy the bond with the base. For this reason richer mixes should be avoided. The usual water cement ratio varies from 0.35 to 0.5 or 14 litres of water per 50 kg of cement is quite satisfactory.

23.13.2. Grading of sand

The grading of sand to be used for guniting is very important. If the sand is very fine, it will produce a weak layer subject to excessive shrinkage. If too coarse, the amount of rebound will be excessive and a rough textured surface will be obtained. The maximum size of the particle may be 6 mm and fineness modulus may vary from 2.5 to 3.3. The following grading has been found most suitable. Table 23.2.

Table 23.2. Grading of sand

Size	*Commulative percentage*	
	Passing	*Retained*
4.75 mm	100 – 95	0 – 5
1.18 mm	80 – 44	20 – 56
300 micron	30 – 10	70 – 90
150 micron	2 – 0	98 – 100

The sand should have a moisture content between 3.0 to 6.0% for satisfactory operation of the equipment, but in no case it should exceed 8%. 4% moisture content has been found to give best results. If the sand is too dry, it will not flow uniformly, but will come out in bursts and dry patches will be formed. If the sand is too wet, it will clog the nozzles of the equipment. Dry sand will produce more rebound.

23.13.3. Rebound

The material which bounces back from the working faces is known as *rebound*. Largely it is the course particles of sand which rebound. The amount of rebound depends upon the following factors:

1. Greater rebound occurs when guniting is done on vertical or over hanging surfaces than level or sloping surfaces.
2. Greater the nozzle velocity, higher the rebound.
3. Lower the w/c ratio, greater the rebound.

The amount of rebound varies from 20% to 40% of the material used or handled.

23.13.4. Mixing of ingredients

Before putting the dry materials into the cement gun, the sand and cement should be mixed thoroughly for about 1½ minutes till a homogeneous mixture of one colour is obtained. Any mixed material not used with in 45 minutes of mixing, should be rejected.

23.13.5. Placing the mortar on the surface

For placing the mortar, on the surface, the length of the hose pipe should be kept as small as possible as long hose requires greater pressures for air and water. Though hose lengths upto 110 m (330-335 ft.) have been used, but preferably hose length longer than 30 to 45 m should not be used. For hose length upto 30 m, the air and water pressures at the nozzle should be about 3.5 kg/cm^2 4.2 kg/cm^2 respectively. Both air and water pressures should not be increased by 0.35 kg/cm^2 for each additional length of 15 m and 0.55 kg/cm^2 for each 7.5 m rise of nozzle above the gun. Though the volume of air required depends upon the size of the nozzle and air pressure, but for an average work using 3 cms diameter nozzle about 7.25 m^3 air per minute is required.

23.13.6. Operation

The line diagram of a cement gun is shown in Fig. 23.8. The cement and sand mixture is placed in vessel C of the gun. After filling the cement sand mix in the vessel, air at a pressure of 2.2 kg/cm^2 to 3.6 kg/cm^2 is sent from a compressor A to vessel C through moisture extractor B. At B moisture in air is absorbed and only dry air reaches the vessels C. This air pushes the cement sand mixture through pipe D and ejects it through nozzle E as shown in Fig. 23.8. Through an other pipe, air is sent from compressor A at a pressure of 3.0 to 4.6 kg/cm^2 to water tank F. From this tank water is delivered through pipe G and ejected at E. Pressures for water and air are controlled at E.

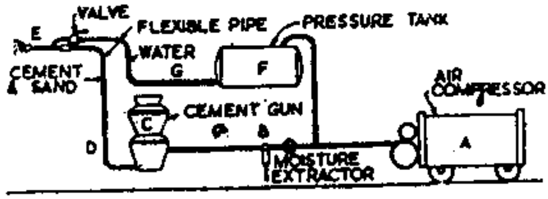


Fig. 23.8. General Arrangement for shotcreting

While guniting, the nozzle should be held normal to the surface and about 1 m away from it. In order to obtain a uniform layer, it should be kept moving. In case for a thicker layer, it should be provided in layers not thicker than about. 5 cm using stiffer mix, as thicker layer tends to slough from vertical and over head surfaces. Successive layers should be applied before the first layers have dried. All rebound material should be removed carefully, as there is a tendency to collect the rebound material in form works or to coat the surface of completed work. Wooden templates should be used at corners, edges and on surfaces where it is necessary to obtain true lines and proper thickness.

If a smooth surface is desired, steel trowling can be done, but it should be done at least one hour after placing the mix. The process of guniting should be suspended when wind is blowing, as it will not be possible to obtain the consistency of the mix during wind blowing.

23.13.7. Curing

The completed work should be protected from direct sun rays at least for 3 days and should be moist cured at least for 14 days.

23.13.8. Advantages and disadvantages of shot crete

These are shown in Table 23.3.

Table 23.3. Advantages and disadvantages of guniting

S. No.	*Advantages*	*Disadvantages*
1.	The shot crete or guniting layer can be made very strong by applying pneumatic pressure	1. The success of shotcrete depends on the performance of the operator
2.	4 to 5 cm thickness of shot crete lining is sufficient	2. The cost of construction/application of shot crete is more than ordinary concrete of the same proportion and same thickness
3.	Shot crete lining does not need expansion and constraction joints	3. It is less durable than ordinary lining of the same thickness
4.	Shot crete can be applied even on un even base successfully	4. Shotcrete lining in canals is damaged very soon due to settlement etc.
5.	Shot crete can be used for repair of disintegrated and leaking lining	5. To obtain perfect bond with the base is impossible
6.	Shot crete can be applied atleast from a distance of one metre. Hence it is very useful to apply lining while tunneling	

23.13.9. Uses of shot crete or guniting

Usually shot crete is used for the following works:

1. For the construction of thin and lightly reinforced sections such as curtain walls.
2. For the construction of shell or folded plate roofs.
3. For tunnel lining and for protective covering of soft rocks.
4. For prestressed tanks.
5. For repairing deteriorated concrete and for stabilizing the rock slopes.
6. For encasing steel for fire proofing.
7. For repair or laying new canal and reservoir lining.
8. It can also be applied on a surface covered by running water, in such cases an accelerator producing flash set such as washing soda should be used. Though it adversely affects its strength, but makes repair work possible.
9. For repairing old structures.

QUESTIONS

1. Enumerate the maintenance works of a major bridge.
2. Write short note son:
   (*a*) Loss of camber
   (*b*) Loose rivets
   (*c*) Epoxy grouting
3. Discuss the process of painting and Jacketing of a bridge.
4. Jacketing is a process of:
   (*a*) Strengthening of sub structure of a existing bridge.
   (*b*) Construction of sub structure for a new bridge.
   (*c*) Strengthening super structure of a existing bridge.
   (*d*) All are correct.
5. Strengthening by jacketing consists:
   (*a*) Grouting the structure by cement sand mixture
   (*b*) Laying new concrete around the existing surface
   (*c*) Constructing the new structure with the help of special shuttering
   (*d*) By using Epoxy grouting
6. Epoxy grouting is used
   (*a*) To give a good aesthetic look to the structure
   (*b*) To give better bond between the old and new surfaces of old concrete and grout
   (*c*) To develop higher compressive strength in old concrete
   (*d*) To develop higher resistance against tensile stresses
7. Painting of steel bridges mainly is done
   (*a*) To give good aesthetic look (*b*) To protect the structure from rusting
   (*c*) To develop more strength in structure (*d*) None of the above is true
8. Severe scour protection by sheet piling is most suitable
   (*a*) In situations where big boulders are present in river bed in large number
   (*b*) In situations where the river flows in fissured rocks
   (*c*) It is ideally suitable in alluvial river beds
   (*d*) It is suitable in clayey soils
9. Shot crete can be used for
   (*a*) Tunnel lining (*b*) Canal lining
   (*c*) Encasing of steel for fire protecting (*d*) Repairing old structures
   (*e*) All the above

10. For shot crete, usually the mix proportion adopted is
    (*a*) 1:3 (*b*) 1:4.5
    (*c*) 1:6 (*d*) 1:2
11. Shot crete should be applied from about a distance from the face
    (*a*) 5 m (*b*) 7 m
    (*c*) 1.0 m (*d*) 12 m
12. While shot creating the ejecting pressure of air and water varies:
    (*a*) Directly with the length of the hose pipe
    (*b*) Indirectly with the length of the hose pipe
    (*c*) There is no effect of length of hose pipe on the pressure
    (*d*) None of the above is true
13. While shot creating the nozzle should be held... to the surface
    (*a*) Inclined at 45° (*b*) Inclined at 60°
    (*c*) Inclined at 90° or normal (*d*) Inclined at 120°
14. Completed shot crete work should be at least protected from direct sun rays for
    (*a*) 14 days (*b*) 9 days
    (*c*) 5 days (*d*) 3 days

ANSWERS

4. (*a*)	7. (*b*)	10. (*b*)	13. (*c*)
5. (*b*)	8. (*c*)	11. (*c*)	14. (*d*)
6. (*b*)	9. (*e*)	12. (*a*)	

24
River Training Works

24.1. INTRODUCTION

During monsoon period the flood discharge in rivers varies from 50 to 100 times the normal discharge of the river. Under such conditions the beheviour of river becomes uncertain. This is an inherrent property of water that it can not flow without silt in clear form while flowing in erodable formations. The silt carrying capacity of water varies with the velocity of flow raised power 2.5 app. Thus higher the value of flowing velocity, higher the silt carrying capacity of the water. When the silt load becomes more than its carrying capacity then it deposits the silt load at bottom and picks up its silt load from cutting banks and eroding bed at some other place. The river flow path is never in one fixed path way. It remains changing its path during rainy season every now and then. Thus it is very essential to keep river flow in a definite path near hydraulic structure such as a bridge so that at should not out flank the existing bridge or hydraulic structure. Works constructed to keep river flow in a well defined course are called river tracing works or river protection appurtenances.

24.2. OBJECTIVES OF RIVER TRAINING WORKS

Followings are the main objects of river training works:

1. To provide a safe and expedious passage to flood flow without over flowing of the banks to protect the inhabitated areas, standing crops, Railway track, and other important properties of the area. This is achieved by constructing marginal embankments or dikes. Thus the aim is to protect the property of the area and the surrounding cultivated and inhabited land from flooding.
2. To prevent the out flanking of hydraulic structures such as bridges, barrages etc. constructed across the river by directing the flow in a well defined and restricted channel. This is achieved by constructing guide bunds.
3. To ensure maximum depth of flow of water for navigation etc.
4. To deflect the river away from the bank which is damaged by the river. This can be achieved by constructing spurs or groynes.
5. To fix the direction of flow through certain well defined alignment.

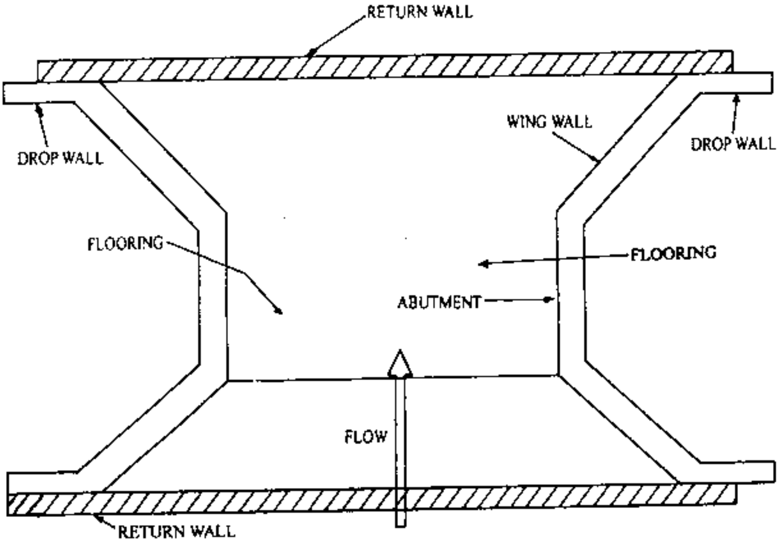
24.3. PROTECTION WORKS

Protection works are the appurtenances provided to protect the bridge and its approaches from the damages during high flood conditions. Following works may be classified as protection works.

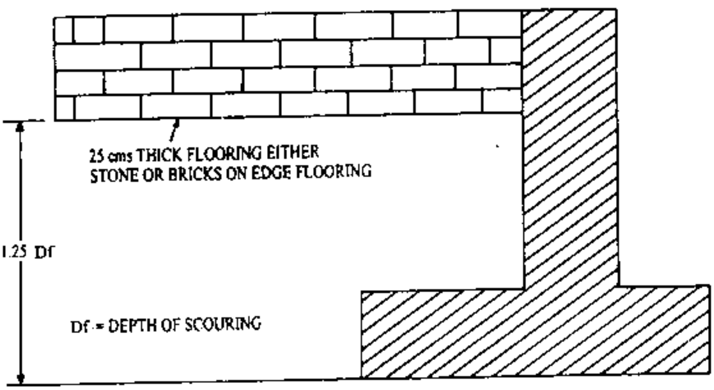
1. Flooring
2. Curtains and drop walls
3. Pitching
4. Toe walls
5. Guide bunds
6. Marginal bunds
7. Spurs or Groynes
8. Aprons
9. Rectangular crates

24.3.1. Flooring

Flooring is provided to prevent scouring in shallow foundation bridges. To prevent disturbance to flooring, curtain and drop walls are provided on upstream and down stream respectively. Generally flooring is provided in small bridges. The length of floor and depth of drop wall depends on the scour depth. The scour depth can be determined by using Lacy's equation, using design discharge. The depth of drop wall may be



(*a*) Plan of a bridge floor with abutment and wing wall



(*b*) Section of bridge floor

Fig. 24.1.

taken as 1.25 times the normal scour depth determined. Floor should be carried over the entire width and length of abutment including wing wall as shown in Fig. 24.1 (*a*), (*b*). The slope of the floor should match the bed slope. The wall also should match the slope. If necessary local dressing may be done. It has been observed that neglect of flooring has led to the failure of the bridge. Mostly heavy scour has been observed on the down stream side of the drop wall as shown in Fig. 24.2. It is necessary to repair this scour by dumping wire crates filled with boulders as shown in Fig. 24.3. In locations where water impinges with high velocity, dumping of loose boulders has been found quite ineffective as loose boulders are carried away to down stream by high velocity water currents. In such situations rectangular crates with stone, may be used.

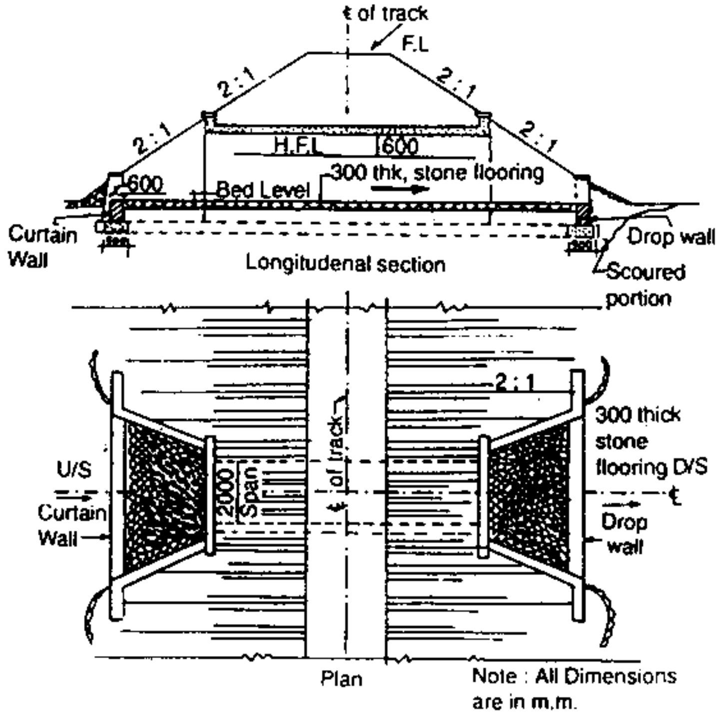


Fig. 24.2. Floor with curtain and toe wall

24.3.2. Rectangular crates

Rectangular crates are rectangular cages made of 6 to 8 mm round steel bars. Usually the size of the cage is kept 1 m × 1 m or 1 m × 0.8 m as shown in the Fig. 24.3. These are fixed in the bed of the river and filled with boulders.

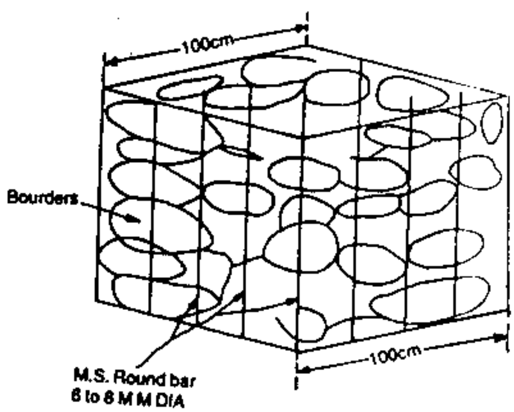


Fig. 24.3. Rectangular crate

24.3.3. Pitching

To prevent erosion of banks by the flowing water of the river, some times stone pitching is provided on the approach banks of alluvial riveres. Pitching is also provided on guide bunds, spurs, marginal embankments etc. to prevent their erosion. Pitching acts like an armour on the earthen banks.

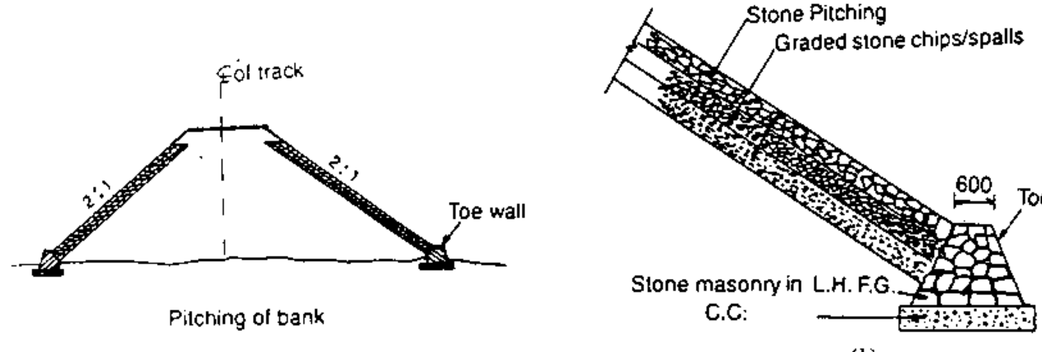
24.3.4. Toe wall

It is a short wall in height built in river to support the bank pitching. It is an important component of pitching. If the toe wall gets damaged, the pitching is also likely to slip into the water. Provision of proper foundation to toe wall is essential.

The size of pitching stone may be such, so that they may be handled by one labourer. Usually their weight may vary from 35 kg to 55 kg. The thickness of stone pitching for small works of 25 cm to 30 cm will be sufficient. The gap between the boulders should be filled with smaller pieces. Toe wall and pitching of bank is shown in Fig. 24.4.

24.3.5. Guide bunds

Guide bunds are constructed to guide the stream near a hydraulic structure like bridge, so that it may



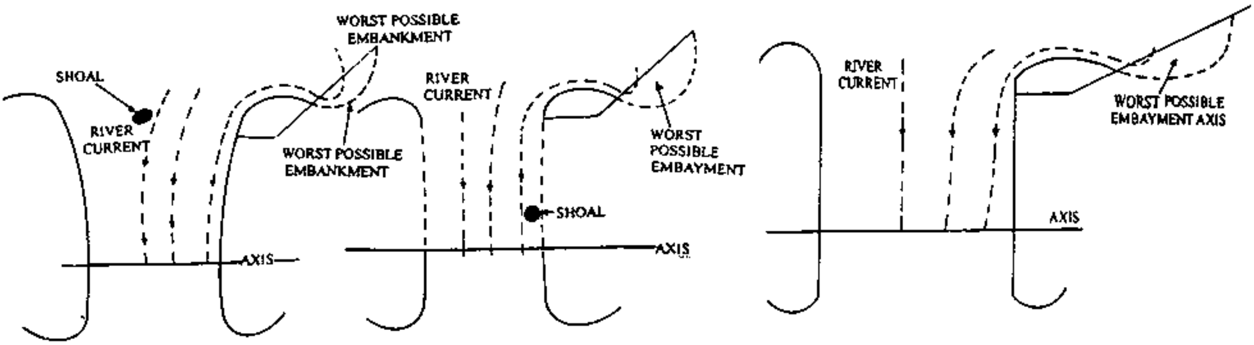
(*a*) (*b*)

Fig. 24.4. Toewall and Pitchings slope

flow through a well defined channel of reasonable width to ensure its safe and expedious passage.

24.3.5.1. Layout

The layout of guide bund should be such as to guide the flood smoothly through a hydraulic structure like a bridge, or aquaduct constructed across the river.They guide bunds are provided in pairs symmetrical in plan and may either be parallel, divergent or convergent slightly towards the work as shown in Fig. 24.5.



(*a*) Divergent Upwards (*b*) Convergent Upwards (*c*) Parallel

Fig. 24.5.

For important bridges, elliptical guide bunds have been found advantageous particularly for wide and shallow rivers to induce the flow to hug the guide bund better. This is also has been advocated in IS 8408-1976. This type of guide bund has been constructed on river Gandak of Chhitauni-Bagha Railway line. However as a rule unless model studies suggest any special type of guide bund, or for smaller works, straight parallel guide bunds only should be provided.

