

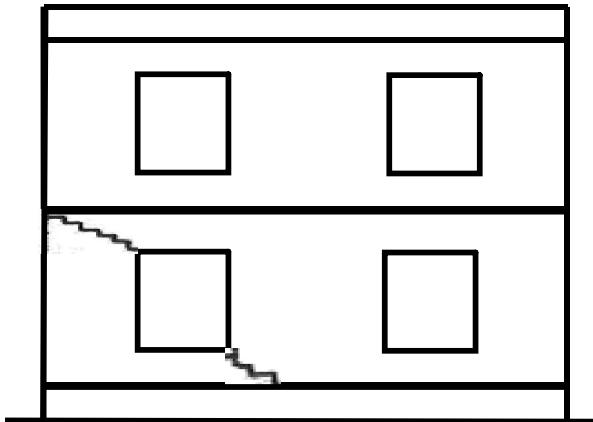
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GOVERNMENT OF INDIA  
MINISTRY OF RAILWAYS

# CRACKS IN BUILDING

(Causes and Prevention)



CAMTECH/2004/C/CRACKS/1.0

February - 2004

Centre  
*for*  
Advanced  
Maintenance  
**TECHnology**



*Excellence in Maintenance*

Maharajpur, GWALIOR - 474 020

# **CRACKS IN BUILDING**

(Causes and Prevention)

## **Foreword**

Indian Railways hold the major chunk of Civil Engineering assets in country. It is looked upon as a premier organisation in respect of, quality & workmanship. Therefore, it is essential for the field officials to construct the high quality structures.

It has been observed that even after ensuring strict quality control, workmanship and using best material, cracks do occur in structures. These cracks are normally non-structural cracks and can be prevented by adopting sound construction practices/techniques and precautions during construction stage.

Through this handbook CAMTECH has attempt to provide the technical knowledge about cracks, their causes & prevention. Efforts have been made to cover need/requirement of the field officials who are directly involved in construction.

I hope, this handbook will certainly prove to be a valuable source of technical knowledge and will be quite helpful to civil engineering supervisors in Railways.

*CAMTECH/Gwalior  
Date : 12 .02.2004*

*C.B.Middha  
Executive Director*

## Preface

Indian Railways is having large assets of civil engineering structures and buildings, spread all over the country. Every year numbers of new buildings are being added on additional as well as on replacement account. However, very oftenly, field officials are facing a problem of occurrence of cracks in buildings, and it is matter of concern since long. Therefore, a genuine need of technical reference book is being felt on the subject for the guidance of field officials.

For the design purpose, final strength of the materials is considered however in reality building materials are subjected to stresses during their strength development stage also. Stresses are caused either due to externally applied forces i.e. dead load, live load, erection load etc. or may be induced internally due to shrinkage, elastic deformation, thermal movement etc. In design, internally induced stresses are accounted indirectly by considering secondary stresses or suitable factor of safety. But in practice, stresses due to these phenomenon may cause cracks in building even with the use of best quality material and workmanship, if certain construction practices/techniques or precautions are not observed.

With the objective to provide informative technical details on the non-structural cracks for the guidance of field officials of civil engineering department, CAMTECH has brought out this handbook on "**Cracks in building (Causes and Prevention)**". It covers principle causes of non-structural cracks, general measures for prevention, with commonly observed crack patterns in buildings and their preventive measures.

This handbook does not supersede any existing instructions from Railway Board, RDSO & Zonal Railways and the provisions of IRWM, BIS codes & reports on the subject. This handbook is not statutory and contents are for the purpose of guidance only. Most of the sketches, data & information mentioned herein are available in some form or the other in various books and other printed matter.

I am grateful for the assistance given by Shri D.K.Shrivastava, CTA/DC, who went through the complete text/graphics, collected information, data etc. and done text-editing work. Nice data entry and formatting has done by Shri Ramesh Bhojwani, Console Operator, CAMTECH.

We welcome any suggestions from our readers for further improvement.

*CAMTECH/Gwalior  
Date : 12.2.2004*

*Manoj Agarwal  
Director/Civil*

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## **ISSUE OF CORRECTION SLIPS**

The correction slips to be issued in future for this handbook will be numbered as follows:

CAMTECH/2004/C/CRACKS/1.0/CS. # XX date .....

Where “XX” is the serial number of the concerned correction slip (starting from 01 onwards).

## **CORRECTION SLIPS ISSUED**

## CHAPTER - 1

### INTRODUCTION

- 1.0** Occurrence of various crack patterns in the building during construction, after completion when it is subjected to super imposed load or during the service life, is a common phenomenon. A building component develops cracks whenever the stress in the components exceeds its strength. Stress in the building component could be caused by externally applied forces, such as dead, live, wind or seismic loads, foundation settlement etc. or it could be induced internally due to thermal movements, moisture changes, elastic deformation, chemical action etc.
- 1.1** Cracks in buildings could be broadly classified as structural and non-structural cracks.
- 1.1.1. Structural Cracks :** These occur due to incorrect design, faulty construction or overloading and these may endanger the safety of a building. **e.g.** Extensive cracking of an RCC beam.
- 1.1.2 Non structural Cracks:** These are mostly due to internally induced stresses in buildings materials and do not endanger safety of a building but may look unsightly, or may create an impression of faulty work or may give a feeling of instability. In some situations due to penetration of moisture through them non structural cracks may spoil the internal finishes thus adding to the cost of maintenance, or corrode the reinforcement, thereby adversely affecting the stability of the Structure in long run. **e.g.** Vertical crack in a long compound wall due to shrinkage or thermal movement.
- 1.2** Cracks may appreciably vary in width from very thin hair crack barely visible to naked eye to gaping crack. Depending upon the crack width cracks are classified as :
- (a) **Thin Crack** - less than 1 mm in width,
  - (b) **Medium Crack** - 1 to 2 mm in width,
  - (c) **Wide Crack** - more than 2 mm in width.
  - (d) **Crazing** - Occurrence of closely spaced fine cracks at the surface of a material is called crazing.
- 1.3** Cracks may of uniform width through out or may be narrow at one end gradually widening at the other. Crack may be straight, toothed, stepped, map pattern or of random type and may be vertical, horizontal or diagonal. Cracks may be only at surface or may extend to more than one layer of material. Cracks due to different causes have varying characteristics and by the careful observations of these characteristics, one can diagnose the cause of cracking for adopting the appropriate remedial measures.

**1.4 This handbook deals with the causes and the prevention of non structural cracks only**, i.e. the cracks in the building components which are not due to structural inadequacy, faulty construction & overloading.

The commonly used building material namely masonry, concrete, mortar etc. are weak in tension and shear. Therefore the stresses of even small magnitude causing tension and shear stresses can lead to cracking. Internal stresses are induced in the building components on account of thermal movements, moisture change, elastic deformation, chemical reactions etc.. All these phenomenon causes dimensional changes in the building components, and whenever this movement is restraint due to interconnectivity of various member, resistance between the different layers of the components etc., stresses are induced and **whenever these stresses (tensile or shear) exceed the strength of material cracking occurs**.

Depending upon the cause and certain physical properties of building material these cracks may be wide but further apart or may be thin but more closely space. **As a general rule**, thin cracks even though closely spaced and greater in number, are less damaging to the structures and are not so objectionable from aesthetic and other considerations as fewer number of wider cracks.

Keeping above in view, in the subsequent chapters the various precautions and the preventive measures for mitigating the **non-structural cracks**, or containing them in less damaging fine cracks has been enumerated in detail.

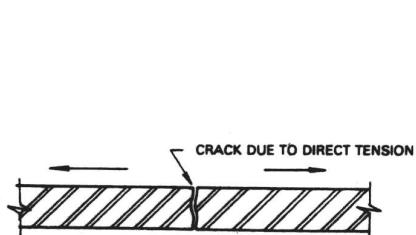


Figure -1 : Tensile crack in masonry wall

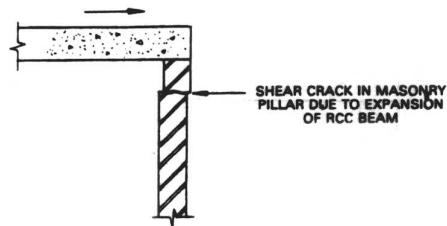


Figure – 2 : Shear crack in masonry pillar at beam support

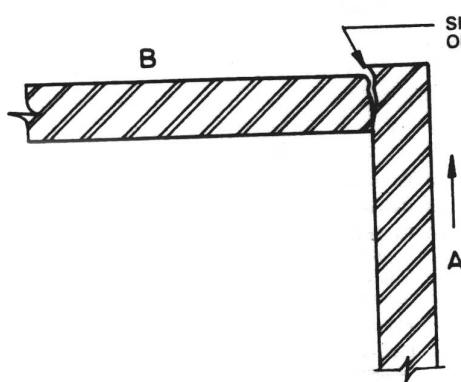


Figure –3 : Shear crack in masonry wall

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## CHAPTER - 2

### PRINCIPAL CAUSES OF CRACKS

**2.0** For prevention or minimising the occurrence of non-structural cracks it is necessary to understand the basic causes and mechanism of cracking, and certain properties of building materials which may lead to dimensional changes of the structural components. The principle mechanism causing non-structural cracks in the building are :

- **Moisture change**
- **Thermal movement**
- **Elastic deformation**
- **Creep**
- **Chemical reaction**
- **Foundation movement & settlement of soil**
- **Growth of vegetation**

#### **2.1 Moisture change**

Most of the building materials (e.g. Concrete, mortar, burnt clay brick, timber, plywood etc.,) are porous in their structure in the form of inter-molecular space, and they expands on absorbing moisture from atmosphere and shrinks on drying. These movements are **reversible** i.e. cyclic in nature and are caused by increase or decrease in the inter-pore pressure with moisture change. Extent of movement depends upon molecular structure and porosity of a material.

Apart from reversible movement certain materials undergo some irreversible movement due to initial moisture changes after their manufacture or construction. The incidences of irreversible movement in materials are shrinkage of cement and lime based materials on initial drying i.e. **initial shrinkage/plastic shrinkage** and expansion of burnt clay bricks and other clay products on removal from kilns i.e. **initial expansion**.

##### **2.1.1 Reversible movement**

Depending upon the extent of reversible movement, with variation in moisture content the various building materials are classified as :

- **Small movement** – Burnt clay bricks, igneous rock, lime stone, marble, gypsum plaster.  
These material does not require much precautions.
- **Moderate movement** – Concrete, sand- lime brick, sand stones, cement and lime mortar.  
These materials requires certain precaution in design and construction.

- **Large movement** – Timber, block boards, plywood, wood, cement products, asbestos cement sheet.  
These materials require special treatment at joints and protective coats on surface.

### 2.1.2 Initial shrinkage

Initial shrinkage, which is partly irreversible, normally occurs in all building materials or components that are cement/lime based (e.g. concrete, mortar, masonry units, masonry and plaster etc.) and is one of the main cause of cracking in structure. Initial shrinkage of concrete and mortar occurs only once in the life time, i.e. at the time of manufacture/construction, when the moisture used in the process of manufacture/construction dries out. It far exceeds any reversible movement due to subsequent wetting and drying and is very significant from crack consideration.

The extent of initial shrinkage in cement concrete and cement mortar depends on a nos. of factors namely :

- a) **Cement content** – It increase with richness of mix.
- b) **Water content** – Greater the water quantity used in the mix, greater is the shrinkage.
- c) **Maximum size, grading & quality of aggregate** – With use of largest possible max. size of aggregate in concrete and with good grading, requirement of water for desired workability is reduced, with consequent less shrinkage on drying due to reduction in porosity. E.g., for the same cement aggregate ratio, shrinkage of sand mortar is 2 to 3 times that of concrete using 20 mm max. size aggregate and 3 to 4 times that of concrete using 40 mm max. size aggregate.
- d) **Curing** – if the proper curing is carried out as soon as initial set has taken place and is continued for at least 7 to 10 days than the initial shrinkage is comparatively less. When the hardening of concrete takes place under moist environment there is initially some expansion which offsets a part of subsequent shrinkage.
- e) **Presence of excessive fines in aggregates** - The presence of fines increases specific surface area of aggregate & consequently the water requirement for the desire workability, with increase in initial shrinkage.
- f) **Chemical composition of cement** – Shrinkage is less for the cement having greater proportion of tri-calcium silicate and lower proportion of alkalis i.e. rapid hardening cement has greater shrinkage than ordinary port-lan cement.
- g) **Temperature of fresh concrete and relative humidity of surroundings** – With reduction in the ambient temperature the requirement of water for the same slump/workability is reduced with subsequent reduction in shrinkage. Concreting done in mild winter have much less cracking tendency than the concreting done in hot summer months.

