CHAPTER – 1

CIVIL ENGINEERING DECIPLINES AND BUILDING SCIENCE

INTRODUCTION

Engineering is the profession that puts scientific knowledge to practical use. i.e., Engineering is an applied science. Engineers look for better and optimized ways to use existing resources and often develop new resources & new materials.

In general, the field of engineering includes a wide variety of activities. Engineering projects range from the construction of huge dams to the design of tiny electronic circuits. Engineers may help to produce guided missiles, industrial robots, or artificial limbs for the physically handicapped. They develop complex scientific Equipments to explore the reaches of outer space and the depths of the oceans. Engineers also plan electric power and water supply systems, and deal with automobiles, television sets, and other consumer products.

They work to reduce environmental pollution, increase the world's food supply, and make transportation faster & safer.

Out of all branches of engineering, Civil Engineering is the one that is directly associated with the welfare of the society. 'Civil Engineering', a branch full of human activities, has been pursued from very early times when man began to adopt the environment to his needs. The motto of the civil engineering.

The term civil in civil engineering refers to the discipline's involvement in public works, including government buildings, military bases, mass transit systems (i.e., highways, railways, airports, and water ways), water treatment works, waste management, irrigation etc. In ancient times, there was no formal engineering education. The earliest engineers-built structures and developed tools by experience and by methods which were empirical in nature. However, the present-day engineering activities are based on sound theoretical knowledge. Guided by theory and the past experience, the present-day civil engineers work for the benefit of the society, carrying out the works according to certain standards. Maintaining the quality in their works help them to achieve good performance from their outputs.

SCOPE OF CIVIL ENGINEERING

The scope of Civil Engineering is very vast, and it has many diversified fields which help in the total development of any civilization. Various subdivisions that come under civil engineering branch are listed below.

- Surveying
- Building Materials Technology
- Geotechnical Engineering
- Structural Engineering
- Construction Technology
- Hydraulics
- Water Resources and Irrigation Engineering
- Transportation Engineering
- Environmental Engineering

A brief description of the contents of study of each of these sub-divisions is given below

- ***Surveying***

It is a field of specialization which involves processes through which the relative positions of various points are objects on the earth's surface are determined on a horizontal plane as well as on a vertical plane. The results of such processes are represented in the form of map or plan. A plan is a graphical representation of various ground features as projected on a horizontal plane, to some convenient scale, on a sheet of paper.

Surveying is an essential work which is carried out in the beginning of any constructional activity, such as development of an area, construction of transportation facilities such as road ways, railways and air field pavements, construction of structures such as buildings, bridges, dams and the like.

Conventional methods of surveying include chain surveying, compass surveying, theodolite surveying, plane table surveying and levelling. The modern day surveying, by virtue of developments in technology, include the use of sophisticated instruments like total station and other electronic, electro-magnetic, electro-optical instruments and tools such as Geographic Information System (GIS), Global Positioning System (GPS) and the like. It also makes use of allied fields such as remote sensing and photogrammetric.

• ***Building Materials Technology***

Any constructional activity invariably requires the use of different types of materials.
These materials of construction can be broadly classified in to

- Conventional materials (Ex: soil, stones, bricks, timber, cement / lime, tiles, plain and reinforced cement concrete, pre-stressed concrete).
- Modern building materials (Ex: Fibre reinforced concrete, aluminium, glazed tiles, plaster of Paris).
- Alternate building materials (Ex: Fly ash, polymeric materials, industrial wastes, recycled aggregates).
- Smart materials.

Depending upon the requirement, budget and other constraints, any combination of these materials can be used in the construction works. Building materials technology deals with a detailed study of these materials of construction origin / fabrication–/ manufacture, types, properties, functional advantages, limitations. These information help in judging the suitability of different materials to be used in the proposed constructional activity.

• ***Geotechnical Engineering***

All structures built on earth transfer the superimposed loads to the ground (soil / rock) underneath, through appropriate foundation. Soils are complex geological materials which are expected to receive the loads transferred to them safely without causing damage to the structure. The soils are physico-chemically active materials, and their engineering behaviour depends upon their water content. This subject encompasses

 a detailed study of soils –formation, composition, properties and their determination

 a detailed study of rocks–types, properties, strength and deformation characteristics and their determination.

 different types foundations, their relative merits and limitations, suitability and design aspects.

 design and analysis of various earth structures such as embankments, dams, retaining walls etc.

 site investigation, sub-soil exploration and field tests.

 Ground improvement techniques

Geotechnical earthquake engineering is a specialized field of geotechnical engineering, which deals with earthquakes, their effects on foundation soil, different types of seismic hazards, study of dynamic soil properties, seismic design of earth structures, soil improvement to withstand / minimize seismic hazards etc.

- ***Structural Engineering***

All structures constructed on this earth are subjected to various types of loads of different complexities / nature. Various components of a structure are expected to respond to these loads favorably and to withstand them safely. The satisfactory performance of structures requires the know ledge of materials' behaviour and selection of appropriate material for use, proportioning / designing different components of a structure, estimating the stresses developed in different component of a structure and back checking the design. This field includes subjects like engineering mechanics, strength of materials, structural analysis and design of structures. It also requires the knowledge of different tools to carry out the analysis and design of structural components such as matrix method of analysis, finite different techniques, finite element methodof analysis and the like.

- ***Construction Technology***

All activities undertaken in the construction of any structure come under this field. Construction of various types of structures, making use of various types of constructional materials available, study of different technologies of construction, management of various constructional activities with respect to different parameters like resources (material / human), time, finance and legal aspects are included in this field of civil engineering.

- ***Hydraulics***

Water is an integral part of human life and of almost all constructional activities. This subject deals with

- basic properties of water
- study of water at rest as well as in motion
- flow through pipes
- open channel flows
- flow measurements
- different analytical, computational and experimental approaches to analyse the flow problems.

- ***Water Resources and Irrigation Engineering***

There are different sources of fresh water on this earth such as rain, ground water, streams / rivers. These waters have to be harnessed and stored properly before they are utilized for different purposes such as drinking, irrigation and water power generation. This subject deals with

- different sources of water on this earth
- estimation of total water available and water requirement.
- construction and maintenance of structures to tap the available resources of water
- planning and building of water retaining structures such as tanks / dams
- construction and maintenance of water carrying structures
- different irrigation schemes
- flood control methodologies
- depletion and replenishment of water resources

• ***Transportation Engineering***

The social and economic development of any country is a function of transportation facilities available in that country. Different means of transportation include roadways, railways, air ways and water ways. This field deals with a detailed study of planning, design, construction and maintenance of different types of road ways, railways, airports and runways, harbours and docks, bridges and tunnels.

• ***Environmental Engineering***

This subject deals with

- study of available water quality and checking against the standards
- water collection and water purification through various treatment processes
- supply and distribution of quality water for urban and rural areas, for domestic and industrial usage
- study of domestic water supply system and sanitary system
- waste water collection, treatment and safe disposal
- study of wastes and waste management
- study of different kinds of pollution and pollution control measures
- study of environmental safety

INFRASTRUCTURE

Infrastructure is a system of services and communication that is required for the over all development of the society. It refers to facilities such as transportation (i.e. Railways, Highways, Air ways, Water ways etc.,), hospitals, education; energy (coal, electricity, oil etc.), irrigation, farm equipments & machineries, science and technology, communication, health & hygiene, banking that facilitate and contribute in the process of production of goods and services for the overall development of the economy of the society.

The infrastructure is of two types.

a) **Economic infrastructure:** It contributes directly to the economic development of any country.

It consists of transport and communication, power supply, irrigation networks, financial institutions etc.

b) **Social infrastructure:** It contributes to the process of economic development of any country indirectly. It consists of education & training, health & family welfare, housing & water supply and other civic amenities.

Transport and Communication:

In this modern age, transport along with electricity and power forms the basic infrastructural requirement for industrialization. Transport provides vital link between production centres and distribution points. It also exercises a unifying and integrating influence upon the economy. Indeed, transport facilitates agricultural development by supply of modern inputs like seeds, chemical fertilizers, pesticides, farm implements and machinery. Transport helps the movement of agricultural produce from scattered farms to the distant markets. It helps the industrial development by facilitating the regular and prompt movement of raw materials and labour to the factories and finished products to market. It helps to widen the market for wide variety ofindustrial goods. Transport helps to widen the market and trade. It facilitates exploitation of natural resources, helps the mobility of labour, and serves administration and defence requirements.

The important means of transport are railways, roadways, waterways and airways. The importance of transport services in economy depends on several economic factors such as interdependence, mutual co-operation and co-existence of different regions. Therefore, to integrate diversified economic regions within the country and economies of the world, a well-developed network of transport system is of vital importance.

Railways provide an economical mode of transport for freight over long distances. The roadways are most ideal transport for short distance travel and light freight and to cater to diverse points of production, distribution and consumption. Well-constructed roads have become main components of economic infrastructure today. The other main components of transport networkin the economy along with roads and railways are coastal shipping, inland waterways and domestic airlines.

Communication means imparting or transmission of information. The difference between transport and communication is that while the former implies the conveyance of goods and passengers from one place to another, the latter implies the conveyance of information. The conveyance of information is necessary for the development of industry, commerce and trade of any country. Today, a very large network of communication media exists. These include postal

services, telegraph and the telephone, radio and television (Door Darshan), tele printers, telex, fax services, the cinema and the press. The responsibility of building and extending the services is fixed to specialized departments and agencies like postal department, telegraph department etc.

The communication network is also claimed to be formed under social infrastructure of the economy. Communication can also be seen as a service in imparting education.

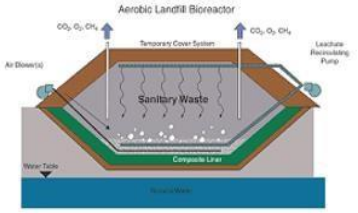
GEOTECHNICAL, WATER RESOURCES AND ENVIRONMENTALENGINEERING

GEOTECHNICAL ENGINEERING:

- Geotechnical Engineering is the study of rock and soil supporting Civil Engineering systems.
- Identification of soil properties presents challenges to geotechnical engineers as the soil properties vary from place to place and with depth.
- The material properties and behavior of soil are difficult to predictdue to its variability and limitation on investigation.
- It involves in the design of foundations, tunnels, embankments, dams, retaining walls, stability of natural slopes, mining, petroleumexploration, offshore structures, landfills etc.

TUNNELS, EARTHEN EMBANKMENTS AND DAMS

DESIGN OF RETAINING WALLS, SOIL SLOPES, MINING & FOUNDATIONS OF OFFSHORE STRUCTURES

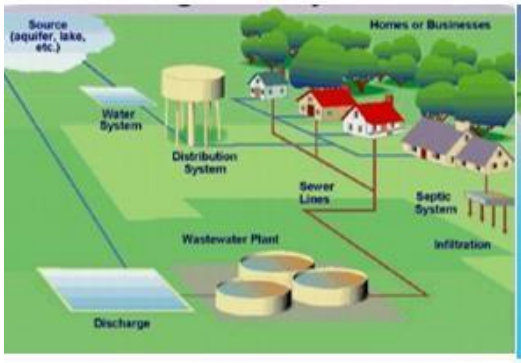


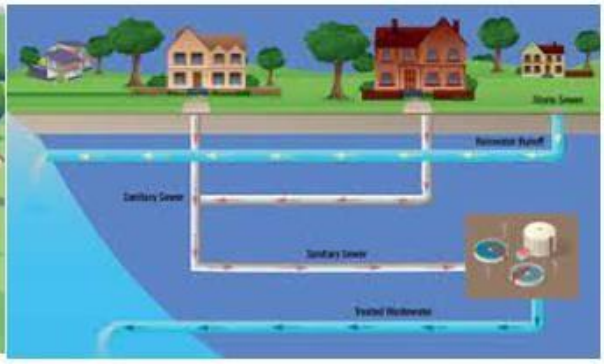
DESIGN OF LANDFILLS & GROUND IMPROVEMENT

WATER RESOURCES ENGINEERING

- Water Resources Engineering is the quantitative study of the hydrologic cycle. It is concerned with the collection and management of water (as a natural resource).
- As a discipline it therefore combines elements of hydrology, environmental science, meteorology, conservation and resource management.
- This area of Civil Engineering relates to the prediction and management of both the quality and quantity of water in both ground and surface water resources.
- Applications include the management of the urban water supply, the design of urban storm – sewer systems, flood forecasting, design of hydraulic structures, irrigation systems etc.