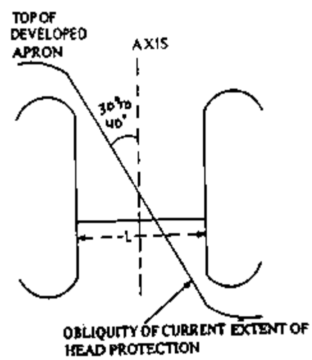


Fig. 24.6. Obliquity of current

24.3.5.2. Length of upstream/downstream guide bund

The most important factor for determining the length of upstream portion of guide bund is the maximum obliquity of the current which must be limited to reasonable value, so that it could provide protection to the approach embankment behind the noze of the training works.

The upper limit of obliquity of the current flow through the bridge axis has been found as 30° to 34° as shown in Fig. 24.6.

Thus upstream length of guide bund should vary from 1.25 L to 1.5 L depending upon the discharge between 2100 m^3/sec to 42500 m^3/sec where L is the length of the bridge between the abutments. The value of L may also be determined from the relation.

$$L = 4.75\sqrt{Q}$$

where Q is the estimated maximum discharge in m^3, and L is the width of the channel in metres. In this length, an extra allowance of 20% may be made for the thickness of bridge piers etc. Fig. 24.7 shows different parts of a guide bund in plan.

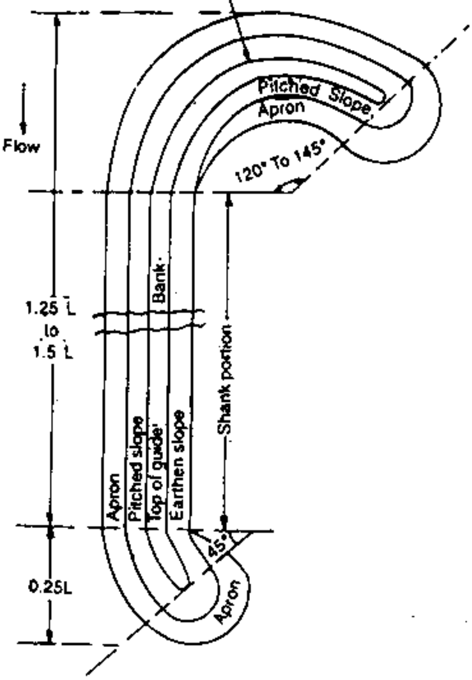


Fig. 24.7. Guide bund

24.3.5.2. Down stream end length

This length may vary from 0.2 L to 0.25 L.

24.3.5.3. Main parts of a guide bund

The main parts of a guide bund are as follows:

1. U/s curved head or impregnable head
2. D/s curved head
3. Shank or straight portion which joins two curved parts
4. Slope and toe protection

24.3.5.3.1. U/s curved head

At the u/s end, the curvature has a central angle of 120° to 145°. The radius of curvature of the worst embankment loop should be taken as 2 to 2.5 times of the average radius R. Rivers having maximum discharge more than 5660 m^3, it should be taken as 2 R and for rivers having discharge upto 5660 m^3, it should be taken as 2.5 R.

The average value of radius of curvature may be taken as 0.45 L (where L is the length of the hydraulic structure or Lacey's perimeter). It may also be taken as suggested by spring or Gale based on their studies of Indian rivers. Spring suggested the value of R equal to 180 m to 250 m for rivers having velocities 2.4 m/s to 3.1 m/s respectively. Gale on the other hand suggested the value of R as 250 for rivers having flood discharge between 7000 to 20,000 cumecs. Sharper curves may be permitted for rivers having discharge less than 7000 cumecs. A value of 580 is recommended for discharges ranging from 40,000 to 70,000 cumecs.

24.3.5.3.2. D/s Curved head

To attain the normal width, the rivers fans out at the d/s end. For the safety of the approach

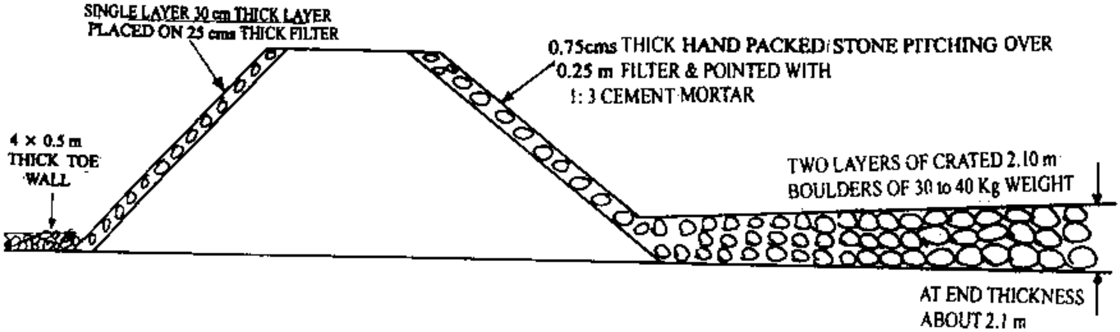


Fig. 24.8 (*a*) Cross-section of guide bund at u/s curved head

embankment a proper shape is essential. Studies have showed that the radius of d/s end may be kept 0.3 to 0.5 of the radius of the u/s end and the central angle as 45° to 60°. Fig. 24.8 (*a*) shows section at u/s curved head and Fig. 24.8 (*b*) shows section at straight part.

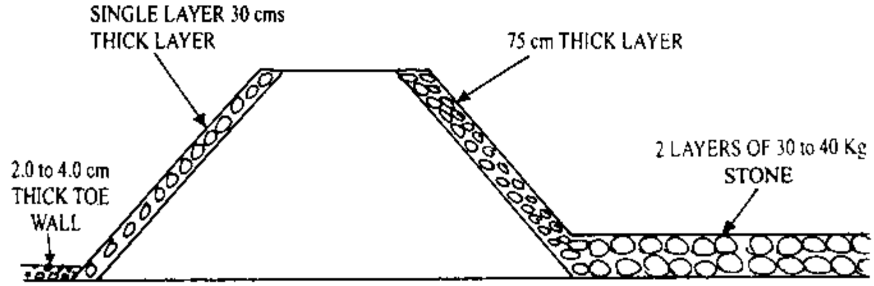


Fig. 24.8 (*b*) Cross-section at sank of guide bund

24.3.5.4. Section of the guide bund and material of construction

24.3.5.4.1. Top width of the bund

The top width of the bund should be kept 6 m to 9 m so that vehicles carrying construction material may pass easily and also to store boulders on it. In no case top width should be adopted less than 4 m.

24.3.5.4.2. Side slopes

Side slopes may be adopted as 2:1 to 3:1. How ever 2:1 is quite satisfactory.

24.3.5.4.3. Construction material

Usually local available river sand is used as construction material.

24.3.5.4.4. Free board

Usually adopted free board varies from 1.25 to 1.5 m.

24.3.5.4.5. Protection of slopes of guide bund and approach embankment

The most common method of protection is by stone pitching. For satisfactory working of these structures they should be provided good drainage. For this purpose a graded filtre of 20 cm to 30 cm thickness should be provided below the pitching. The graded filtre should satisfy the norms laid down by IS 8237-1976.

For pitching, stones boulder weighing 35 to 55 kg may be used. This size usually is quite satisfactory for velocities upto 2.5 m/sec. Beyond this velocity limits, stones may be laid in grid with proper pointing. These boulders can not easily be displaced by water current. For small works a 25 to 30 cm thick pitching will be sufficient. Gaps in between may be filled with smaller pieces. For larger works the thickness of pitching may be adopted as suggested by Inglis as

$$T = 0.06\, Q^{1/3}$$

where,

T is the thickness of pitching in feet and

Q is the discharge in cuses.

The thickness should vary between 0.3 m to 1.0 m IS 84084-1976 has suggested following relation, which is related with velocity.

$$V = 4.893\, D^{1/2}$$

where V is velocity and D is diameter of the stone. The stone pitching should be done upto 1 m above high flood level. The thickness of pitching at impregnable head should be 25% more than other parts of the bund. The relation between velocity, diameter of stone and weight of stone is shown in Fig. 24.9.

In case of guide bund, the pitching should be continued right upto the top of the formation for the river side, including the curved head on both sides and tail head. Rivers having large ponding, the pitching should be done on the rear side of the guide bund also. For approach embankments on the u/s side the

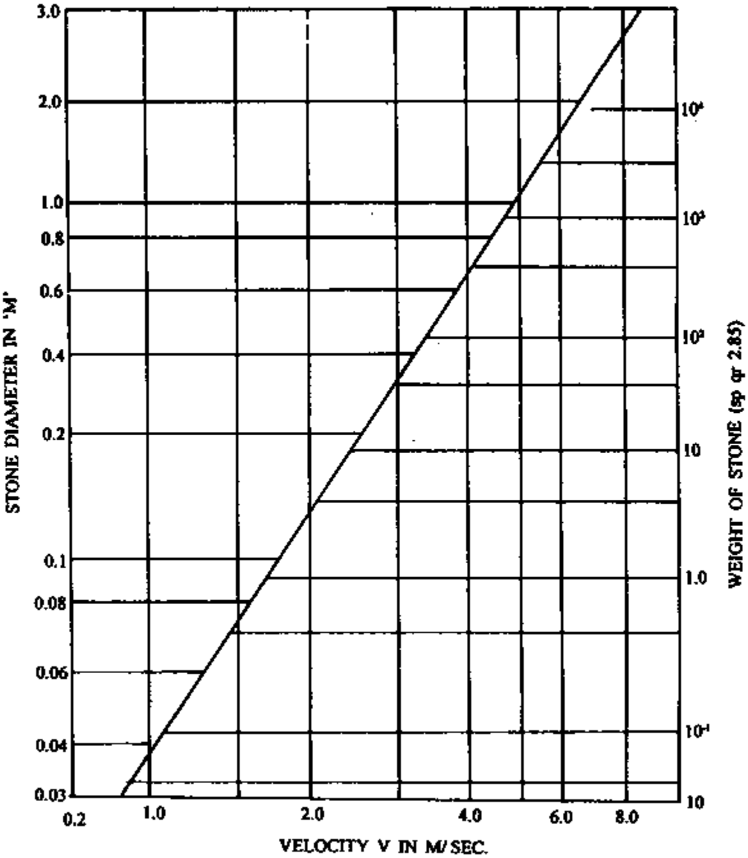


Fig. 24.9. Relation between velocity, weight of stone diameter of stone

pitching should continue upto free board level which should be determined not only on H.F.L., but also velocity head $v^2/2g$ should also be taken into consideration for wave action.

For the d/s side pitching should be done upto the water level, observed in model studies or general water level observed. Otherwise toe protection upto about 1 m height is sufficient. In addition to this a toe protection with short apron of 1 m width and 25 cm to 30 cm thick should be provided. For rest of the slope generally good turfing has been found satisfactory. No filtre generally is provided on d/s of the approach embankment.

Generally for high banks more than 6 m in height, a good drainage is the key for protection of slopes from rain cuts. Longitudinal and cross drainage should be provided.

The rear or out side shank portion is not pitched, but covered with 0.3 to 0.6 m thick layer of earth for the growth of vegetation, which will make it resistant against wind and rain effect.

24.3.6. Scour in river bed at different locations of the bridge

Normal scour depth R is given by Lacey's formula as:

$$R = 0.47\left(\frac{Q}{f}\right)^{1/3}$$

where Q is discharge in cumecs and f is silt factor.

Maximum depth of scour as suggested by Inglis and Joglekor.

(*a*) Maximum scour depth d/s of bridge, $D_s = 1.9\left(\frac{Q}{f}\right)^{1/3}$

(*b*) Maximum scour depth around bridge pier, $D_p = 0.95\left(\frac{Q}{f}\right)^{1/3}$

(*c*) Maximum scour depth at nose of guide bund, $D_n = 1.3\left(\frac{Q}{f}\right)^{1/3}$

where Q and f have the same meaning as in case of Lacey's relation.

24.3.7. Slope and toe protection

The toe of slope is protected by the falling or launching apron.

On the river side of the guide bund, suitably designed apron should be provided. In alluvial beds apron should be capable to adjust it self due to uneven scour. In such cases adequate quantity of boulders is provided. How ever for inerodable bed, rocky bed or bouldery beds having water velocity more than 4m/sec, concrete blocks should be provided with proper anchoring or chaining arrangement.

24.3.8. Design aspects of apron

For the proper and efficient working of a apron, following elements require proper designing:

24.3.8.1. Thickness of the apron

The thickness of the apron is governed by the thickness of the slope pitching. In general the thickness of launched apron should be kept as 1.25 T, where T is the thickness of the slope pitching. In more severe cases it may be kept as 1.5 T.

24.3.8.2. Level at which the apron is to be laid

This is the most important factor. Normally apron should be laid on dry bed as low as possible, usually upto water depth not more than 0.9 m (preferably it should be 0.6 m to 0.9 m). If it is not available, the bed should be made up by temporary filling or by diverting the current of flow by any suitable means. To lay the apron, generally the bed should be excavated upto low water level. The excavated material may be used for the construction of guide bund and approach bank.

24.3.8.3. Width of apron

The width of apron has to be designed based on scour depth. For alluvial conditions this is determined by Lacey's equation as noted above. The scour depth varies depending on the location as discussed above. The scour depth may be adopted as below for different locations:

(*a*) U/s of the curved head of guide bund, scour depth is taken as 2.5 D.

(*b*) Straight portion of the guide bund including tail on the d/s side of the bund, scour depth is taken as 1.5 D.

(*c*) For very large radius of guide bund having severe attack, scour depth may be taken as 2.75 D, where D is the scour depth given by Lacey's equation. The length of scoured face will be $\sqrt{5}\,D$ with a slope of 2:1. A launching apron is shown in Fig. 24.10.

24.3.8.4. Side slope of apron

It may be adopted as slope of guide bund *i.e.* 2:1 is quite sufficient.

24.3.8.5. Quantity of boulders

It should be sufficient to cover the scoured face fully after it has launched fully at a slope of 2:1 with a thickness of 1.25 T to about 2 T. Some sections of guide bund with launching apron are shown in Fig. 24.10.

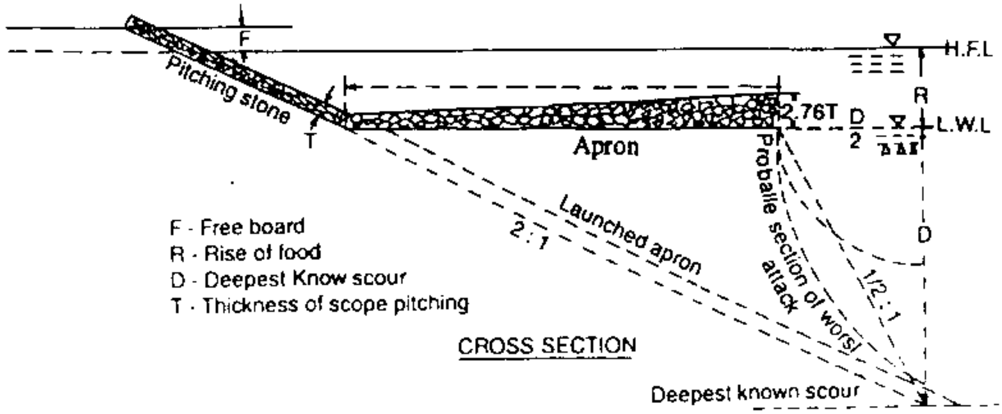


Fig. 24.10. Launching apron

24.3.9. Marginal Embankments or bund

Marginal embankments are provided on those rivers in which flood level is very high and the adjoining areas are flooded rendering them useless for cultivation. Thus to prevent the submergence of the adjoining areas and cities and to contain the flood water of the river to the cross section in between the embankments, marginal embankments are constructed. Marginal embankments are constructed parallel to the river channel. They may be constructed on one side or both sides as per requirements.

24.3.9.1. Classification of marginal embankments

Depending upon the position of the embankments, they may be Classified into the following two categories:

24.3.9.1.1. Close embankments

These embankments are constructed as close to the bank of the river as possible, so that the flood water is confined between the embankments. The actual distance from the river bank is not subject to theoretical treatment, but it is decided by technical and human considerations, keeping in view the cost of land. The section of the embankment is governed by the material available. It will be economical to use the local available materials for their construction.

Section of embankment. Following section may be adopted:

Height of the section. Usually the height of the section should not be more than 12 m.

Top width. The top width may vary from 3 to 5 m as per need, but it should not be less than 3.0 m.

Side slope. 3:1 to 4:1 on water side and 4:1 to 7:1 an land side may be adopted.

24.3.9.1.2. Retired embankments

Embankment constructed at a distance from the river banks are called *retired embankments.* This is an intermediate arrangement between the close embankments and no embankments at all. These embankments cause minimum interference with the regime of the river.

24.3.10. Groynes or spurs

These are structures constructed transverse to the flow and extended from bank to the river channel.

24.3.10.1. Objects of groynes construction

The objects of groynes construction are as follows:

1. To protect the river bank by deflecting, repelling or attracting the flow of the river.
2. To create a still pond or slack flow along a particular bank to silt up the neighborhood.

3. To train the river to flow along a specified course by attracting, deflecting or repelling the flow of the river.
4. To contract the wide shallow river channel to improve navigation.

24.3.10.2. Classification of groynes or spurs

Groynes or spurs may be classified as follows:

1. According to their method of construction as:
   (*a*) Permeable or impermeable
2. According to their height as:
   (*a*) Submerged, or
   (*b*) Non submerged
3. According to their action as deflecting, Repelling and attracting
4. Special type of groynes or spurs.

24.3.11. Permeable groynes

The river training works are very expensive and difficult to construct. For temporary protection of river banks from erosion, this may be protected by using permeable groynes. These groynes are cheap to construct and silt up the area in due course of time. There are many types of permeable groynes.

24.3.11.1. Bamboo groynes

These bamboo groynes are suitable for water depth in rivers upto 1.2 m only. For their construction 50 to 65 mm diameter bamboos are nailed forming a square of about 60 cm. The plan of such a groyne is shown in Fig. 24.11. For good effect they can be filled with bushes, branches of trees or grass etc. They can

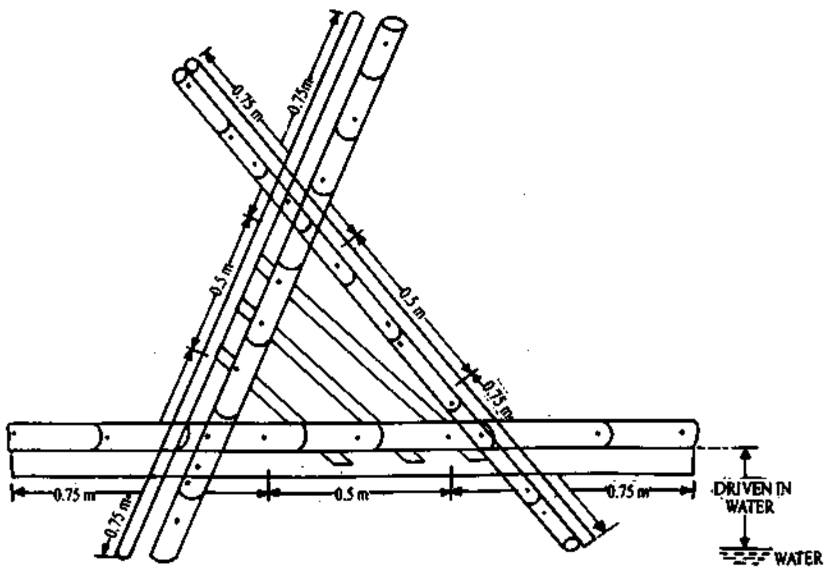


Fig. 24.11. (*a*) End view of bamboo groynes

also be made as a screen by tieing the branches of trees with leaves or bushes with nylone rope. These branches work as screen and allow water, but retain large size flowing material, which silts up the surrounding area. These spurs are known as PORCUPINES. These groynes are pushed in bed or weighed down by putting big boulders or sand bags on them. As scour takes place they go down and settle there. These groynes are found very effective in dampening the flow and causing heavy siltation if used intellegently. They are also found very effective in diverting the existing flow into a different channel. Fig. 24.11 (*a*) shows end view and 24.11 (*b*) plan, where as Fig. 24.11 (*c*) shows arrangement of dampening the flow of water.

(*ii*) In case, the depth of water in the river is more than 1.2 m, in that case bamboo squares of 60 cm size are prepared as above and tied in series with nylon rope and the space in between is filled with tree benches, bushes etc. as above and weighed down.

(*iii*) Bank erosion may also be saved by dumping bundles of SARKANDA and dead cotton plants or tree branches with leaves or bushes at the scoured place. Mud, stones or bags filled with sand may be placed over them to check their movement. They may allow water to pass through them. They reduce the velocity of flow resulting dropping of silt by water in the vicinity and silting it up.