In cement concrete  $\frac{1}{3}$ rd of the shrinkage take place in the first 10 days,  $\frac{1}{2}$  within one month and remaining  $\frac{1}{2}$  within a year time. Therefore, shrinkage cracks in concrete continues to occur and widens up to a year period.

### 2.1.3 Plastic shrinkage :

In the freshly laid cement concrete some times cracks occurs on the surface before it has set due to plastic shrinkage. Immediately after placing the concrete, solid particles tends to settle down by gravity action and water rises to the surface. This process – known as **bleeding**- produces a layer of water at the surface and this process continues till concrete has set. As long as the rate of evaporation is lower than the rate of bleeding, there is a continuous layer of water at the surface known as “**water sheen**”, and shrinkage does not occur. When the concrete surface loses water faster than the bleeding action bring it to the top, shrinkage of top layer takes place, and since the concrete in plastic state can't resist any tension, cracks develops on the surface. These cracks are common in slabs.

The extent of plastic shrinkage depends on :

- temperature of concrete,
- exposure to the heat from sun radiation,
- relative humidity of ambient air and velocity of wind.

### 2.1.4 Plastic settlement cracks

In freshly laid/placed cement concrete in reinforced structure, some times cracks also occurs on the surface before concrete has set, when there is relatively high amount of bleeding & there is some form of obstruction (i.e. reinforcement bars) to the downward sedimentation of the solids. These obstruction break the back of concrete above them forming the voids under their belly. These cracks are normally observed;

- Over form work tie bolts, or over reinforcement near the top of section.
- In narrow column and walls due to obstruction to sedimentation by resulting arching action of concrete due to narrow passage.
- At change of depth of section.

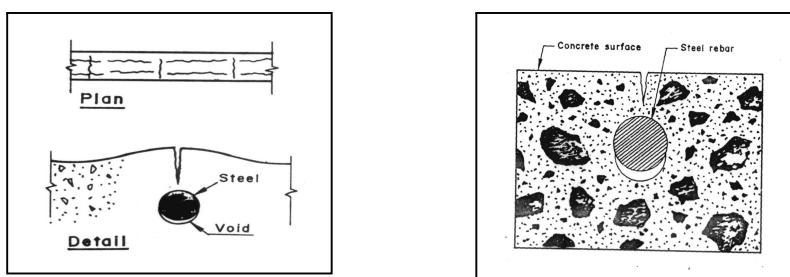


Figure - 4: Typical plastic settlement cracks

### 2.1.5 Initial expansion:

When the clay bricks are fired during manufacturing, due to high temperature not only the intermolecular water but also water that forms a part of molecular structure of clay is driven out. After burning, as the temperature of the bricks falls down, the moisture hungry bricks starts absorbing moisture from the environment and undergoes gradual expansion, bulk of this expansion is **irreversible**.

For the practical purpose it is considered that this initial expansion ceases after first three months.

Use of such bricks before cessation of initial expansion in brickwork, will cause irreversible expansion and may lead to cracking in masonry.

## 2.2 Thermal movement

All materials more or less expands on heating and contracts on cooling. When this movement is restraint, internal stresses are set-up in the component, and may cause cracks due to tensile or shear stress. Thermal movement is one of the most potent causes of cracking in buildings and calls for careful consideration. The extent of thermal movement depends upon :

- **Ambient temperature variation**
- **Co-efficient of thermal expansion** – Expansion of cement mortar & concrete is almost **twice** of the bricks and brick work. Movement in brickwork in vertical direction is 50% more than in horizontal direction.
- **Dimensions of components**

The cracks due to thermal movement is caused either due to external heat i.e. due to variation in ambient temperature, or due to internally generated heat i.e. due to heat of hydration in mass concrete during construction.

Cracks in the building component due to thermal movement opens and closes alternatively with changes in the ambient temperature. The concreting done in summer is more liable for cracking due to drop in temp. in winter since thermal contraction and drying shrinkage act in unison. Whereas the concrete job done in the winter is less liable to cracking though it may require wider expansion joints.

Generally speaking, thermal variation in the internal walls and intermediate floors are not much and thus do not cause cracking. It is mainly the external walls exposed to direct solar radiation, and the roof, which are subjected to substantial thermal variation, are more liable to cracking.

Typical cases of cracking due to thermal movement in buildings are as under:

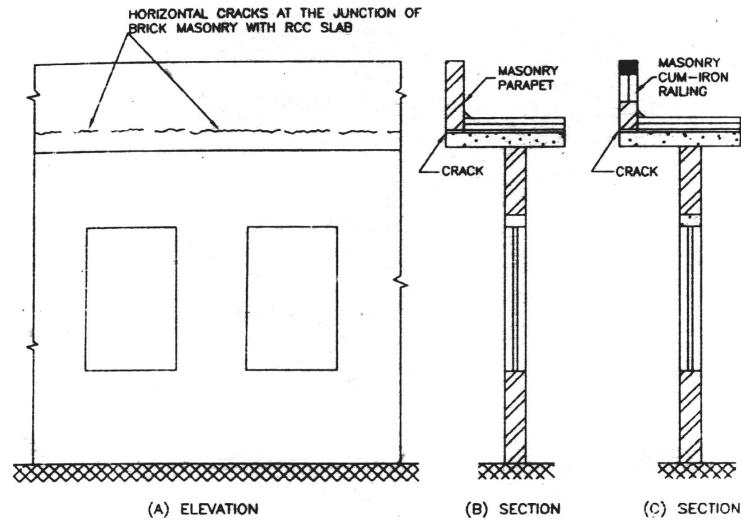


Figure - 5 : Horizontal crack at the base of brick masonry parapet (or masonry-cum-Iron railing) supported on a projecting RCC slab.

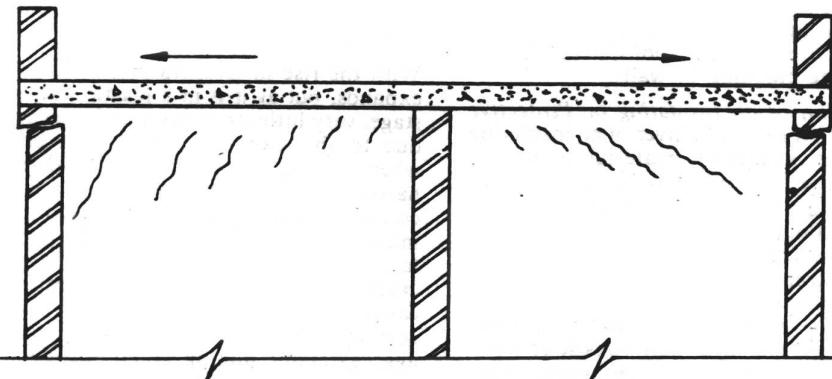


Figure – 6 : Cracking in cross walls of top most storey of a load bearing structure

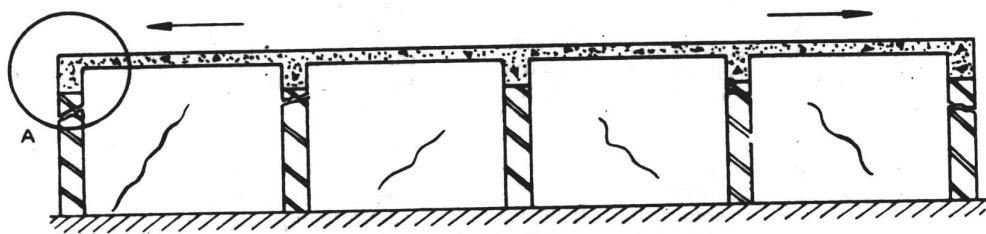


Figure – 7 : Cracking in cladding and cross walls of a framed structure (continued)

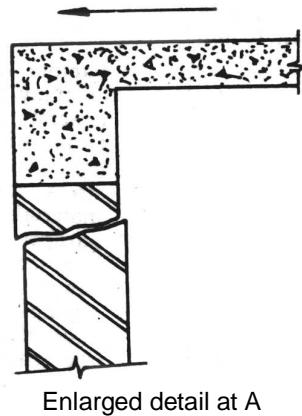


Figure – 7 : Cracking in cladding and cross walls of a framed structure

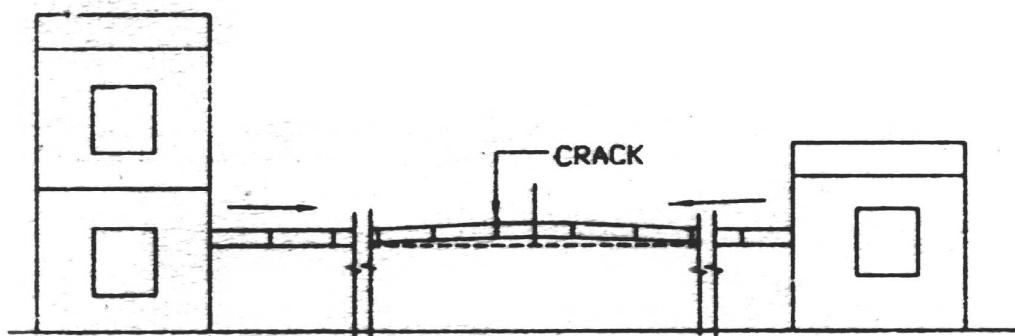


Figure – 8 : Arching up and cracking of coping stones of a long Garden wall

### 2.3 Elastic Deformation

Structural components of a building undergo elastic deformation due to dead and the super imposed live loads, in accordance with hook law. The amount of deformation depends upon elastic modulus, magnitude of loading and the dimension of the component. This elastic deformation under certain circumstances causes cracking in the building as under :

- When walls are unevenly loaded with wide variations in stress in different parts, excessive shear stress is developed which causes cracking in walls.
- When a beam or slab of large span undergoes excessive deflection and there is not much vertical load above the supports (as in the case of roof slab), ends of beam /slab curl up causing cracks in supporting masonry.
- When two materials, having widely different elastic properties, are built side by side, under the effect of load, shear stresses are set up at the interface of the two materials, resulting in cracks at the junction. Such a situation is commonly encountered in the construction of RCC framed structure and brick masonry panel (external) and partition (internal) walls.

Typical cases of cracking due to elastic deformation are as under :

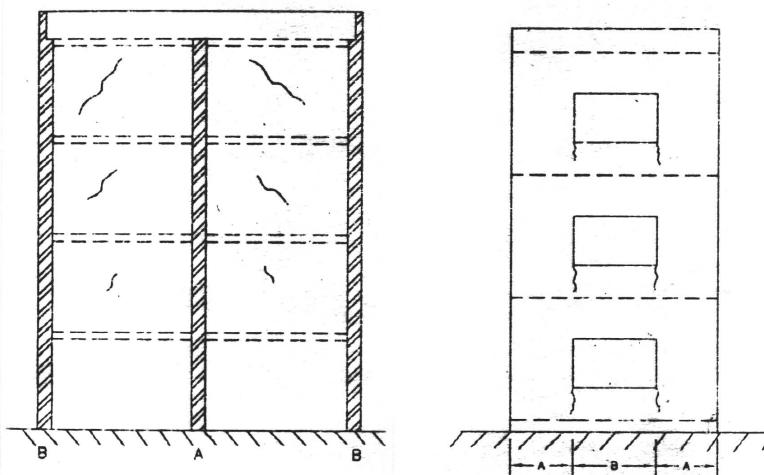


Figure – 9 : Diagonal cracks in cross walls of multi-storied bearing structures.

Figure – 10 : Vertical cracks in multi-storeyed buildings having window opening in load bearing wall.

**E.g. :** If a glazed, terrazzo or marble tiles are fixed to a masonry wall before wall has undergone normal strain due to plastic deformation, drying shrinkage and creep, excessive shear stress will develop at the interface of masonry and tiles, resulting in dislodging or cracking of tiles.

## 2.4 Creep

Normally used building material such as concrete, brickwork, mortar, timber etc. when subjected to sustained load not only undergo instantaneous elastic deformation but also undergo a gradual and slow time dependent deformation known as creep or plastic strain.