APPLICATIONS OF WATER RESOURCES ENGINEERING

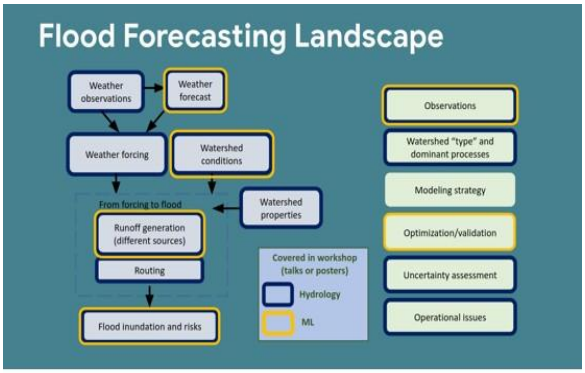




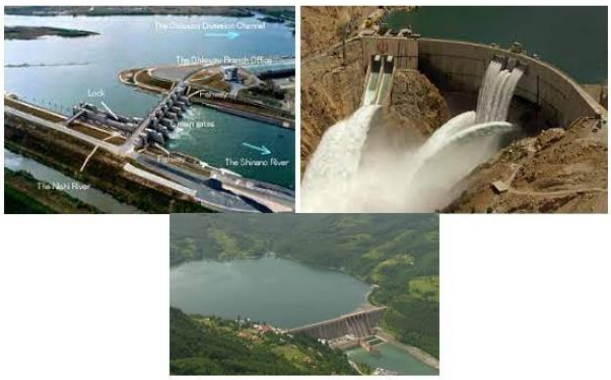
WATER SUPPLY SYSTEM

SEWER SYSTEM

DESIGN OF WATER SUPPLY AND SEWER SYSTEMS



FLOOD FORECASTING



DESIGN OF HYDRAULIC STRUCTURES

DESIGN OF IRRIGATION SYSTEMS

ENVIRONMENTAL ENGINEERING

- It involves waste management, waste disposal systems, pollution control, environmental sustainability, public health, water supply and treatment, waste water treatment, water resources management, air pollution management, pollutant transport, hazardous waste management etc.

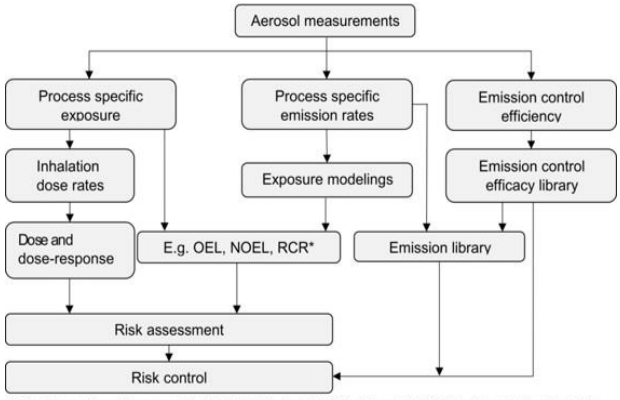
- Applications include quantification of different types of pollutants, fixing standards for effluents, monitoring / prevention of different types of pollution, environmental impact assessment for factories and industries, conservation and preservation of natural resourcesand environment, design and construction of pipe lines etc.

- Environmental engineering also deals with the remediation of contaminated sites after waste disposal or accidental contamination.

- Environmental engineers administer pollution reduction, green engineering, industrial ecology and compile information on environmental consequences of proposed actions.

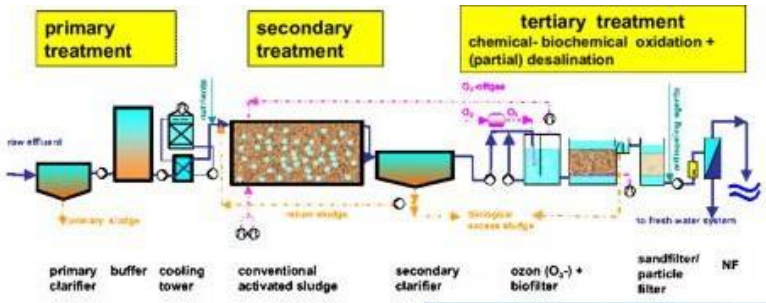
APPLICATIONS OF ENVIRONMENTAL ENGINEERING

WASTE MANAGEMENT



*OEL: Occupational Exposure Limit; DNEL: Derived No Effect Level; RCR: Risk Characterization Ratio

AIR POLLUTION MANAGEMENT



WASTE WATER TREATMENT

HAZARDOUS WASTE MANAGEMENT

REMEDIATION OF CONTAMINATED SITES

GREEN BUILDING TECHNIQUES

Construction Planning and Project Management

Planning, scheduling is an important part of the construction management. Planning and scheduling of construction activities helps engineers to complete the project in time and within the budget. The term ‘Construction’ does not only denote physical activities involving men, materials and machinery but also covers the entire gamut of activities from conception to realization of a construction project. Thus, management of resources such as men, materials, machinery requires effective planning and scheduling of each activity.

Management is the science and art of planning, organizing, leading and controlling the work of organization members and of using all available organization resources to reach stated organizational goals. Construction management deals with economical consumption of the resources available in the least possible time for successful completion of construction project. ‘Men’, ‘materials’, ‘machinery’ and ‘money’ are termed as resources in construction Management.

Objectives of Construction Management:

The main objectives of construction management are,

- Completing the work within estimated budget and specified time.
- Maintaining a reputation for high quality workmanship
- Taking sound decisions and delegation of authority
- Developing an organization that works as a team.

Functions of Construction Management:

The functions of construction Management are

1. Scoping
2. Planning
3. Estimating
4. Scheduling
5. Organizing
6. Staffing
7. Directing
8. Controlling & Coordinating.

1. Scoping

The scoping function is an activity that covers the boundaries of the realm of work that must be done so that the project is completed.

2. Planning

The planning function is the activity of identifying the desired project objectives, reducing the opportunity for the risk to arise, anticipating the work to be completed on time so it can finally be produced as a product or service that has been mutually agreed upon.

3. Estimating

The estimating function is part of a form of project planning whose activities include quantitative estimates of project costs, resources used, to the duration of project completion.

4. Scheduling

The scheduling function is the activity of compiling a list of activities that includes the start and finish time of each job, the ideal completion duration, and the person in charge of each type of work. Effective scheduling is an important factor to create good time management.

5. Organizing

The organizing function is an activity to confirm or ensure that all team members are fully aware of their respective roles, responsibilities, and their relationship with you as the project manager.

6. Directing

The directing function centers on the leadership style of a project. This directing activity includes instructing, mentoring, and training team communication in order to achieve the project goals.

7. Controlling

The controlling function is the activity of controlling all work that takes place in the project so that it goes according to plan or does not deviate. The project manager will use the standard measurement matrix to monitor each ongoing activity. This function can be said to be the most difficult and important function because it determines the effectiveness and success of the project.

8. Closing

The closing function is an activity of evaluating and scoring the final results of projects that have ended.

Brick

A brick is a type of block used to build walls, pavements and other elements in masonry construction. Properly, the term brick denotes a block composed of dried clay, but is now also used informally to denote other chemically cured construction blocks. Bricks can be joined using mortar, adhesives or by interlocking them. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities.

A brick is an important construction material which is generally available in rectangular shape manufactured from clay. They are very popular from olden days to modern days because of low cost and durability.

Classification of bricks

Different types of bricks are used in masonry construction based on material such as clay, concrete, lime, fly ash etc. Filed field identification of bricks for their properties, uses and suitability for different construction works are important.

Based on the manufacturing process, bricks are broadly classified into two types,

1. Sun-Dried or unburnt bricks

2. Burnt bricks

1. Sun-Dried or Unburnt Clay Bricks

Sun-dried or unburnt bricks are less durable and these are used for temporary structures. Unburnt bricks preparation involved in 3 steps they are preparation of clay, molding and drying. After molding, bricks are subjected to sunlight and dried using heat from sun. So, theyare not that much strong and they also have less water resistance and less fire resistance. Thesebricks are not suitable for permanent structures.

2. Burnt Clay Bricks

Burnt bricks are good quality bricks but however they also consist some defected bricks. So, burnt bricks are classified into four types and they are

a) First class bricks
b) Second class bricks
c) Third class bricks
d) Fourth class bricks

a) **First class bricks:** First class bricks are good quality bricks compared to other classes. They are molded by table-molding and burnt in large kilns. So, these bricks contain standard shape, sharp edges and smooth surfaces. They are more durable and having more strength. They can be used for permanent structures. However, because of their good properties they are costly than other classes.

b) **Second class bricks:** Second class bricks are moderate quality bricks and they are molded by ground-molding process. These bricks are also burnt in kilns. But because of ground molding, they do not have smooth surfaces as well as sharp edges. The shape of bricks also irregular due to unevenness in ground. These also will give best results in strength and durability.

c) **Third class bricks:** Third class bricks are poor quality bricks which are generally used for temporary structures like unburnt bricks. These are not suitable for rainy areas. They are ground-molded type bricks and burnt in clamps. The surface of this type of bricks are rough and they have unfair edges.

d) **Fourth class bricks:** Fourth class bricks are very poor-quality bricks and these are not used as bricks in the structure. They are crushed and used as aggregates in the manufacturing of concrete. They are obtained by over burning, because of this they get overheated and obtains brittle nature. So, they can break easily and not suitable for construction purpose.

a) First class bricks

b) Second class bricks

c) Third class bricks

d) Fourth class bricks

Identification of Bricks Quality at Construction Site

1. To build a good quality structure, observing quality of materials is important. Here we discuss about how good bricks are identified at construction site.
2. The color of bricks should be bright and uniform.
3. They should be well burned and having smooth surfaces and sharp edges.

4. Thermal conductivity of bricks should be less and they should be sound proof.
5. They shouldn't absorb more than 20% by weight when we placed it in water.
6. When we struck two bricks together, ringing sound should be delivered.
7. Structure of bricks should be homogeneous and uniform.
8. The bricks should not break when we dropped it form 1m height.
9. There should not be any scratch left on the brick when we scratched with finger nail.
10. There should not be any white deposits on brick, when we soaked it in water for 24 hrs.

Qualities of a Good Brick Properties of good brick

1. **Brick Earth**
   Brick earth should be free from pebbles (kankars), stones, organic matter, saltpeter (potassium nitrate) and other harmful chemical, as it makes poor quality of bricks.
2. **Size of a Brick**
   A good brick should have a uniform size with plain and rectangular surfaces and should be parallel from the sides having sharp and straight edges, as per standards. A brick should not exceed 3 mm tolerance in length and 1.5 mm tolerance in width and height. According to 'IS 1077: 1992' (Common Burnt Clay Building Bricks – Specification), the standard or conventional size of clay brick is 190mm X 90mm x 90mm. However, the size of bricks may vary from country to country and from place to place even in big countries like India.
3. **Shape**
   The shape of a brick should be uniform. The edges of a good brick should be sharp, straight and at a right angle. However, bricks used for special purpose may be either cut or manufactured in various other shapes. These are generally modifications of rectangular shapes.
4. **Colour**
   There are wide range of colours, such as red, white, grey, brown, purple, blue and black, along with some intermediate shades. According to 'W. B. McKay' (Author of Building Construction), the colour is influenced by the chemical constitution of the clay, its temperature while burning, the atmospheric condition of kiln, and staining. Good quality bricks should be well burnt and should have a uniform colour throughout the body of brick. Over burnt and under burnt bricks loses the uniformity of colour on its surface and strength. Very dark shades of red indicate over burnt bricks whereas, yellow colour indicates under burnt bricks.
5. **Frog in Brick**
   A good quality brick should have a proper frog (Depression made on the face of bricks during moulding), so that the mortar can be properly filled in the frog. The size of the frog should be 100 mm in length, 40 mm in width and 10 mm in depth.
6. **Texture and Compactness**
   There is a considerable variation in the texture of bricks. The good bricks should have a pre-compacted and uniform texture. The surfaces of brick should not be too smooth to cause slipping of mortar. A fractured surface should not show cracks, holes, grits or lumps of lime.
7. **Compressive Strength**
   The compressive strength of brick depends upon the composition of the clay and degree of burning. As per 'National Building Code of India' (1983), the compressive strength of brick should be of minimum 3.5 N/mm^2 i.e. 35 Kg/cm^2. We have also written an article on how to check the compressive strength of brick.
8. **Hardness**

Bricks should be sufficiently hard. No impression should be left on the surface of a brick when it is scratched with fingernails.

9. **Water Absorption**
   Water absorption of a good brick should not exceed 20 % of its dry weight when immersed in water for 24 hours. Bricks, when soaked in water for 24 hours, should not show deposits of white salts, when allowed to dry in the shade. Bricks should not absorb water more than 20 per cent by weight especially for bricks of the first class and 22 per cent by weight for bricks of the second class when they are soaked in water for 24 hours. Testing should be done in the laboratory in order to check water absorption of brick.
10. **Soundness**
    When the brick is struck with a hammer or with another brick, it should give a metallic ringing sound.
11. **Efflorescence:** Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in shade. White patches are due to the presence of sulphate of calcium, magnesium and potassium. They keep the masonry permanently in damp and wet conditions.
12. **Thermal Conductivity:** Bricks should have low thermal conductivity, so that buildings built with them are cool in summer and warm in winter.
13. **Sound Insulation:** Heavier bricks are poor insulators of sound while light weight and hollow bricks provide good sound insulation.
14. **Fire Resistance:** Fire resistance of bricks is usually good. In fact, bricks are used to encase steel columns to protect them from fire.