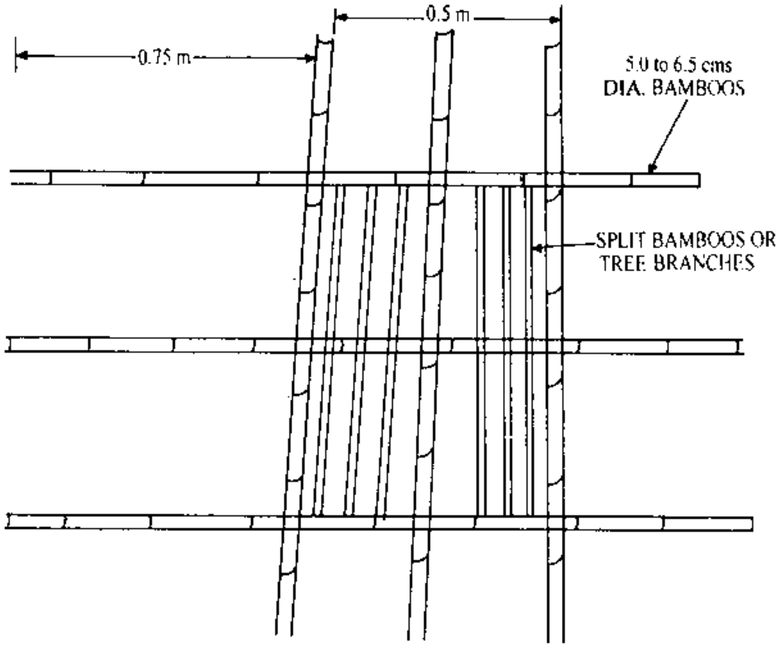


Fig. 24.11. (*b*) Plan of porcupines

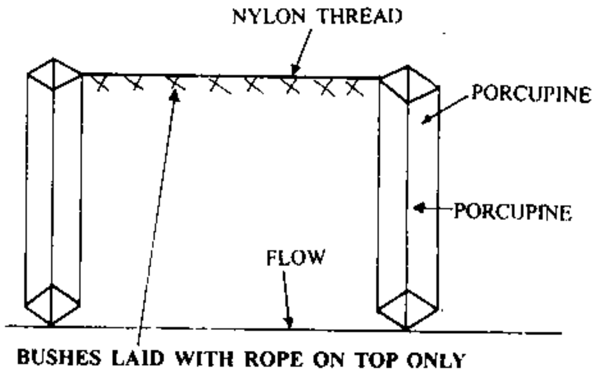


Fig. 24.11. (*c*) For dampning flow

24.3.11.2. Advantages of Permeable groynes

The basic advantages of permeable groynes are as follows:

1. They are cheap in the cost of construction.
2. Small quantity of stone is required for their construction.
3. Their performance is better than impermeable groynes.
4. These groynes do not change the flow abruptly. Hence there is no serious formation of eddies and scour.
5. It is more suitable for deep and narrow rivers.

Their only disadvantages is that they are not strong enough to resist shock and pressure from the floating debris and ice etc.

24.3.12. Impermeable groynes

This class of groynes does not allow any flow through them. They are constructed of a core by the locally available materials such as sand, clay or gravel and protected on sides by stone or concrete block pitching. In short they are small dams.

24.3.12.1. Salient dimensions of impermeable groynes

(*i*) Top width = 2.5 to 3.0 m
(*ii*) Side slope = 2:1
(*iii*) Free board = 1.0 to 1.5 m
(*iv*) Head square having slope = 5:1
(*v*) Thickness of pitching = Same as for guide bund
(*vi*) Material of construction = Local available materials

B. Rock fill groynes (Low spur)

(*i*) Top width = 1.5 m to 2.0 m
(*ii*) Side slope = u/s 1.5:1 and d/s 2:1
(*iii*) Free board = 0.75 m
(*iv*) Mattress = 6 m wide and 0.3 m thick on u/s side

24.3.13. Groynes according to their action

24.3.13.1. Deflecting groynes

The groynes aligned at right angle or normal to the bank are known as deflecting groynes. They deflect the flow locally is shown in Fig. 24.12 (*a*). The head of the groyne deflects the water in a direction nearly

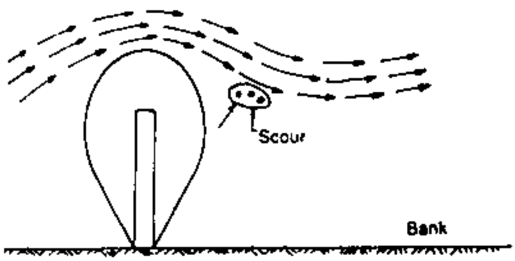


Fig. 24.12 (*a*) Deflecting groyne

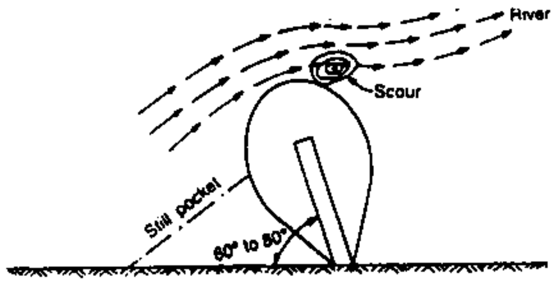


Fig. 24.12 (*b*) Repelling groyne

perpendicular to itself. The current of water causes scour just d/s of the groyne. The best result of deflection may be obtained by locating the groyne on convex portion of the bank.

24.3.13.2. Repelling groyne

These groynes are inclined towards upsteam side of flow as shown in Fig. 24.12 (*b*). Their inclination with the normal varies from 10° to 30° and with the bank 60° to 80°. For bank protection this type of groynes have proved more effective. The still pond is created on the up stream side of the groyne and sediment brought by the river gets deposited in this pocket. There is heavy attack on the nose of the groyne as shown in the Fig. 24.12 (*b*). It needs very strong protection. These groynes should be constructed at 0.45 to 0.55 of the meander length up stream of the object to be protected. Some authors have suggested this distance as 0.4 times the length of meandering.

24.3.13.3. Attracting groynes

These groynes are inclined towards the down-stream side as shown in Fig. 24.12 (*c*) and called attracting groynes. Their inclination from normal varies from 30° to 45° and from d/s bank from 45° to 60°. They attract the flow at their nose and cause heavy scour holes near the banks on which they are

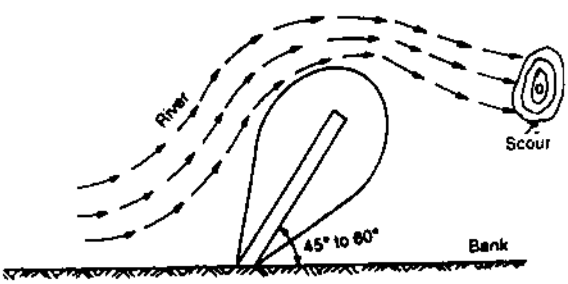


Fig. 24.12 (*c*) Attracting groyne

built. The main attack of water is on the u/s side of the groyne. Thus this portion needs very heavy protection. It is recommended that these groynes should be located at 0.4 of the meander length u/s of the object to be protected. This type of groynes have not been proved effective for river traing works.

24.3.13.4. Spacing of groynes

For convex banks spacing varying from 4 to 6 times the length of the groyne has been found very effective, while for concave banks a spacing of 2.0 to 2.5 times the length of the groyne is quite effective. In other words spacing on convex banks is more than the concave banks. Also for wider rivers spacing is more than for narrow rivers.

24.3.13.5. Length of groynes

The length of groynes depends upon the position of the original bank line and the designed normal line of the trained river channel. Too long groynes are easily erodable by river and are liable to damage and failure. In such cases it is better to start with shorter lengths and extend them gradually as silting up proceeds between them. Usually the groynes should be extended upto 1/3rd of the width of the stream. Its best location is just at the beginning of the damaging loop. Fig. 24.13 (*a*) shows the normal section of the groyne while Fig. 24.13 (*b*) shows the section at the nose.

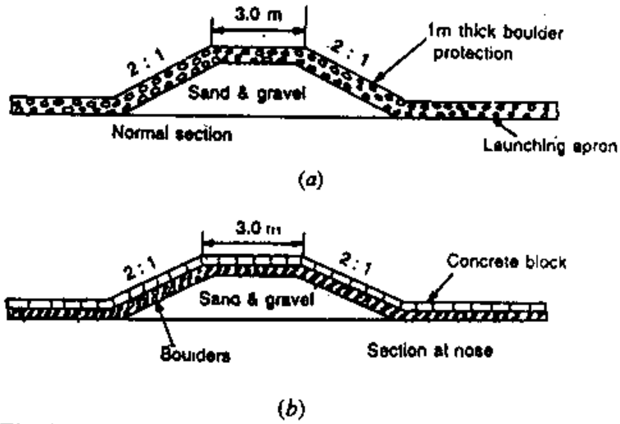


Fig. 24.13. Groyne sections (*a*) Normal, (*b*) Section at nose

Indian Railways, based on their studies and experience have suggested the length of the groyne not less than 2½ times the local scour depth. The local scour depth may be taken as 2 to 2.5 times the normal scour depth calculated by the Lacey's relation $D = 0.47\ (Q/f)^{1/3}$. OR the scour depth may be found from model studies. Scour depth determined from model studies should be taken as such. It should not be multiplied by any multiple. Some authors have pointed out that Repelling groynes have been found more effective than attracting groynes and are commonly used in practice. The other two types of groynes should not be used with out model studies.

If groynes not properly selected, designed and constructed, they may prove more harmful than advantageous. Hence their design and selection and construction is very important.

24.4. METHODS OF RIVER TRAINING

Normally following works are adopted for river training:

1. Guide bund	2. Marginal embankments or levees
3. Groynes or spurs	4. Cut off
5. Pitched island	6. Pitching of banks

Works from No. 1 to 3 have already been discussed.

24.5. CUT-OFF

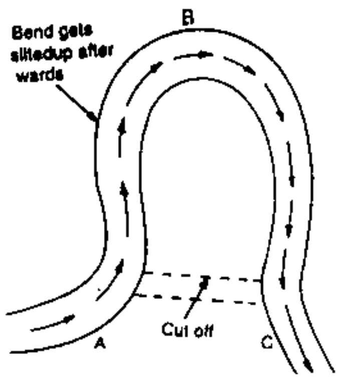


Fig. 24.14. Cut-off

When the meandering of a river reaches extreme conditions and develops into a horse shoe bend or hair pin bend as shown in Fig. 24.14 the land between the two portions of bend may gradually reduce to a narrow neck, which may easily be cut across by the natural flood flow. The chord channel connecting the two portions of bend is known as *natural cut off*. Some times to improve the flood capacity of a given reach and thus to reduce the flood level in that reach and to make the river flow straight, artificial cut off may be introduced as a river training measure. Artificial cut off is adopted when the loop length exceeds the chord length by 1.5 to 2.5 times *i.e.* loop length is 1.5 to 2.5 times of the chord length. In the beginning a pilot cut is introduced with a carrying capacity of 8 to 10% discharge. Sub-sequently it is allowed to develop for carrying capacity of 40 to 50% discharge of the river.

24.5.1. Design parameters of artificial cut-off

1. The direction of cut should be tangential to the main direction of flow.
2. The alignment of pilot cut should preferably be made at a curvature much flatter than the curvature of the river itself.
3. Entrance to cut off should be given bell mouth shape.
4. The pilot section should be made very deep as deeper sections develop rapidly.
5. The curvature of artificial cut off should be flatter than that of main channel.

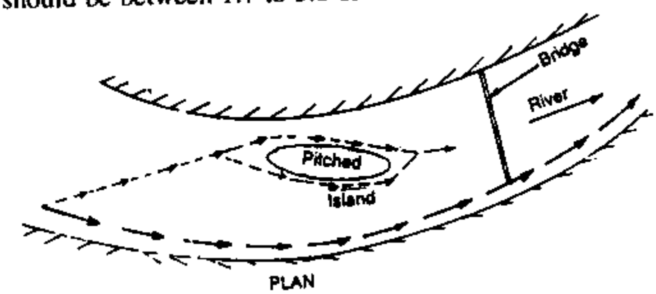
24.5.2. Natural cut-off

This may develop due to scour by flood water. Due to the development of natural cut-off, violent disturbance in the regime of the river for some distance upstream and down stream both are developed. Erosion and drawdown conditions are developed on tne upstream side of cut-off. Silt deposition takes place on the down stream side of the cut-off. The disturbed conditions prevail till the river finds a new equilibrium by developing new curve else where. For natural cut off development following two conditions must be satisfied:

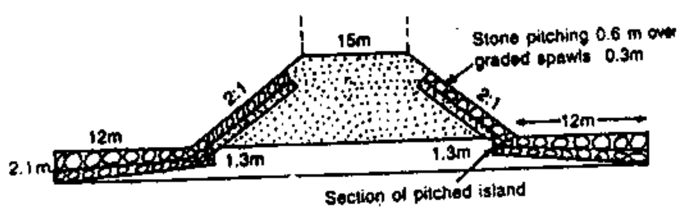
1. The ratio of bend to the chord length should be between 1.7 to 3.0 or more.
2. The ratio of radius of curvature R and the square root of discharge Q in m^3 should be between 13 to 24. *i.e.* $R/\sqrt{Q}$ = 13 to 24.

24.6. PITCHED ISLANDS

It is an artificially constructed island in the river bed and protected by stone pitching all-round. The use of pitched island is made when the river is flowing towards one bank only and it is desired to change this flow condition. The construction of island becomes an obstruction to the flow of the water and turbulence starts to develop in the river, which starts scouring in the vicinity or around the island. Gradually river becomes deeper around the island, when the depth of water around the island becomes sufficiently more, it attracts the current of water from the other side of the banks towards it and holds it permanently and the concentration of the current at the other side is reduced as shown in Fig. 24.15 (*a*). The dotted arrows show the path of water flow after the construction of pitched island. The solid arrow shows original flow of river. The actual design details of pitched island are carried out with the help of model studies. However maximum scour may be determined from Lacey's equation as



(*a*)



SECION

Fig. 24.15. Pitched island

$$2R = 2.70\,(q^2/f)^{2/3}$$

24.6.1. Use of pitched island

Pitched island may be used for the following purposes:

1. To direct the river to have axial flow.
2. To improve the depth of channel for navigation purposes.
3. To correct the adverse curvature for effective sand exclusion.

However the use of pitched island has not been found effective in shallow and wide rivers, where the obstruction caused by pitched island is very small to cause sufficient scour.

24.7. BANK PROTECTION

The bank protection is carried for the following purposes:

(*a*) To check erosion of banks due to water current or waves.

(*b*) To check sliding of slope due to its gradual steepening due to erosion.

(*c*) To prevent piping due to any cause.

(*d*) To prevent sloughing or sliding of slope when saturated with water.

(*e*) To prevent undermining of the toe of the lower bank due to waves, water currents, eddies etc.

(*f*) To check sliding due to draw down of the flood.

24.7.1. Methods of Protection

Following methods may be adopted for bank protection:

1. *Protection of bank by vegetation cover.* In this method certain varieties of grass or bushes may be grown on the bank, which is not subjected to strong water current. The roots of the plants hold the soil particles together and provide stability to it. This is most effective method of slope protection.
2. Pavement of bank slopes by materials which can resist the quick erosion of the bank. Along with pavement, the slope may also be provided a covering of bushes or mattresses which are weight down with stones. This method is useful if the current is strong.
3. When the current is very strong, protection is provided by stone pitching or other methods such as planting willows (a tree with long leaves) or provision of asphaltic concrete.

24.7.2. Pitching of the banks

The required length of river bank is cut to a suitable uniform slope of 1:1 or 2:1 depending upon the nature of the bank material and pitching is done with the help of boulders or concrete blocks as shown in Fig. 24.16.

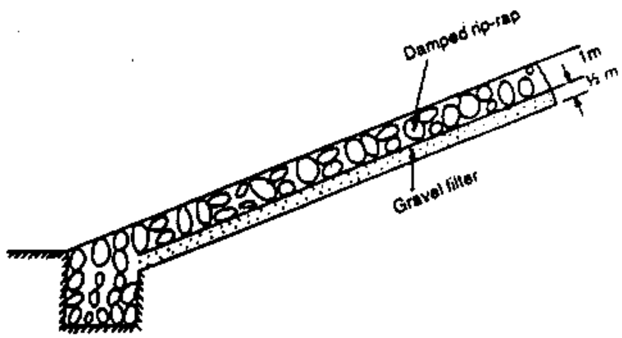


Fig. 24.16. Bank pitching

Due to pitching of the bank, deep scour develops at the toe of the bank, which attracts the water towards it from the other side. In this way the river channel is held permanently at the pitched bank.

QUESTIONS

1. What are the objects of river training works.
2. Name different methods of river training works and describe in detail groynes method.
3. Write short notes on the followings:

   (*a*) Guide bund (*b*) Marginal embankments

   (*c*) Pitched island

4. The main aim of river training works near a bridge is
   (*a*) To check the out flanking of the bridge
   (*b*) to check scouring of bed of the river
   (*c*) To ensure river flow in the central portion of the river channel
   (*d*) None of the above
5. The scour hole develops on a normal groyne at:
   (*a*) Nose of the groyne (*b*) Down stream of the nose
   (*c*) Up stream of the nose (*d*) Any where
6. For best results of deflection of water current, the groyne should be located at
   (*a*) Convex portion of bank (*b*) Concave portion of bank
   (*c*) Straight portion of bank (*d*) At any part of the bank
7. Construction of island protects the bank by
   (*a*) Deflecting the water current towards itself
   (*b*) Attracting the water current towards it self
   (*c*) Repelling current away from itself.
   (*d*) None of the above
8. Construction of island is effective for river training measure in
   (*a*) Shallow and wide rivers (*b*) Narrow and deep rivers
   (*c*) Only in shallow rivers (*d*) Only in deep rivers
9. Bamboo groynes are useful where depth of water is
   (*a*) upto 9.5 m (*b*) upto 7.5 m
   (*c*) upto 3.5 m (*d*) 1.2 m

ANSWERS

4. (*a*)	6. (*a*)	8. (*b*)
5. (*b*)	7. (*b*)	9. (*d*)

25

Safety Measures in Maintenance Works

25.1. INTRODUCTION

After independence, construction and industrial development has grown significantly. For the execution and maintenance of different types of works skilled and unskilled workers along with machines and equipments are employed. With the introduction of machines for increasing the output of the work, number of accidents is also increasing. Thus safety is one of the most important aspect of the modern management. Maintenance department often is the key to success of any programme in any industry. This department is not only responsible for the safety of its personnel, but is also responsible for providing mechanical safe guards and maintaining machines etc. in safe operating condition. It is a hard fact that where safety ends, accidents start. Though no one wants to be injured, but it happens so fast that one can not help it. Thus the workers should be taught to work safely in any odd situation. The percentage of injuries in various industries varies from 2.0 to 14.5%.

25.2. DEFINITION OF ACCIDENT

An accident may be defined as an unplanned and unexpected occurrence which upsets the planned sequence of events and actions, resulting in the loss of production, injury to person and damage to plant and equipment.

25.3. IMPORTANCE OF SAFETY

In India most of the Industries are labour oriented. Construction industry employs the largest labour force after agriculture. The injury rate is found about 10 to 14.5% of all occupational injuries and about 20% deaths The cost of accident is very expensive. The economic cost is not the only criteria for taking safety measures. Actually the reasons for the safety considerations are as follows:

1. Humanitarian reasons. The sufferings and agony undergone by the injured worker and his family members is difficult to quantify in economic terms. Thus accidents should be prevented more on humanitarian considerations than others.

2. Economic reasons. The accidents have their own costs, which include direct and indirect costs:

(*a*) Direct cost. It includes the following expenses:

(*i*) Medical expenses for the injured.

(*ii*) Compensations amount to the injured.

(*iii*) Legal expanses.

(*iv*) Cost incurred in replacement of equipment and damaged materials etc.

(*b*) Indirect costs. These costs include the following expenses:

(*i*) Slow down in progress of work.

(*ii*) Productive time lost by the injured worker and his fellow workers.

(*iii*) Decrease in productivity due to moral decrease after injury.

(*iv*) Over time payment to make up the loss of time.

(*v*) Loss of administrative work due to accident.

(*vi*) Loss of confidence by the client etc.

3. Organisational image. Good safety measure record boosts the morals of the workers, resulting in higher productivity and better loyalty of the workers to the organisation. Good safety measures will also enhance the public image of the organisation.

4. Laws and Regulations. The employer has to adhere to the laws and regulations laid down by the government for the safety of the employees. The violation of these laws and regulations will attract punishment to the employer.

25.4. CAUSES OF ACCIDENTS

Though actually there are many causes of accidents, how ever broadly accidents may be classified in three categories:

A. Physical causes

B. Physiological cause

C. Physchological causes

A. Physical causes

Under this head of physical causes following factors may be grouped:

1. Relating to machines
2. Relating to tools
3. Relating to materials
4. Relating to uniform
5. Relating to environment
6. Fixing unsuitable time table

1. Causes relating to machines. Under this head following causes may be classified:

(*a*) The working space for the machines may be inadequate. Due to obstruction, free movement of man and material is not possible, which may cause accidents.

(*b*) The machines not properly placed or adjusted.

(*c*) Unsuitable machines being used for the job.

(*d*) The machines not being properly guarded.

(*e*) The electric motor for the machine may not be properly insulated.

This factor may also be called as defective technical planning.

2. Causes relating to tools. Under this head following causes may be classified:

(*a*) Due to constant use, the tools being blunt and worn out.

(*b*) Tools employed on the job being too small for the job.

(*c*) Tools used may be of brittle nature and break suddenly. For example blades of a circular saw.

(*d*) The handle of the tool may be too short or loose.

(*e*) Tools used may be unsuitable for the job.

3. Causes relating to materials. Under this head following causes may be classified:

(*a*) The materials used may be poisonous and dangerous as acids and some salts etc.

(*b*) The materials may be too hot as tar or bitumen at the time of use of road construction and no proper precautions observed.

(*c*) Explosives, petroleum products and brittle materials being handled carelessly.

(*d*) Not observing proper precautions while cleaning sewer which emit foul gases.

4. Causes relating to uniform. Under this head following causes may be classified:

(*a*) The uniform may be loose.

(*b*) The shoes may be slippery and loose.

(*c*) No protective device being used while working on welding job.

(*d*) The sleeves of shirt being with out bottom.