### 2.4.1 In concrete, the extent of creep depends on :

- Water & cement content
- Water cement ratio
- Temperature and humidity
- Use of admixture and pozzolanas
- Age/strength of concrete at the time of loading
- Size and shape of the component

Creep increases with water and cement content, water cement ratio and temperature, it decreases with increase in humidity of surroundings and the age/strength of the material at the time of loading.

Use of admixtures and pozzalanas in concrete increases the creep. Creep also increases with increase in surface to volume ratio of component.

**2.4.2 In brickwork**, the creep depends upon stress/strength ratio therefore the creep in brickwork with weak mortar is generally higher. For example : For same quality of brick, creep of brick work in 1:1:6 mortar is 2 to 3 times that of brick work in 1:1:3 mortar.

**2.4.3** Generally creep in brickwork is approx. 20 to 25% that of concrete. In brickwork it ceases after 4 months while in concrete it may continued up to a year or so, and most of creep takes place in 1<sup>st</sup> month there after it pace slows down.

**2.4.4** The major affect of creep in concrete is the substantial increase in the deformation of structural members, which may be to the extent of **2 to 3 times** the initial elastic deformation. This deformation sometimes causes cracks in brick masonry of frame and load bearing structures. When the deformation due to elastic strain and creep occurs in conjunction with shortening of an RCC member due to shrinkage, cracking is much more severe and damaging.

## 2.5 Movement due to chemical reaction

Certain chemical reactions in building materials result in appreciable increase in volume of materials, due to which internal stresses are setup which may results in outward thrust and formation of cracks. The material involve in reaction also become weak in strength. The common instances of chemical reactions are :

- **Sulphate attack**
- **Carbonation in cement based materials**
- **Corrosion of reinforcement in concrete and brickwork**
- **Alkali-aggregate reaction.**

### 2.5.1 Sulphate attack

Soluble sulphates which are sometimes present in soil, ground water or clay bricks reacts with tri-calcium aluminate content of cement and hydraulic lime in the presence of moisture and form products which occupies much larger volume than the original constituents. This expansive reaction causes weakening of masonry, concrete and plaster and formation of cracks. For above reaction it is necessary that soluble sulphate, tri-calcium-aluminate and moisture, all the three are present.

It takes about 2 or more years before the effect of this reaction becomes apparent. Movement and cracks due to this reaction in the structures appears after about 2 years or more. The severity of sulphate attack depends upon

- amount of soluble sulphates present
- permeability of concrete and mortar
- content of tri-calcium-aluminate in the cement used for concrete and mortar
- duration for which the building components remains damp.

The building components, which are, liable to sulphate attack are concrete and masonry in foundation and plinth, and masonry and plaster in super structure. The sulphate attack on these components will result in weakening of these components and in course of time may result in unequal settlement of foundation and cracks in super structure.

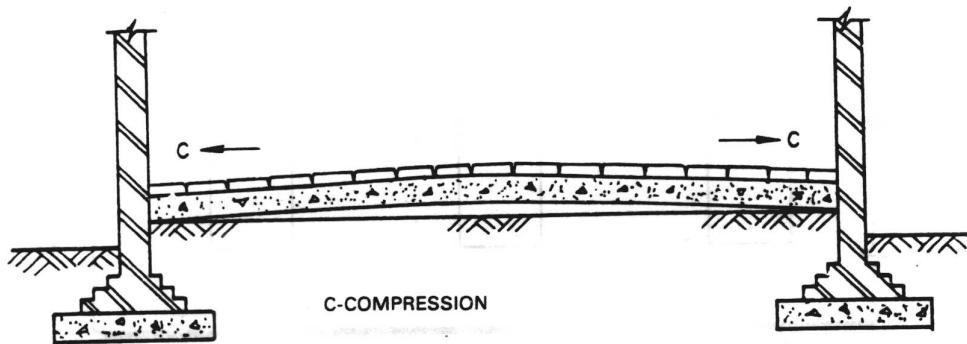


Figure – 11 : Cracking and up-heaving of a tile floor due to sulphate action in base concrete (brick aggregate containing more than 1% of soluble sulphates and there is long spell of dampness due to high water table).

### 2.5.2 Carbonation

During hardening of concrete some calcium hydroxide is liberated in the process of hydration of cement. It provides protective alkaline medium inhabiting galvanic cell action thus preventing corrosion of steel. In course of time, free hydroxide in concrete reacts with atmospheric carbon-di-oxide forming calcium carbonate resulting in shrinkage cracks, since calcium carbonate occupies lesser volume than calcium hydroxide. This phenomenon known as **carbonation**, also reduces the alkalinity of concrete hence its effectiveness as a protective medium for reinforcement.

In good dense concrete carbonation is confine mainly to surface layer and depth of carbonation normally not exceeds 20 mm in 50 years. In porous concrete it may reach 100 mm in 50 years. The affect of carbonation is more severe in industrial locality having higher percentage of carbon-di-oxide in the atmosphere.

### **2.5.3 Corrosion of reinforcement in concrete and brick work**

Normally, concrete provides good protection to steel reinforcement embedded in it. Protective quality of concrete depends upon high alkalinity and relatively high electrical resistivity of concrete. Extent of protection depends upon the quality of concrete, depth of concrete cover, and workmanship.

However, when the reinforcement steel gets corroded, it increases in volume with setting up of internal stress in concrete. In course of time it first causes cracks in the line with the direction of reinforcement, later on causing spalling of concrete, dislodging cover of reinforcement from the body of the concrete, thus seriously damaging the structure.

Factors, which contribute to corrosion of reinforcement in concrete are :

- Presence of cracks in concrete
- Permeability of concrete
- Carbonation
- Formation of corrosion (galvanic) cells,
- Electrolysis,
- Alkali - aggregate reaction,
- Use of calcium chloride as accelerator,
- presence of moisture
- Ingress of sea water into porous of concrete
- Presence of soluble sulphates
- Inadequacy of cover to reinforcement
- Impurities in mixing/curing water – Excessive sulphates and chlorides

### **2.5.4 Alkali aggregate reaction**

In ordinary Portland cement sodium oxide and potassium oxide are present to some extent. These alkalis chemically react, with certain siliceous mineral constituents of aggregate and causes expansion, cracking and disintegration of concrete. In RCC member it also causes corrosion of reinforcement. Cracking due to this reaction is usually of a map pattern, and the reaction being very slow, it takes nos. of years for cracks to develop.

## **2.6 Foundation movement and settlement of soil:**

Shear cracks in buildings occurs when there is large differential settlement of foundation due to one of the following cause.

- (a) Unequal bearing pressure under different parts of the structure.
- (b) Bearing pressure being in excess of safe bearing strength of the soil.
- (c) Low factor of safety in the design of foundations.
- (d) Local variations in the nature of supporting soil, which remained

undetected and could not be taken care of in the foundation design at the time of construction.

- (e) Foundation resting in active zone on expansive soil.

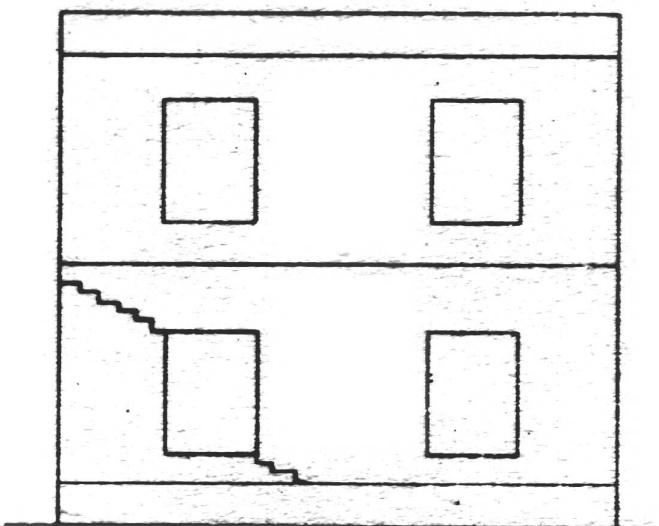


Figure – 12 : Crack at the corner of a building due to foundation settlement

## 2.7 Growth of vegetation :

- 2.7.1 Roots of a tree generally spread horizontally on all sides to the extent of height of the tree above the ground and when the trees are located in the vicinity of a wall, they can cause cracks in walls due to expansive action of roots growing under the foundation.

Sometimes plants take root and begin to grow in fissures of walls, because of seeds contained in bird droppings. If these plants are not removed well in time, these may in course of time develop and cause severe cracking of wall.

- 2.7.2 When soil under the foundation of a building happens to be shrinkable clay, cracking in walls and floors of buildings can occur in following ways :

- (a) Growing roots of trees cause de-hydration of soil which may shrink and cause foundation settlement, or
- (b) In areas where old trees had been cut off to make way for building construction roots had dehydrated the soil. On receiving moisture from some sources, such as rain etc., the soil swells up and causes an upward thrust on a portion of the building resulting in cracks in the building.

Typical cases of cracking due to vegetation are as under :

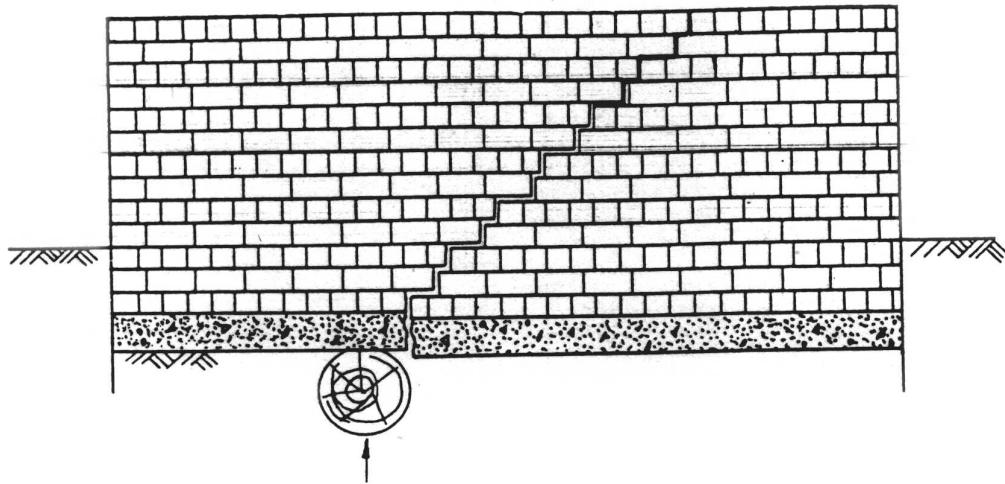


Figure – 13 : Cracking of a compound wall due to growing roots under the foundation.  
(Wide at base & narrow upward)

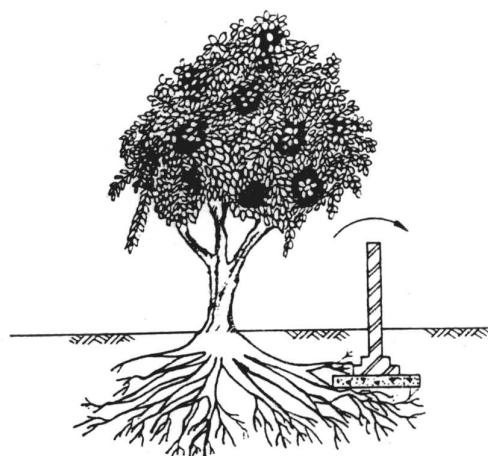


Figure – 14 : Roots of fast growing tree under the foundation of compound wall may topple down the wall.