Field and Laboratory tests on Bricks

Field Test of Bricks

1. Shape and Size Test

Good quality of bricks should have a uniform in size and have rectangular faces. It shall be checked by doing observation.

2. Colour Test

Good quality of Bricks should have a uniform in colour throughout. A check shall be made before purchasing the bricks.

3. Sound Test

Bricks should have a metallic ring when one brick stuck against another brick. The dull sound shows a bad quality.

4. Structure

Bricks should be free from holes, lumps, or grit.

Broken bricks if observed shall be removed and not be used for masonry work.

5. Hardness Test

In this test, scratch shall be done on bricks with a nail. If no impression is marked on the surface that shows good quality and adequate hard surfaces.

6. Efflorescence Test

Bricks shall be placed in a glass dish having water to a height of 25 mm in a well-ventilated room. After some hours, water is absorbed or gets evaporated; again, water is added for a depth of 1 inch. After the second evaporation, a white/grey patch is observed in bricks. Efflorescence shall be reported as ‘

Nil: No patches.

Slight: Not more than 10% of the area covered with deposit salts.

Moderate: 10 to 50% of area bricks but unaccompanied by powdering or flaking of the surface.

Laboratory Test of Bricks

1. Dimension Test of Bricks

Following are the procedure of Dimension test of bricks

- In this test, twenty numbers of bricks shall be randomly selected from the stack sample.
- Loose particles of clay, sand, and blisters shall be removed from the surface of bricks.
- All the bricks shall be arranged on the leveled surface. All bricks shall be close with each other and should be in a straight line.
- The length of the laid 20 bricks shall be measured with Measurement Tape. If found any kind of technical problem to measure the bricks in one row, then a sample of 20 bricks shall be divided in two-row of 10 bricks each which shall be measured separately.
- Measurement shall be done in lengthwise, widthwise, and height wise separately.
- The tolerance in the dimension of the 20 bricks shall be within the following limits.

For Modular Size of Bricks **(**190 mm x 90 mm x 90 mm and 190 mm x 90 mm x 40 mm)	**Measurements of 20 bricks**	**Tolerance Value**
Along Length	190 x 20 = 3800 mm	3800 mm + 80 mm
Along width	90 x 20 = 1800 mm	1800 mm + 40 mm
For 90 mm height bricks	90 x 20 = 1800 mm	1800 mm + 40 mm
For 40 mm height bricks	40 x 20 = 800 mm	1800 mm + 40 mm
For Modular Size of Bricks **(**230 mm x 110 mm x 70 mm and 230 mm x 110 mm x 30 mm**)**	**Measurements of 20 bricks**	**Tolerance Value**
Along Length	230 x 20 = 4600 mm	4600 mm + 80 mm
Along width	110 x 20 = 2200 mm	2200 mm + 40 mm
For 70 mm height bricks	70 x 20 = 1400 mm	1400 mm + 40 mm
For 30 mm height bricks	30 x 20 = 800 mm	mm + 40 mm

2. Water absorption Test

Following are the procedure of water absorption test of bricks:

Code of Reference: IS 3495 (Part 2): 1992.

Apparatus required: Weighing Balance, Specimen, and oven dry.

- The specimen shall be dried in an oven-dry at a temperature of 105 to 1150 C till it achieves substantially constant mass.
- The specimen shall be cooled to room temperature of 27+20 C.
- After cooling the specimen in Room temperature and measure the weight of the specimen say (W1).
- Now the dried specimen shall be immersed in a clean temperature of 27+20 C for up to 24 hours.
- The specimen shall be removed after 24 hours and wipe out with dry clothes and measure the weight say W2. The weighing of the specimen shall be completed within 3 minutes after removal from water.

- Water absorption in percentage after 24-hour immersion in cold water is calculated by the following formula
    - Water absorption (%) = (W2-W1/W1) x 100
- It shall not be more than 20% by weight up to class 12.5 and 15 percent by weight of higher classes.

3. Compressive Strength of Bricks

The procedure of compressive strength test of bricks are as follows;

Code of Reference: IS 3495 (Part 2): 1992.

Apparatus required: Compression Testing Machine (CTM), Specimen.

- Brick is immersed in water at room temperature for 24 hours. It shall be removed and drain out any surplus moisture at room temperature.
- The frog of bricks is filled flush with 1 part of cement and 3 part of sand.
- The specimen shall be stored under the damp jute bags for 24 hours and immersed in clean water for 24 hours and then wipe out the moisture with dry clothes.
- Brick is then placed on a compressive testing machine with 6 mm plywood on top and bottom of it in order to get a uniform load on the specimen.
- The Axial load then be applied at a uniform rate of 14 N/mm2 per minute till the failure occurs. The maximum load at failure is noted.
- The load at failure shall be the maximum load at which the specimen fails to produce a further increase in the indicator reading on the testing machine.
- The compressive strength of bricks is the ratio of maximum load at failure in N to the Area of the bed faces in mm^2. The average specimen is taken as compressive strength.
- Minimum average compressive strength for various classes

Class Designation	Average Compressive Strength not less than (N/mm^2)
35	35
30	30
25	20
17.5	17.5
15	15
12.5	12.5
10	10
7.5	7.5
5	5
3.5	3.5

As per IS 1077-1976, bricks compressive strength shall not be less than 3.5 N/mm2.

Advantages of Bricks

- Economical (Raw material is easily available)
- Hard and durable
- Compressive strength is good enough for ordinary construction
- Different orientations and sizes give different surface textures
- Very low maintenance cost is required
- Demolishing of brick structures is very easy, less time consuming and hence economic
- Reusable and Recyclable
- Highly fire resistant
- Produces less environmental pollution during manufacturing process

Disadvantages of Bricks

- Time consuming construction
- Cannot be used in high seismic zones
- Since bricks absorb water easily, therefore, it causes fluorescence when not exposed to air
- Very Less tensile strength
- Rough surfaces of bricks may cause mold growth if not properly cleaned
- Cleaning brick surfaces is a hard job
- Colour of low-quality brick changes when exposed to sun for a long period of time

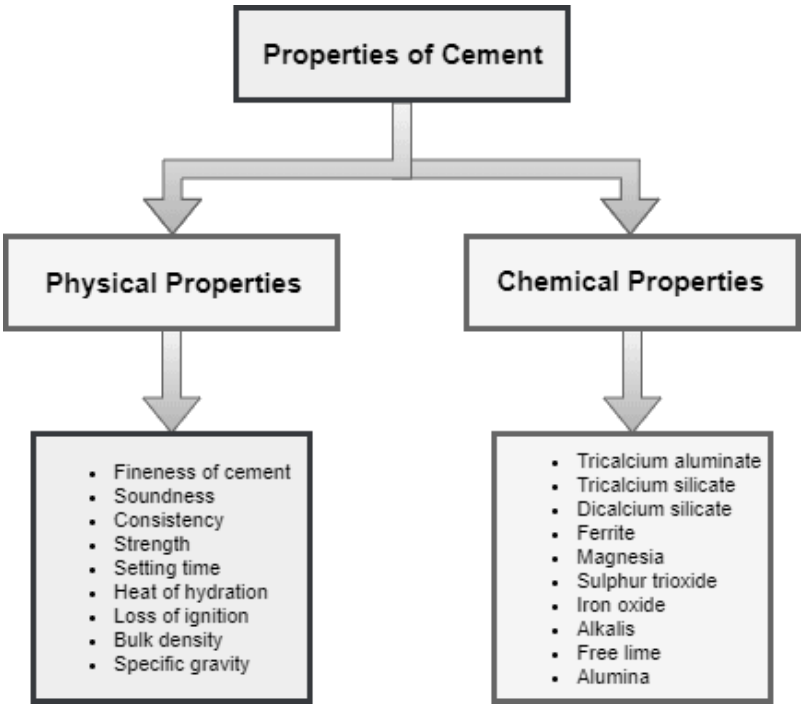
Cement

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together.

Cements used in construction are usually inorganic, often lime or calcium silicate based, which can be characterized as non-hydraulic or hydraulic respectively, depending on the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Non-hydraulic cement does not set in wet conditions or under water. Rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.

Properties of Cement



Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cement are based on:

- Fineness of cement
- Soundness
- Consistency
- Strength
- Setting time
- Heat of hydration
- Loss of ignition
- Bulk density
- Specific gravity (Relative density)

These physical properties are discussed in details in the following segment. Also, you will find the test names associated with these physical properties.

Fineness of Cement

The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last step of cement production process. As

hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.

Soundness of Cement

Soundness refers to the ability of cement to not shrink upon hardening. Good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia.

Tests:

Unsoundness of cement may appear after several years, so tests for ensuring soundness must be able to determine that potential.

- **Le Chatelier Test**
  This method, done by using Le Chatelier Apparatus, tests the expansion of cement due to lime. Cement paste (normal consistency) is taken between glass slides and submerged in water for 24 hours at 20+1°C. It is taken out to measure the distance between the indicators and then returned underwater, brought to boil in 25-30 mins and boiled for an hour. After cooling the device, the distance between indicator points is measured again. In a good quality cement, the distance should not exceed 10 mm.
- **Autoclave Test**
  Cement paste (of normal consistency) is placed in an autoclave (high-pressure steam vessel) and slowly brought to 2.03 MPa, and then kept there for 3 hours. The change in length of the specimen (after gradually bringing the autoclave to room temperature and pressure) is measured and expressed in percentage. The requirement for good quality cement is a maximum of 0.80% autoclave expansion. Standard autoclave test: AASHTO T 107 and ASTM C 151: Autoclave Expansion of Portland Cement.

Consistency of Cement

The ability of cement paste to flow is consistency.

It is measured by **Vicat Test.**

In Vicat Test Cement paste of normal consistency is taken in the Vicat Apparatus. The plunger of the apparatus is brought down to touch the top surface of the cement. The plunger will penetrate the cement up to a certain depth depending on the consistency. A cement is said to have a normal consistency when the plunger penetrates 10±1 mm.

Strength of Cement

Three types of strength of cement are measured – compressive, tensile and flexural. Various factors affect the strength, such as water-cement ratio, cement-fine aggregate ratio, curing conditions, size and shape of a specimen, the manner of molding and mixing, loadingconditions and age. While testing the strength, the following should be considered:

- Cement mortar strength and cement concrete strength are not directly related. Cement strength is merely a quality control measure.
- The tests of strength are performed on cement mortar mix, not on cement paste.
- Cement gains strength over time, so the specific time of performing the test should be mentioned.

Compressive Strength

It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be within 20 seconds and 80 seconds.

Standard tests:

i. AASHTO T 106 and ASTM C 109: Compressive Strength of Hydraulic Cement Mortars (Using 50-mm or 2-in. Cube Specimens)
ii. ASTM C 349: Compressive Strength of Hydraulic Cement Mortars (Using Portions of Prisms Broken in Flexure)

Tensile strength

Though this test used to be common during the early years of cement production, now it does not offer any useful information about the properties of cement.

Flexural strength

This is actually a measure of tensile strength in bending. The test is performed in a 40 x40 x 160 mm cement mortar beam, which is loaded at its centre point until failure.

Standard test:

i. ASTM C 348: Flexural Strength of Hydraulic Cement Mortars

Setting Time of Cement

Cement sets and hardens when water is added. This setting time can vary depending on multiple factors, such as fineness of cement, cement-water ratio, chemical content, and admixtures. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured:

- Initial set: When the paste begins to stiffen noticeably (typically occurs within 30-45 minutes)
- Final set: When the cement hardens, being able to sustain some load (occurs below 10 hours)

Again, setting time can also be an indicator of hydration rate.

Standard Tests:

i. AASHTO T 131 and ASTM C 191: Time of Setting of Hydraulic Cement by Vicat Needle
ii. AASHTO T 154: Time of Setting of Hydraulic Cement by Gillmore Needles
iii. ASTM C 266: Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

Heat of Hydration

When water is added to cement, the reaction that takes place is called hydration. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress. The heat of hydration is affected most by C_3S and C_3A present in cement, and also by water-cement ratio, fineness and curing temperature. The heat of hydration of Portland cement is calculated by determining the difference between the dry and the partially hydrated cement (obtained by comparing these at 7th and 28th days).

Standard Test:

ASTM C 186: Heat of Hydration of Hydraulic Cement

Loss of Ignition

Heating a cement sample at 900 - 1000°C (that is, until a constant weight is obtained) causes weight loss. This loss of weight upon heating is calculated as loss of ignition. Improper and prolonged storage or adulteration during transport or transfer may lead to pre-hydration and carbonation, both of which might be indicated by increased loss of ignition.

Standard Test:

AASHTO T 105 and ASTM C 114: Chemical Analysis of Hydraulic Cement

Bulk density

When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from 62 to 78 pounds per cubic foot.

Specific Gravity (Relative Density)

Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of 3.15, but other types of cement (for example, Portland-blast-furnace-slag and Portland-pozzolan cement) may have specific gravities of about 2.90.