5. **Causes relating to environment.** Under this head following causes may be classified:
   (*a*) Poor lighting arrangement at the site of work.
   (*b*) Poor ventilation and un hygienic conditions at the site of work.
   (*c*) Un insulated wires left carelessly.
   (*d*) Loose electric cables.
   (*e*) Obstacles in the working area.
   (*f*) Floor being sleepry.
   (*g*) Building used being unsafe.
   (*h*) Use of weak, or short *i.e.* unsuitable ladder.
   (*i*) External disturbances as noise.
   (*j*) Loose discipline among workers.

B. Physiological causes

This factors relates to the health conditions of the workers. Under this head following causes may be classified.

1. **Poor eye sight.** This is a very important factor for every worker, especially for the workers handling machinery, automobiles and cranes etc. If a driver can not see an vehicle or obstacle ahead clearly especially in poor visibility conditions, will result in accident.
2. **Over work.** A tired worker due to over time, loses control over his limbs easily and may meet accident.
3. **Poor health.** A worker due to poor health may not control his load of work and may meet an accident.
4. **Old age.** Generally in old age, eye sight becomes poor and also one becomes hard of hearing along with general poor health. These factors cause accident easily.
5. **Intoxication.** One loses control over his limbs and becomes prone to accident under the influence of intoxication.
6. **Physical handicapness.** A physical handicapped person is more prone to accidents.

C. Physchological factors

Under this head, factors causing accidents are related to mental condition of a worker.

1. **Mental tension and worry**. Under mental tension and worry one loses control over his mind and may meet accident.
2. **Emotional attitude.** An emotional person loses mental balance easily.
3. **Impulsiveness.** When a person works under impulse, with out proper thinking, the chances of accidents are more.
4. **Nervousness.** A nervous person loses control over his limbs quickly and has more chances of meeting an accident.
5. **Over confidence**. Many a times over confidence results in accidents.
6. **Carelessness.** A careless worker has more chances of meeting a accident than a conscious worker.
7. **Fear.** Under fear also one loses control over his limbs quickly.

25.4.1. Measures to avoid accident

To reduce the accident rate following measures may be adopted:

1. Before allotting the work, the physical condition of the worker or labourer should be judged properly.
2. Proper instructions to handle the machine, he is required to handle should be given in the language,

he under stands fully.

3, For hard and tedious job, period of duty or work should be reduced.
4. Scaffolding and centering should be quite strong.
5. At work site unnecessary crowding should be avoided.
6. Work place should be properly ventilated.
7. For handling heavy loads, clear instructions should be given regarding the procedure of work.
8. For carrying out special type of job, workers should be given proper education and guidance to handle that work.
9. At proper places warning notice boards should be provided.

25.5. OBJECTIVES OF ACCIDENT PREVENTION

Following are the objectives of accident prevention:

1. The main objective of accident prevention is to save human lives.
2. Prevention of temporary or permanent injury to workers.
3. Prevention of damages to plants, equipments and loss of materials.
4. Saving in the cost of compensation to workers.
5. Saving in loss of time due to injury.

25.5.1. Classification of accidents

Accidents may be classified as follows:

1. According to the causes of their occurrence
2. According to the nature of injury suffered as:

(*a*) Temporary disablement (*b*) Partial disablement

(*c*) Permanent disablement (*d*) Death

3. According to the severity of injury as:

(*a*) Minor accident (*b*) Major accident

25.5.2. Compensation to injured worker

The worker who has been injured is paid compensation as per 1923 act.

25.6. MEASURING SAFETY OF WORKERS

Following terms indicate the measure of injury:

1. Injury frequency rate. It is defined as the number of disabling injures per one lakh (10^5) man hour worked. It denotes, how frequently an accident occurred. It does not take into account the time lost due to the injury. It is expressed as:

$$\text{Injury frequency rate} = \frac{\text{No of disabling injures} \times 10^5}{\text{Total No. of man hours worked}}$$

The disabling injury means an injury which causes a loss of working time beyond the day during which the injury occurred.

It is illustrated by the following example.

Example 25.1. *On a certain work 400 laborers were engaged for 45 weeks. They worked 8 hours per day. It was observed that during this period 20 workers got disabling injuries. Determine the rate of injury frequency.*

Solution. No. of workers = 400

disabling injury = 20

$\therefore$ Rate of injury frequency $= \dfrac{\text{No of disabling injures} \times 10^5}{\text{Total No. of man hours worked}}$

$$= \frac{20 \times 10^5}{400 \times 45 \times 8 \times 6} = 2.9 \text{ app. say } 3.0$$

2. Injury severity rate. It is the number of days lost per 1000 man hours worked. It is expressed by the following equation and illustrated by example 2.

$$\text{Injury severity rate} = \frac{\text{No of days lost} \times 10^3}{\text{No. of man hours worked}}$$

Example 25.2. *If in the example 1, the 20 injuries occurred in 100 days, determine the injury severity rate.*

Solution. Injury severity rate $= \dfrac{100 \times 1000}{400 \times 45 \times 48} = 0.208$

or 20.8%

3. Injury index. It is expressed by the following equation

$$\text{Injury index} = \frac{\text{Injury frequency rate} \times \text{Injury severity rate}}{1000}$$

From the above examples, injury index $= \dfrac{2.9 \times 0.208}{1000} = 6.09 \times 10^{-4}$ Ans.

25.7. ACCIDENT HAZARDS

The term "accident hazards" is applied to those situations or circumstances which are potentially dangerous and liable to harm the persons. The accidental injuries from a recognised hazard may be eliminated or reduced by the following measures.

1. **Decisions during planning and design process.** At this stage safety measures should be incorporated to minimise the hazards during construction and maintenance of the works. Some designs and construction plans are inherently difficult and dangerous to implement. Thus to reduce the possibility of accident hazards, the plans may be modified. Similarly construction plans may be modified to reduce the accidental hazards. For example clear separation of traffic from construction zones can greatly reduce the possibility of accidents.
2. **Identification of hazardous situations.** To reduce the possibility of accidental hazards, hazardous situations should be identified carefully by proper inspection.
3. **Training and education of workers.** Proper and adequate education and training has been found very effective in reducing the possibility of occurrence of accidents. They should be given detailed and expert advice in the maintenance and handling of mechanical and electrical machines, storing and handling of materials etc. They should also be told clearly the advantages of proper ventilation and illumination.
4. Choice of proper technology and machines also reduces accidental hazards to a great extent.
5. Periodical inspection of machines, equipment, building etc. is essential to ensure safety and to reduce accident hazards.
6. Educating managers and workers about proper procedures and related hazards has been found to have a impact on the safety at the job site.

25.8. GENERAL MEASURES TO BE ADOPTED TO MINIMISE ACCIDENTS

Generally following measures have been found effective in reducing the accidents:

1. The work place should be spacious for normal operations.
2. For efficient and safe working, the machines and work units should be arranged in logical sequence.

3. To minimise the dependence on material availability, the machines and units of correlated capacity should be selected.
4. For uninterrupted conveyance there should be proper and safe passage.
5. The tool boxes, elevators and wash rooms should be located centrally.
6. The power system should be such so that individual exposure to human beings is minimum.
7. The main switches of electrical, mechanical, and steam power etc. should be so located, so that they can be easily shut off during emergency.
8. At the place of work, there should be proper arrangement of ventilation and illumination.
9. There should be separate route for out side traffic, both vehicular and pedestrian.

25.9. SAFETY MEASURES IN DIFFERENT TYPES OF MAINTENANCE WORK

25.9.1. Safety measures in the maintenance of buildings:

25.9.1.1. Precautions of safety in painting:

(*a*) **General.** For painting, ladder is one of the essential part for the execution of painting work. Statistics data has established that the common ladder leads to maximum injures than any other type of equipment if proper attention is not paid to it.

(*b*) **Causes of accidents:**

(*i*) Failure to secure ladder properly at top or bottom or at both places

(*ii*) Structural failure of the ladder itself.

(*iii*) Improper working.

(*iv*) Unsafe conditions of placing the ladders.

(*c*) **Construction of ladder:**

(*i*) All ladders should be designed properly to carry the load they are intended to carry.

(*ii*) Side rails for metal ladders should be of sufficient cross- section, so that excessive deflection may not develop.

(*iii*) In bamboo ladders, the rungs should be fixed to the rails with spikes of proper design and strength.

(*iv*) To avoid danger of slipping, safety shoes should be used.

(*d*) **Portable ladders:**

(*i*) The over all length of stock ladders should not be more than 10 m. The mimimum internal width of ladder should be 29 cm for ladders upto 3 m length. For longer ladders this width may be increased by 6 mm for every additional length of 0.3 m.

(*ii*) In case of metal ladders, rungs must be made of solid round steel rod, steel pipe, or angle sections securely fastened to the side rails by bolting, riveting or welding. Metal treads should be flanged down wards not less than 50 mm at each end and secured at each end and secured to each side rail by two bolts or rivets.

25.9.1.2. Use of ladder

While using a ladder following precautions should be adopted:

1. Before use all ladders should be tested. The ladder should be strong and rigid.
2. A defective ladder with missing rung or repaired or showing signs of cracks should never be used.
3. The splicing of ladder should be avoided.
4. Ladders leading to landing should be extended at least one metre above the lending and secured at the upper end properly.
5. Ladders should not be supported against window panes, sashes or other un safe or yielding objects. Ladders should also not be placed infront of door opening towards it. When ladders are used in public walk ways, suitable barricades should be provided.

6. While using ladder, one should not lean side ways more than 30 cm. It is safer to get down and shift the ladder to the new place.
7. While ascending or descending, the user should face the ladder. He should place his feet near the end of the rungs and not in the centre.
8. To prevent slipping, the ladder should be placed in such a way that it does not make an angle more than 75 degrees with the ground *i.e.* the distance between the vertical wall or face and the lower end of the ladder should not be more than one fourth of the length of the ladder. Nor the ladder should be placed too steep unless held by some one.
9. Metal ladders should never be used around the electric circuit or equipment.
10. Extension ladders should be used upto 10 m length. To ensure proper locking and full extension of the section, locks and guides should be checked properly.
11. When workers are working over head, sufficient warning and danger signs should be used.
12. Workers engaged in spraying operations should wear respirator; goggles, and have life line.
13. Workers painting from a plank should never be allowed to work beyond its edge. Planks should be kept clean.
14. In situations where ventilation is not sufficient and foul gases are likely to be met, the workers should wear the gas masks and goggles. In confined areas where fumes are lungs burning, in such situations the workers should wear masks which may filter out the harmful fumes.
15. In situations where the worker is exposed to acids or is supposed to remove chemical substances, he must wear goggles for eyes protection.
16. In confined places of painting to avoid fire risk, proper ventilation must be maintained by the continuous use of compressors and related equipment.
17. Paints and thinners should be kept in sealed containers and never be exposed near flames.

25.10. SAFETY MEASURES IN DISMANTLING OF BUILDING

Some times during maintenance operations, dismantling of some part of a building structure has to be done due to the damage caused by fire, earth quack, floods etc. Dismantling of building is a very hazardous work. Thus the dismantling of the building should be properly planned and executed in different stages. To ensure safety, cooperation between management, supervisors and workers is essential. Before starting the demolishing work, various parts of the building should be supported by shoring, and bracing etc. and the extent of damage to be caused to the adjoining buildings is studied and protective measures taken. After these studies, plan of demolition is prepared carefully and executed systematically, so that demolition operations should not endanger the adjoining structures. Workers should be guided at each stage by an experienced supervisor.

25.10.1. Precautions before demolition

1. Prominent danger sign boards should be displaced all-round the structure to be demolished and all entrances to the building should be barricaded except for the workers. Sign boards should be displayed at 30 m distance from the site.
2. At night, red signals should be provided around the building to be demolished and if possible a watch man should be posted.
3. All service connections such as electricity, water and gas system should be disconnected from the building to be demolished. It is essential for the safety of workers.
4. The passage to be used by workers should be well lighted and free from obstacles.
5. For the safety of the public, danger signs should be placed at the prominent points leading to the property site. All main roads should be kept open. If necessary diversion route for pedestrians should be provided.
6. As far as possible demolition work should be carried out at nights and during heavy rains.

25.10.2. Precautions during demolition of the structure

1. Before starting the demolition work, all glazed door, windows, and ventilators should be removed.
2. All exterior wall openings and floor openings through which a worker may fall down should be barricaded.
3. Demolition work should start from top and should be completed in top most story before starting in the story below it.
4. The demolished material should be thrown on ground only after taking all safety measures.
5. Metallic chute should be used for removing the debris. After lowering the building to the ground level, the debris should be stored in side the building with in safe limits.
6. Stairs and ladders should be kept intact till the demolition work of the story above it is completed.
7. While working at high levels, safety belts should be used by workers.
8. Warning system such as sirn should be installed to inform the workers in case of any emergency or danger.
9. At the time of demolition operation, workers should wear the safety appliances such as goggles, leather gloves, etc.
10. Proper arrangement of lighting and ventilation must be provided.
11. During emergency safe and easy exit should be available for safe evacuation of workers.

26.10.3. Precautions to be adopted during demolition of walls

1. The walls should be demolished in small heights, layer by layer so that falling debris may not damage the floor.
2. To avoid over loading, debris should be removed constantly.
3. Weaker walls whose height is more than 15 times of its thickness should be braced laterally.
4. Before starting demolition of walls in a story, the openings not required for use should be covered with planks.
5. In framed structures, the steel frames may be left in place during demolition of the masonry work, provided the frame work is sufficiently strong to act as an independent structure.
6. At the time of close of work, the wall should be supported against sudden collapse.
7. The load supporting members should be demolished after the demolishing work in the story above it, is complete.
8. Foundation walls should be demolished after under pinning the adjoining structures. Till then they should be allowed to remain intact.
9. Walls less than 30 cm in thickness and dangerous to work by standing on them, workers should work standing on, suitable stages.
10. For demolishing arches, the workers should stand on scaffolding clear of the arch.

25.10.4. Demolition of Floors

1. For demolishing the floor, first of all a 30 cm wide slit should be cut in the full length of the slab and 25 cm wide and 5 cm thick planks are placed at 40 cm spacing for standing workers doing the demolishing work.
2. Demolished steel structural members should be lowered from the building. They should neither be thrown nor dropped from the building.
3. Beams should be cut only after ensuring all safety measures to the workers.
4. While demolishing external walls of multistory building of height more than 20 metres, catch platforms of heavy planks should be provided for the safety of workers as well as that of public.
5. While demolishing a R.C.C. beam, a supporting rope should be put around the beam. Afterwards the concrete is removed from both ends by pneumatic drills and reinforcement is exposed.

6. The reinforcement is cut in such a way that the beam could be lowered safely to the floor level.
7. No person should be allowed directly underneath this area and access to such an area should be barricaded.

25.11. SAFETY MEASURE WHILE WORKING FOR ROAD MAINTENANCE

While working for the road maintenance work, following safety measures should be adopted.

1. For the maintenance of flexible highways usually tar is used. The tar boilers should be equipped with suitable temperature recording device.

   The tar or bitumen should not be over heated. By over heating, the binding properties of the tar are destroyed and on further heating it may catch fire. To maintain constant temperature, the tar should be stirred constantly.
2. The roller used for the work, should be parked on road side while idle. At night red light should be placed over or around it. This precaution will reduce chances of accidents.
3. For handling bituminous work, only trained, experienced, physically fit and mentally alert workers should be engaged.
4. The work should be planned in such a way that workers get rest at suitable interval.
5. The workers should be provided with protective wear such as goggles, proper foot wears etc. It should be ensured that every worker is wearing tarring out fit for his safety.
6. To avoid damage to eyes from bitumen fumes, workers should wear goggles.
7. To safe guard against fire hazzards, work should be stopped during stormy weather.
8. Bitumen spraying should be done carefully, when the wind is blowing fast. it should not be done against the direction of the wind.
9. Warning signals such as siren must be kept ready at the site of work and must be sounded promptly in case of fire hazzards.
10. Fire fighting equipment also should be kept ready at the site of work.
11. First aid box and some trained persons in first aid be available at site of work.
12. Both ends of the road or culvert under repair should be closed for traffic and proper diversion road should be provided. At both ends sign boards indicating "bitumen work is in progress' must be displayed.
13. To check the entry of road users in the portion under construction, it should be barricaded from all sides by keeping empty drums. Proper diversion should also be provided.
14. At a time only half the portion should be tackled and the other half be allowed to be used by road users.
15. To divert the traffic, barricades at both ends should be provided. At night red lights should be provided at both ends for the guidance of the road users.
16. At the time of actual bitumen spraying, a man with red flag should be posted at each end of the stretch of the road under maintenance to divert the traffic.

25.12. SAFETY MEASURES WHILE TUNNELING

25.12.1. Safety measures while handling explosives

1. **Transportation of explosives.** Following safety measures should be adopted while transporting explosives.
   (*a*) During transportation, explosives and their caps should be kept separately.
   (*b*) While transporting, explosives, the word 'explosives' should be marked or play carded on all sides of the vehicle in bold batters 10 cms in height in colour contrast with the back ground of the vehicle. It should also carry a red flag 60 cm square in size. On the flag also word 'Explosives' should be written clearly in bold letters.
   (*c*) Detonators or blasting caps should not be transported along with explosives. Metal tools, match

boxes, oils, fire arms, acids, inflammable substances also should not be carried in the vehicle along with explosives.

(*d*) Vehicles carrying explosives should not be over loaded. In no case explosives be piled in the container higher than the closed sides of the body.

(*e*) Open body vehicles carrying explosives should be covered with tarpaulin.

(*f*) All vehicles carrying explosives should be checked carefully for the followings.

(*i*) Brakes and steering mechanism of the vehicle must be in perfect condition.

(*ii*) Electric fittings should be well insulated and firmly secured.

(*iii*) Body and chassis should be clean and free from accumulation of oil and grease etc.

(*iv*) Fuel tank and feed line should be well secured and should not have any leakage.

(*v*) Two fire extinguishers in working condition should be located near the driver's seat.

(*vi*) General condition of the vehicle should be good.

(*g*) The floor of the vehicle should be tight. Any exposed metal in side the body should be well covered, so that explosive may not come in its contact.

(*h*) No trailer should be attached to the vehicle carrying explosives.

(*i*) No passenger or unauthorised person be allowed to ride in the vehicle carrying explosives.

(*j*) Packages of explosives should not be thrown while loading or unloading. Explosive packets should be handled and lifted carefully.

(*k*) Before loading or unloading explosives, the engine of the vehicle should be stopped.

25.12.2. Safety measures while handling explosives

(*a*) The packages containing explosives should be lifted up or lowered carefully. They should never be dropped or slide from one level to another level.

(*b*) Package containing explosives should neither be opened in side a magazine nor with in 20 m of the magazine.

(*c*) Non metallic or wooden tools should be used for opening or packing the boxes containing explosives.

(*d*) Explosives and detonators should be placed in separate insulated and closed carriers.

25.12.3. Safety measures while storing the explosives

(*a*) Explosives should be stored in dry, well ventilated, fire resistant and bullet proof building.

(*b*) Primers or blasting caps should be stored separately.

(*c*) Explosives, fuse lighters etc. should not be stored in damp places or near oil or near any source of heat.

(*d*) No grass or leaves should be stored with in 8 m of a magazine.

(*e*) Smoking or lighting any flame should not be allowed near a magazine. Warning notice should be displayed.

25.12.4. Safety measures while drilling and loading explosives

(*a*) Before planning the drilling operations, the nature of the strata should be examined carefully to avoid sliding after blasting.

(*b*) Drilling should not be done in places where un detonated explosives are suspected.

(*c*) Before loading the explosive in the hole, it should be ensured that the hole is bored in full length and free from dust etc.

(*d*) While loading the hole, excessive explosive should not be left near the site.

(*e*) Before loading a hole, it should be ensured that the hole is cool and has no burning material in it.

(*f*) No force should be applied while inserting the explosive into a bore hole.

(*g*) While inserting the blasting cap into the explosive, no force should be applied.
(*h*) While placing the explosive into the hole, tamping should be done with wooden tools. In no case metal tamping rod should be used for this purpose.
(*i*) Explosive should be confined to the bore hole with stemming material as earth, clay, or sand etc.
(*j*) While tamping, it should be ensured that fuse wire is not damaged.
(*k*) Detonating fuse should be connected to the blasting cap or electric plastic cap according to the instructions issued by the manufacturers.

25.12.5. Safety measurers while using the explosives

(*a*) Lighting of fire or smoking should not be allowed at the site of using explosives.
(*b*) The explosive container should be covered properly after taking required quantity from it.
(*c*) Explosives should not be carried in the pockets of clothing's.
(*d*) No body should be allowed to remove or investigate the contents of a blasting cap.
(*e*) No unauthorised person should be allowed to go near the place of use of explosive.
(*f*) Explosives should not be handled in electrical stores.
(*g*) Detonated explosives should not be used.
(*h*) Hard set explosives should not be softened by heating over the fire or rolling it on the ground.

25.12.6. Safety measures adopted while electrical short firing

(*a*) Uncoiling of wires and opening out of bare leading wires of blasting caps should not be allowed during stormy weather.
(*b*) Firing circuits should be fully insulated from pipes, rails or ground.
(*c*) Electric line wires should not be kept near the blasting caps or other explosives except at the time of firing the blast.
(*d*) Electric cap wires or leading wires should be kept short circuited till ready to fire.
(*e*) In case blasting is to be done from power circuit, then the voltage should not be more than 220 volts.
(*f*) Blasting operations near the over head power lines, communication lines or other structures should be done after obtaining prior permission from the competent authority and after ensuring all necessary precautions.
(*g*) For the size of wires, fuses, circuits etc. the instructions issued by the manufacturers should be followed.
(*h*) For firing of a circuit of electric blasting cap with less current than specified value by manufacturers should not be allowed.
(*i*) All holes loaded on a shift should be fired in the same shift.