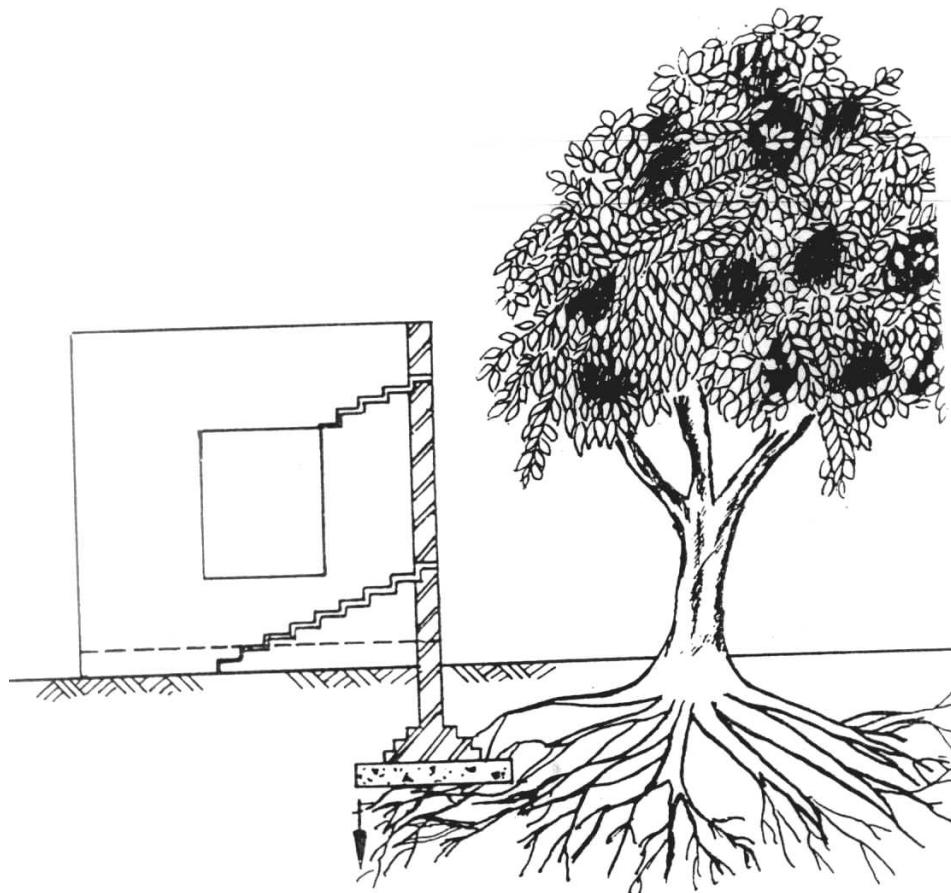


Figure - 15 : Trees growing close to building on shrinkable soil may cause cracks in the walls due to shrinkage of soil  
(Narrow at base and wide upward)

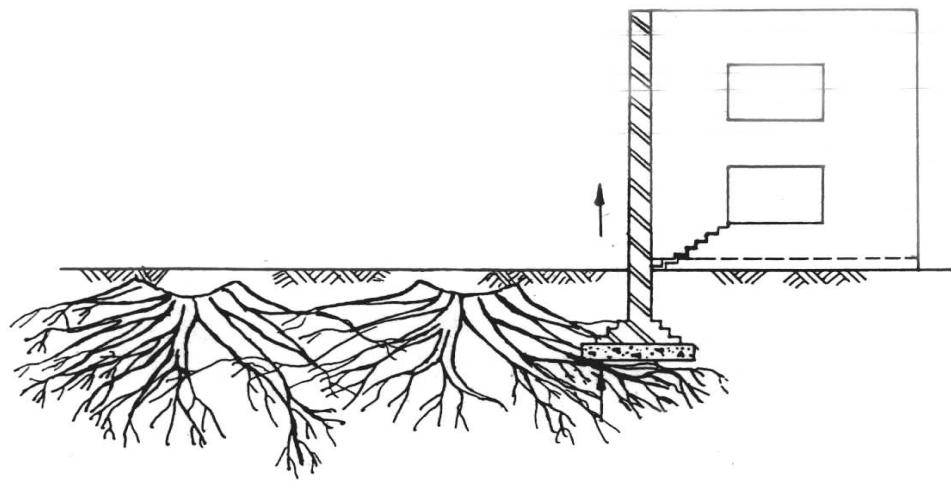


Figure – 16 : Cracking due to expansion of soil, on moisture absorption if construction is taken up soon after removal of trees.  
(Wide at base and narrow upward)

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## CHAPTER - 3

### GENERAL MEASURES FOR PREVENTION OF CRACKS

**3.0** Non-structural cracks in buildings usually occurs due to more than one cause as already mention in previous chapter, therefore measures for prevention of cracks in many cases are common to more than one cause. Measures for prevention of cracks could be broadly grouped under the following sub-heads:

- **Choice of materials**
- **Specifications for mortar and concrete**
- **Design of buildings (architectural, structural and foundation)**
- **Construction techniques and practices, and**
- **Environment**

#### **3.1 Choice of materials**

For selecting materials for building construction following precautions shall be taken:

##### **3.1.1 Masonry units :**

- Only well burnt bricks should be used for masonry.
- Burnt clay bricks and other burnt clay products should not be used in masonry for a period of at least **2 weeks in summer and 3 weeks in winter** after unloading from kilns. They should be kept exposed to atmosphere during this period.
- Use of burnt clay bricks containing excessive quantity of soluble sulphates should be avoided if there use can not be avoided than rich cement mortar shall be used for masonry as well as plaster or super-sulphate cement shall be used. All possible steps shall be taken to prevent dampness in masonry.
- Use of porous stone with high drying shrinkage e.g. sand stone should be avoided for masonry & concrete work.
- While using manufactured masonry units having high value of drying shrinkage for e.g. Concrete blocks and sand lime bricks, suitable precautions should be taken i.e.
  - (i) They should be protected from wetting at site due to rains, and should be lightly wetted before use.
  - (ii) The use of strong and rich mortar for laying should be avoided. Mortar used should have high water retentivity hence composite cement lime mortar are more preferred.
  - (iii) Curing of masonry should be done sparingly to avoid body of blocks getting wet.
  - (iv) Before plastering masonry shall be allowed to dry and undergo initial shrinkage. Excessive wetting of masonry at the time of plastering and curing should be avoided.

### **3.1.2 Fine Aggregate:**

Use of fine aggregate for mortar and concrete which is too fine or contains too much of clay or silt and is not well graded should be avoided. Percentage of clay and silt in fine aggregate (uncrushed) should not exceed 3 percent.

### **3.1.3 Coarse Aggregate:**

- Coarse aggregate for concrete work should be well graded so as to obtain concrete of high density.
- Maximum size of coarse aggregate should be largest possible consistent with the job requirements.
- Coarse aggregate of stones that are porous and having high shrinkage properties, e.g. Sand stone, clinker, foamed slag, expanded clay etc. should be avoided. Aggregate made from lime stone, quartzite, granite, dolomite and basalt are more desirable.
- Use of brick aggregate containing excessive amount of soluble sulphates for concrete in base course should be avoided.
- Coarse aggregate should not contain fines more than 3%.

### **3.1.4 Cement:**

- When use of bricks containing excessive quantity of soluble sulphates is unavoidable, content of cement in mortar should be increased or super-sulphated cement should be used.
- If use of alkali-reactive aggregate is unavoidable, alkali content of cement should not exceed 0.6 percent. If low alkali cement is not economically available, use of pozzolanas should be made to check alkali-aggregate reaction.
- In massive structures, in order to limit heat of hydration, low-heat cement should be used.

### **3.1.5 Calcium Chloride:**

Its use in concrete as accelerator should be avoided as far as possible. If unavoidable, its quantity should be limited to 2 percent of cement content.

### **3.1.6 Gypsum (Plaster of Paris):**

Gypsum plaster ( $\text{CaSO}_4$ ) should not be used for external work, or internal work in locations, which are likely to get or remain wet. It should be remembered that gypsum and cement are incompatible, since in the presence of moisture, a harmful chemical reaction takes place.

### **3.1.7 Steel reinforcement in brick masonry:**

Use of steel reinforcement in brick masonry should be avoided in exposed situations unless special precautions are taken to prevent rusting.

### **3.2 Specifications for mortar and concrete**

Specifications of mortar and concrete have a very important role to play in regard to the incidence of cracking in the buildings. Apart from strength and durability, specifications for mortar and concrete should be decided on considerations of obtaining products with minimum of drying shrinkage and creep with adequate resistance against sulphate attack. Some of the important considerations for deciding specifications of mortar and concrete are given below.

**3.2.1 Mortar for Plaster:** Mortar for plaster should not be richer than what is necessary from consideration of resistance to abrasion and durability. Plaster should not be stronger than the background otherwise due to shrinkage it will exert sufficient force to tear off the surface layer of weak bricks. Composite cement-lime mortar of 1:1:6 mix or weaker for plaster work is less liable to develop shrinkage cracks, as compared to plain cement mortar and should thus be preferred.

Plaster with coarse well-graded sand or stone chips (roughcast plaster) is liable to suffer from less shrinkage cracks, hence use of such plaster on external surface of walls, from considerations of cracking and resistance against penetration of moisture through walls, shall be preferred.

**3.2.2 Mortar for masonry work:** Rich cement mortar, which has high shrinkage, should be avoided. Composite cement-lime mortar should be preferred. Mortar for masonry should not contain excessive water.

While using concrete blocks or sand lime bricks as masonry unit in non-load bearing wall, use of rich cement mortar should be avoided. 1:2:9 in summer and 1:1:6 cement lime mortar for the work done in winter will be adequate.

**3.2.3 Cement Concrete:** Mix should not be richer than what is required from strength considerations. Aim should be to obtain strong and durable concrete by careful mix design, grading of aggregates, control of water-cement ratio, thorough mixing, proper compaction and adequate curing, etc. An over sanded mix should be avoided.

Quantity of water used in concrete should be the minimum, consistent with requirements for proper laying and compaction. This is one of the most important single factor responsible for shrinkage and consequent cracks in concrete.

**3.2.4 Compaction:** As far as possible, concrete should be compacted by vibration as to allow use of low-slump concrete. Concreting should not be done when it is very hot, dry and windy. If unavoidable, quick drying of concrete should be prevented.

**3.2.5 Curing:** Curing should be done for a minimum period of 7 to 10 days for masonry and concrete works. It should be discontinued slowly so as to avoid quick drying. It should start immediately after initial setting of concrete but before the surface sheen fully disappears.

### 3.3 Design of building

**3.3.1 Architectural design:** Factors which affect cracking are large span of rooms, provision of large windows in external walls, introduction of short return walls in external elevation, etc.

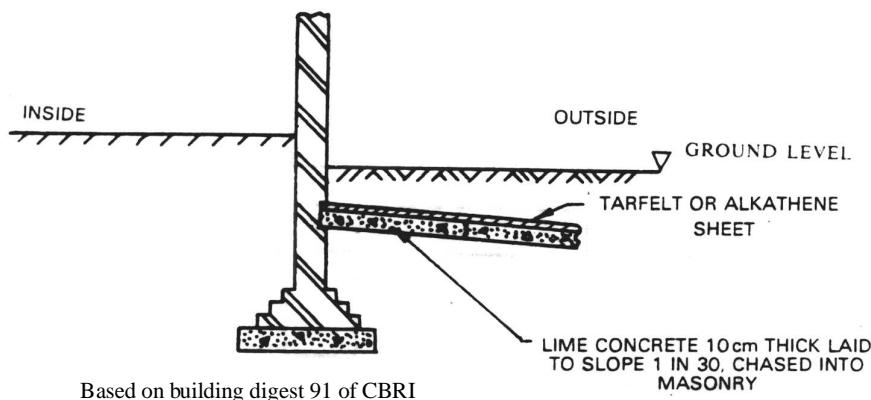
Doors and windows frames should not be placed flush with plastered surface, if unavoidable, the joint should be either concealed with molding strip or the preventive arrangement shall be made to avoid shrinkage.

#### 3.3.2 Structural design:

- Stresses in different parts of masonry walls should be more or less uniform so as to limit differential strain and resultant shear stress and cracking.
- Slabs and beams should have adequate stiffness so as to limit deflection.
- Flexural cracks in concrete should be limited in width to 0.30 mm for protected internal members and 0.20 mm for unprotected external members.
- In a rigid structure, such as rigid frames and shells, since movement joints are not feasible, thermal and shrinkage stresses should be taken care of in the design.

#### 3.3.3 Foundation design :

- Bearing pressure on soil should be more or less uniform to avoid differential settlement.
- Bearing pressure on the soil shall be commensurate to the overall settlement of the structure within a reasonable/permissible limit for a type of superstructure.
- In expansive clays soil movement due to alternate wetting and drying and consequent swelling and shrinkage should be taken care by –
  - i. Taking the foundation to 3.5 M deep and using moorum, granular soil or quarry dust for filling in foundation trenches and in plinth.
  - ii. Using under –ream piles. The bulb of the pile should be kept at the depth, which is not much affected by moisture variation.
  - iii. By providing 2 M wide water proof apron (figure 17) all round the building at a depth of about 0.5 M below the ground level. The apron should be provided after 1 or 2 months, after the monsoon.