Standard Test:

AASHTO T 133 and ASTM C 188: Density of Hydraulic Cement

Chemical Properties of Cement

The raw materials for cement production are limestone (calcium), sand or clay (silicon), bauxite (aluminium) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnaceslag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

1. **Tricalcium aluminate (C3A)**
   Low content of C3A makes the cement sulphate-resistant. Gypsum reduces the hydration of C_3A, which liberates a lot of heat in the early stages of hydration. C3A does not provide any more than a little amount of strength. Type I cement: contains up to 3.5% SO_3 (in cement having more than 8% C_3A) Type II cement: contains up to 3% SO_3 (in cement having less than 8% C_3A)
2. **Tricalcium silicate (C_3S)**
   C3S causes rapid hydration as well as hardening and is responsible for the cement's early strength gain an initial setting.
3. **Dicalcium silicate (C_2S)**
   As opposed to tricalcium silicate, which helps early strength gain, dicalcium silicate in cement helps the strength gain after one week.
4. **Ferrite (C_4AF)**
   Ferrite is a fluxing agent. It reduces the melting temperature of the raw materials in the kiln from 3,000°F to 2,600°F. Though it hydrates rapidly, it does not contribute much to the strength of the cement.

5. **Magnesia (MgO)**
   The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO-based cement also causes less CO2 emission. All cement is limited to a content of 6% MgO.
6. **Sulphur trioxide**
   Sulphur trioxide in excess amount can make cement unsound.
7. **Iron oxide/ Ferric oxide**
   Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the colour of the cement.
8. **Alkalis**
   The amounts of potassium oxide (K_2O) and sodium oxide (Na_2O) determine the alkali content of the cement. Cement containing large amounts of alkali can cause some difficulty in regulating the setting time of cement. Low alkali cement, when used with calcium chloride in concrete, can cause discoloration. In slag-lime cement, ground granulated blast furnace slag is not hydraulic on its own but is "activated" by addition of alkalis. There is an optional limit in total alkali content of 0.60%, calculated by the equation $Na_2O + 0.658\ K_2O$.
9. **Free lime**
   Free lime, which is sometimes present in cement, may cause expansion.
10. **Silica fumes**
    Silica fume is added to cement concrete in order to improve a variety of properties, especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume, it can grant exceptionally high strength. Hence, Portland cement containing 5-20% silica fume is usually produced for Portland cement projects that require high strength.
11. **Alumina**
    Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical-resistant. It also quickens the setting but weakens the cement.

Field Tests of Cement

Date of Manufacturing: As the strength of cement reduces with age, the date of manufacturing of cement bags should be checked.

Cement Colour: The colour of cement should be uniform. It should be typical cement color i.e., grey colour with a light greenish shade.

Presence of lumps: Cement should be free from hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere.

Temperature Inside Cement Bag: If the hand is plunged into a bag of cement, it should be cool inside the cement bag. If hydration reaction takes place inside the bag, it will become warm.

Smoothness Test: When cement is touched or rubbed in between fingers, it should give a smooth feeling. If it felt rough, it indicates adulteration with sand.

Water Sinking Test: If a small quantity of cement is thrown into the water, it should float some time before finally sinking.

The smell of Cement Paste: A thin paste of cement with water should feel sticky between the fingers. If the cement contains too much-pounded clay and silt as an adulterant, the paste will give an earthy smell.

Glass Plate Test: A thick paste of cement with water is made on a piece of a glass plate and it is kept under water for 24 hours. It should set and not crack.

Block Test: A 25mm × 25mm × 200mm (1" ×1" ×8") block of cement with water is made. The block is then immersed in water for three days. After removing, it is supported 150mm apart and a weight of 15kg uniformly placed over it. If it shows no sign of failure the cement is good.

LABORATORY TESTS ON CEMENT

The following tests are conducted on cement in the laboratory (IS: 4031 – PT 1 to 15, 1989):

1. Fineness Test
2. Consistency Test
3. Setting Time Test
4. Strength Test
5. Soundness Test
6. Tensile Strength Test
7. Heat of Hydration Test
8. Chemical Composition Test

Types of Cement

1. Ordinary Portland Cement (OPC)

Ordinary Portland cement is the most widely used type of cement, which is suitable for all general concrete construction. It is the most commonly produced and used type of cement around the world, with annual global production of around 3.8 million cubic meters per year. This cement is suitable for all kinds of concrete construction.

2. Portland Pozzolana Cement (PPC)

Portland pozzolana cement is prepared by grinding pozzolanic clinker with Portland cement. It is also produced by adding pozzolana with the addition of gypsum or calcium sulfate or by intimately and uniformly blending Portland cement and fine pozzolana.

This cement has a high resistance to various chemical attacks on concrete compared with ordinary portland cement, and thus, it is widely used. It is used in marine structures, sewage works, sewage works, and for laying concrete underwater, such as bridges, piers, dams, and mass concrete works, etc.

3. Rapid Hardening Cement

Rapid hardening cement attains high strength in the early days; it is used in concrete where formworks are removed at an early stage and are similar to ordinary Portland cement (OPC). This cement has increased lime content and contains higher c3s content and finer grinding, which gives higher strength development than OPC at an early stage.

The strength of rapid hardening cement at the three days is similar to 7 days strength of OPC with the same water-cement ratio. Thus, the advantage of this cement is that formwork can be removed earlier, which increases the rate of construction and decreases the cost of construction by saving formwork cost. Rapid hardening cement is used in prefabricated concrete construction, road works, etc.

4. Quick setting cement

The difference between the quick setting cement and rapid hardening cement is that quick-setting cement sets earlier. At the same time, the rate of gain of strength is similar to Ordinary Portland Cement, while quick hardening cement gains strength quickly. Formworks in both

cases can be removed earlier.
Quick setting cement is used where works is to be completed in very short period and for concreting in static or running water.

5. Low Heat Cement
Low heat cement is produced by maintaining the percentage of tricalcium aluminate below 6% by increasing the proportion of C2S. A small quantity of tricalcium aluminate makes the concrete to produce low heat of hydration. Low heat cement suitable for mass concrete construction like gravity dams, as the low heat of hydration, prevents the cracking of concrete due to heat.
This cement has increased power against sulphates and is less reactive and initial setting time is greater than OPC.

6. Sulfates Resisting Cement
Sulfate resisting cement is used to reduce the risk of sulfate attack on concrete and thus is used in the construction of foundations where the soil has high sulfate content. This cement has reduced the contents of C3A and C4AF.
Sulfate resisting cement is used in construction exposed to severe sulfate action by water and soil in places like canals linings, culverts, retaining walls, siphons, etc.

7. Blast Furnace Slag Cement
Blast furnace slag cement is obtained by grinding the clinkers with about 60% slag and resembles more or less in properties of Portland cement. It can be used for works where economic considerations are predominant.

8. High Alumina Cement
High alumina cement is obtained by melting a mixture of bauxite and lime and grinding with the clinker. It is a rapid hardening cement with initial and final setting time of about 3.5 and 5 hours, respectively.
The compressive strength of this cement is very high and more workable than ordinary portland cement and is used in works where concrete is subjected to high temperatures, frost, and acidic action.

9. White Cement
It is prepared from raw materials free from Iron oxide and is a type of ordinary portland cement, which is white. It is costlier and is used for architectural purposes such as precast curtain wall and facing panels, terrazzo surface, etc. and for interior and exterior decorative work like external renderings of buildings, facing slabs, floorings, ornamental concrete products, paths of gardens, swimming pools, etc.

10. Colored cement
It is produced by mixing 5- 10% mineral pigments with ordinary cement. They are widely used for decorative works on floors.

11. Air Entraining Cement
Air entraining cement is produced by adding indigenous air-entraining agents such as resins, glues, sodium salts of sulfates, etc. during the grinding of clinker.
This type of cement is especially suited to improve the workability with a smaller water-cement ratio and to improve frost resistance of concrete.

12. Expansive Cement
Expansive cement expands slightly with time and does not shrink during and after the time of hardening. This cement is mainly used for grouting anchor bolts and prestressed concrete ducts.

13. Hydrographic cement
Hydrographic cement is prepared by mixing water-repelling chemicals and has high workability and strength. It has the property of repelling water and is unaffected during monsoon or rains.
Hydrophobic cement is mainly used for the construction of water structures such as dams, water

tanks, spillways, water retaining structures, etc.

Mortar

The term mortar is used to indicate a paste prepared by adding a required quantity of water to a mixture of binding material like cement or lime and fine aggregate like sand. This is used to bond masonry or other structural units.

The following are the major functions of mortar:

1. To bind building materials such as bricks and stones into a solid mass.
2. To carry out pointing and plasterwork on exposed surfaces of masonry.
3. To form an even and soft bedding layer for building units.
4. To form joints of pipes.
5. To improve the general appearance of a structure.
6. To prepare moulds for coping, corbels, cornice, etc.
7. To serve as a matrix or cavity to hold the coarse aggregates, etc.

Qualities or properties of mortar: -

- The mortar mix should be workable- easily transported to the place of application.
- It should develop adequate strength in tension, compression and bond for the work for it is used.
- It should capable of retaining sufficient water during its application.
- It should be sufficiently plastic easily placed on the bed is construction in the form of thin, smooth and uniform layer.
- It should be durable and strong in itself on drying and hardening at the same time. It should not react in anyway with construction units.
- It should set and garden quickly construction could be done with speed.
- It should not develop any cracks on drying and should be able to maintain their appearance for quite long period.
- It should capable of developing the designed stresses.
- It should be economical to make without compromising on any of the qualities.

Types of Mortar

1. Cement mortars
2. Lime mortars
3. Surki Mortars
4. Ganged Mortars
5. Mud mortars

Cement Mortars

Cement Mortars is a homogeneous pate of cement, sand, and water. Different cement mortars are obtained by mixing different proportions of cement and sand. To prepare cement mortars, cement and sand are properly mixed in dry conditions. Water is then added gradually and mixed using a hovel The water sho be free from clay and other impurities. To safety, strength, and durability of the resulting wall or any structure depend upon the quality of mortars used as a binding medium.

- For Plaster in on walls and slabs, to make them impervious.
- To fill cracks and joints in the wall
- For pointing the joints of the masonry.
- For preparing the building blocks.

Lime mortars

Lime mortar is a type of mortar where lime is used as binding material and sand is used as fine aggregate. There are two types of limes namely fat lime and hydraulic lime. Fat lime in lime mortars requires 2 to 3 times of sand and its uses for dry work. The lime mortars have plasticity so they can place easily. The pyramids at Giza plastered with lime mortars.

Gauged mortars

Ganged mortar is economical than cement concrete. Cement and lime both use as binding material and sand uses as fine aggregate. It is a lime mortar where cement adds to gain higher strength. The process of known as gauging. The cement to the lime proportion varies from 1:6 to 1:9.

Surkhi Mortars

Lime uses as binder material and surkhi is employed as fine aggregate. The surkhi is finely-powdered burnt clay which provides more strength than sand and cheaply.

Mud mortars

Mud mortar is a type of mortar. They use as binding material and sawdust, rice husk, or cow-dung is used as fine aggregate. Mud mortars are useful where lime or cement is not available.

Uses of mortar

Different mortars use for different purposes in civil engineering constructions owing to their plasticity, workability, binding, and setting properties.

- It uses to distribute in uniform load over the lower bricks.
- Mortars used to form soft layers from bricks and stones in masonry work.
- It also used to bind the bricks and stones with each other.
- It also provides water lightness against the weather.
- Mortars use as the plaster or impermeable covering for walls and roofs.
- For various types of painting work to protect the joints of bricks.
- It uses to hide the open joints of brickwork and stonework.
- Mortars use to repair cracks of any structure.
- It uses to improve the general appearance of the structure.
- It also uses for various ornamental works to improve the general appearance of a building or structure.

Tests on mortar

- Flow test
- Compressive strength test
- Air content test
- Setting time test

Flow Test

The mortars flow test utilizes a specially designed table that repeatedly raises and drops a known quantity of mortar times. During the test, the mortar will spread or flow to from a circular mass and the diameter of the mass measures and compared to the initial size. The increase in size express as a percentage of the initial size:

For most mortars, the required flow is 110%. The flow test repeated, using a fresh batch of mortars each time until the desired flow achieves. The quantity of water needs to achieve flow record, and this mortar then tests for compressive strength.

Compressive strength Test

This is probably the most relevant test to evaluate the performance of fly ash since concrete value mainly for its high compressive strength, and the pozzolanic withing the concrete produced additional cement and thus higher strengths. Once the proper flow achieved, the mortar places and compacted into bronze cube-shaped molds. The surface of each cube finish using a trowel, and the molds placed into a moist curing cabinet.

After 24 hours of curing, the molds stripe from the cube specimens. The compressive strength then tests at specified curing intervals, usually 1 or 3 days, 7 days, 28 days, and 56 days.