25.12.7. Safety measures for short firing with safety fuse

(*a*) To safe guard against damages of fuse cover, it should be handled carefully.
(*b*) The length of fuse wire should not be less than 1.2 m.
(*c*) The time of burning of the full length of the fuse should not be less the 20 minutes. The rate of burning of fuse should be such that the person igniting the fuse reaches the place of safety before the blast.
(*d*) The fuse should be ignited with a fuse lighter of proper design.
(*e*) Before igniting the fuse, sufficient stemming should be placed over the explosive.
(*f*) At the time of lighting the fuse, spare explosive should not be held in hand.
(*g*) Excessive quantity of explosives should not be taken under ground.

25.12.8. Safety measures to be adopted before and after firing

(*a*) Before firing, sufficient warning time should be given to persons working at the site to go to a safe place or away from the danger zone.

(*b*) Flag men should be posted on all approaches to keep the vehicles and public at least 400 m away from the danger zone.

(*c*) No tools or other articles should be placed on the rock to be blasted.

(*d*) Blasting should be done as per schedule, during the fixed hours of the day. Wide publicity should be given of the programme. Daily blasting hours should be displayed on the notice boards on all roads leading to the blasting site. At the time of actual firing traffic should be stopped 400 m away with the help of barriers. At the beginning and at the end of firing loud sirens should be sounded.

(*e*) The person who fires the shot should not return to the blasting site untill at least 5 minutes have passed from the time of lighting the fuse. In case of electric shot firing, the shot holes should be examined after firing and in case of misfiring, no one should be allow4d to come near the blasting site at least for 3 minutes. In case of firing with safety fuse, the time for preventing entry of any one to blasting site is 30 minutes.

(*f*) In case of misfire, the stemming should be removed by the use of water jet or air jet, till the hole has been opened to within 60 cm of the cartridge. The water is then pumped out and fresh new charge placed and detonated.

(*g*) No explosive should be abandoned or thrown away. It should be disposed off after consulting the appropriate authority.

(*h*) Material used in packing of the explosive should not be stored at a place where it could prove dangerous to the human life. Papers used for packing explosives should be destroyed. They should not be used any where else.

25.12.9. Safety measures against falling of rocks

In tunnelling rock fall is the major factor causing accident than any other cause. Except for premature explosion, rock falls are the most serious of all tunnel accidents, as they always involve one or more fatalities. Thus following precautions should be adopted against rock fall.

(*a*) Careful and frequent inspection of walls and roof should be done. To detect seams and planes of weakness visual inspection is sufficient.

(*b*) To locate hollowness of the rock, hand hammer test is sufficient. Dull sound from the rock on striking from hand hammer is the indication of hollowness. It needs investigation.

(*c*) Sealing down of the freshly blasted heading and face should be done before starting the mucking.

(*d*) Weak spots should be supported by timbering.

(*e*) The design of all vertical posts and planks should be checked carefully.

(*f*) Defective and weak timber should not be used under any circumstances.

(*g*) To safe guard against head injury all persons working in the tunnel should wear helmets.

25.12.10. Safety measures while working in cramped space

Generally in all tunnels, the working space in the heading is very crowded. Thus to avoid accidents following safety measures should be adopted.

(*a*) For the safety of workers and others, the safe and adequate walk way should be provided in the tunnel.

(*b*) The walking (path) should not be slippery.

(*c*) Proper and sufficient lighting arrangement should be done at the face and the point where work is in progress, such as at equipment installations, at track switches and sidings, at under ground material supply and storage point etc. This proverb is quite true that poor lighting or darkness and accidents go hand in hand. Thus to avoid accidents, it is essential that there should be proper and sufficient lighting at the work space in tunnel.

(*d*) All electric lights and power lines should be properly laid and the connections should be well insulated.

(*e*) Extra light should be provided where essential materials, are stored.

(*f*) There should be good drainage system in side the tunnel and no water should be allowed to stand any where in side the tunnel. The standing water will cause obstruction in walking and may lead to sliding, rusting of steel and other tools etc.

(*g*) For safety and efficient working, all debris and refuse should be kept clean both on surface and as well as under ground.

25.12.11. Safety measures while loading and hauling muck

In tunneling mechanical loading and its hauling operations are always dangerous Thus following safety measures are suggested to reduce accident probability.

(*a*) The loading zone should be well lighted.

(*b*) During loading operations, workers should be kept away from the vicinity of loading operations, as there is always risk of sliding rocks from the loaded car and injure the workers working near by.

(*c*) Loading cars should be loaded evenly and the muck should not be piled up dangerously high above the sides of the car. It should be checked by an authorised person. He should have authority to stop mucking operation if he is not satisfied with proper loading.

(*d*) Loading cars should be inspected before they leave for their destination.

(*e*) Cars carrying pipes, rails, steel, timber etc. should be properly loaded for safe passage through the tunnel. The load should be within safe limits of the cars. The loads should not project over the sides as it is dangerous for the persons working in the runnel.

(*f*) Cars or trains carrying muck in the tunnel should be properly controlled with signals during their journey.

25.12.12. Safety measures during shaft operations.

Following safety measures should be adopted while sinking and other operations of the shaft:

(*a*) Over break should be minimum.

(*b*) To support the latteral thrust, proper timbering should be provided.

(*c*) The shaft should be shunk vertically.

(*d*) All the hoists, cables and other equipments should be in proper working condition and capable to bear shocks due to sudden stops and over loads in addition to regular loads.

(*e*) At the surface, the shaft opening should be fully protected to prevent men and material from falling acidentially into the shaft hole.

(*f*) For the safety of men riding the cage, the cage should be protected by a sloping roof.

(*g*) All hoists should be provided with automatic brake system which should come in operation during power failure.

(*h*) All shafts should be provided with safety ladder which may be used in emergency.

(*i*) For safe operation, the hoist should be equipped with limit switches and indicators indicating the top and bottom limits.

(*j*) To prevent any one from falling off, during the journey of the cage, it should have barriers of some kind on open ends.

(*k*) All key points should have sufficient lighting arrangements.

(*l*) Telephone facility should be provided in side the shaft and other important places in side the tunnel.

(*m*) At all key points fire fighting equipment should be provided.

25.13. SAFETY MEASURES IN SEWERAGE SYSTEM

Sewers and deep manholes produce dangerous gases or oxygen deficiency, which are very harmful to the person working in such conditions with out proper protection. Hence before entering a manhole following safety measures should be adopted.

1. The oxygen deficiency can be checked by taking a burning candle near the mouth of the man hole. It will extinguish in the absence of oxygen.
2. Before entering into a man hole, or sewer a worker should wear a general purpose gas mask to protect against respiratory troubles.
3. If there is oxygen deficiency, in that case the worker should use oxygen breathing apparatus which will protect respiratory system from atmosphere deficient in oxygen and containing high percentage of toxic gases.
4. For proper lighting, portable electric hand lamps of permissible type as electric cap lamps and explosion proof flash lights should be allowed in side the sewer.
5. To safe guard against sparks, smoking or open flames should not be allowed in side the sewer.
6. For proper ventilation of the sewer line or man hole etc., portable air blower powered by enclosed explosion proof electric motors should be used.
7. During sewage maintenance work, non sparking tools made of an alloy containing at least 80% of copper should be used.
8. Before entering into a sewer or man hole, a worker should use a safety belt.
9. Warning system as warning sirens should be provided at the site of work.
10. While descending into a man hole to inspect or clean the sewer, he should test each step carefully before putting his full weight on it.
11. To avoid any accident by falling a vehicle or animal in the man hole, it should be fenced all-round.
12. The sewer line or pipe line should be properly barricaded. At night time a red light should be lighted to prevent any accident.
13. Only experienced workers should be allowed to enter the sewer either for inspection or clean it.
14. The workers should be educated to guard themselves against water born diseases through sewage and tetanus through wounds.
15. The atmosphere in sewer lines should be tested for poisonous and harmful gases.

Presence of hydrogen sulphide (H_2S) gas can be detected by the use of acetate paper and its pungent smell.

25.14. SAFETY IN RAILWAY TRACK MAINTENANCE

While executing engineering works, protection of the track is essential. No maintenance work should be under taken unless the site protection measures have been completed. The protection work is done by hand danger signals, banner flags and detonators. In case of single track, the protection works should be done in both directions of the work place while in double line track it is essential only in the direction of approaching the train.

The signals, banner flag and detonators may be placed as follows:

Case I.

The maintenance work is likely to be completed with in one day or less and train is required to stop.

In this case the hand danger signals, banner flag and detonators should be placed as below:

1. Placement of hand danger signals. They should be placed at the following positions:

(a) First flag at a distance of 30 m from the place of work.

(b) Second flag at the banner flag which is to be placed at least 50 m away from the place of work.

(c) The next flag should be placed at least 45 m away from the second detonator as shown in Fig. 25.1 (a).

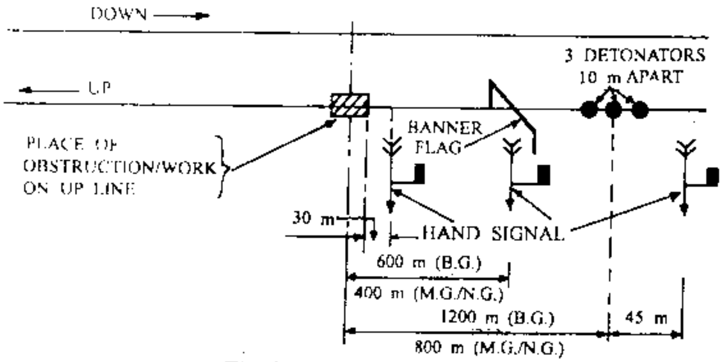


Fig. 25.1 (*a*). Single line

2. Placement of banner. Banner flag should be placed at least 600 m away from the place of work on B.G. track, 400 m M.G. and N.G. track.

3. Three detonators are placed at 10 m apart from each other as shown in Fig. 25.1 (*b*). The distance of 1st detonator from the place of work should be at least 1200 m for B.G. and 800 m for M.G. and N.G. track.

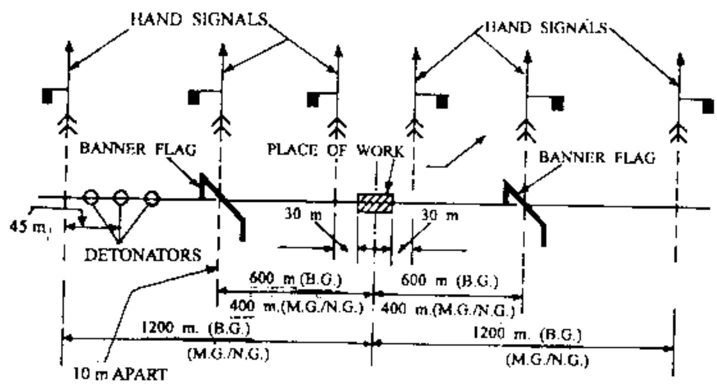


Fig. 25.1 (*b*). Double line

Case II.

The maintenance work is likely to be over with in a day or less and the train is not required to be stopped.

In this case sequence of hand signals, banner flag and detonators is as follows:

1. Hand signals.

(a) First signal is to be placed at 30 m from the place of work.

(b) Second signal at banner flag which is to be placed at 400 m from the place of work.

(c) at a distance of 45 m from the second detonator as shown in Fig. 25.1 (*c*).

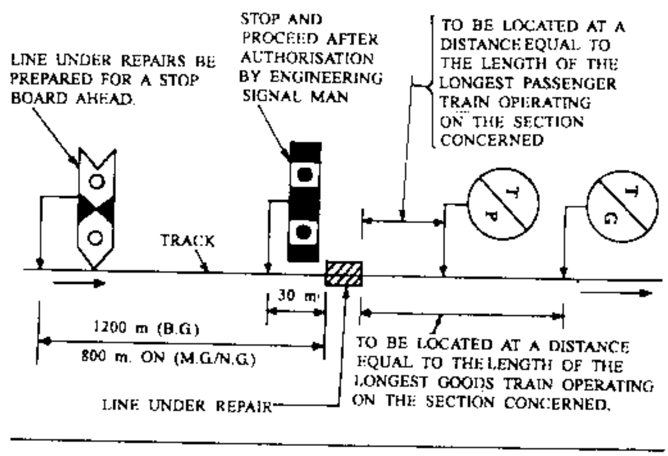


Fig. 25.1 (*c*)

2. Banner flag. At 400 m from the place of work.

3. Three detonators are placed at 10 m apart from each other.

The distance of 1st detonator from the place of work is 800 m.

Case III.

The maintenance work is likely to continue for more than a day and train is required to be stopped:

In this case following precautions should be adopted.

Temporary fixed engineering signal should be erected as follows:

(*a*) **Stop indicator.** It should be placed at 30 m from the place of work.

(*b*) **Caution indicator.** It should be placed at 1200 m for B.G. and 800 m for M.G. and N.G. from the place of work.

(*c*) **Termination indicator (T).** It should be placed at a place from where the driver may resume normal speed. This distance may be 610 m from the place of work on the opposite side of stop indicator as shown in Fig. 25.1 (*d*)

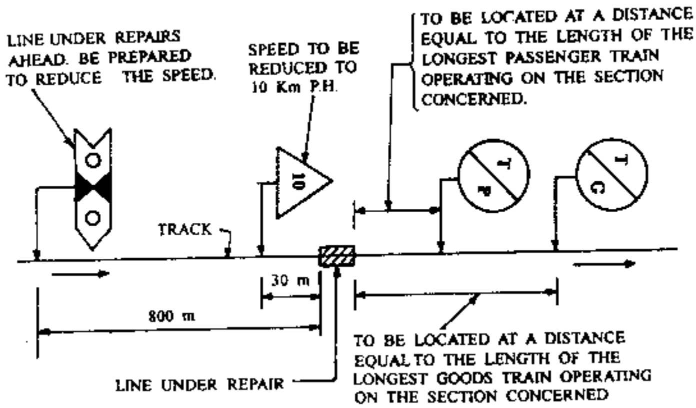


Fig. 25.1 (*d*)

Case IV.

The maintenance work is likely to continue for more than a day and train is not required to stop.

In this case following arrangement is sufficient.

(*a*) **Sped indicator.** It should be placed at distance of 30 m away from the place of work.

(*b*) **Caution indicator.** It should be placed at a distance 800 m from the place of work.

(*c*) **Termination indicator.** It should be placed at a location from where the driver may resume normal speed. This distance may be about 610 m from the place of work.

25.15. SAFETY MEASURES WHILE INSPECTING A BRIDGE

While inspecting a bridge following safety measures should be adopted:

1. The dress should neither be loose nor too tight. Loose dress may get stuck some where and tight dress may hamper free movement of the body.
2. Shoes and clothings should be free from grease.
3. Platform or scaffolding should be free from slippery substance like grease.
4. Platform or scaffolding should be of adequate strength and screwed against slipping or over turning.
5. If one uses eye sight glasses, he should wear them while climbing up or down the sub structure or super structure.

25.16. APPROACH TO IMPROVE SAFETY IN CONSTRUCTION AND MAINTENANCE WORKS

Based on the research conducted by several organizations, the approach to the safety problems can be made as follows:

25.16.1. Organisational approach

To look after the safety aspect of workers and job site representatives, management may set up a safety department. It should record and analyse the safety and other accident prevention programmes.

(*a*) **Setting up safety committees.** The safety committee should guide the operation of safety programme.

(*b*) **Development of a safety system.** To process the safety suggestions from the workers, a system should be developed.

(*c*) **Incentives.** For field management and supervisors incentives may be declared on the basis of safety record, productivity and cost.

25.16.2. Physical approach

Under this head, to improve the safety performance, following guide lines may be used:

(*a*) New workers should be taught safety features as they are more prone to accidents than experienced workers.

(*b*) For hazardous jobs, use of safety devices as use of safety belt, goggles, helmet, gloves and hearing devices should be made compulsory for workers.

(*c*) To ensure proper maintenance and up keep of equipment and tools, periodical checking should be carried out.

(*d*) To provide safety education to workers, periodic safety meeting should be held.

25.16.3. Behavioural approach

Statistics on accidents have revealed that 80% accidents occur due to unsafe acts of workers and only 10% due to the failure of equipment or faulty procedures etc. Thus for improving safety, following guide lines may be useful.

(*a*) The management during its meetings should give some stress to safety as to the schedule of production, time and cost. This will give an message to the workers that safety is equally important as that of production schedule.

(*b*) Unnecessary pressure on foreman should not be put to meet the schedule of work. Usually this pressure encourages the foreman to adopt unacceptable methods, that often lead to higher accidents.

(*c*) The relations between the management and workers should be cordial.

25.17. SAFETY CAMPAIGN

For every industry or maintenance organisation safety campaign is very essential. It should be made compulsory to be conducted by law. Following steps may be adopted to carry out safety campaign.

(*a*) An capable and experienced man should be made the incharge of the safety campaign. He should be fully supported by the management.

(*b*) The safety director should ensure that all new workers have been educated to observe the safety measures. He should have the power to get safety measures adopted by the workers.

(*c*) Safety rules to be observed in each section, should be written on notice boards in the language easily understood by the workers.

(*d*) Do's and dont's should be written on separate notice boards and placed at such places where workers could see them daily easily.

(*e*) Suitable safety quotations should be displaced written in bold letters on sign boards. Following quotations may be displayed:

(*i*) To save time at the cost of life is a bad bargain.
(*ii*) Accidents do not happen, they are caused.
(*iii*) Where caution ends, accidents begin.
(*iv*) Safety first and speed after wards.
(*v*) Machines are good servant only if handled carefully.
(*vi*) Make safety a habit.
(*vii*) Safely first and luck after wards.
(*viii*) If married diverce speed.

(*ix*) Safe driving is a pleasure.

(*x*) Safety saves.

25.18. SAFE GUARDS AGAINST INJURIES

Government enacted an act in 1923 to compensate workers for injuries suffered during the duty hours.

This act covers all the persons employed in any capacity in a hazardous occupation specified in the schedule II of the act. The cover of compensation starts immediately on joining the employment. The employer is liable to pay compensation to a worker under the following conditions.

1. The personal injuries resulting in temporary or permanent disabilities and death.
2. Injuries took place by accident while on duty.

25.19. TYPES OF INJURIES

Injuries may be classified in two groups as follows:

1. Temporary disablement. It may be partial or total. As this disablement reduces the working capacity of the worker, the compensation equal to half the monthly pay of the worker is paid to him. The temporary disablement compensation can be paid upto a maximum period of 5 years.

2. Permanent disablement. This disablement renders the worker incapable of doing any work in any employment. This act specifies following injuries as total disablement.

(*a*) Loss of one hand and one foot.

(*b*) Amputation of one leg and loss of foot of the other.

(*c*) Loss of eye sight of both eyes.

(*d*) Absolute deafness.

(*e*) Very severe facial disfigurement.

(*f*) Loss of both hands.

3. Death. In case of fatal accidents the amount of compensation varies from 7200 to 30,000/- depending upon the wages of the worker. In 1948 Govt. enacted employees state insurance act. Under this act employees are provided certain benefits. Under this act following benefits are provided:

1. Benefits for sickness
2. Maternity benefits
3. Disablement benefits
4. Dependent's benefits
5. Medical and funeral

QUESTIONS

1. Discuss the importance of safety in maintenance works.
2. Define accident and discuss different causes of accidents in construction and maintenance works.
3. Discuss the safety measures to be adopted in the following works:
   (*a*) During demolition of a building (*b*) During drilling and blasting a rock
   (*c*) During painting work (*d*) During shaft operations
   (*e*) During loading and hauling muck (*f*) While working in cramed place
   (*g*) Safety measures against falling rocks
4. In tunnelling, the rock falling is the major factor of accident except
   (*a*) Premature explosion (*b*) Slippery walk way
   (*c*) Inadequate ventilation and lighting (*d*) Improper dress
5. The aim of accident prevention is except
   (*a*) To save human lives (*b*) To earn more profit
   (*c*) To save loss of time (*d*) To prevent loss of material
6. Safety in construction and maintenance works is important due to
   (*a*) Medical expenses (*b*) Humanitarian concerns
   (*c*) Economic considerations (*d*) All the above

7. While painting the walls of a room whose floor is made of marble, the ladder is likely to slip down. What measures you would suggest to check the slip of the ladder.
   (*a*) One person should hold the ladder in position
   (*b*) Sand may be spread over the floor
   (*c*) Ladder may be tied to a door or window
   (*d*) Ladder may be kept on the gunny bag laid on the floor
8. To lay a telephone line, a trench is dug on one side of the road. What precaution you would suggest to prevent the accident
   (*a*) Warning notice may be placed on both sides
   (*b*) Warning notice and temporary barricade may be provided
   (*c*) Only temporary barricade may be provided along the trench
   (*d*) No safety measure is required as the excavated earth will be sufficient to form barricade.
9. A railway track is laid nearby a reservoir. The reservoir is full to its capacity, and the rain water is flowing in due to heavy rains in the catchment area. The reservoir has developed hair cracks in it on the track side. Which of the following measures you would prefer to check the flow from the reservoir.
   (*a*) To inform superior officers first (*b*) To arrange the sand bags
   (*c*) Start stone pitching (*d*) Construct a coffer dam at the earliest
10. At the time of track maintenance at a site, the period of maintenance is likely of one day and train is required to be stopped. What measures will be sufficient to protect the track
    (*a*) Placing only banner flag
    (*b*) Using detonators and banner flag
    (*c*) Using hand danger signals and detonators
    (*d*) Using hand danger signals, banner flag and detonators
11. While doing maintenance of a road, the road roller is left on road side. What measures you would suggest to avoid the accident at the night time
    (*a*) Fixing of red light on the roller (*b*) Engaging an chowkidar for the night
    (*c*) Shift the roller to a safer place (*d*) Provide a timber barricade around the roller
12. Identify the incorrect statement/statements
    (*a*) Accidents may be minimised by providing adequate space, lighting and ventilation at the place of works
    (*b*) Accidents may be minimised by providing very sophisticated machines
    (*c*) Accidents may be minimised by educating and providing accident free atmosphere to the workers
    (*d*) The walk way should be dry, spacious and free of obstacles
13. Identify the correct statement/statements
    (*a*) In painting work, ladder is the most injury causing element than any other equipment
    (*b*) Ladder is not the injury causing element in painting
    (*c*) A painter may fix a ladder in any position
    (*d*) Fixing ladder against door and window panes is quite safe
14. While demolishing a building work, following precautions are necessary except
    (*a*) Major danger sign boards should be displaced all-round the site of work
    (*b*) At night no red light or chowkidar is essential at the demolishing site
    (*c*) All service connections like electricity, gas, and water system should be disconnected before starting the demolishing work
    (*d*) Passage to be used by workers should be well lighted and free from obstacles

ANSWERS

4. (*a*)	7. (*b*)	10. (*d*)	13. (*a*)
5. (*b*)	8. (*d*)	11. (*a*)	14. (*b*)
6. (*d*)	9. (*b*)	12. (*b*)	

26

Thermal Comforts of Buildings

26.1. INTRODUCTION

The primary aim of building design and choice of materials is to create an conducive thermal environment for the well being of the occupants. The most important physiological requirement of human health and general well being is the ability of the human body to maintain a constant internal temperature of 37°C. The necessary condition of maintaining internal temperature of 37°C is that the rate of heat production with in the body should balance the rate of heat loss from it, regard less of variation in the external environment. The heat is constantly generated in the body. A minor fraction of this heat is consumed as work and the rest of the heat is exchanged with the surroundings through the usual heat transfer processes, namely convection, radiation and evaporation. The evaporative loss depends on humidity of the surrounding environment. It has been observed that evaporative loss at 20°C air temperature may be only 20% of the total heat loss from the body and at 40°C air temperature it may go upto 50% for low relative humidity conditions.