Based on building digest 91 of CBRI

Figure 17 : Flexible waterproof Apron around a building to reduce moisture variation in soil under the building.

### 3.4 Construction Practices and Techniques

To prevent the occurrence of non-structural cracks in structure, following construction practices and techniques shall be observed at the construction stage.

#### 3.4.1 Movement joints :

To mitigate/relieve the magnitude of stresses due to thermal movement and shrinkage movement joints i.e. Expansion joint, Control joint and Slip joint shall be provided in the structure as per guideline given in chapter 5.

#### 3.4.2 Filling in plinth :

Filling in plinth should be done with good soil free from organic matter, brickbats and debris etc. It should be laid in 25 cms thick layers, well watered and compacted to avoid possibility of subsequent subsidence and cracking of floors.

#### 3.4.3 Masonry work :

- To avoid differential loading/settlement of foundation and consequent cracking in walls, it shall be ensured that masonry wall work proceed more or less at a uniform level in all parts of the structure. Difference in the height of masonry in different parts of a building should normally **not exceed 1 M** at any time during construction.
- Curing for masonry work should be done for a minimum period of 7 to 10 days.
- Masonry work on RCC slabs and beams should not be started till atleast 2 weeks have elapsed after striking of centering.

#### 3.4.4 Concrete work :

- In case of RCC members which are liable to deflect appreciably under load e.g. cantilever beam and slabs, removal of centering and imposition of load should be differed atleast one month so that concrete attains sufficient strengths before it bears the load.

- Curing should be done for a minimum period of 7 to 10 days and terminated gradually so as to avoid quick drying.
- As far as possible concreting should not be done if it is very hot, dry and windy, if unavoidable, precautions should be taken to keep down the temperature of fresh concrete and to prevent quick drying.
  - Aggregate and mixing water should be shaded from direct sun.
  - Part of mixing water may be replaced by pounded ice.
  - As far as possible concreting should be done in early hours of the day.
  - Re-trowelling the concrete surface slightly, before its initial setting to mitigate plastic shrinkage cracks

#### **3.4.5 RCC frame work**

- As far as possible frame work should be completed before starting work of panel walls for cladding and partitioning.
- Work of construction of panel walls and partition should be deferred as much as possible and should proceed from **top to down ward**.
- When partition walls are to be supported on floor beam or slab upward camber should be provided in floor slab/beam to counter act deflection.
- Horizontal movement joint should be provided between top of panel wall and soffit of beam and when structurally required little support to the wall should be provided at the top by using telescopic anchorage or similar arrangement.

Horizontal movement joint between top of wall and soffit of beam/slab shall be filled which some compressible jointing material.

- If door opening is to be provided in partition wall a center opening is more preferable than off center opening
- Light re-vibration of concrete shall be done, before it has set, for the member and section prone for plastic settlement cracks i.e. narrow column and walls, at change of depth in section.

#### **3.4.6 Plastering :**

- When plastering is to be done on masonry, mortar joints in masonry should be raked out to 10 mm depth while the mortar is green. Plastering should be done after masonry has been properly cured and allowed to dry so as to undergo initial shrinkage before plaster.
- For plastering on concrete background, it should be done as soon as feasible after removal of shuttering by roughing of concrete surface where necessary by hacking, and applying neat cement slurry on the concrete surface to improve the bond.
- When RCC and brick work occurs in combination and to be plastered, then sufficient time (**atleast 1 month**) shall be allowed for RCC and brickwork to undergo initial shrinkage and creep before taking up plaster work.

In such case either groove shall be provided in the plaster at the junction or 10 cms wide strip of metal mesh or lathing shall also be provided over the junction to act as reinforcement.

### 3.4.7 Concrete and terrazzo floor :

- Control joint should be provided in the concrete and terrazzo floor either by laying floors in alternate panels or by introducing strips of glass, aluminium or some plastic material at close interval in grid pattern.
- When flooring is to be laid on RCC slab, either a base course of lime concrete should be provided between the RCC slab and the flooring or surface of slab should be well roughened, cleaned and primed with cement slurry before laying of floor.

### 3.4.8 RCC Lintels:

Bearing for RCC lintels should be on the liberal side when spans are large so as to avoid concentration of stress at the jambs.

### 3.4.9 RCC roof slab :

- The top of the slab should be provided with adequate insulation or protective cover together with some high reflectivity finish cover to check the thermal movement of the slab and consequent cracking in supporting wall and panel/partition wall.
- In load bearing structure, slip joint should be introduced between the slab and supporting/cross walls. Further either the slab should project for some length from the supporting wall or the slab should rest only on part width of the wall as shown in figure below :

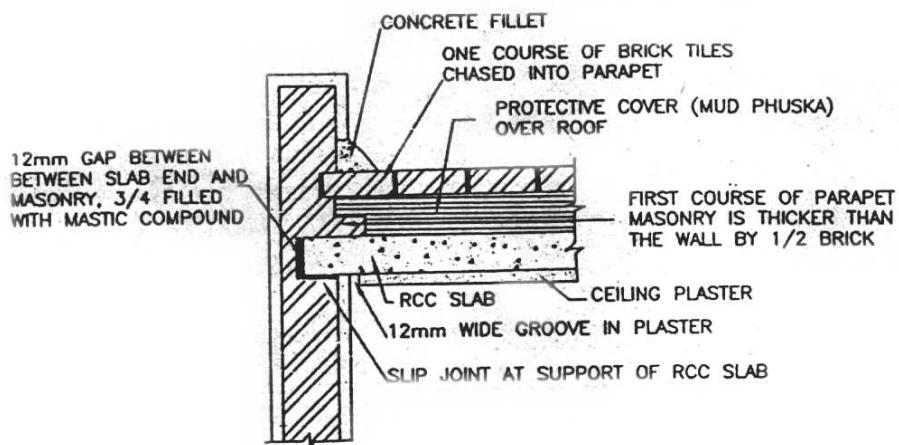


Figure – 18 : Constructional detail of bearing of RCC roof slab over a masonry wall.

On the inside, wall plaster and ceiling plaster should be made discontinuous by a groove of about 10 mm.

For introducing the **slip joint**, the bearing portion of supporting wall is rendered smooth with plaster (preferably with neat cement finish), which is then allowed to set and partly dry. Thereafter either it is given thick coat of whitewash, or 2 to 3 layers of tarred paper is placed over the plaster surface, before casting of slab.

### **3.4.10 Provision of glazed, terrazzo or marble tile on vertical surface :**

Before fixing of these tiles on vertical surface background component should be allowed to undergo movement due to elastic deformation, shrinkage & creep otherwise tiles are likely to crack and dislodged.

### **3.4.11 RCC work in exposed condition :**

For RCC work in exposed condition i.e. sunshades, balconies, canopies, open verandah etc., to prevent shrinkage\_cum\_contraction cracks, adequate quantity of temperature reinforcement shall be provided. In such condition quantity shall be increased by 50 to 100 % of the minimum amount prescribed.

### **3.4.12 Finish on wall :**

Finishing items i.e. distemper and painting etc. should be carried out after the plaster has dried and has undergone drying shrinkage.

### **3.4.13 Pace of construction :**

The construction schedule and the pace of construction should be regulated to ensure :

- All items of masonry are properly cured and allowed to dry before plastering work is done, thus concealing the cracks in masonry in plaster work.

Similarly plaster work should be cured and allowed to dry before applying finishing coat. So as to conceal the cracks in plaster under finish coat.

- In case of concrete work before taking masonry work either over it or by its side, the most of the drying shrinkage, creep and elastic deformation of concrete should be allowed to take place, so as to avoid cracks in masonry or at the junction of masonry and concrete.

### **3.4.14 Provision of reinforcement for thermal stresses:**

To control the cracks in concrete due to shrinkage as well as temperature effect, adequate temperature re-inforcement shall be provided. This temperature reinforcement is more effective if smaller diameter bars and the deformed steel is used than plain reinforcement.

### **3.4.15 Extension of existing building:**

- (a) **Horizontal extension:** Since foundation of an existing building undergoes some settlement as load comes on the foundation, it is necessary to ensure that new construction is not bonded with the old construction and the two parts are separated by a slip or expansion joint right from bottom to top. Otherwise, when the newly constructed portion undergoes settlement, an unsightly crack may occur at the junction.

Care should also be taken that in the vicinity of the old building, no excavation below the foundation level of that building is carried out.

When plastering the new work, a deep groove should be formed separating the new work from the old.

When it is intended to make horizontal extension to a framed structure later on than the twin column with combined footing shall be provided at the time of original construction itself as under :

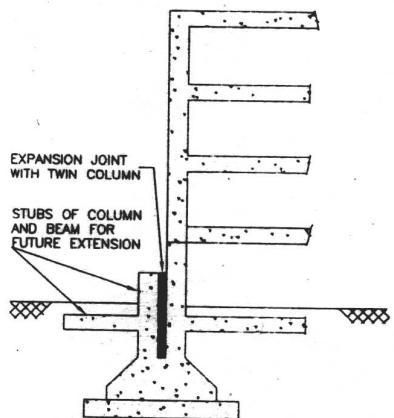


Figure -19 : Future extension of framed structure – provision of expansion joint.

- (b) **Vertical extension:** When making vertical extension to an existing building (that is adding one or more additional floors) work should be proceeded at a uniform level all round so as to avoid differential load on the foundation. In spite of this precaution, however, sometimes cracks appear in the lower floors (old portion) at the junction of RCC columns carrying heavy loads and lightly loaded brick masonry walls due to increase in elastic deformation and creep in RCC columns. Such cracks cannot be avoided.

Renewal of finishing coats on old walls of old portion should be deferred for 2 or 3 months after the imposition of additional load due to new construction so that most of the likely cracking should take place before finish coat is applied thus concealing the cracks.

#### **3.4.16 Rich cement treatment on external walls :**

When it is proposed to give some treatment on external walls of some rich cement based material i.e. artificial stone finish, terrazzo etc., the finish should be laid in small panels with deep grooves in both direction.

### **3.5 Environment**

During construction stage following precaution from environmental consideration should be observed.

#### **3.5.1 Construction in cold weather:**

Work done in cold weather is less liable to shrinkage cracking than that done in hot weather, since movement due to thermal expansion of materials will be opposite to that due to drying shrinkage. Moreover, concrete being strong in compression, can withstand thermal expansion but being weak in tension, it tends to develop cracks due to contraction.

#### **3.5.2 Construction in hot & dry weather:**

Concrete work done in hot weather is highly crack prone due to high shrinkage. It is therefore desirable to avoid concreting when ambient temperature is high.

Concreting done in dry weather is likely to get dried quickly after laying, which would result in plastic cracking. It is, therefore, necessary to take suitable precautions to prevent quick drying. If windy conditions prevail and ambient temperature is high, damaging effect will be much more severe.

#### **3.5.3 Vegetation :**

Following precaution shall be taken in regard to growing or removal of trees in close vicinity of building.

- Do not let trees grow too close to building, compound walls etc. (within a distance of expected height of trees) if any sapling of trees start growing in fissures of walls, etc. remove them at the earliest opportunity.
- If some large trees exist close to a building and these are not causing any problem as far as possible, do not disturb these trees if soil under the foundation happens to be shrinkable clay.
- If removal of old trees within a distance of the height of the tree from the building is unavoidable then these trees should not be removed all at once in one operation, rather removal should be done in stages.
- If from any site intended for new construction, vegetation including trees have been removed and the soil is shrinkable clay do not commence construction activity on that soil until it has undergone expansion and stabilised after absorbing moisture in at least one rainy season.

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## CHAPTER - 4

### COMMON CRACK PATTERNS IN BUILDINGS

**4.0** The commonly observed crack pattern in building can be group as, cracks in :

- **Walls,**
- **RCC members,**
- **Renderings and plasters,**
- **Concrete and terrazzo floors, and**
- **Roof terrace**

Each of these has been covered in this chapter along with preventive measures and feasibility of repairs in specific cases. However, **main emphasis is given on prevention of cracks**, as in many cases there may be no satisfactory method of repairing the cracks after they have appeared.