Air Content test

Mortar prepares using a similar method as for compressive strength, except that coarser sand uses and an AEA mix with mortars to centenarian air within the mix. After mixing, the flow of the mortar determines. If the flow is within the specified range, then a portion of the mortar places and compacted into a brass cup of known volume, and the mass of the cup mortars determined.

Subtracting the mass of the cup, and knowing the density of each component, the air content of the mortars calculate. The test result report is the quantity o AEA requires to achieve a mortar air content of 18%.

Setting Time test

The elapsed time after mixing whereupon the mortar begins to harden is the set time. This test is most commonly performed on cement paste but can conduct using mortar. The test completed by measuring the penetration of a steel needle into the paste or mortar over the course of several hours. The needle is part of an instrument called a “Vicat apparatus”.When

the penetration of the needle into the material is less than 25mm for paste or 10 mm for mortar, the material has achieved its “initial set”. The time requires to achieve this degree of hardening reported as the test result.

Special Purpose Mortars

1. Fire Resistant Mortar
When there are fire warnings or similar dangers to a building structure in a particular zone, then fire resistant mortar is used as these acts as a fireproofing shield. Mortar attains fire resistance properties when aluminous cement is added to the fine powder of fire bricks.

2. Packing Mortar
The main ingredients of packing mortars are normally cement-loam, cement-sand or sometimes even cement-sand-loam. This kind of mortar is commonly used in the packing of oil wells. Packing mortar needs to be high homogeneity and strength, and also should be resistant to water.

3. Sound Absorbing Mortar
Just as the name suggests, this kind of mortar helps in reducing noise levels by acting as a soundproofing layer. The mortar mixture contains cement, lime, slag, gypsum, etc. as binding materials and cinders and pumice as adulterants.

4. Chemical Resistant Mortar
This type of mortar is suitable for those structures which are more prone to chemical attacks. Such mortar contains additives which can fight chemical attack. Typically, there are many different types of chemical resistant mortars which can be prepared but eventually, the selection of mortar is largely dependent on expected damage by a particular chemical or group of chemicals.

5. Lightweight Mortar
Generally used in heat-proof and soundproof constructions. This kind of mortar is obtained by adding wood powder, sawdust, or, jute fibers coir, asbestos fibers, etc. to the cement or lime mortar.

6. X-ray Shielding Mortar
To offer protection against the ill effects of the X-ray machines, the walls and ceilings of the X-ray rooms are plastered by X-ray shielding mortar. This is a very heavy mortar which has a bulk density of around 22KN/m3. To prepare this special mortar, fine aggregates from heavy rock and suitable admixtures are used.

When working with brick and other masonry units, it is very important that one uses the right type of mortar for the masonry. This is because few mortars are too hard for some types of masonry and it can further lead to cracks in the structure and reduce the strength of the structure.

Plain Concrete:

Plain cement concrete is the mixture of cement, fine aggregate(sand) and coarse aggregate without steel. PCC is an important component of a building which is laid on the soil surface to

avoid direct contact of reinforcement of concrete with soil and water.

Material Used in Plain Cement Concrete

The general specifications of materials used in PCC are -

1. Coarse Aggregate

Coarse aggregate used in the PCC must be of hard broken stone of granite or similar stone, free from dust, dirt and other foreign matter. The stone ballast shall be 20 mm in size and smaller. All the coarse material should be retained in a 5mm square mesh and should be well graded so that the voids do not exceed 42%.

2. Fine Aggregate

Fine aggregate shall be of coarse sand consisting of hard, sharp and angular grains and shall pass through a screen of 5 mm square mesh. Sand shall be of standard specifications, clean and free from dust, dirt and organic matter. Sea sand shall not be used.

3. Cement

Portland Pozzolana cement (P.P.C) is normally used for plain cement concrete. It should conform to the specifications and shall have the required tensile and compressive stresses and fineness.

4. Water

Water used shall be clean and reasonably free from injurious quantities of deleterious materials such as oils, acids, alkalis, salts and vegetable growth. Generally, potable water shall be used having a pH value not less than 6. The maximum permissible limits for solids shall be as per IS 456:2000 Clause 5.4, Page No 15.

Advantages of Laying Plain Cement Concrete

- Required cover to bottom reinforcement is ensured, as cover blocks rest on a firm PCC.
- The effective depth of RCC members is achieved as the formworks can be easily, uniformly and sturdily fixed, resulting in better dimension accuracy of foundation RCC member.
- Reinforcement steel bars placed on PCC, are never in touch with the ground soil, which may be chemically active and may lead to steel corrosion in the immediate future.
- Ease in the placement of steel cages and increased productivity.
- Concrete does not bond with ground soil (clay); PCC acts as a barrier to soil and bond well to overlayed structural grade concrete.

Reinforced cement concrete

Reinforced cement concrete is a combination of concrete and steel bars (reinforcement bars) where they carry the compressive force and tension of a structure simultaneously.

As we know that concrete is very strong in compression but weak in tension and its resistance to tension is also low. That’s why plain concrete can be used only where the member is in pure compression, but on the other hand, steel is equally strong in compression and tension.

So the combination of steel and concrete works very well and they are used to take up all the stresses. Such a combination of steel and concrete is called reinforcement cement concrete.

Advantages Of Reinforced Cement Concrete:

1. Reinforced concrete has high compressive strength.

2. It is economical in ultimate cost.

3. It can be produced easily at the construction site.

4. Reinforced concrete has monolithic characters which gives much rigidity to the structure.

5. It is durable, fire-resistant, and almost impermeable to moisture.

6. The materials used in reinforced concrete are easily obtainable.

7. Maintenance cost of the reinforced concrete structure is almost ignorable.

8. Due to the flexibility and fluidity nature, reinforced concrete can be moulded into any desired shape.

9. It is the most useful and economical material in constructions such as footings, piers, damp, etc.

Prestressed concrete

Pre-stressed concrete is a form of concrete where initial compression is given in the concrete before applying the external load so that stress from external loads is counteracted in the desired way during the service period. This initial compression is introduced by high-strength steel wire or alloys (called ‘tendons’) located in the concrete section.

Methods of Prestressing: The prestressing can be performed by two methods:

- Pre-tensioning
- Post-Tensioning

- Pre-tensioning

In the pre-tensioning method, the stress is induced by initially tensioning the steel tendons. These are wires or strands that are tensioned between the end anchorages. After this tensioning process, the concrete casting is performed. Once the casted concrete has hardened sufficiently, the end anchorages arranged are released. This releasing transfers the prestress force to the concrete. The bond between the concrete and the steel tendons facilitates this stress transfer. As shown in figure-2, the tendons that are protruding at the ends are cut and a finished look is achieved. In order to induce prestress force in the pre-tensioning method, a large number of tendons and wires are used. This arrangement hence demands a large area of surface contact to make the bond and stress transfer possible.

- Post Tensioning

The procedure in post-tensioning is depicted in the figure-3 below. Here, the steel is prestressed only after the beam is cast, cured and attain strength to take the prestress. Within the sheathing, the concrete is cast. For the passage of steel cables, ducts are formed in the concrete.

Advantages:

The major advantages of Prestressed Concrete are:

- The prestressing of concrete by using high tensile steel improve the efficiency of the materials
- The prestressing system works for a span greater than 35m.
- Prestressing enhances shear strength and fatigue resistance of concrete
- Dense concrete is provided by prestressing systems thus improving the durability
- Best choice for the construction of sleek and slender structures.
- Prestressing helps to reduce the dead load of the concrete structure
- Prestressed concrete remains uncracked even at service load conditions which proves the structural efficiency
- Composite construction by using the prestressed concrete unit and cast-in-unit derives the economical structure

Disadvantages of Prestressed Concrete

- Higher material costs
- Prestressing is an added cost
- Formwork is more complex than for RC (flanged sections, thin webs) – thus, precast not as ductile as RC

Steel: Steel is one of the most important building materials used in construction. Steel is the backbone of a structure. The strength and durability of a structure significantly depend upon the steel used. With technological advancement, various types of steel have been introduced like mild steel, TMT, steel, alloy steel, etc.

Structural steel

Structural Steel is a special kind of Steel. It is used for construction purposes. Due to its rigidity and high strength-to-weight ratio, structural Steel is mainly employed in buildings. Structural Steel is used in houses, warehouses, airplane hangars, educational facilities, bridges, stadiums, etc.

Structural Steel is Steel that contains carbon, not more than 2.1%. These are also called Carbon Steel, and structural Steel typically has a carbon content of less than 0.6%.

Properties of structural steel:

- Density: The density of Structural Steel is 7750 to 8100 kg/m3.

- Young's Modulus of Elasticity: Typical values for structural steel range from 190-210 GPa
- Poisson's ratio: For structural Steel, the acceptable value ranges from 0.27 to 0.3.
- Tensile strength: Structural Steel has high tensile strength, so it is preferred over other construction materials.
- Yield strength: The yield strength, also known as the yield point, is the stress at which an object permanently deforms. When stress is removed, it does not revert to its former shape. Carbon structural steel has a yield strength ranging from 187 to 758 MPa. The values of structural Steel constructed of alloys range from 366 to 1793 MPa.
- Shear strength: The shear strength of steel structure is specified at the failure under shear stress, and it is about 0.57 times the yield stress of structural Steel.
- Hardness: The resistance of an object to shape change when force is applied is referred to as hardness. There are three different types of hardness tests. Scratch, indentation, and rebound are all terms used to describe the process of scratching and indenting, and the hardness of structural Steel manufactured with alloys ranges from 149 to 627 kg. Carbon structural steels have a weight range of 86 to 388 kg.
- Melting point: Because there are so many different types of structural Steel, there is no standard melting point.
- Specific heat: The amount required to raise an object's temperature by a particular quantity is known as specific heat or heat capacity. A higher specific heat value indicates that the thing is more insulating. The units of measurement are Joules per Kilogram Kelvin. Specific heat for carbon structural steel ranges from 450 to 2081 J/kg-K, while for structural alloy steel, it ranges from 452 to 1499 J/kg-K.

Types of Steel Sections

Structural steel members are fabricated in factories according to their intended use. Continuous casting molds are used to cast rolled steel parts with no joints. The following sections describe the various shapes and forms of rolled steel sections.

Rolled Steel I-sections (Beam sections).

Rolled Steel Channel Sections.

Rolled Steel Tee Sections.

Rolled Steel Angles Sections.

Rolled Steel Bars.

Rolled Steel Tubes.

Rolled Steel Flats.

Rolled Steel Sheets

Composition of Structural Steel

The chemical compositions influence the properties of Structural Steel. Some chemical elements used to enhance the mechanical properties are listed below. Structural Steel is a mixture of iron and other metals. Some parts are purposefully added to iron to achieve specific properties and features; the various compositions have been discussed in the following:

Carbon: One of the most significant chemical ingredients in Steel is carbon. Carbon concentration rises, resulting in a material with less flexibility and more strength.

Chromium: Small levels of chromium are present, combined with copper and nickel, to strengthen the material's corrosion resistance.

Manganese: Manganese, along with oxygen and sulphur, is employed as a neutralizer in the hot rolling of Steel, and it has effects on the material properties of steel grades that are similar to those of carbon.

Aluminum: Aluminum is a key deoxidizer that contributes to forming a finer-grained crystalline microstructure.

Copper: Copper is used to promoting corrosion resistance.

Sulphur and phosphorus: Sulphur and phosphorus are often limited in steel alloys because they negatively impact the Steel's durability and strength.

Molybdenum: Molybdenum increases the Steel's strength at high temperatures and its corrosion resistance.

Construction Chemicals:

Construction chemicals have always been playing important roles in virtually all sorts of construction projects, be it industrial projects, residential building projects, commercial building projects and so on. These chemicals are often used in various elements of projects in order to achieve various important qualities such as workability, durability etc. Construction chemicals exist in many varieties from a large number of manufacturers worldwide.

Concrete curing compounds

Concrete curing compound consists essentially of waxes, natural and synthetic resins, and solvents of high volatility at atmospheric temperatures. The compound forms a moisture retentive film shortly after being applied on a fresh concrete surface. White or gray pigments are often incorporated to provide heat reflectance, and to make the compound visible on the structure for inspection purposes. Curing compound should not be used on surfaces that are to receive additional concrete, paint, or tile which require a positive bond, unless it has been demonstrated that the membrane can be satisfactorily removed before the subsequent application is made, or that the membrane can serve satisfactorily as a base for the later application.

Polymer bonding agents

Polymer Bonding Agent is an aqueous emulsion of a polymer and chemical admixtures. It is designed for use as a bonding agent with concrete and cement-based products in interior or exterior applications. Polymer Bonding Agent is also designed for use as a polymer modifier in mortars and concretes to develop increased tensile, flexural and bond strengths. The use of Polymer Bonding Agent in concrete and shotcrete also gives significant improvements in resistance to penetration by chlorides and de-icing salts.

Mould releasing agents

Mould release agents come in handy when you have materials that are shaped and constructed in moulds. Without the releasing agent, your mould may become damaged or even break when it is time to remove it. Mould release agents come in a variety of textures with the most commonly used one being an oil type base. If you have never used a releasing agent before, it is similar to placing oil or butter in the bottom of a dish to remove your final baking product.