The radiative loss is high at low ambient temperature but decreases as the temperature of the surrounding reaches the skin temperature. At the higher temperature of the surrounding than the skin temperature, the radiative heat loss turns into radiative heat gain. Similarly the convective heat loss is high at low air temperature and decreases with rise of air temperature, turning into radiative heat gain when the air temperature rises above skin temperature.

26.2. CLIMATE

It has a great effect on the life of human beings. The basic elements which constitute the climate of a place are:

1. Air temperature and solar radiation
2. Rainfall
3. Wind
4. Humidity

The variation in the levels of these elements goes on through out the year all across the country. All these four factors essentially determine the heat exchange of the human body. These factors may vary independently of each other and can influence the one or more modes of heat transfer at a time.

26.3. CLASSIFICATION OF CLIMATIC ZONES

As per Indian specifications code 3792-1978, India has been divided into the four zones for the purpose of heat insulation requirements for buildings design. The list of various cities under various climatic zones is shown in Table 26.1.

1. **Hot and arid zone.** The altitude of this zone is not more than 300 m above the mean sea level. In this zone the mean daily maximum dry bulk temperature goes upto 38°C and above. The relative humidity remains 40% or less during the hottest months of the year.

2. **Hot and humid zone.** The altitude of this zone is not more than 500 m above the mean sea level. In this zone the daily mean maximum dry bulb temperature is above 32°C and relative humidity above 40%.
3. **Warm and humid zone.** The altitude of this zone is not more than 100 m above mean sea level. In this zone the temperature ranges between 26°C to 32°C and the relative humidity remains 70% or more.
4. **Cold zone.** The altitude of this zone is not more than 1200 above mean sea level. The mean daily minimum dry bulb temperature of 6°C or less prevails during the coldest month of the year.

Table 26.1. List of representative cities of various zones

Hot and arid zone		*Hot and humid zone*		*Warm and humid zone*	*Cold zone*
Agra	Khandwa	Ahmedabad	Mangalore	Cochin	Darjeliling
Ajmer	Kota	Asansol	Masulipattam	Dwarka	Dras
Akola	Lucknow	Bhav Nagar	Midnapur	Guwahti	Gulmarg
Aligarh	Ludhiana	Bhuj	Mumbai	Puri	Leh
Allahbad	Nagpur	Calcutta	Nellore	Sibsagar	Mussories
Ambala	Neemach	Calicut	Patna	Silchar	Ootacmund
Bareilly	New Delhi	Chennai	Rajkot	Tezpur	Shillong
Bikaner	Roorkee	Cuttack	Ratnagiri	Trivandrum	Shimla
Gaya	Sambalpur	Dohad	Salem	Veraval	Skardu
Jabalpur	Sholapur	Jamnagar	Surat		Srinagar
Jaipur	Umaria	Jamshedpur	Thiruchirapalli		
Kanpur	Varanasi	Madurai	Vellore		
			Visakapatnam		

Note: Heat insulatin is not needed for buildings not covered under any of the above zones.

26.4. SOME DEFINITIONS

1. **Dry bulk temperature (DBT).** The temperature of the air, read on a thermometer, taken in such a manner as to avoid errors due to radiations.
2. **Wet bulb temperature (WBT).** The steady temperature given by a thermometer when its bulb is covered with a gauge moistened with distilled water and placed in air stream of not less than 4.5 m/sec.
3. **Globe temperature (G.T.).** It is the temperature measured by a thermometer whose bulb is enclosed in a matt black painted thin copper globe of 150 mm diameter. It combines the influence of air temperature and thermal radiation emitted or received by the bounding surfaces.

26.5. INDICES OF THERMAL COMFORT

The climatic factors such as temperature, humidity and wind etc. vary independently of each other, but act simultaneously on the human body. It has not been found possible to express the thermal response of the human body in terms of any of the above single factor as the influence of any one factor depends upon the level of others. How ever efforts of researchers have found the following two indices of thermal comfort.

26.5.1. Effective temperature (ET)

It is the temperature of still, and saturated air which has the same general effect upon comfort as the atmosphere under consideration. The combinations of humidity, wind velocity and temperature producing the same thermal sensation in the individual are taken to have the same effective temperature.

This was developed by Houghton and Yaglou in 1923 by sampling the instantaneous thermal sensation of human beings moving between rooms maintained at different environmental conditions.

2. Tropical summer index (T.S.I.). It is the temperature of calm air at 50% relative humidity which produces the same thermal sensation as the given environment. The 50% relative humidity has been chosen as it is reasonable intermediate value for the prevailing humidity conditions. Mathematically TSI °C is expressed as

$$TSI = 0.308\, t_w + 0.745\, t_g - 2.06\sqrt{V + 0.845}$$

where,

t_w = Wet bulb temperature in °C

t_g = Globe temperature in °C

V = Air velocity in m/sec.

TSI has been developed by Central Building Research Institute Roorkee. It is simple to compute and is based on the relevant conditions of living habits and clothing pattern in the Northern part of the country.

26.6 LIMITS OF THERMAL COMFORT

TSI value for summer comfort ranges between 26.5°C and 29.5°C. This corresponds to a dry bulb temperature range of 27°C to 30°C with different air velocities from 0.5 to 2.0 m/sec. It has been observed that increasing the air velocity from 0.5 m/sec to 1.5 m/sec gives same comfort as created by decreasing the air temperature by 3°C. For summer comfort conditions, precise control of indoor temperature is not necessary. Thus the level of comfort temperature can be increased from 25°C to 28°C with out decreasing the efficiency of personnels. This will reduce energy requirements of cooling appliances.

During winter, comfortable TSI values range from 21°C to 18°C corresponding to dry bulb temperature of 22°C to 18°C. Here also the comfort temperature limits can be lowered by a certain extent.

26.7. ORIENTATION OF BUILDINGS (IS-7662-1974)

26.7.1. Definition

Orientation of a building can be defined as a method of fixing the direction of the plan of the building in such a way that it derives maximum benefits from the elements of nature such as sun, wind, and rain. Proper orientation is to utilize the natural resources in achieving functional comforts inside the buildings through planned aspects of the building units.

26.7.2 Objectives of orientation

The main objective or aim of orientation of a building is to provide comfortable living conditions inside the buildings by successfully removing or controlling the undesirable effects of severe weather.

26.7.3. Factors affecting the orientation of a building

Usually following factors govern the orientation of a building:

1. Solar radiation and temperature
2. Humidity
3. Prevailing winds
4. Clouds and rains

26.7.3.1. Solar radiation and temperature

Sun's radiation raises the temperature of a structure and living space in the following ways:

(*a*) Directly by the penetration of the sun rays through openings and

(*b*) Indirectly through the absorption and radiation of heat by the walls and roof materials.

The intensity of solar radiation depends on the direction of the sun rays. Thus for comfortable living at least during summer, both the factors should be given due attention. The roof of the building is the most affected part of the structure as it receives the direct sun rays through out the day both in summer and winter. Thus from comfort point of view it should be paid due attention.

26.7.3.2. Humidity.

(*a*) *Impact of air flow.* In hot periods human body gives out moisture called perspiration in order to regulate the body temperature. As long as surrounding air has a capacity to absorb the moisture, no discomfort is felt. But as soon as the surrounding air of the body gets saturated with the moisture, a sensation of discomfort is felt.During such conditions the movement of air removes saturated air from the vicinity of the human body and replaces it with fresh air which is not saturated with moisture. This change of air gives a relief, although there may not be any change in the room temperature. In this way the movement of air and the use of prevailing winds are very important during the period of high humidity.

(*b*) *Classification of humidity.* Relative humidity can be classified into the following categories:

0 to 25%	—	very dry
25 to 50%	—	dry
50 to 75%	—	Humid
75 to 100%	—	Very humid

For humidity upto 50% (dry or very dry condition), it is easy to take advantage of evaporative cooling in summers. In case of humid or very humid conditions, it is desirable to regulate the rate of air movement either artificially such as with electric fans or with the help of prevailing winds.

26.7.3.3. Prevailing winds

The prevailing wind helps to create natural ventilation in a building and provides comforts during the periods of high humidity. Desirable wind movement and indoor ventilation can be ensured by locating suitable windows at proper points in the room. For comforts in buildings, it is also necessary that air movement should take place at the level of occupancies and use.

26.7.3.4. Clouds and rains

Clouds and rains are not as important as other factors. The direction of the rain generally is the same as that of prevailing wind, except in case of storms.

26.8. DESIRABLE ORIENTATION IN INDIA

From the point of view of orientation, India has been divided into the following three zones:

26.8.1. Hot and aird zone

In this zone the walls and the roofs absorb and store large amount of solar radiation during the day and get heated. At night the internal surfaces of walls and roofs radiate thermal heat causing the interior space un bearable to the occupants. Walls and roofs should have adequate thermal capacity and time lag. Air movement should as a rule, be restricted to the minimum required for ventilation, but fresh air is very useful during the evening to counteract the heat gained by the structure, which would be radiated to the interior by the evening. For such conditions C.B.R.I. Roorkee has suggested the orientation of buildings as follows:

(*a*) **Northern part (as Punjab).** The orientation should be done along the direction East and West, Facing North.

(*b*) **Central India.** Orientation in this part should be done along the direction E-SE and W-NW, facing N-NE.

(*c*) **Delhi proper.** Best orientation of the building will be when longer side makes an angle of 22.5° on the East-West line towards the East-South.

Note. It has been found that the variation of 25° to 30° with respect to prevailing wind direction does not have any impact on the ventilation of the inside of a building.

26.8.2. Hot and Humid zone

For the purpose of orientation, the hot and humid and warm and humid zones have been combined into one zone. The Main problem of this zone is to counteract the discomfort of humidity by providing maximum ventilation, natural if possible. To increase the humidity is easy, but it is not possible to reduce it by any economical method. Thus the best solution is to make use of the prevailing winds. Screens and jallies have been found more effective.

For assuring comfort in humid regions, the temperatures with in the buildings should be kept as near as possible to the ambient or shade temperature by the use of fans and forced ventilation to achieve air movement of upto 60 to 100 cm/sec. If possible, the walls and roofs should be made light weight, so that their thermal capacity may be reduced.

According to C.B.R.I. Roorkee best orientation in this zone will be as follows:

(*a*) **West coastal region as Bombay.** The orientation should be along the direction S-E and N-W, facing S-W.

(*b*) **East cost regions.** Orientation should be along the direction of S-E and N-W, facing N-W.

(*c*) **Bengal.** The best orientation is considered along E and W facing S.

26.8.3. Cold zone

In cold zone, especially in hills, walls and roofs should be made of heavy weight with high thermal capacity for absorbing and storing heat during the day and using the stored heat to warm the inside of the building during night. If construction of heavy weight walls and roofs is not possible, then they should be insulated against loss of heat of the interior during night. Air movement and ventilation should be restricted to the minimum. To avoid concentration of carbon monoxide when open coal fires are used for heating the enclosed rooms in winter, regular flues or permanent ventilation at night should be provided minimum.

26.9. VENTILATION (IS-3362-1977)

Generally ventilation is defined as the supply of out side air to the interior for air motion and replacement of stale or vitiated air. Ventilation is required for comfort, and health. Health ventilation is also called as permanent ventilation. It is necessary for the following factors.

1. **Control of odors.** All people give off odor in the form of foul breath, and smell. The amount of odors produced varies with the socio-economic status of people, their race and temperature of the surroundings. Though odor is harm less but objectionable. Hence it is desirable to provide such ventilation which is capable to remove objectionable odors such as tobacco smell and cooling smell etc.
2. **Removal of product of combustion.** Products produced from kitchen appliances such as chullahs, stoves etc. are likely to accumulate there and also likely to penetrate into other rooms. Anghetics used in colder places to heat the rooms produce carbon monoxide and other gases. Hence natural ventilation is required to control and remove them.
3. **Maintenance of carbondioxide with in safe limits.** It is a well known fact that in the process of breathing, oxygen is taken in or inhaled and carbon dioxide given off. For non industrial buildings provision of ventilation from the point of view of containing carbon dioxide with in safe limits is not critical. Carbon dioxide present in atmospheric air is about 0.04%. A person seated at one place produces or gives out about 0.0168 m^3 carbon dioxide per hour. Thus the amount of fresh air required to maintain the concentration of carbon dioxide with in safe limits is very small. Hence provision of ventilation in residential buildings from this point of view is not necessary.

Thus the necessity of ventilation may arise due to the following reasons:

1. To prevent undue concentration of body odors, fumes, dust and other industrial products.
2. To prevent the undue concentration of bacteria carried by particles.
3. To remove products of combustion, to remove body heat, and heat liberated by the operation of electrical and mechanical equipments.
4. To create air movements, to replace the stale or vitiated air by fresh air.
5. To create healthy living conditions by controlling the undue accumulation of carbon dioxide and

moisture and removal of oxygen deficient air. For comfortable living conditions the contents of carbon dioxide should not be more than 0.6% by volume in air.

6. To prevent concentration of flammable gases or vapours or dust in case of industrial buildings.

26.9.1. Requirements of comfort ventilation

For securing thermal comfort and avoiding heat stresses, the maintenance of thermal equilibrium of the body is very essential.

In hot environments for securing thermal comfort, evaporation is the most important process of heat loss from the human body. As the air around the body becomes nearly saturated due to humidity, the evaporation of perspiration becomes difficult and a sense of discomfort is felt. In such circumstances even a slight movement of air near the body gives good relief. This explains the importance of use of fans inside buildings in rainy season.

In hot and arid regions, the main problem in summer is to provide protection from the sun's heat during the day in order to keep the inside temperature lower than out side. For this purpose windows and other openings usually are kept closed and only minimum ventilation is provided for the control of odors etc. Thus in hot and humid regions, the residential buildings are designed to allow the sufficient passage for air to maintain the inside temperature close to out door shade temperature. For this purpose the buildings should be oriented to face the direction of the prevailing winds, and windows and opening are kept open on both wind ward and lee ward sides.

In winter months in cold regions, the windows and other opening are kept closed, particularly during nights. The necessary minimum ventilation is achieved either by stack action or by infiltration of out side air due to wind action.

26.9.2. Standards of permanent ventilation

Following standards of general ventilation are suggested as shown in Table 26.2 based on maintenance of required oxygen, carbon dioxide, and for the control of body odors when no other products of combustion are present in the air.

Table 26.2.

S. No.	*Space to be ventilated*	*Air changes per hour*	*S. No.*	*Space to be ventilated*	*Air changes per hour*
1.	Assembly halls, auditorium	3-6	8.	Bath rooms, toilets	6-12
2.	Bed rooms, living rooms	3-6	9.	Restaurents	12-15
3.	Class rooms	3-6	10.	Cimena theatres	6-9
4.	Factories (Medium metal works)	3-6	11.	Garages	12-15
5.	Hospital wards	3-6	12.	Kitchen (common)	6-9
6.	Kitchen (domestic)	3-6			
7.	Laboratories and offices	3-6			

In addition to number of air passes, minimum amount, quantity of air and space should also be provided in places where large no of people gather as suggested below:

Table 26.3.

	Type of space or building (Space per person)	*Minimum rate of fresh air supply*
1.	Assembly halls, canteens, restaurents and places of entertainment	28 m^3/person per hour
2.	Factories and workshops	23 m^3/person per hour
3.	Offices (space)	
	(*a*) 5.5 m^3 per person	28 m^3/person per hour

Type of space or building (Space per person)	Minimum rate of fresh air supply
(b) 8.5 m^3 per person	20 m^3/person per hour
(c) 11.0 m^3 per person	17 m^3/person per hour
4. Schools occupied room	
(a) 5.5 m^3 per person	28 m^3/person per hour
(b) 8.5 m^3 per person	20 m^3/person per hour

26.9.3. Standards for comfort ventilation

For achieving thermal comfort, the minimum desirable wind speed is required at different temperatures and relative humidity. Such speeds are given in Table 26.4. Figures indicated in parenthesis indicate minimum wind speed acceptable in warm conditions such as in offices having no noticeable sources of heat gain.

Table 26.4. Minimum wind speed for thermal comfort conditions

Day's temperature °C	Relative humidity						
	30%	40%	50%	60%	70%	80%	90%
	Wind speed in m/sec for thermal comfort (tolerable with out disconfort)						
28	*	*	*	*	*	*	*
29	*	*	*	*	*	0.06 (*)	0.19 (*)
30	*	*	*	0.66 (*)	0.24 (*)	0.53 (*)	0.85 (*)
31	*	0.06 (*)	0.29 (*)	0.53 (*)	1.04 (*)	1.47 (0.06)	2.10 (0.23)
32	0.20 (*)	0.46 (*)	0.94 (*)	1.59 (0.09)	2.26 (0.29)	3.04 (0.60)	+ (0.94)
33	0.77 (*)	1.36 (0.44)	2.12 (0.24)	3.00 (0.60)	+ (1.04)	+ (1.85)	+ (2.00)
34	1.85 (0.15)	2.72 (0.46)	+ (0.94)	+ (1.60)	+ (2.28)	+ (3.05)	+ (+)
35	3.2 (0.68)	+ (1.36)	+ (2.10)	+ (3.05)	+ (+)	+ (+)	+ (+)
36	+ (1.72)	+ (2.70)	+ (+)	+ (+)	+ (+)	+ (+)	+ (+)

Note: * None.
+ Higher than those acceptable in practice.

Values in parenthesis are minimum wind speeds for just acceptable warm conditions. These are applicable for offices and other places having no noticeable sources of heat gain.

26.9.4. General design guide lines

The rate of ventilation by natural means through doors, windows and other openings depends on the direction and velocity of out side wind and size and position of the openings. Some guide lines are listed below for designing the buildings for the best possible utilization of out door wind etc.

1. Inlet openings in the buildings should be well distributed. They should be located at a low level on the wind ward side. The out lets openings should be located on the lee ward side.

While designing windows for schools, dormitories, the following levels of windows may be adopted:

(a) For sitting in chair = 75 cm
(b) For sitting on bed = 60 cm
(c) For sitting on floor = 40 cm

For getting greatest flow of air per unit area of opening, the areas of inlet and outlet openings should be nearly equal and their levels also should be the same.

26.9.5. Total area of openings

The total area of inlet and out let openings should be 20 to 30% of the floor area and the average wind velocity around 30% of the out door wind velocity. Though the increase in window size increases the available wind velocity, but not in the same proportion. It has been observed that under most favourable conditions, the maximum average indoor wind velocity does not exceed 40% of the out door wind velocity.

26.9.6. Size of windows

Locations where the direction of wind is quite constant and dependable, the size of the inlet windows should be kept within 30 to 50% of the total area of openings and the building should be oriented perpendicular to the incident wind. In case the direction of wind is un certain, the openings of equal sizes should be provided on all sides. In any case effective movement of air should be assured.

26.9.7. Living room

Windows of living rooms should open directly to an open space. In case the building sites are restricted, open space may be created by providing adequate court yard in the building.

26.9.8. In case of one wall only exposed to out side

In case only one wall of the room is exposed to the out side then on that wall provide two windows in stead of one big window.

Further it has been found that windows located diagonally opposite to each other with the wind ward window near the upstream corner give better performance than other window arrangements for most of the building orientations.

26.9.9. Mechanical ventilation

Artificial means used to create air movement are called mechanical ventilation devices. Mostly ceiling fans are used for inducing air movements for comfort. In few cases as in kitchens, bath rooms, stores etc. exhaust fans are also used as mechanical ventilators.