#### **4.1 Cracks in walls**

Cracks in walls can be further grouped as :

- In masonry structure
- In RCC frame structure
- In free standing walls

##### **4.1.1 In masonry structure:**

Commonly observed cracks in masonry structures are :

**(i) Cracks at ceiling level in cross walls (fig. 6):** In load bearing structures, where a roof slab undergoes alternate expansion and contraction due to temperature variation, horizontal cracks may occur (shear cracks) in cross walls, due to inadequate thermal insulation or protective cover on the roof slab. **To prevent such cracks**, the following measures may be adopted :

- a) Over flat roof stabs, a layer of some insulating material having good heat insulation capacity, preferably along with a high reflectivity finish, should be provided so as to reduce heat load on the roof slab. In Western India, it has been a common practice to lay a layer of broken china in lime mortar over lime concrete terracing which, because of high reflectivity coefficient reduces heat load on the roof and at the same time gives a good wearing and draining surface on the terrace.
- b) **Slip joint** (Para 3.4.9) should be introduced between slab and its supporting wall, as well as between slab and cross walls.

- c) The slab should either project for some length from the supporting wall or the slab should bear only on part width of the wall (fig. 18 & 23). On the inside, wall plaster and ceiling plaster should be made discontinuous by a groove about 10 mm in width.
- (ii) **Cracks at the base of a parapet wall:** An instance of very frequent occurrence of thermal cracks in buildings is the formation of horizontal crack at the support of a brick parapet wall or brick-cum-iron railing over an RCC cantilevered balcony. Factors, which contributes to this type of cracking, are:
  - a) Thermal coefficient of concrete is twice that of brickwork and thus differential expansion and contraction cause of horizontal shear stress at the junction of the two materials.
  - b) Drying shrinkage of concrete is 3 to 4 times that of brick masonry.
  - c) Parapets are generally built over the concrete slab before the latter undergone its drying shrinkage fully, and
  - d) Parapet or railing does not have much self-weight to resist horizontal shear force at its support caused by differential thermal movement and differential drying shrinkage.

The following measures may be adopted **to reduce the severity of such cracking.**

- a) Concrete for slab should be of low shrinkage and low slump.
- b) Construction of masonry over the slab should be deferred as much as possible (at least one month) so that concrete undergoes some drying shrinkage before construction of parapet.
- c) Mortar for parapet masonry should be 1 cement: 1 lime: 6 sand and a good bond should be ensured between masonry and concrete.
- d) Plastering on masonry and RCC work should be deferred as much as possible (at least one month) and made discontinuous at the junction by providing V-groove in plaster. This way the cracks if they occur, will get concealed behind the groove and will not be conspicuous. Alternatively, a 10 cm. Wide strip of metal mess or lathing may be fixed over the junction to act as reinforcement for plaster.
- e) In case of brick-cum-iron railing, cracks could be avoided by substituting the brickwork (of which there are only a few courses) with a low RCC wall, supporting RCC railing.

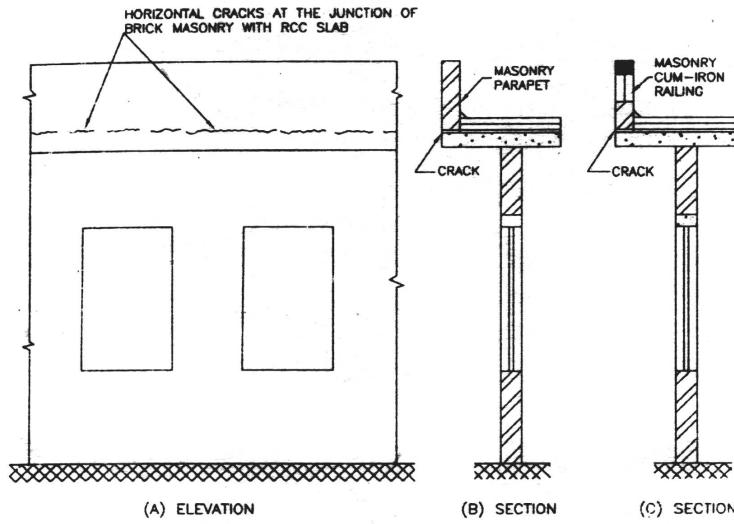


Figure – 20 : Horizontal cracks at the base of brick masonry para-pet (or masonry cum iron railing) supported on a projecting RCC slab.

(iii) **Horizontal cracks in the topmost story below slab level:** These cracks are due to deflection of slab and lifting up of edge of the slab, combined with horizontal movement in the slab due to shrinkage. These cracks appear a few months after construction and are more prominent if the span is large. These cracks are mostly confined to the top most storey because of light vertical load on the wall due to which, end of slab lifts up without encountering much restraint. In the lower stories, lifting of the corners is prevented by the vertical load of the upper stories.

Sometimes horizontal cracks develop in the topmost storey of a building at the corners, due to lifting of the slab at corners on account of deflection of slab in both directions. **These cracks could be avoided** by providing adequate corner reinforcement in the slabs.

When large spans cannot be avoided, deflection of slabs or beams could be reduced by increasing depth of slabs and beams so as to increase their stiffness. Adoption of special bearing arrangement (fig. 18 & 23) and provision of groove in plaster at the junction of wall and ceiling will be of some help in mitigating the cracks.

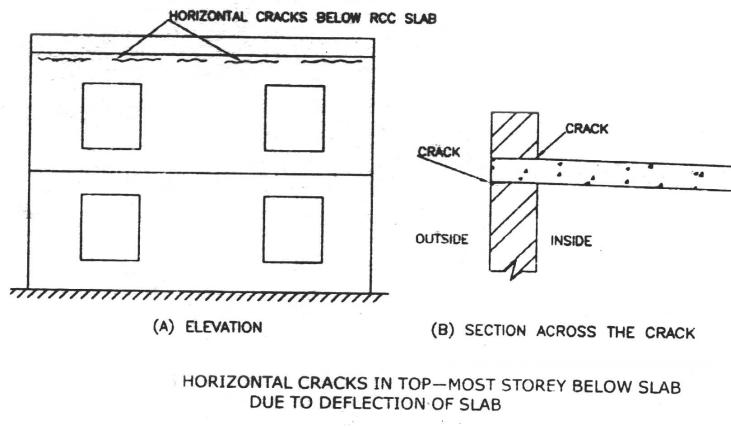


Figure – 21 : Horizontal cracks in top-most storey below slab due to deflection of slab.

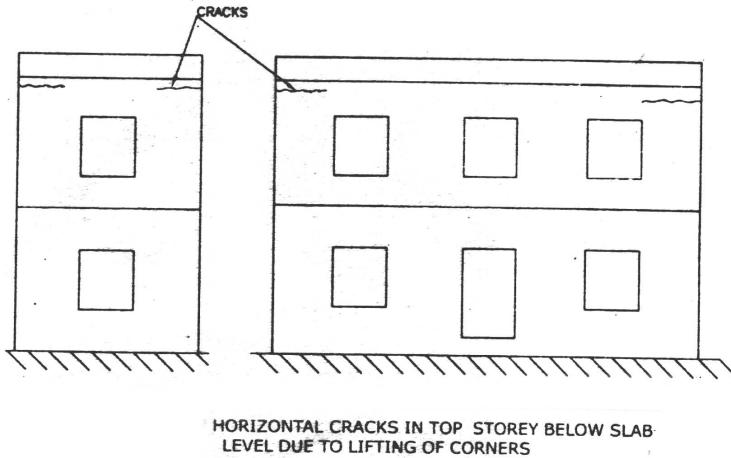


Figure – 22 : Horizontal cracks in top- storey below slab due to lifting of corners.

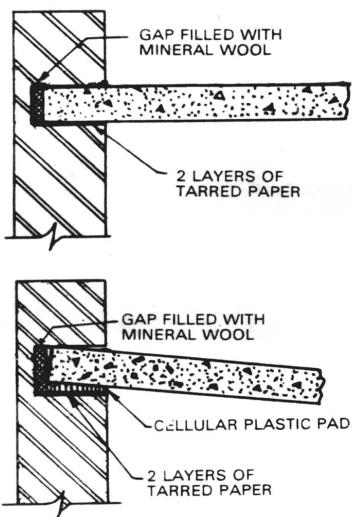


Figure - 23: Details of bearing at the support for a roof slab

**(iv) Diagonal cracks in cross walls of a multi-story load bearing structure:**

These cracks are due to differential strain in the internal and external load bearing walls to which the cross walls are bonded. When walls are unevenly loaded with wide variation in stress in different parts, excessive shear stress is developed which causes cracking in the walls.

Figure 24 shows, a multi story load bearing structure having brick walls and RCC floors and roofs. When the central wall 'A', which carries greater load than external walls 'B' and has either the same thickness as wall 'B' or is not correctly proportioned, it is stressed more than walls 'B'. This results in shear stress in the cross walls, which are bonded to the load bearing walls 'A' and 'B' and causes diagonal cracking as illustrated in figure.

**For prevention of such cracks,** it should be ensured that stress in various walls of a load bearing structure is more or less uniform at the design stage only.

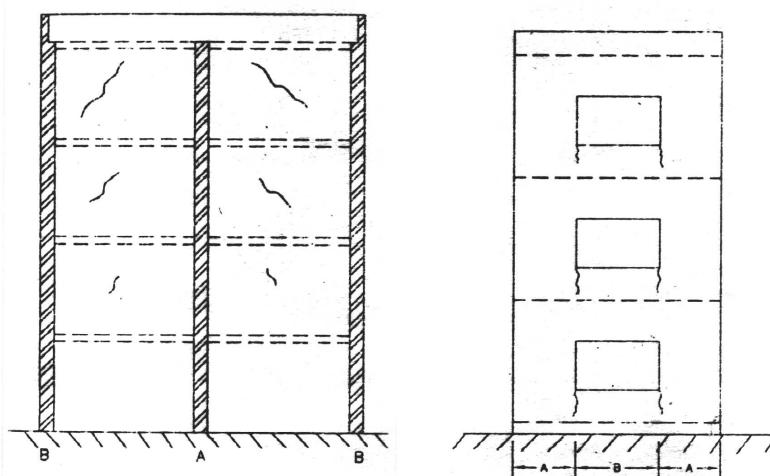


Figure – 24 : Diagonal cracks in cross walls of multi-storey load bearing structure.

Figure – 25 : Vertical cracks in of multi-storey building having window openings in load bearing wall.

**(v) Vertical cracks below openings in line with window jambs:** Elevation of another load bearing multi-storey structure having large window openings in the external walls is shown in Figure 25. It can be seen that portions of wall marked 'A' act as pillars and are stressed much more than the portions marked 'B' below the windows. Thus, as a result of differential stress, vertical shear cracks occur in the wall as illustrated in the Figure.

**To minimize these cracks,** too much disparity in stress in different walls or parts of a wall should be avoided. If RCC lintels over openings and the masonry in plinth and foundation have good shear strength, cracking in question would not be very significant.

#### (vi) Vertical cracks in the top most storey at the corner

These cracks are caused due to shrinkage of RCC roof slab on initial drying as well as due to thermal contraction, exerting an inward pull on the walls in both directions.

**These cracks can be mitigated/prevented** by providing proper movement joint i.e. **slip joint** between slab and supporting walls

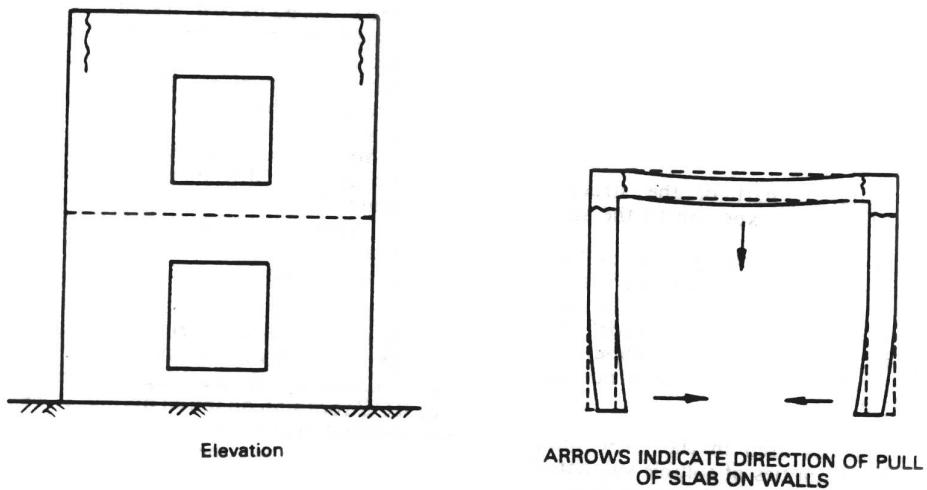


Figure – 26 : Vertical cracks at corners in the top storey of a building due to drying shrinkage and thermal contraction of slab

#### (vii) Vertical cracks around staircase / balconies opening

These cracks are caused due to drying shrinkage/elastic shortening and thermal movement in the building. Generally these cracks are not very conspicuous, and **can be mitigated** by delaying the rendering/plastering so as to allow shrinkage/elastic deformation of masonry/concrete to take place.