Below, you will find the three most commonly used types and their purpose in the manufacturing industry.

Form release agents

These compounds are applied on the inner surfaces of forms, not only facilitate stripping of formwork but also render concrete surfaces smoother. They also help enhance the life-span of the forms. Form releasing agents can be oil based, resin based, water based, organic chemical based etc.

Protective and decorative coatings

A protective coating is a layer of material applied to the surface of another material with the intent of inhibiting or preventing corrosion. A protective coating may be metallic or non-metallic. Protective coatings are applied using a variety of methods, and can be used for many other purposes besides corrosion prevention. Commonly used materials in non-metallic protective coatings include polymers, epoxies and polyurethanes. Materials used for metallic protective coatings include zinc, aluminum and chromium. Special materials are used in the finishing coats of plastering or over the plastered surfaces to meet one or more of specific requirements such as decorative appearance, high durability,fire – proofing,heat insulation,sound insulation,early completion,high strength etc..

Concrete floor hardeners

These are chemicals added in floor concrete in order to render it denser and more durable. They also usually enhance chemical resistance, impact & abrasion resistance, waterproofing capability etc. besides reducing dusting. All these are required attributes especially for industrial, commercial or factory floors. Ultimately good quality floor hardeners reduce repairs and maintenance of concrete floors drastically besides making them long lasting thus adding to cost effectiveness as well. Floor hardeners can be liquid or solid, metallic or nonmetallic. Metallic floor hardeners (solid) are well graded ferrous aggregates. Liquid floor hardeners are water, silicate etc. based solutions. Pigmented floor hardeners also improve the appearance of floor surfaces. Floor hardeners are usually applied as per manufacturer's specifications This construction chemical Improves the abrasion resistance of dusty or poorly cured concrete by up to 3 times. Has good resistance to alkali solution and petroleum solvents but poor resistance to strong acids.

Epoxy coatings

These can come as water or oil-based solutions or as solvent-free. They can be single or two-component. Single-component epoxy paints are usually oil based. Two-component epoxy coatings are mixed in situ in proportions as prescribed by their manufacturers and they are quite suitable for factory, industrial or commercial building applications by dint of their excellent chemical & thermal resistant characteristics, hardness, durability, waterproofing characteristics etc. They are solvent-free. Epoxy coatings are also used in flooring for decorative purposes.

Structural elements of a building

Foundation

These can come as water or oil-based solutions or as solvent-free. They can be single or two-component. Single-component epoxy paints are usually oil based. Two-component epoxy coatings are mixed in situ in proportions as prescribed by their manufacturers and they are quite suitable for factory, industrial or commercial building applications by dint of their excellent chemical & thermal resistant characteristics, hardness, durability, waterproofing characteristics etc. They are solvent-free. Epoxy coatings are also used in flooring for decorative purposes.

FOUNDATION

Foundation is the lower portion of the building usually located below ground level, which transmits the loads of the super structure to the supporting soil. A foundation is therefore that part of the structure which is in direct contact with the ground to which loads are transmitted.

Functions and Requirements of good foundation

Functions of good foundation.

1. Reduction of Load Intensity

Foundation distributes the loads of the super structure, to a larger area so that the intensity of the load at its base (i.e. total load divided by the total area) does not exceed the safe bearing capacity of the sub-soil.

2. Even Distribution of Load

Foundations distribute the non-uniform load of the super structure evenly to the sub soil. For example, two columns carrying unequal loads can have a combined footing which may transmit the load to sub soil evenly with uniform soil pressure. Due to this, unequal or differential settlements are minimized.

3. Provision of Level Surface

Foundation provide levelled and hard surface over which the super structure can be built..

4. Lateral Stability

It anchors the super structure to the ground, thus imparting lateral stability to the super structure. The stability of the building, against sliding and overturning, due to horizontal forces (such as wind, earthquake etc.) is increased due to foundations.

5. Safety against Undermining: It provides the structural safety against undermining or scouring due to burrowing animals and flood water.

6. Protection against Soil Movements

Special foundation measures prevents or minimizes the distress (or cracks) in the super structure, due to expansion or contraction of the sub soil because of moisture movement in some problematic soils.

Requirements of good foundation.

1. The foundations shall be constructed to sustain the dead and imposed loads and to transmit these to the sub-soil in such a way that pressure on it will not cause settlement which would impair the stability of the building or adjoining structures.

2. Foundation base should be rigid so that differential settlements are minimised, especially for the case when super-imposed loads are not evenly distributed.

3. Foundations should be taken suficient1y deep to guard the building against damage or distress caused by swelling or shrinkage of the sub-soil.

4. Foundations should be so located that its performance may not be affected due to any unexpected future influence.

Foundation is classified on the basis of load transmission to the ground into two sub-categories i.e., shallow foundation and deep foundation.

Shallow Foundation

Shallow foundation are those foundations in which the depth at which the foundation is placed is less than the width of the foundation (D < B). Shallow foundations are generally termed as spread footing as they transmit the load of the super structure laterally into the ground.

Classification of Shallow Foundation:

On the basis of design, the shallow foundation are classified as:

- Wall Footing
- Isolated column or Column Footing
- Combined Footing
- Cantilever (Strap) Footing
- Mat (Raft) Foundation

Wall Footing

This type of foundation runs continuous along the direction of the wall and helps to transmit the load of the wall into the ground. Wall footing are suitable where loads to be transmitted are small and are economical in dense sands and gravels. In this type of foundation, the width is 2-3 times the width of the wall at ground level. Wall footing may be constructed through stone, brick, plain or reinforced cement concrete.

Column Footing

Column footing are suitable and economical for the depth greater than 1.5m. In this type of foundation, the base of the column is enlarged. Column footing is in the form of flat slab and may be constructed through plain or reinforced concrete.

Combined Footing

Combined footings are those foundations that are made common for two or more columns in a row. It is used when the footing for a column may extend beyond the property line. It is also suitable when the two columns are closely spaced and the soil on which the structure resist is of low bearing capacity. It may be rectangular or trapezoidal in shape.

Strap Footing

When an edge footing cannot be extended beyond the property line the edge footing is linked up with the other interior footing by means of a strap beam. Such footings are called as strap footing. It is also known as cantilever footing.

Mat Foundation

A mat foundation is a combined footing which covers the entire area beneath of a structure and supports all the walls and columns. It is also known as raft foundation. Mat foundation is applicable when

- Allowable bearing pressure is low.
- The structure is heavy.
- The site is with highly compressible layer.

The mat foundation can be further classified into following types:

- Flat slab type.
- Flat Slab thickened under column.
- Two-way beam and slab type.
- Flat slab with pedestals.
- Rigid frame mat.
- Piled mat.

Deep Foundation

Deep Foundation are those foundations in which the depth of the foundation is greater than its width (D>B). The D/B ratio is usually 4-5 for deep foundation. Unlike shallow foundation, the deep foundation transmits the load of the superstructure vertically to the rock strata lying deep. Deep foundations are used when the shallow foundation cannot support the load of the structure.

Classification of Deep Foundation

The mat foundation can be further classified into following types:

- Pile Foundation
- Pier Foundation
- Well (Caissons) Foundation

Pile Foundation

Pile is a slender member with small area of cross-section relative to its length. They can transfer load either by friction or by bearing. Pile foundation are used when:

- The load is to be transferred to stronger or less compressible stratum, preferably rock.
- The granular soils need to be compacted.
- The horizontal and the inclined forces need to be carried from the bridge abutments and the retaining walls.

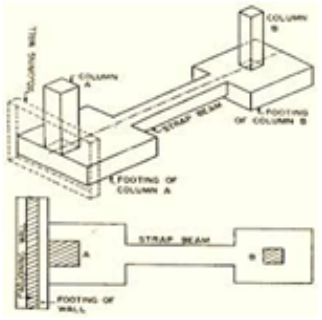
Pier Foundation

Pier foundation are underground cylindrical structural member that support heavier load of the structure which shallow foundations cannot resist. Unlike pile foundation, pier foundation can only transfer load by bearing. Pier foundation are shallower in depth than the pile foundation. Pier foundation are used when:

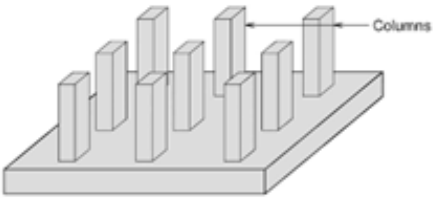
- The top strata is a decomposed rock underlying as sound rock strata.
- The soil is a stiff clay that occurs large resistance for driving the bearing pile.

Well (Caissons) Foundation

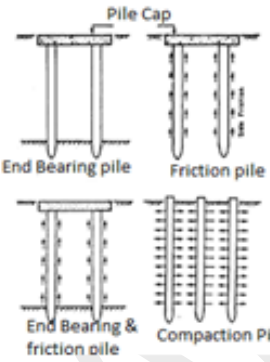
The term caisson refers to box or a case. These are hollow inside and are usually constructed at the site and sunk in place into a hard bearing strata. As they are expensive in construction, they are usually restricted to major foundation works. Well foundation are suitable when the soil contains large boulders obstructing the penetration during installation of pier or pile foundations. Caissons are used for bridge piers, abutments in rivers and lakes and other shore protection works. They are used to resist heavy vertical and horizontal loads and are used in the construction of large water front structures as pump houses.

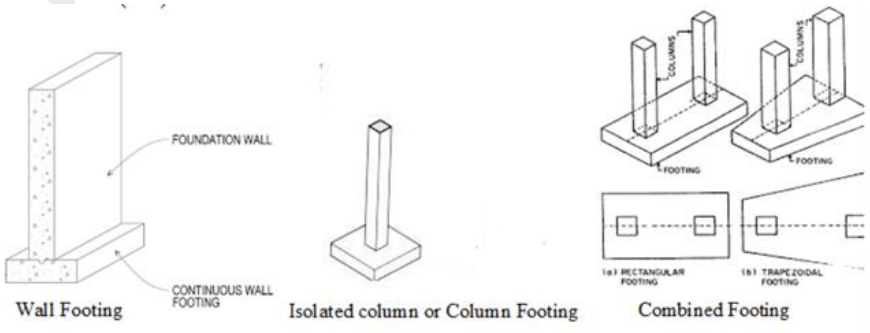


Cantilever (Strap) Footing



Mat (Raft) Foundation





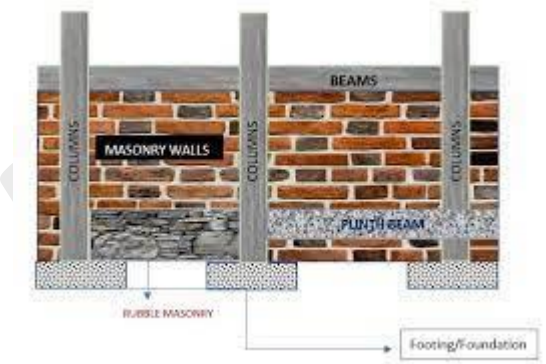
Wall Footing | Isolated column or Column Footing | Combined Footing

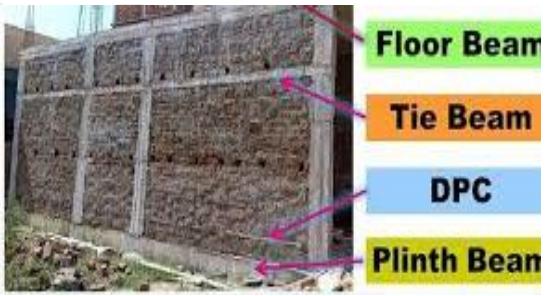
Plinth: A plinth level forms the foundation of a house. It is a rectangular block of stone on which a column and pillar of a building stands. It is a wall between the ground level and the ground floor level. Column bears the weight of the building's structure but all this weight presses down on the column. The main function of a plinth in construction is to distribute the load of the columns over the foundation evenly

Advantages of plinth when constructing a house.

- It evenly distributes and disperses the load of the columns to the foundation evenly
- It acts a barrier or a retaining wall that keeps the concrete filled ground floor below the raised floor of the building
- The plinth doesn't allow the dampness and moisture of the ground floor to reach the building's top structure
- In framed structure houses and buildings plinth beams are used as a barrier for protection from water seepage. Plinth protects the rest of the house from dampness, mold and mildew. It is a kind of waterproofing sheet laid above the ground floor level to protect the house from any damage because of added moisture
- Gives strength and durability to the residential unit
- Provides a better aesthetic appeal to the building
- It also prevents cracks in the building when the foundation suffers from settlement
- Houses are normally constructed around 150-300 mm over the adjoining road level. The plinth functions as a retaining structure for the compacted soil which is applied to fill the empty space from foundation level to the top of the plinth.

Plinth beam: It is a reinforced concrete beam constructed between the wall and its foundation. Plinth beam is provided to prevent the extension or propagation of cracks from the foundation into the wall above when the foundation suffers from settlement. Plinth beams distributes the load of the wall over the foundation evenly.