26.9.10. Performance of ceiling fans

It has been observed that ceiling fans gave best performance when their height from the floor was kept at $(3H + W)/4$, where H is the height of the room and W the height of work plane above the floor. A fan hanging too high or too low does not produce the rated out put and results in wastage of energy.

Normally the height of rooms in residential buildings is 3.0 m and the average height of work plane is 0.9 m, then the optimum height of ceiling fan should be $(3 \times 3 + 0.9)/4 : (9 + 0.9)/4 = 2.5$ m. Further it should be noted that the clear distance between the ceiling and blades of the fan in no case should be less than 30 cm. If it is not so, the performance of the fan will be affected adversely and the power input will not be utilized fully.

26.10. THERMAL DESIGN OF BUILDING (IS 3792-1978)

When an temperature difference exists between the inside and out side of the building, heat transfer takes place through conduction, convection and radiation. The rate of flow depends on the properties of the materials used in the construction of the structural elements such as walls, roofs, floors, doors and windows etc.

The indoor thermal conditions may be improved by proper selection of building component materials, orientation, required glazing area and shading devices etc. The main problem in the design of thermal comfort are concerned with minimising solar heat gain and reducing wall and roof surface temperature.

26.11. DEFINITIONS

Before discussing further details of thermal design, some terms related with it are defined below.

26.11.1. Thermal conductivity

The quantity of heat flowing in steady state condition through a unit area of slab of uniform material of infinite extention and unit thickness in a unit time when the unit temperature difference is established between the two faces is called *Thermal conductivity* of the material. Generally it is denoted by the letter 'K'.

The rate of heat transfer through solid building materials and components depends on (*i*) Temperature difference between the two faces, (*ii*) Thickness of the material/component, (*iii*) Area of exposed surface, (*iv*) Time of heat flow. Thus thermal conductivity of a material is its characteristic property and its value depends on density, porosity, pore size, fibre diameter, mean temperature and out side temperature range.

The unit of thermal conductivity is W/mk, where W is in watts, m is in metres and k is its thermal conductivity. One watt is equivalent to 0.8598 K calories per hour. It can also be expressed in K.cal cm per m^2 per hour per °C.

Thermal Conductance (C)

Thermal conductance is a measure of the thermal transmission per unit area through the total thickness of the structure under consideration where as thermal conductivity refers to unit thickness. Further thermal conductance applies to a single layer of material only and not to a composite insulation or to a structure made up of several layers of the materials.

Thermal transmittance (U)

The thermal transmission through a unit area of a building element divided by the temperature difference between the air on either side of the building element is called *thermal transmittance* in steady state condition. This is the reciprocal of thermal resistance. Its unit is W/m^2 K.

In case of the thermal conductance the temperatures on the two surfaces of the structure or material are measured where as in case of thermal transmission the temperature difference between air on the two sides of the material is measured. Conductance is a characteristic of the structure while transmittance depends on conductance and surface coefficients of the structure under the condition of use. The value of thermal transmittance U of a building component serves a usefull guide for the extent of thermal insulation required in a building.

Rate of heat flow or thermal transmission (q)

The quantity of heat flowing in unit time under the prevailing conditions at the time is known as rate of heat flow. The unit of rate of heat flow is taken as watt (w).

Thermal resistance (R)

The thickness L of a structure having parallel planes divided by its thermal conductivity K is known as its thermal resistance. Hence it is the reciprocal of thermal conductance. Its unit is m^2K/W.

Thermal performance Index (TPI)

It is given by the following equation for a non airconditioned building element. It is expressed as percent

$$TPI = \frac{(T_{is} - 30) \times 100}{8}$$

where T_{is} = peak inside surface temperature.

A temperature drop of 8°C over a base temperature of 30°C is taken as reference. TPI depends upon the total heat gain through the building section both by steady and periodic part and is a function of out side surface temperature.

Thermal time constant

The ratio of heat stored (Q) and the thermal transmittance (U) of the structure is called thermal time constant. It is expressed in hours (h).

Thermal damping (D)

It is given by the following relation and expressed as percent.

$$D = \frac{(T_o - T_i)}{T_o} \times 100$$

where

T_0 = Out side temperature range

T_i = In side temperature range

Thermal damping or decreased temperature variation is a characteristic dependent on the thermal resistance of the materials used in the structure.

Absorptivity (α)

It is a factor which indicates the relative amount of radiation absorbed by a surface as compared to a absorbing black body under the same conditions. Its value is dependent on the temperature of the source and also that of receiving surface.

Surface coefficient (f)

It is the quantity of heat transmitted by all the methods *i.e.* convection, conduction and radiation from unit area of the surface when unit temperature difference is maintained between the surface and the surrounding medium. Its value depends on many factors such as position of surface, air velocity, temperature difference and emissivity of the surface etc.

26.12. THERMAL PERFORMANCE STANDARDS

The minimum thermal performance requirements of a building elements are specified in terms of thermal transmittance (U). Thermal performance index (TPI), Thermal time constant (T) and thermal damping (D) in the three zones hot dry, hot humid and warm humid of the country. These are indicated in the Table 26.5 below. These are the maximum values and should not be exceeded.

Table 26.5.

Building component	*Hot dry and hot humid zones*				Warm humid zones			
	U (max.) W/m²K	*TPI (max.)*	*T(min.) in hours*	*D (min.) in %*	*U (max.) W/m²K*	*TPI (max.)*	*T(min.) in hours*	*D (min.) in %*
Roof	2.33	100	20	75	2.33	125	20	75
Walls	2.56	125	16	60	2.91	175	16	60

Note: Heat insulation is not required for buildings, situated out side the four zones as indicated in table 26.1 under this category towns as Indore, Banglore, Balgaun, Mysore, Pune, Ranchi and Sagar may be placed.

26.13. THERMAL INSULATION OF BUILDINGS

In the thermal design of buildings following factors must be considered carefully.

1. Indoor thermal conditions must be evaluated carefully as they are most conducive to comfort, health and safety of the occupants.
2. The out side climatic data must also be evaluated carefully.
3. The physical properties of the structural materials that are to be used must also be evaluated in detail.

The main factors which determine the thermal response of a building are (*i*) the heat gains or losses through various structural components, as walls, roofs, windows and floors etc., (*ii*) the internal heat loads and, (*iii*) the rate of ventilation. Heat gain through walls depends on the colour of the out side surface, the heat storing capacity of the walls and their thermal resistance or insulation property.

26.14. OVER ALL THERMAL INSULATION PERFORMANCE OF BUILDING SECTIONS

The thermal insulation performance depends upon thermal properties of materials used in the construction, out side surface finish, orientation and climatic conditions. Author also had a chance to work on such a project during 1954 and 1960, while working in Central Building Research Institute. The report was submitted to the ministry of housing Govt. of India. Thermal performance of walls and roofs are shown in the Table 26.6 below.

Table 26.6. Thermal performance of walls and flat/pitched roofs

Element	*Particulars of elements*	*U values* W/m^2K	*Thermal time constant in hours*	*Damping D in %*	*TPI %*
Walls	1.25 cm P.L + 11.5 cm b/w + 1.25 cm P.L.	3.00	7.72	58.9	164
	1.25 cm P.L + 22.5 cm b/w + 1.25 cm P.L.	2.13	21.16	78.8	93
	1.25 cm P.L + 11.25 cm b/w + 1.5 cm air cavity + 11.25 cm b/w + 1.25 cm P.L.	1.55	30.5	85.4	78
	22.5 cm cavity b/w	1.69	41.0	81.0	85
	1.25 cm P.L + 2.5 cm EPS + 22.5 cm b/w + 1.25 cm P.L.	0.85	52.0	85.8	79
	1.25 cm P.L + 22.5 cm b/w + 2.5 cm EPS + 1.25 cm P.L.	0.85	6.7	92.4	82
	25.4 cm rubble wall + 1.25 cm P.L.	3.47	6.5	32.0	103
Flat Roofs	10 cms R.C.C. slab	3.59	4.3	30.0	184
	10 cm R.C.C. slab + 10 cms lime concrete	2.78	10.3	71	131
	10 cm R.C.C. slab + 5 cm foam concrete + water proofing	1.08	5.9	88	70
	5 cm R.C.C. slab + 2.5 cm EPS	1.08	1.8	84	64
	5 cm EPS + 5 cm R.C.C. slab + water proofing	0.62	40.0	83	61
	2.5 cm EPS + 5 cm R.C.C. slab	1.09	21.0	78	72
	11.5 cm R.C.C. + 5 cm mud Phuska + 5 cm Brick tile	2.31	24.5	87.3	97
	11.5 cm R.C.C. slab + 7.5 cm mud Phuska + 5.0 cm Brick tile	2.01	31.2	91.3	84
Sloped roof	0.625 cm A.C. sheet	5.47	0.015	12	186
	0.625 cm A.C. sheet + 2.5 cm air space + insulating board	2.44	0.029	39	111
	0.625 cm A.C. sheet + 2.5 cm air space + 5 cm sand witch of fibre board or EPS	0.65	1.8	17	75
	0.3 cm G.I. sheet	0.21	6	198	—
	5 cm thatched roof + 2.5 cm bamboo reinforcement	1.69	18.0	20	102
	Manglore tiles on wooden rafters	4.07	6	98	150

u-Thermal transmittance, T.P.I.-Thermal performance index, PL- Plaster, b/w-Brick work, EPS-Expanded polystyrene (Thermocole).

From Table 26.6 above it will be seen that the roof thickness made of 11.5 cms R.C.C + 5 cms mud phuska + 5 cm brick tile gave a heat damping 87.3% and Thermal performance index as 97%. Author observed during his experimental studies that it gave a time log of 6 to 8 hours between the maximum out side temperatures and in side temperature. Usually out side maximum temperature in hot and arid zone is at about 2 P.M. If there is a time lag of 6 hours, then maximum inside temperature will be at about 8 P.M. It was supposed that at 8 P.M. mostly people would be out side the rooms on terrace or in court yards on ground floors. Hence this concept of temperature time lag was correct from thermal comfort point of view. But now due to paucity of land availability and change in habits, people like to sleep inside the room. Thus problem of thermal comfort not solved by the provision of thick roofs. To solve this problem, heat insulation of roofs may be adopted. Fig. 26.1 shows thermal insulation and water proofing of a flat roof.

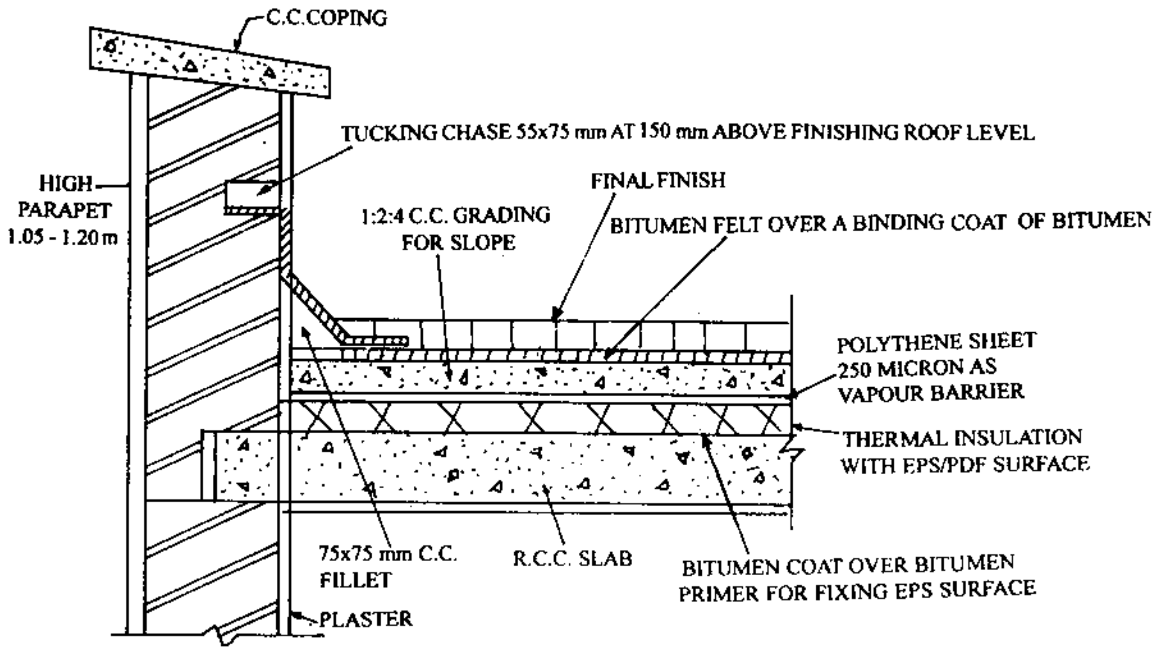


Fig. 26.1. Thermal insulation cum water proofing of flat roofs with bitumen felt

26.15. HEAT INSULATION OF ROOFS

Heat gain through roofs can be reduced by adopting following techniques:

26.15.1. Application of heat insulating materials on roofs

In case of external application, the insulating materials should be protected by water proofing treatment. For internal application these materials can be applied directly on the ceiling by an adhesive or can be applied in the form of false ceiling with an air gap. Optimum thickness of various types of insulating materials both for air conditioned and non air conditioned buildings are given in the following Table 26.7.

Table 26.7. Optimum thickness of insulation for Roofs in hot dry climates

S. No.	*Name and type of insulating material*	*Density range*		*Max. thermal conductivit*	*Optimum thickness in cms*			
					Flat roof		*Sloped roof*	
		Min. in kg/m³	*Max. in kg/m3*	*W/mk*	*Non A.C.*	*A.C.*	*Non A.C.*	*A.C.*
1.	Cellular concrete	320.0	350.0	0.081	5.0	7.5	—	10.0
2.	Light weight brick	400.0	450.0	0.081	5.0	7.5	—	10.0
3.	Vermiculite concrete	480.0	560.0	0.105	5.0	10.0	—	12.5
4.	Wood-wool board	350.0	450.0	0.076	2.5	5.0	—	7.5
5.	Foamtex	150.0	200.0	0.046	2.5	5.0	2.5	5.0
6.	Thermocole	16.0	20.0	0.041	2.5	3.5	2.5	5.0
7.	Fibre-glass	24.0	32.0	0.041	2.5	3.5	2.5	5.0
8.	Mineral wool	48.0	64.0	0.041	2.5	3.5	2.5	5.0
9.	Fiber insulating boards	200.0	250.0	0.053	1.5	2.5	1.5	2.05

26.15.2. White washing

Providing white washing on the roof before the on set of summer has shown good results. By white washing a reduction of 2 to 3°C temperature has been observed in the inside temperature. It is the cheapest and most effective method.

26.15.3. Spraying of water on the roof

Some light weight material such as brick aggregate may be spread on the roof. The thickness of 5.0 cm to 7.5 cm is sufficient. Water may be sprinkled over this brick aggregate at a fixed interval of time. Evaporation of water will reduce the temperature. Water may also be sprinkled with out placing brick aggregate. In both thee conditions problem of dampness in the building may arise. hence it is not a very sound proposition.

26.15.4. Shining and reflecting materials may be used on roof top

A layer of broken china tiles in lime mortar may be laid over lime concrete. Due to its high reflective coefficient heat load on the roof reduces significantly. It also gives a good wearing and draining surface to the roof.

Due to these treatments on the roof, the ceiling surface temperature reduces significantly, as shown in Fig. 26.2. It may be seen that the ceiling temperature can be reduced below the body temperature of 37°C so that the ceiling acts as a heat receiver and the radiant heat load on the human body is reduced.

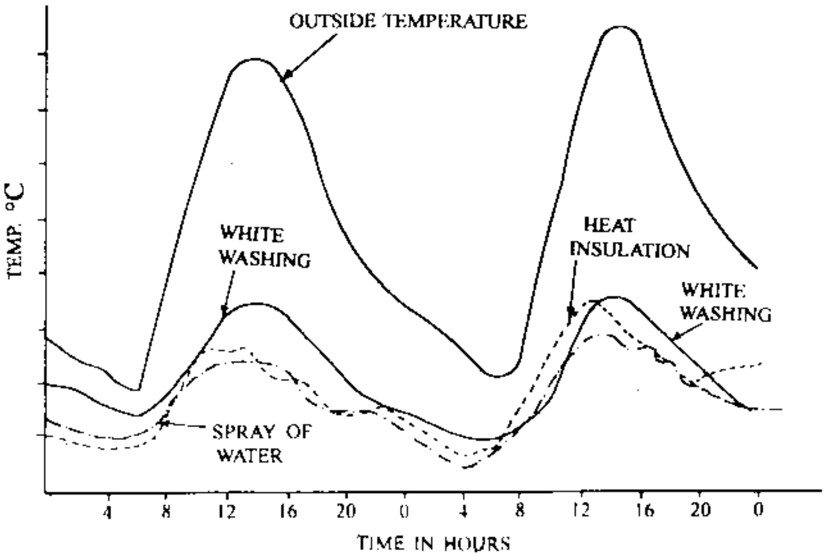


Fig. 26.2. Ceiling surface temp due to various treatments

26.16. CEILING HEIGHT OF A BUILDING

From the point of view of thermal comfort the minimum ceiling height is based on the following factors:

1. Required ceiling surface temperature.
2. Safety requirements and minimum clear space for fixing ceiling fans etc.
3. Radiation load on occupants.

Experiments conducted at Central Building Research Institute Roorkee have shown negligible effect on indoor temperatures due to variation of ceiling height from 3.0 m (10 ft.). Raising of height from 3.0 m to 3.3 m (10 ft. to 11 ft.) has shown a decrease in temperature by 1°C and above 3.3 m height no appreciable effect was observed.

Some other researchers have reported that very negligible effect on indoor temperature has been observed due to the variation in ceiling height from 2.4 to 3.3 m. They have reported that the extent of temperature reduction with the increase in ceiling height is of the order of 0.3°C for every 30 cm increase in height for single story building. Hence 3.0 m height is sufficient from the thermal comfort point of view.

26.17. HOW TO MAKE KITCHEN MORE COMFORTABLE

A common house wife has to spent much of her time in the Kitchen. Hence it should be comfortable. As the area of the kitchen is small, the increase in natural ventilation is not always possible. The most suitable method would be to use Exhaust system. It will increase the rate of air change to desired level. How ever it should be ensured that inlet air should be humid, cool and does not contain impurities and able to maintain the inlet temperature with in the range of 22°C. This system is based on principle of creation of vacuum in the room by exhausting the foul air by exhaust fans. In this system the air inlet should be provided at a level of 1.2 to 1.8 m high and out let near the ceiling at about 30 cm below it on the opposite side of the inlet from where air enters in the room.

26.18. DAY LIGHTING OF BUILDINGS (IS 2440-1975)

Actually the light requirement depends on the type of building and the tasks to be executed by the occupants. Different visual tasks need different amount of light for the same visual efficiency. Here only general guide lines are given for the design of windows.

26.19. GENERAL PRINCIPLES OF WINDOW DESIGN TO PROVIDE GOOD DAY LIGHTING

Following broad principles may be kept in view for the design of windows:

1. Total openings for windows and doors having 15 to 20% of floor area are found quite adequate both for ventilation and lighting in hot and humid climates.
2. As a general rule unilateral lighting from side windows will be un satisfactory if the room depth is more than 2½ times the height of the window top above the floor level.
3. Taller windows provide greater penetration of light while broader windows give better distribution of light. The broader windows may also be equally efficient in giving desired penetration if their sills are raised by 30 to 60 cm.
4. For a given penetration, a number of small windows properly positioned along the same wall, adjacent or opposite walls will give better distribution of illumination than a single large window.
5. Windows should be provided with chajjas, Louvers, baffles or other shading device to exclude the direct sum light entering the room. Broad and low windows in general are much easier to shade against sun light entry. Direct sun light increases the inside illumination very considerably. Glare results, if it falls on walls at low angles. Glare is more when it falls on floors of reflective surface or dark coloured surface.

   Chajjas or Louvers etc. reduce the height of window. Hence due allowance should be kept for providing chajja etc.
6. Translucent glass panes reflect part of the light to the ceiling, there by increasing the diffuse lighting with in, and light up further areas in the room. Thus they provide more uniform illumination through out.
7. To get a good level of diffused lighting, all internal surfaces should be light coloured and should have good reflectance. The illumination level in a given room with a window will be higher if the walls are light coloured than of dark coloured.
8. For a good day light on the working plane, following dimensions of the windows should be adopted:

   (a) Residential buildings:

   (i) Window height may be 1.0 to 1.1 m

   (ii) Sill level or sill height 0.9 to 1.0 m above floor

   (b) Office buildings:

   (i) The height of window may be 1.2 m or more in the centre of the wall

   (ii) Sill height or sill level may be kept 1.0 to 1.2 m above floor level

   (c) Width of the widows. Window width may be adjusted depending upon the required area of the opening.

   (d) If the room depth is more than 10 m, window should be provided on the opposite sides for bilateral lighting.

   (e) Reflectance. For good lighting the ceiling should be given white finish and off white to white to walls. If the wall finish is changed from moderate to white, 7% improvement has been observed in lighting level. Reflectance of some finishes is shown in Table 26.8 below.