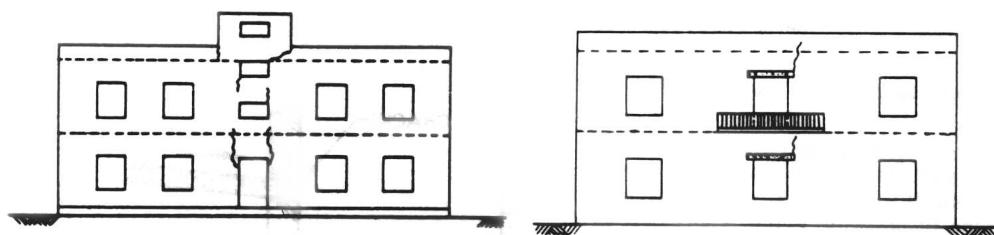


Figure – 27 : Vertical cracks in the external wall around staircase openings in a long building.

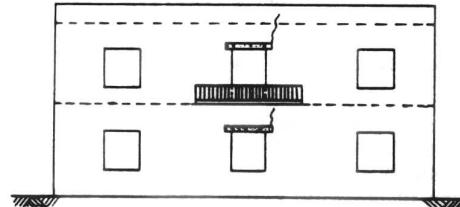


Figure – 28 : Cracks in external wall around RCC balcony

#### (viii) Vertical cracks in the side walls at the corner of long building :

These cracks are mainly due to thermal expansion, aggravated by moisture expansion of brickwork and are notice during hot weather. Chances of such cracks are more in the building constructed in cold weather.

These cracks starts from DPC level and travel up-ward, and are more or less straight and passes through masonry units. **These cracks can be mitigated/prevented** by providing movement joints as per guidelines given in chapter 5.

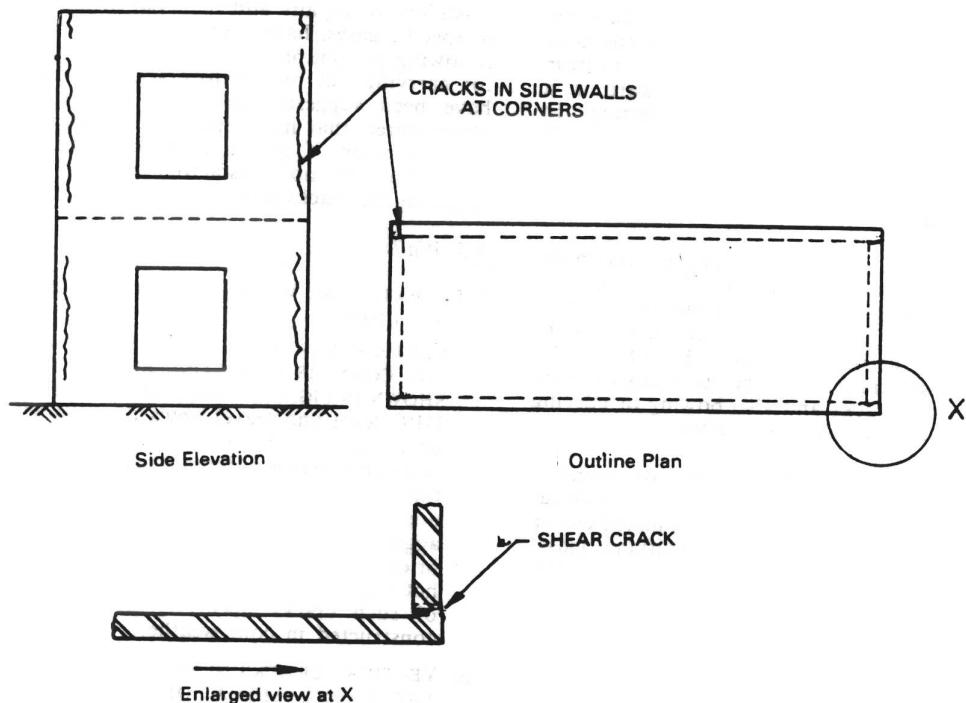


Figure – 29 : Vertical cracks at corners in the side walls of a long building due to thermal movement

#### (ix) Horizontal cracks at lintel/sill level in top storey :

These cracks are caused due to pull exerted on the wall by the slab on account of drying shrinkage and thermal contraction. Such cracks generally occur when window and room spans are large. **These cracks could be prevented** by providing **slip joint** at supporting walls.

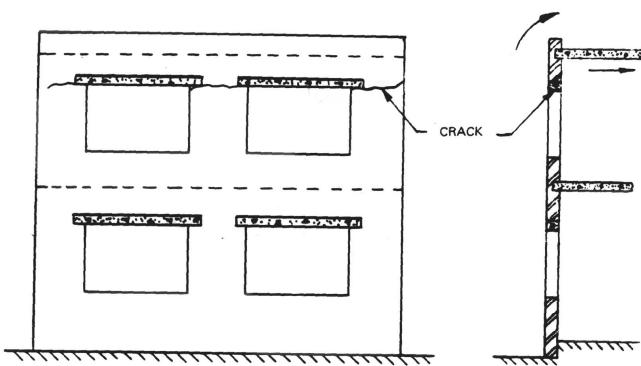


Figure – 30 : Horizontal cracks at window Lintel level in top most storey

**(x) Diagonal cracks over RCC Lintels spanning large opening :**

These cracks are caused due to drying shrinkage of in-situ RCC Lintel and are observed during the 1<sup>st</sup> dry spell after construction. **These cracks could be prevented** by using low shrinkage and low slump concrete or using pre-cast lintels.

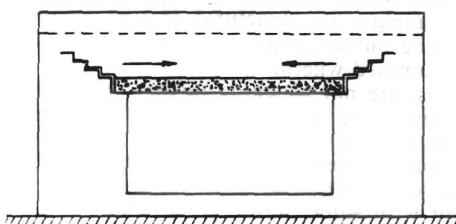


Figure – 31 : Diagonal cracks in brick masonry wall over Lintel of long span openings.

#### 4.1.2 RCC Framed Structures :

- (i) **Cracking of panel walls:** The external non-load bearing walls in a framed structure are termed as panel walls.
  - (a) **Horizontal cracks :** Brick panel wall of a framed structure supported on a beam and built right up to the soffit of the upper beam. Due to shortening of columns, caused by elastic deformation, creep and drying shrinkage, or due to comparatively greater deflection of upper beam under heavy loads, wall is subjected to a Large compressive force, with the result that it gets buckled. and horizontal flexural cracks occur as illustrated in Figure 32.

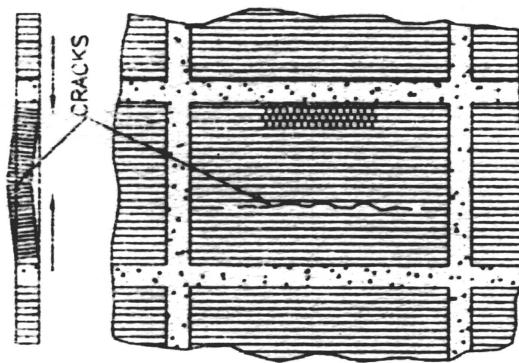


Figure – 32 : Horizontal cracks in brick panels of a framed structure.

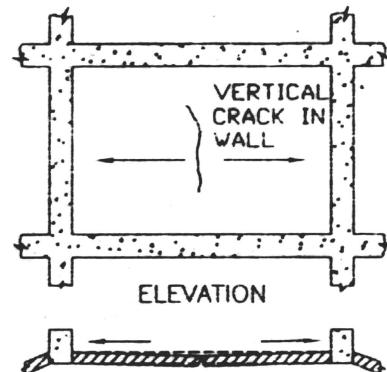


Figure – 33 : Vertical cracks in brick panel of framed structure.

These cracks generally become apparent a few years after construction and are accompanied by bowing of the walls. Likelihood of damage due to these cracks is more if time interval between casting of the frame and building up of masonry wall has been small.

- (b) **Vertical Cracks:** In case of long panels built tightly between RCC columns brick work may get compressed due to thermal and moisture expansion and buckle, thus developing vertical cracks as shown in figure 33.
  - (c) **Remedial Measures:** To remedy these cracks, force in the panel should be relieved by opening out the horizontal joint between the top of the wall and the soffit of the beam and filling the joint with some joint filling compound. If damage is extensive and bowing is very conspicuous, rebuilding of panel wall may be necessary.
- (ii) **Cracking of partition walls:** The internal non-load bearing wall in a framed structure is generally termed as partition walls. Due to excessive deflection of support, masonry partition walls may crack. Location and pattern of cracks depend upon the length-to-height ratio of the partition and position of door opening in the partition as described below.

**(a) Length to height ratio of Partition Is large (Fig. 34)**

**Case – A : There is no opening:** Due to deflection in the floor, middle portion of the partition loses support and because of large length to height ratio, load of the partition gets transferred to the ends of the supports mostly by beam action. Thus, horizontal cracks occur in masonry at the support or one or more courses above the supports as illustrated in Figure. Also vertical cracks appear near the bottom in the middle of the partition due to tensile stress, because of bending. These vertical cracks can be quite significant if the partition is built up to the soffit of the upper floor slab or beam and some load is transmitted to the partition due to the deflection of the latter. Shortening of the columns supporting the floor due to elastic strain, creep and shrinkage, often aggravates the cracking of the partition.

**Case B - There is a central opening:** In this case, diagonal cracks occur because of combined action of flexural tension in the portion of masonry above the opening and self-weight of unsupported masonry on the Sides of the opening. Cracks start from lintels where they are widest and get thinner as they travel upward.

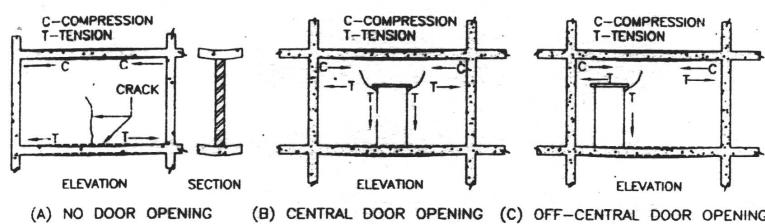


Figure – 34 : Cracking in a partition wall supported on RCC slab/beam when length to height ratio of partition is large.

**Case C - Opening is off center:** In this case, diagonal cracks occur due to combined action of flexural tension in the portion of masonry above the opening and horizontal tension in the unsupported portion of masonry on the side of the opening due to loss of support in the middle. It is important to note that a partition with off-center opening is more prone to cracking than the one with central opening.

**(b) Length to height ratio of partition is small (Fig. 35)**

**Case A - There is no opening :** In this case, self load of the partition is transmitted to the ends of the support, mainly by arch action and horizontal cracks occur at some height from the support because of tension developed due to self weight of unsupported portion of partition in the central region. There is not much of beam action in the partition due to small length to height ratio.

**Case B - There is a central Opening:** Horizontal cracks appear in this case in the fewer portion of the partition, mainly because of tension due to self-weight of unsupported masonry on the sides of the opening.

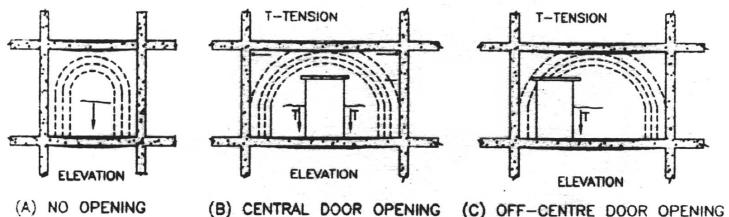


Figure – 35 : Cracking in a partition wall supported on RCC slab/beam when length to height ratio of partition is small.

**Case C - Opening is off center:** In this case, crack is mainly due to tension caused by self load of unsupported masonry on one side of the opening. There is not much of beam action in this case.