Masonry wall:

A masonry wall is the process of constructing a wall from individual bricks/blocks laid in a specific pattern and bounded usually by cement mortar and is often plastered with cement plaster on both surfaces. Brick (Burnt & Fly Ash) is one of the most common types of masonry used apart from Blocks (AAC, Solid &Hollow) and stone.

In terms of their function, all walls are either load bearing or non-load bearing walls. A load bearing wall is part of the structure of the building – it holds the building up. A non-load bearing wall is only a partition that divides the various rooms of a building. We can demolish and rearrange wall if it is a non-load bearing wall; we cannot move or demolish a load bearing wall

Load-Bearing Walls

A load-bearing masonry wall is most common in large buildings, such as large houses or tall commercial buildings. Usually created with bricks, stones, or concrete blocks, load-bearing walls transfer the weight from the building's foundation to ensure even distribution and create a safe structure. Without load-bearing walls to support the weight of the building, the foundation can become unstable. Load-bearing walls are necessary on both the exterior and interior of buildings.

Cavity or Hollow Walls

Masonry walls are often used both in the foundation and in the load-bearing areas of a building. Masonry walls are often used both in the foundation and in the load-bearing areas of a building.

Cavity walls are made with cement blocks and are essential for protecting the inside of a building from excess dampness. Hollow walls create space between the exterior and interior walls to protect the inside from the elements. Modern versions combine the hollow and solid masonry units.

Composite Walls

Composite walls are created with at least two different building materials, such as hollow and solid bricks or stones and bricks. Composite walls reduce the cost of construction without compromising the integrity of the structure. The materials are still very high-quality and create safe walls that maintain a beautiful look as well. These types of walls typically have bricks or other aesthetically appealing materials in the visual area and the concrete or rubble backing where the naked eye can't see it.

Post-Tensioned Wall

A post-tension wall creates an additional axial load for structures, increasing their abilities to resist lateral forces. Post-tensioned walls typically have increased in-plan strength and do not see any wall displacements post-earthquake. They are common in parking structures, elevated residential and commercial buildings, and bridges. They also help architects to have more freedom with their work by creating more open spaces within a structure.

Reinforced Walls

Like load-bearing walls, reinforced walls are made with brick, concrete, or other strong materials. These types of masonry walls create more resistance for weight-bearing walls so that they fight back against deterioration. Typically, reinforced walls are exterior walls that have steel rods worked into their bricks or concrete. Reinforced walls are common in buildings that could see heavy compression loads and in buildings where an earthquake is a possibility.

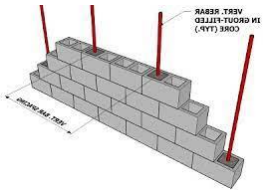
The Benefits of Masonry Walls

Cost-effectiveness is one of the biggest benefits of masonry walls. Some research shows that buildings of up to 10 stories tall see significant savings when building with reinforced masonry techniques because it eliminates the need for formwork and the cost for the associated labor. Masonry is also low-maintenance and durable, which means building owners spend fewer dollars on repairs over the

years.

They are also energy-efficient. Concrete masonry is especially beneficial, as it protects the interior of a building from the heat or cold outside in a feature known as the "thermal mass effect." This means the interior of the building stays at a more comfortable temperature without the need for additional insulation or higher energy bills.

Other benefits of masonry walls include being fire-resistant, durable, and acting as a sound barrier. Insurance providers love masonry because they are less likely to need to pay out benefits due to a fire, and the durable structure is also helpful for insurance bills when other natural disasters are commonplace in an area. Finally, masonry is common in buildings that sit near airports or along freeways because they prevent the sound of the traffic outside from entering the building through the walls



Column

Columns are defined as vertical load-bearing members supporting axial compressive loads chiefly. This structural member is used to transmit the load of the structure to the foundation. In reinforced concrete buildings beams, floors, and columns are cast monolithically. The bending action in the column may produce tensile forces over a part of cross-section. Still, columns are called compression members because compressive forces dominate their behavior.

The size of a column is calculated primarily based on the value of the axial loads that will be on them. Some of the loads to be calculated include the following:

1. Vertical forces, which are received toward the longitudinal axis of the column resulting from loads placed on the horizontal beams and slab loads placed above the columns.
2. Lateral forces are from wind and earthquakes. The column is exposed to the effects of these forces.

There are quite a few different types of columns. Some of the main column types are listed below:

1. Concrete Columns

Concrete columns can have a rectangular section or circular section.

Rectangular sections have a minimum design width of eight inches (8”) in the horizontal section (i.e., column width). These columns that undergo torque moments to resist wind and earthquake forces or dynamic loads must have a horizontal section above ten to twelve inches (10”-12”) per the American Concrete Institute (ACI) standard.

Circular sections have a minimum design diameter of twelve inches (12”), and the column area subject to static loads cannot be less than 100 square inches. Static loads are any load, on a structure that does not change in magnitude or position with time. The area of the column that is subject to dynamic loads cannot be less than 120-140 square inches per the ACI. Columns that are used for aesthetic purposes only are not required to adhere to the code minimums.

2. Steel Columns

Steel columns can have three types of horizontal sections.

C-section columns consist of three sides; thin steel, and they are typically weaker and cheaper than other forms of steel columns. Some of the challenges C-section columns have are load stress, issues with high winds, and construction.

I-section consists of two flanges connected by one vertical component called the web. They can be identified as an "I" shape or "H" shape. Some codes also reference these columns as a "W" section. For construction, their use is based on deflection, vibration, bend, buckling, and tension. I-sections can bend under high stress instead of bucking.

Hollow section, also known as rectangular hollow section (RHS) columns, are fully enclosed steel sections (i.e., four sides). They are thicker, stronger, and they cost the most. RHS columns can withstand heavier loads and stresses. These columns have equal lateral strength in all four directions due to their consistent shape.

3. Composite Columns

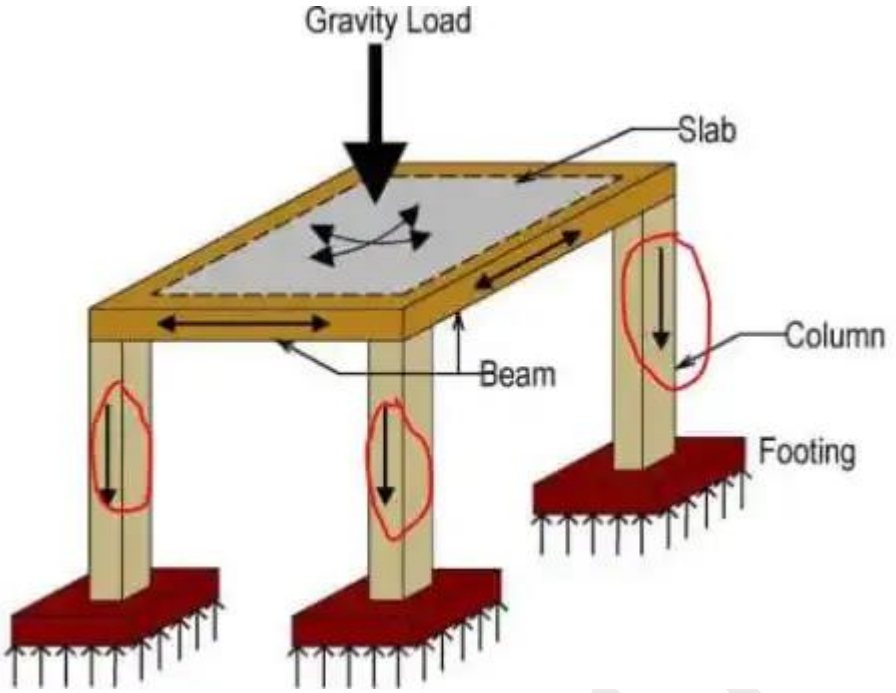
Composite columns are galvanized steel sections that are coated or filled with concrete. Typically, these columns are used when there are large loads on them or when additional corrosion protection or fire protection is warranted. These columns are usually used in the construction of multi-story buildings and industrial facilities. Although they are not architecturally appealing, composite columns can reduce the column section area.

Types of Loads on Columns

- Self-weight of the column multiplies by number of floors
- Self-weight of beams per running meter
- Load of walls per running meter
- Total Load of slab (Dead load + Live load + Self weight)

Loads Transfer Mechanism in column

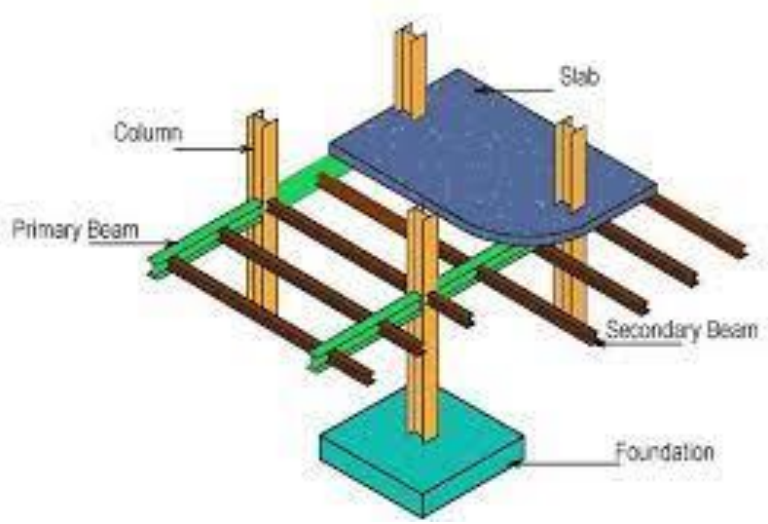
Since the columns are supported by foundation; the load relocated from the all components to the columns. Then, it will be transferred from the column through the column necks adjacent to the footing in the form of axial force. Moreover, Columns transfer lateral loads to foundations as well when such loads imposed. Lastly, It will transfer moment and shear also to the footing.



Beam: Beams act as structural elements that transfer loads from the slab and to columns. This means transfer beams are installed to carry the load from one load-bearing wall to another. They are typically horizontal members. The purpose of a beam is to carry walls and to avoid loading a concrete slab. Beams are used to tighten columns in construction; this provides optimal distribution of the bending moment in the beams and reduces the length of the bending in the columns. Additionally, the length and width of the beams used will be determined by calculating the load being transferred to the beam to support the width in between them. The dimension of a beam is determined by calculating the value of internal forces located on them. Internal forces include the following:

1. Normal forces act perpendicular to the surface or object, which in this case is the beam. Normal stress is exerted.
2. Shear forces act parallel to the surface of an object, and they exert shear stress.
3. Bending Moment is the shearing force or the slope of the moment diagram at a given point.

Beams are used to support the weight of floors, ceilings and roofs of a building and to transfer the load to a vertical load bearing element of the structure. Sometimes bigger and heavier beams called transfer beams are used to support the cumulative weight of stacked walls or other beams and transfer the load to the supports.

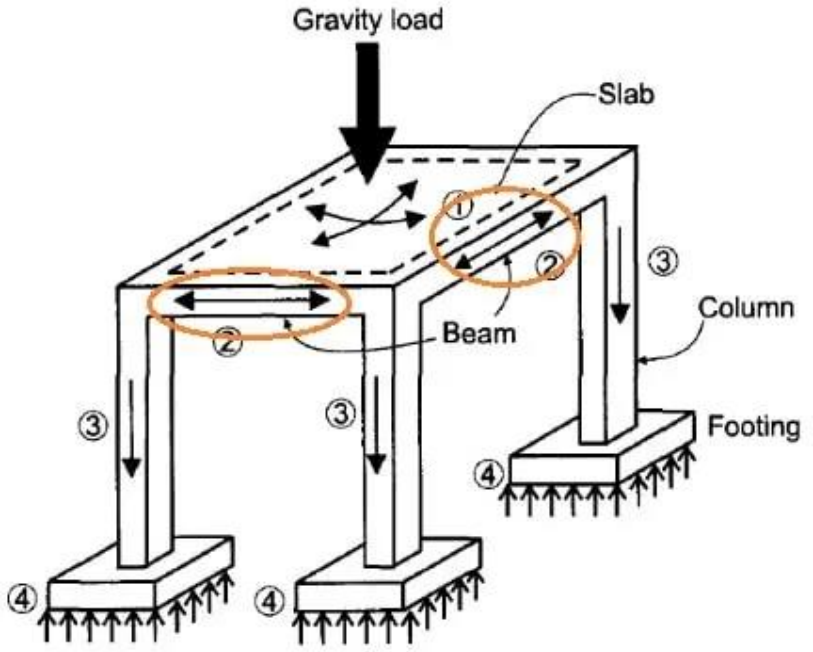


Types of Loads on Beams

- Self-weight of the beam
- Dead load includes point load for instance column constructed on beam, distributed load for example setting slabs on a beam.
- Live load
- Torsional load

Load Transfer Mechanism in Beams

- They transfer loads imposed along their length to their end points where the loads are transferred to columns or any other supporting structural elements.
- Transfer loads from beams to column



Slab: Slab is an important structural element which is constructed to create flat and useful surfaces such as floors, roofs, and ceilings. It is a horizontal structural component, with top and bottom surfaces parallel or near so. Commonly, slabs are supported by beams, columns (concrete or steel), walls, or the ground. The depth of a concrete slab floor is very small compared to its span.