Table 26.8. Reflectance of common finishes

S. No.	*Finish*	*Reflectance*
1.	White wash	0.7 to 0.8
2.	Cream colour	0.6 to 0.7
3.	Light green	0.5 to 0.6
4.	Light pink	0.6 to 0.7
5.	Dark red	0.3 to 0.4
6.	Light blue	0.4 to 0.5
7.	Cement tarrozzo	0.25 to 0.35
8.	Brick	0.4 to 0.5
9.	Vegetation	0.25

QUESTIONS

1. What is the aim of building design from thermal comfort point of view?
2. Give the classification of climatic zones of India.
3. Define orientation of a building? What are its objectives.
4. Define ventilation and discuss its objectives.
5. The area of windows and ventilators should be ....% of the floor area:
   (*a*) 50% (*b*) 40%
   (*c*) 20 to 30% (*d*) 55 to 65%
6. In a residential building the maximum window height should be
   (*a*) 70 to 80 cm (*b*) 100 to 110 cm
   (*c*) 110 to 125 cm (*d*) 130 to 140 cm
7. For best illumination the colour combination of ceiling and walls should be
   (*a*) Ceiling yellow, walls pink
   (*b*) Ceiling black, walls white
   (*c*) Ceiling white and walls off white or white
   (*d*) Ceiling white, walls red
8. For best performance of a ceiling fan, the height of its blades from the floor should be
   (*a*) 2.75 m (*b*) 2.65 m
   (*c*) 2.35 m (*d*) 2.5 m
9. For the best performance of the ceiling fans the distance of its blades from the ceiling should be
   (*a*) 65 cm (*b*) 55 cm
   (*c*) 30 cm (*d*) 20 cm
10. The maximum value of thermal performance index for roof should be
    (*a*) 75 (*b*) 85
    (*c*) 65 (*d*) 100
11. The body temperature of human being is
    (*a*) 32°C (*b*) 37°C
    (*c*) 42°C (*d*) 39°C
12. The comfortable range of temperature for human being is
    (*a*) 20°C to 25°C (*b*) 27°C to 30°C
    (*c*) 30°C to 35°C (*d*) 37°C to 40°C

ANSWERS

5. (*c*)	7. (*c*)	9. (*c*)	11. (*b*)
6. (*a*)	8. (*d*)	10. (*d*)	12. (*b*)

27
Dilapidation of Buildings and Their Rehabilitation

27.1. INTRODUCTION

The term dilapidation is used to denote the decay of a building to such a state that its physical life is tending to an end, that is the building is approaching a condition which would render it unfit for use.

27.2. LIFE OF A BUILDING

The life of a building can be classified into the following categories;

1. **Physical life.** A structure is constructed assuming its certain life. Till a structure is structurally sound, this period is called its physical life. Usually the life of a super structure is assumed as 70 years.
2. **Functional life.** Till a building fulfill its original intended functions for which it was constructed is called its functional life.
3. **Economic life.** The period after which the maintenance cost of the building becomes very exhorbitent, the building is said to have crossed its economical life. The cost of maintenance against its replacement is the best indicator of economic viability.

The physical and economical lives need not be the same. In many cases it has been observed that a building is still physically sound, but its economic life has ended.

27.3. CAUSES OF DILAPIDATION (DECAY) OF BUILDINGS

Following physical causes may render a building to the dilapidated condition:

1. **Natural decay or ageing.** This is a natural phenomenon. Every material used in a building has a definite life to remain in its functional condition. After this period, it gives way and the building gradually drifts toward dilapidated condition.
2. **In adequate or no maintenance or delay in repair.** It is a main cause of dilapidation of buildings.
3. **Misuse of building.** Misuse of building expedites its dilapidation.
4. **Use of inferior materials**. It is clear that inferior materials will have less life and lesser strength than standard materials. Thus in due course, building will head towards deterioration.
5. **Bad workman ship.** Bad workman ship will reduce the life of the structure and in balance in load bearing system leading to the early decay of the structure.
6. **Effect of aggressive environment.** Factors such as salty strong winds prevalent in sea shore, atmosphere polluted with aggressive chemicals, gases, smoke etc. cause damage to structures in various ways and expedite its dilapidation.
7. **Force majure (unforeseen factors).** Floods, cyclonic storms, earth quake, fire and warfare etc.

may cause serious damages to buildings leading them to destruction.

In this chapter we shall discuss some effects of earth quake and fires hazards.

27.4. EARTH QUAKE

Earth quake is one of the natural disaster which strikes with out any warning. It strikes with negligible warning and causes greatest devastations of all. This disaster takes place through out the world. Many standards have been developed to control the damages due to earth quake, but no standard and design has proved totally effective against earth quack.

The primary objective of earth quake or seismic resistant design is to ensure the safety of building occupants during the major events of earth quake. During the earth quake the gravitational force decreases to a great extent approximately to about 10% of its original value as the gravity acceleration (g) reduces due to earth quake. Thus the buildings get deformed beyond their elastic limits during major earth quakes and many buildings collapse.

In order to assess the damage, the seismic areas are divided into the four zones as follows:

1. **Zone A.** This is the zone of highest seismic activities having a seismic intensity of IX or more.
2. **Zone B.** This is the zone of moderate seismic activities having a seismic intensity of VIII.
3. **Zone C.** This is the zone of mild seismic activities having a seismic intensity of VII.
4. **Zone D.** This is the zone of light seismic activities having a seismic intensity upto VI.

27.4.1. Seismic damage

The challenge to the design engineer is to ensure limited seismic damages to an acceptable degree. In current seismic design codes for determining the design forces. Constant, Displacement Ductility-Strength, Demand Spectra (CDDSDS) criteria has been extensively used.

In this system (CDDSDS). Displacement ductility ratio has been used as the index of seismic damage. For the design of buildings in seismic areas the approach of Indian seismic standards is as given below:

1. The ordinary building should be able to withstand or resist the minor level of earth quake ground motion with out any damage.
2. Further a building should be able to withstand or resist a moderate level of earth quake ground motion with out structural damage, but a certain extent of non structural damage might be expected.
3. Finally a building should be able to resist with out collapse, a major level of ground shaking of intensity equal to the strongest, either experienced or predicted earth quake for the building site, with the expected signs of structural and non structural damages.

The code insists on ductile detailing and construction practices to suit the conditions.

Thus damages of buildings are inevitable in any moderate to severe seismic activity. Hence the classification of damages, their assessment, repair and rehabilation is important, especially in the present conditions when frequency of earth quakes is increasing.

27.5. CONSTRUCTION SUGGESTIONS FOR SEISMIC ZONES

Some guide lines for construction in different seismic zones are suggested as follows:

27.5.1. Use of materials

In light seismic activity zone D, good workmanship should be provided for all type of structures. This is the main requirement of this zone. All materials such as sun dried earth brick or random rubble masonry can be used for construction work.

In all other zones A, B, and C, only well burnt bricks having a minimum crushing strength of 35 kg/cm^2 should be used. Squared stones or hollow concrete blocks may also be used in place of bricks. In zones B and C the sum dried mud bricks or random rubble masonry should be avoided. If unavoidable due to economic reasons they can be used with caution. In zone A, the use of random rubble masonry or sun dried mud brick should not be allowed in any case. It should be prohibited by law. How ever in high seismic activity zones light weight materials should be used so that they may not cause heavy damage and causalities at the time of destruction.

In different zones following types of mortar proportion may be used as shown below in Table 27.1.

Table 27.1. Type of mortar to be used

Zone	*Cement*	*Lime*	*Sand*	*Surkhi/Cinder*
A	1	—	3	—
A	1	1	6	—
A	1	2	9	—
B, C	1	—	6	—
B, C	1	1	8	—
B, C	—	1	3	—
B, C	—	1	—	3

27.5.2. Structural Elements

1. In seismic zones load bearing walls should not be more than 15 m in total height *i.e.* the building should not be higher than 4 storeys.
2. The thickness of first story walls from the ground should be 40 cm and second story 30 cms while upto third and forth story, it should be 20 cm for both the storeys.

   These thickness may be increased suitably if the cross walls are provided at more that 6 m apart. To minimise the torsion effect that causes additional shear, as far as possible, walls in both directions of the building should be symmetrical in plan.
3. *Openings in walls.* As far as possible the openings in walls should be minimum and should have their top at the same level, so that a continuous band of reinforcement concrete could be provided in the building at the lintel level.
4. *Location of opening.* The opening should be located away from the corner by a clear distance equal to a minimum of 1/4th of its height and horizontal distance between two openings should be more than half of height of the shorter opening.

If due to any reason either the shortage of materials or otherwise the construction is not upto the desired standards, then the building at certain critical positions should be provided steel reinforcement. Such buildings should be prohibited in zone A. However they can be constructed in other zones with restricted storeys. In zone B, there should be single storey buildings and in zone C they can be built upto up two storeys.

Lintel band reinforcement may be laid in more courses with 1:3 cement sand mix and links may be omitted. In seismic regions all projections such as chajjas, balconies, parapets etc. should be avoided. If unavoidable they should be properly reinforced and tied to the main structure.

In seismic regions walls should be inter connected at corners and junctions by suitable means, such as a continuous reinforced concrete band covering all walls. it acts as a horizontal beam spanning between the cross walls. This beam supports the earth quake force on wall acting normal to its plane. This band may be made of R.C.C. or reinforced brick work. The thickness of this band equal to 7.5 cm and width equal to the width of the wall has been found adequate. In this band one steel bar at each face of the wall is recommended. The size of the bar 16 mm, 12 mm and 10 mm may be adopted in zone A, B, and C respectively. These bars should be held together by 6 mm diameter links provided at approximately 15 cm apart. These bands should be made continuous at the corners and junctions by providing suitable reinforcement. To avoid widening of cracks in walls during continued severe shaking in zones A and B, vertical reinforcement is found necessary at corners and junctions of walls, and jambs of openings. The details of this reinforcement are shown in Table 27.2 below.

IS 1893 gives complete structural design of earth quake resistant structures. In India in semi urban, sub urban and urban areas usually two storeyed masonry structures are made, which are not amenable to structural design.

IS 4326 covers some ready made norms to make structures earth quake resistant. Some of the salient features of this code are reproduced below:

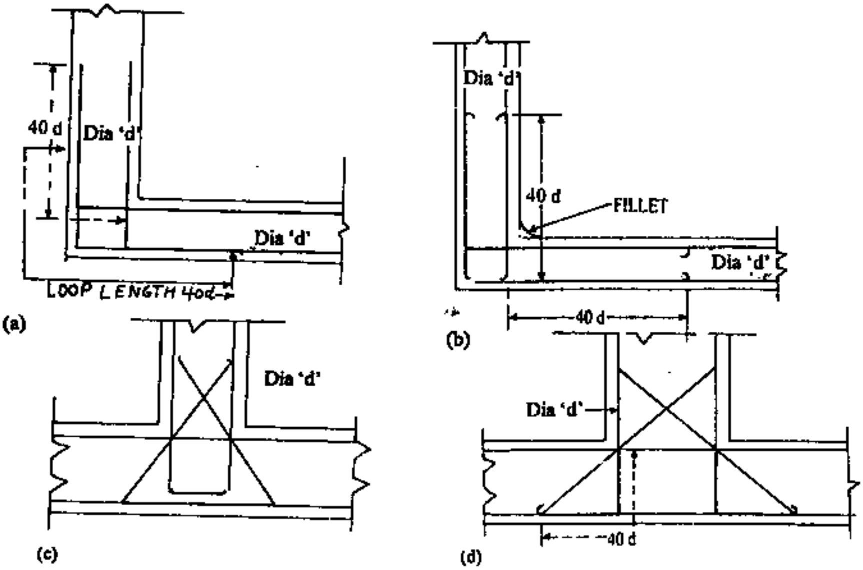


Fig. 27.1. Band reinforcement at corner and junction of walls

1. Un symmetrical building plans and elevations should be avoided.
2. Two adjacent blocks of the same building having different height and area ratio should be separated by suitable separation joints.
3. The construction of stair case should not be made monolithic with the construction of main building.
4. In R.C.C. or steel structures suitable diagonal bracing should be provided in the vertical panels as they add to the resistance of the frame to with stand the earth quake.
5. To have provision of ductility of R.C.C. and steel structures.
6. In highly seismic areas use of mud mortar, sun dried bricks and rubble masonry has not be recommended.
7. For timber frame work details of providing bracing has been given in details.

Table 27.2. Vertical reinforcement in walls at their junctions and Jambs of openings

No. of storeys	*Story*	*Recommended diameter of a single bar in mm*	
		Zona A	*Zone B*
1 (one)	—	12	—
2 (Two)	Top	12	—
	Bottom	16	
3 (Three)	Top	12	12
	Middle	16	12
	Bottom	16	16
4 (Four)	Top	12	12
	Third	16	12
	Second	20	16
	Bottom	25	16

27.6. TYPES OF DAMAGES AND FAILURE IN EARTH QUAKE REGIONS

A particular type of failure is closely related to the type of structural system of the buildings in most of the cases.

27.6.1. Structural system of buildings

The structural system of buildings may be classified as follows:

1. Masonry walls with timber floor or tiled roofs.
2. Masonry walls with R.C.C. floors or roofs for single and multiple storeys.
3. R.C.C. framed structures with infill masonry walls.
4. R.C.C. shear wall construction.
5. Steel frames with infill walls.

27.7. DAMAGES OF DIFFERENT TYPES OF STRUCTURES

1. The lateral loads in plane induce shearing deformations in masonry wall as shown in Fig. 27.2. This deformation introduces diagonal tension and diagonal compression in the orthogonal directions. As the tensile strength of masonry materials is much less than their compressive strength, the in plane forces induce typically diagonal cracking perpendicular to the tension axis. The diagonal tensile cracks extending the full thickness of the masonry indicates the diagonal shear failure of the wall. The effects of lateral seismic forces should be separated from the effects of excessive vertical compressive loads as the combined effect will further widen the crack.

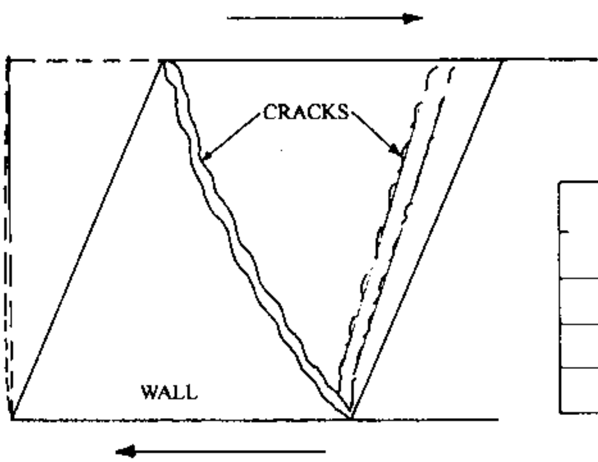


Fig. 27.2. Diagonal shear cracks in masonry

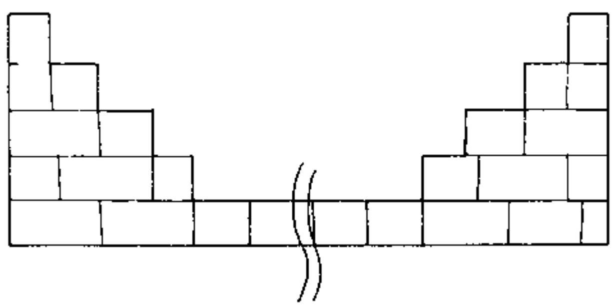


Fig. 27.3. Out of plane failure of a masonry wall

2. For walls carrying light gravity loads, out of plane forces induce a stability failure in which a wall either burst out ward or topples over to sides. The failure line is characterised by a long horizontal section in the middle. Short sections at both ends remaining in position in a shape of a scoop Fig. 27.3. The boundary conditions (that is the nature of the supports at the edges of the walls) strongly influence the out of plane behaviour of the wall. Out of plane failures of a series of parallel walls in a building may cause greatest damage to the whole building. As stated earlier also roofs made of light weight materials may cause less loss of life and property in such cases in comparison to buildings made of R.C.C. floors of density 2300 kg/m^3 or heavy stone panels. Repairs of such masonry is recommended if it is structurally sound and the damages are minor.

27.8. FAILURE OF R.C.C. FRAMED STRUCTURES

1. **Shear failure.** The shear failure of column may be due to the following causes:
   (*a*) The core concrete of column not being properly bonded or inadequate provision of lateral ties.
   (*b*) Lack of cross ties.
   (*c*) No proper hooks anchored into the column core.
2. **Compression failure of the column.** This failure may occur due to the following causes:

(*a*) *Buckling of vertical reinforcement.* This failure is more common.

(*b*) *Crushing of concrete.* This failure is, rarely seen.

(*c*) Pull out of smooth main reinforcement bars due to improper hook system or inadequate provision of over lapping length.

(*d*) Weak axis failure of column due to orientation problem.

3. Failures of column on hinging at the junction of beam and column. This failure may take place due to the following causes:

(*a*) Due to inadequate detailing (*i.e.* lack of laterals with in the column-beam junction, column being weak and beam strong)

(*b*) Poor anchorage of column bars through the joint.

4. Shear wall structures. Shear walls may be subjected to diagonal shear due to the following causes:

(*a*) Improper design and detailing

(*b*) Due to the effects of openings

(*c*) Due to poor quality concreting

(*d*) Rusted or corroded reinforcement.

5. Steel framed structure. Moment resisting frames have been found to be the best for lateral resistance as well as for adequate ductility. But welded framed structures might be affected due to breaking at welds in welded flange moment connections. The joint failure include failures due to:

(*a*) Cracks across the column flange thickness

(*b*) Weld metal fractures

(*c*) Fractures at weld metal/column interface

(*d*) Cracks in fillet welds at shear connection plates

(*e*) Cracks in beam shear connection plates along the bolt line or in the plate at the end of the fillet welds.

These cracks/failures do not result in collapse in the building, but highly stressed joints are extremely sensitive to minor imperfection in the welds. Other than weld failures other common failures are as follows:

1. Damage to claddings
2. Bucklings of bracings
3. Damage of riveted connections due to inadequate capacity
4. Spalling of covering concrete
5. Plastification of steel at lower stresses in case fire broke out with earth quake.

27.9. ASSESSMENT OF DAMAGE AND REPAIR METHODOLOGY

Before taking any rehabilitation measures, the damaged structure or building should be investigated by an experienced person to ascertain the cause, extent and nature of the damage. After the assessment of the damage an estimate of cost of repair should be prepared. For assessment of damage, the damages may be classified as follows:

1. Cracking-Extent of cracking and pattern of cracking should be examined carefully.
2. Whether the collapse is partial or total.
3. Spalling of the materials and reduction of size of the member.
4. Extent of buckling, twisting, distortion and deflection etc.
5. Discoloration of the materials.

After assessing the damage fully, the repair work should be taken in hand. Here some methods of repair are discussed. For repair of cracks please refer chapter 7, 16, and 23 also.

27.10. FIRE DAMAGED STRUCTURES

The damage caused by fire to a reinforced cement concrete structure may be classified into the following categories:

1. **Completely destroyed or burnt.** In this case whole of the damaged portion has to be replaced during restoration operation of the structure.
2. **Slightly damaged or deformed.** In this case only the repair and finishing of the damaged portion is sufficient.

The extent of damage caused to a R.C.C. structure during a fire depends on the duration of the fire and the temperature experienced by the structure during the fire. High temperature during a fire reduces the strength of reinforced concrete structure due to the following causes:

1. The change in the strength and deformability of materials.
2. Reduction in cross-sectional dimensions of the structural members.
3. Weakening of bond between the reinforcement and the concrete. This factor determines the structural action under load.

Normally the maximum temperature reached during a fire is estimated indirectly *i.e.* from the melting of metallic or other non combustible articles. From statistics available on the damaged R.C.C. structures by fire, the duration and maximum temperature reached during the fire are shown in the following Table 27.3.

Table 27.3. Showing duration of fire and maximum temperature reached

S. No.	*Type of structure*	*Duration of fire in hours*	*Range of temperature reached in °C*
1.	Residential and administrative buildings	1 to 2 hours	1000°C to 1100°C
2.	Theaters and departmental stores	more than 2 to 3 hours	1100°C to 1200°C
3.	Industrial buildings and ware houses where considerable quantities of solid and liquid combustible quantities are stored.	more than 2 hours	1300°C

Thus the duration of fire and the maximum temperature reached vary over a wide range. Temperatures of 1000°C to 1100°C in fires lasting, to 2 hours have been observed more frequently than 1300°C.

An accurate estimation of the performance characteristics of structures damaged in a fire helps in taking effective measures of restoration. The performance characteristics take into account the physico-chemical and mechanical properties of the materials burnt and that of heated concrete. There is an accumulation of irreversible damages of mechanical and physico-chemical factors. Under mechanical factors creep, cracking, shrinkage, and plastic deformations may be classified, while under physico-chemical factors corrosion, absorption and degradation etc. may be classified. These informations enhance the reliability of estimation of residual load carrying capacity of the structural members resulting in a considerable saving in the cost of restoration of the structure. How ever from this information the determination of the physico-chemical characteristics of the materials and geometric dimensions of the structure is difficult.

The strength and stiffness of concrete and steel decreases as the temperature of the member increases and dimensional changes take place. The changes in strength and stiffness of the concrete are influenced by the constituent elements of the concrete *i.e.* type of cement and aggregate and water content. The cracks or spalling develop in beams, columns and slabs due to the development of stresses caused by thermal strains. The development of cracks and spalling decreases the area available to resist the applied loads or forces. The behaviour of different structural elements damaged in fire is discussed below.

27.11. AXIALLY LOADED COLUMNS

Normally the failure of axially loaded columns takes place at mid height due to brittleness. The failure occurs due to the disintegration of concrete in the whole section accompanied by buckling of longitudinal bars. Due to the fire, a large variation in temperature between the concrete of periphery and centre of the section takes place. The range of this temperature variation has been found 800°C or even more. This variation in temperature causes variation in the strength of concrete. The strength of concrete varies along