Types of Loads on a Slab

Types of loads acting on a slab include:

- Dead load of the slab
- Live load
- Floor finish load
- Snow load in the case of roof slab
- Earthquake loads

STAIRS

A stair may be defined as series of steps suitably arranged for the purpose of connecting different floors of a building. It may also be defined as an arrangement of treads, risers, and stringers, handrails so designed and constructed as to provide an easy and quick access to the different floors, rendering comfort and safety to the

users. The room or enclosure of the building, in which the stairs is located, is known as stair-case. The opening or space occupied by the stair is known as stairway.

Stairs may be made from various materials like timber, stones, bricks, steel, plain concrete or reinforced concrete.

Technical terms

Fig shows the section of a stairs with its component. The technical terms associated with the design and constructions of stairs are defined as below.

1. Baluster: It is the vertical member of wood or metal, supporting the hand rail.

2. Flight: It is defined as an unbroken series of steps between the landings.

3. Going of step: It is the horizontal distance between two e of provided at successive riser-faces.

4. Hand rail: The inclined rail over the strength is known as a hand rail. It serves as a guard rail and it should be of provided at a convenient height so as to give grasp to the hand during ascent and descent.

5. Header Room: It is the minimum clear vertical distance between the tread and overhead structure (i.e ceiling)

6. Landing: The horizontal platform between two flights of a stair is known as the landing. A landing facilitates change of direction and provides an opportunity for taking rest during the use of a stair.

7. Newel post: This is the vertical member which is placed at the ends of flights to connect the ends of strings and handrails.

8. Nosing: the outer projecting edge of a tread is termed as nosing. Nosing is usually rounded to give good of architectural effect to the treads and makes the staircase easy to negotiate.

9. Pitch or Slope: The angle of inclination of the stairs with the floor is known as pitch.

10. Riser: It is vertical portion of a step providing a support to the tread.

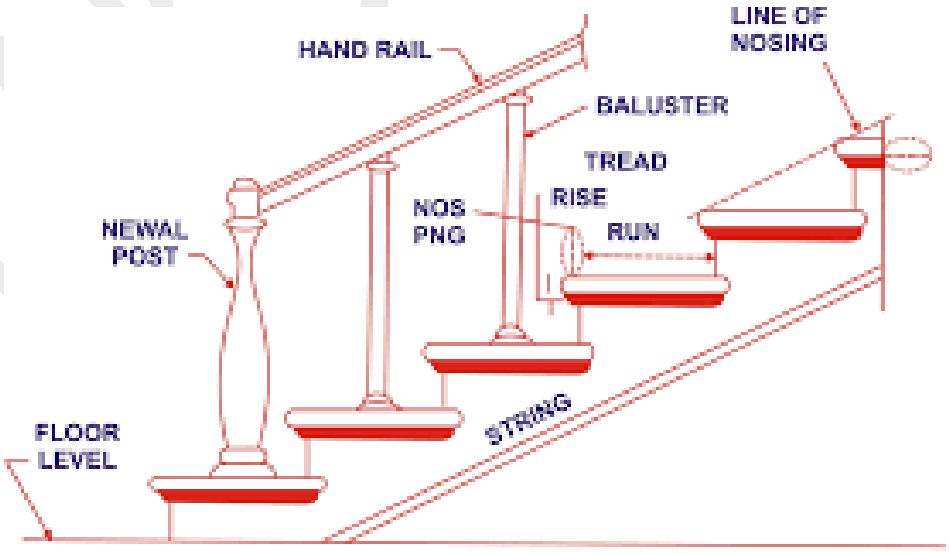


Fig. 6.1. Elevation of a stair.

14. Steps: A portion of a stairway comprising the tread and riser which permits ascent and descent from one floor to another

15. Tread: It is the upper horizontal portion of a step upon which the foot is placed while ascending or descending

16. String: These are the sloping members which support the steps in a stair. They run along the slope of the stair.

Types of Stairs (Classification)

The stairs are classified as follows

1.Straight stairs

2.Turning stairs a)Quarter turn

b) Half turn stair (dog-legged and openwell)

c) Three quarter turn stairs d) Bifurcate a turn

3. Circular or helical or spiral stairs

4. Geometrical stairs

1. Straight Stairs:

In case of a straight stair, al steps lead in one direction only. This stair runs straight between the two floors. These are used when the space available for staircase is long but narrow in width. The stair may consist of either one flight or more than one flight.

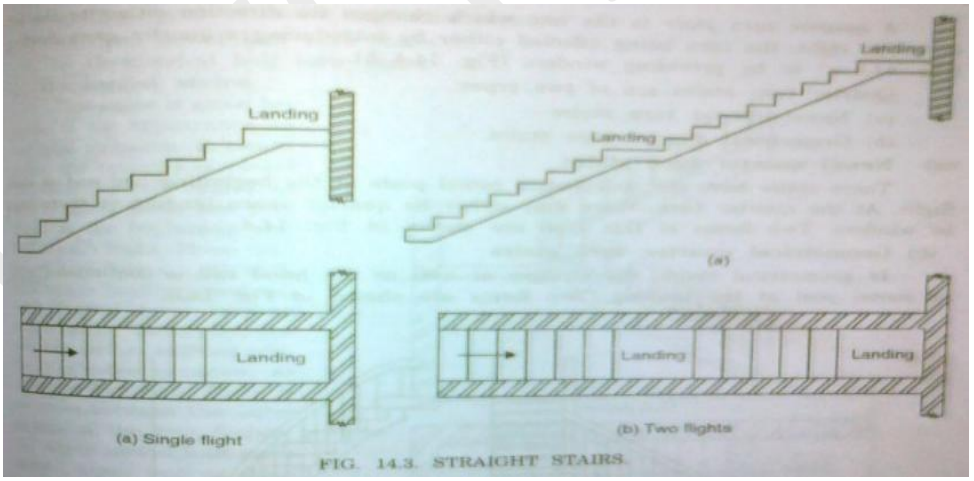


FIG. 14.3. STRAIGHT STAIRS.

2. Turning stairs:

A stair turning through one right angle is known as a quarter-turn stair. The turn being affected either by introducing a quarter-space landing or by providing winders.

Half turn stair: A stair turning through two right angles is known as a half-turn stair. A half turn stair may be of dog-legged type or open newel type .

3.Dog-legged stairs: In this type, the flights run in opposite direction and there is no space between them in plan. These stairs are used for space available for the staircase is equal to twice the width of steps. The name is given because of its appearance in sectional elevation.

4. Open Newel half turn Stairs

In this type, there will be a well or hole or opening between the flights in plan. These stairs are useful where available space for staircase has a width greater than twice the width of steps.

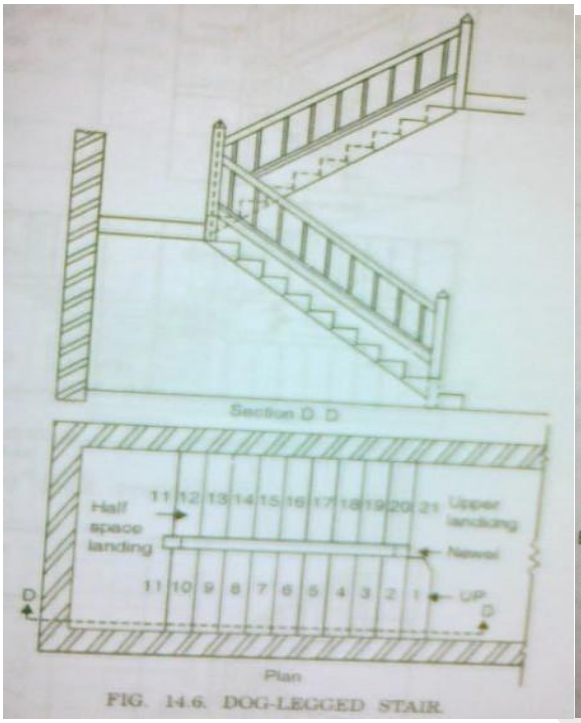


FIG. 14.6. DOG-LEGGED STAIR

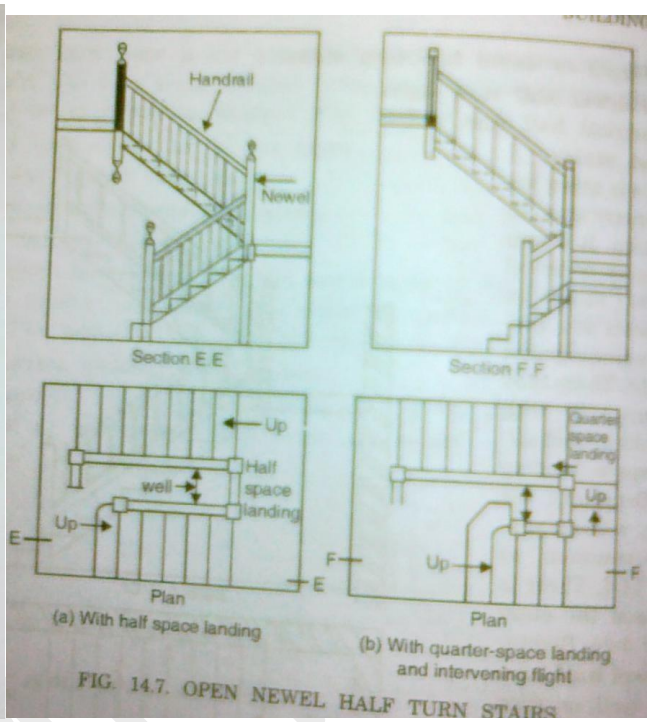


FIG. 14.7. OPEN NEWEL HALF TURN STAIRS

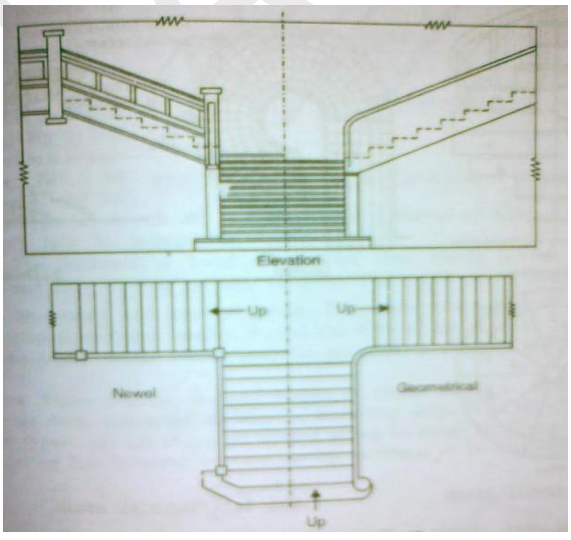
If the width of the stairs case hall is such that it comes difficult to accommodate the number of steps in the two flights, without exceeding the maximum allowable limit of steps in each flight, a short-flight of 3 to 6 steps may be provided along the width of the hall.

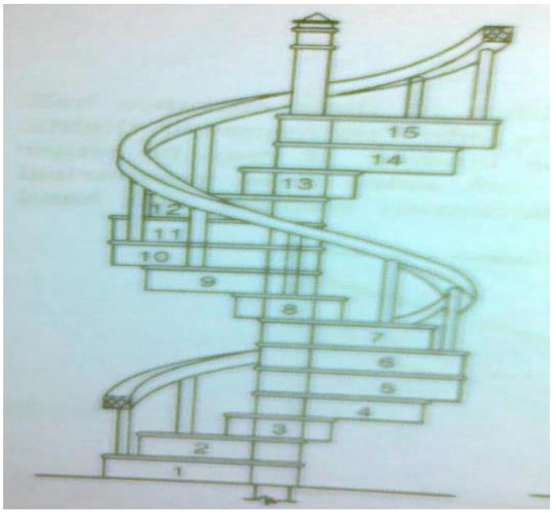
5. Three quarter Turn Stairs

A three quarter turn stairs has its direction changed three times with its upper flight crossing the bottom one. It may either be newel type or open newel type. Such type of stair is used when the length of the stair room is limited and when the vertical distance between the two floors is quite large.

6. Bifurcated Stairs

This type of stair is commonly used in public building at their entrance hall. The stair has a wider- flight at the bottom, which bifurcate into two narrows flights, one turning to the left and other to the right at the landing.





8. Continuous Stairs

These are those which do neither have any landing nor any intermediate newel post. They are therefore, geometrical in shape. They may be of the following types.

1. Circular stairs (similar to geometrical stairs)

2. Spiral stairs

3. Helical stairs

4. Spiral stairs

It is usually made either of R.C.C. or metal and is employed at a location where there are space limitations. All the steps are winders. The stair is therefore, not comfortable.