**(i) Preventive Measures:** Though it may not be possible to eliminate cracking altogether, following measures will considerably help in minimizing cracks in panel walls and partitions in RCC frame structures.

- When brick masonry is to be laid abutting an RCC column, brickwork may be deferred, as much as possible.
- Masonry work on RCC slabs and beams should not be started till at least two weeks elapsed after striking of centering.
- As far as possible, full framework should be completed before taking up masonry work of cladding and partition, which should be started from top storey downward.
- Provide horizontal movement joint i.e. telescopic anchorage between top of brick panel and soffit of beam.

**Telescopic Anchorages :** Horizontal- expansion joint about 10 mm in width should be provided between top of panel or partition walls. The gap should be filled up with a mastic compound finished with some sealant or filled with weak mortar up to a depth of 3 cm on the external face and left open on the internal face. When structurally necessary, lateral restraint to the wall at the top should be provided by using telescopic anchorage as shown in Figure.

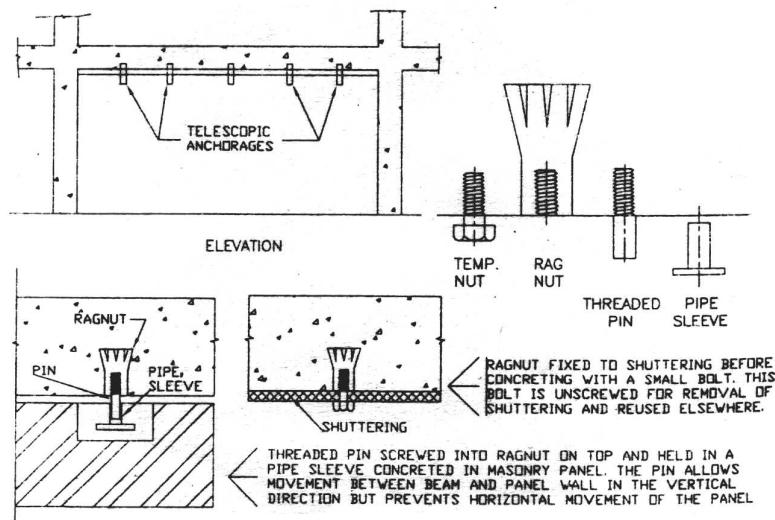


Figure – 36 : Telescopic anchorage for panel walls.

- Provide upward camber in floor slab and beam so as to counter act deflection.
- Provide central door opening in preference to off center opening.
- Provide horizontal reinforcement in masonry partitions, which have length-to- height ratio exceeding 2. In case of panels longer than 5 - 8 m, either provide a groove in the plaster at the junction of RCC column and brick panel, or fix a 10 cm wide strip of metal mesh or lathing over the junction before plastering. The reinforced strip of plaster can accommodate differential movement elastically without cracking to some extent.

#### 4.1.3 Cracks In free standing Walls:

Following types of cracks are generally encountered in freestanding walls, i.e. compound, garden or parapet walls.

- i. Vertical cracks at regular intervals of 5 to 8 m and at change of direction may be due to drying shrinkage combined with thermal contraction. Cracks tend to close in hot weather. If wide enough, cracks may be repaired by enlarging them and filling the same with weak mortar (1 cement, 2 lime, 9 sand). If no expansion joints have been provided earlier, some of the cracks may be converted into expansion joints.

- ii. Diagonal cracks, which are tapering and are wider at the top, are due to foundation settlement. If cracks are wide enough to endanger the stability of the wall, affected portion should be dismantled and rebuilt providing adequate foundation.
- iii. Diagonal cracks, which are tapering and are wider at the bottom, may be caused by the upward thrust exerted by the roots of any trees and plants that may be growing in the vicinity of the wall.
- iv. Arching up and cracking of the coping stone of a parapet or compound wall (Fig. 8) happens if the wall is built between two heavy structures, which act as rigid restraints, and no expansion joints have been provided in the coping stone. Remedy for this defect lies in relaying the affected portion of coping and providing expansion joint at suitable intervals.
- v. Horizontal Cracks in the bed joints of free standing walls, if the same occur two or three years after construction and the wall in question has been subjected to periodic wetting for long spells, may be due to sulphate action. This should be confirmed by chemical test. of mortar and bricks. There is no effective remedy for these cracks and the damaged portion has to be rebuilt when it becomes unserviceable, taking other precautions for preventing recurrence of sulphate attack.

#### **4.1.4 General measures for repairing cracks in masonry walls:**

Main purpose of carrying out repairs to cracks in walls is to :

- (a) Restore normal appearance.
- (b) Minimize the possibility of cracks causing further damage to the building.
- (c) To ensure that the building is serviceable and safe.

Before carrying out any repairs to cracks, it should be examined whether the cracks have stabilized and are not widening any further. Walls which are not more than 25 mm out of plumb, or which do not bulge more than 10 mm in a normal storey height, would not generally require repairs on structural ground. Cracks due to thermal movement generally reoccur when repaired with mortar; therefore such cracks should be filled with some mastic compound.

- (i) **Cracks up to 1.5 mm in width** generally, need no repairing if bricks used are of absorbing type, as is normally the case in India. In case of non-absorbent bricks, there is a possibility of rainwater penetrating through the thin cracks, hence it needs repair even in thin cracks. The cracked joints should be raked out and filled with 1:1:6 (cement, lime, sand) mortar.
- (ii) **Cracks wider than 1.5 mm** generally needs repairing & method depends on the type of mortar used in the brickwork.
  - (a) **With weak mortars**, the cracks should be enlarged and raked out to a depth of about 25 mm and refilled with 1:2:9 (cement, lime, sand) mortar and repainted or re-plastered (10 cm wide strip around crack) with the same mortar.

- (b) **With strong mortar**, bricks adjoining the crack should be cut out and replaced with new bricks using 1:1:6 (cement, lime, sand) mortar. The same procedure should be followed if the bricks are cracked.
- (iii) **Wide diagonal cracks**, which generally occur due to settlement of foundation, if there is a possibility of further movement, repairs should be carried out by removing and replacing all cracked bricks. RCC stitching blocks should be used in every 5<sup>th</sup> or 6<sup>th</sup> course, that is, at about 0.5 m spacing in the vertical direction. The stitching block in width should be equal to the thickness of the wall, in length equal to half to 2 bricks and in thickness equal to 1 or 2 bricks. It is not desirable to use mortar stronger than 1:1:6 (cement, lime, sand) for these repairs.

#### 4.2 CRACKS IN RCC MEMBERS

- (i) **In exposed members (Sunshades, Balconies, etc.):** Drying shrinkage of concrete combined with thermal contraction results in formation of straight cracks in sunshades, balconies, open verandahs, etc. across the length at regular intervals of 3 to 5 m and also at changes in direction. These cracks occur due to non-provision of proper control/expansion joints. Cracks will be widest in winter and may lose partially in summer. Job executed in summer are more prone to such cracks and, there is no effective remedy for these. Sometimes it may be possible to introduce a control joints at cracked sections by sawing across the section.

**These cracks can be prevented by :**

- (a) Adequate provision of temperature reinforcement i.e. 50% to 100 % more of the minimum amount depending upon severity of exposure, size of member & local condition.

This reinforcement is more effective if bars are small in diameter and closely placed.

- (b) As these are liable to large deflection under load, removal of centering and imposition of load should be deferred as much as possible so that concrete attains sufficient strength.
- (c) **Expansion joints** should be provided at about 6 m interval. A typical expansion joint in sunshade is shown in Figure 37.

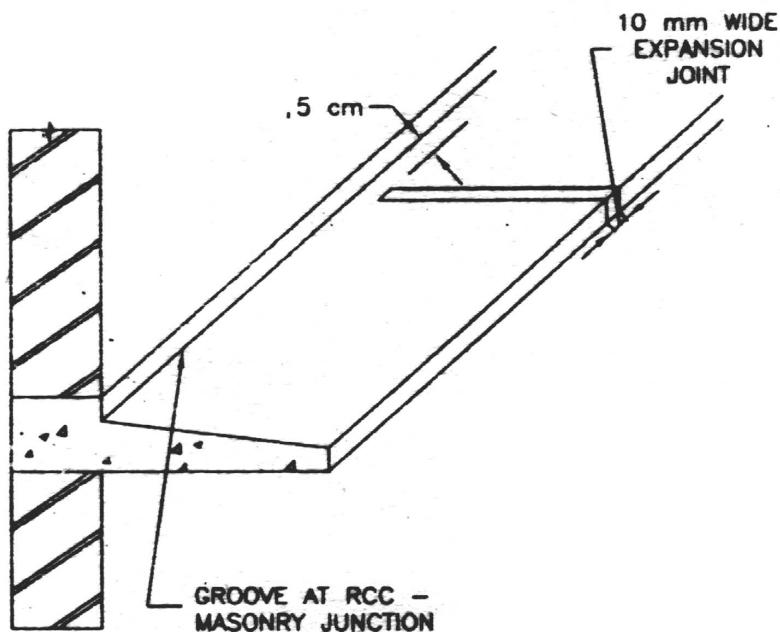


Figure – 37 : Expansion joints in long sun-shade.

- (ii) **Cracks in RCC members due to corrosion of re-inforcement :** Corrosion of reinforcement results in straight cracks in concrete column, beams and slabs parallel to re-inforcement accompanied by spalling of cover and exposure of re-inforcement at places, cracks occurs 10 to 25 years after construction. These cracks would occurs if concrete in question is not sufficiently dense and moisture from some source is causing dampness in the affected portion. .

If corrosion is not severe, it can be repaired by removing all loose and damage concrete, cleaning reinforcement and re-concreting the affected area by guniting.

#### 4.3 CRACKS IN RENDERING AND PLASTERING

- (i) **On Masonry background:** Cracks in plaster should be examined, if necessary, by removal of small portion of plaster, whether these are surface cracks or these extend to the background masonry surface also. In the latter case, it is necessary to investigate the cause of cracks in the background material.

If these are surface cracks, these could be due to :

- (a) Shrinkage because of use of rich mortar & inadequate curing –  
It occurs during 1<sup>st</sup> dry spell after construction.
- (b) Lack of bond With the background due to joints not being raked -  
Gives hollow sound on tapping the affected area.

## (c) Sulphate attack –

Appears after 2 to 3 years after completion if the affected area remains damp for long spell.

**For prevention of such cracks,** the precautions given in chapter 3 shall be observed at construction stage.

**Remedial Measures:**

- Shrinkage cracks are generally thin and could be left as such up to the normal time for renewal of finishing coat of paint & distemper. The surface should then be thoroughly rubbed with emery paper No. 60 or 80 and thereafter two coats of paint may be applied, when the shrinkage cracks will get filled up.
- To repair cracks due to lack of bond, affected portion of plaster should be removed, joints in masonry raked to a depth of 10 mm and re-plastering done taking all precautions as required for a new plaster job.
- To repair cracks due to sulphate attack, source. of dampness should be plugged. If mortar has become weak and un-serviceable, the affected portion should be re-plastered using sulphate resistant cement after removing all old mortar and raking joints in masonry.

(ii) **On concrete background:** Shrinkage cracks occur due to the following causes.

- Mortar used being too rich or wet,
- Curing has been inadequate,
- Sand used is too fine, and
- Rendering and plastering is done too long after casting of concrete.

**For prevention of such cracks,** plastering should be done as soon as feasible after removal of shuttering, by hacking and roughening the surface and applying cement slurry on the concrete surface to improve bond.

**(iii) Cracks around door frames:**

These cracks occurs due to:

- Shrinkage of wood frames if the wood is not properly seasoned.
- Door/window frames fitted flush with the wall/plaster surface.
- Due to slackness between the hold-fasts and frames – Heavy vibrations causes crack in masonry and plaster due to repeated opening and closing of doors.

Cracking due to in-proper seasoning can be concealed with the help of architrave, however for repair the cracks due to slackness in hold-fast masonry is to be dismantled to remove the frame and re-fixing it after securely fastening the hold-fasts to the frame.

When the doors/windows are provided in half brick masonry wall, hold-fast should be at least 25 cms. In length and should embedded in 1:2:4 concrete, in 2 –brick courses in height and 1½ brick in length.

**To prevent such cracks**, as far as possible, door and window frames should not on either side be fitted flush with wall/plaster surface. Where unavoidable, either conceal the junction with architrave or provide the frame of shape and design as shown in figure 38.

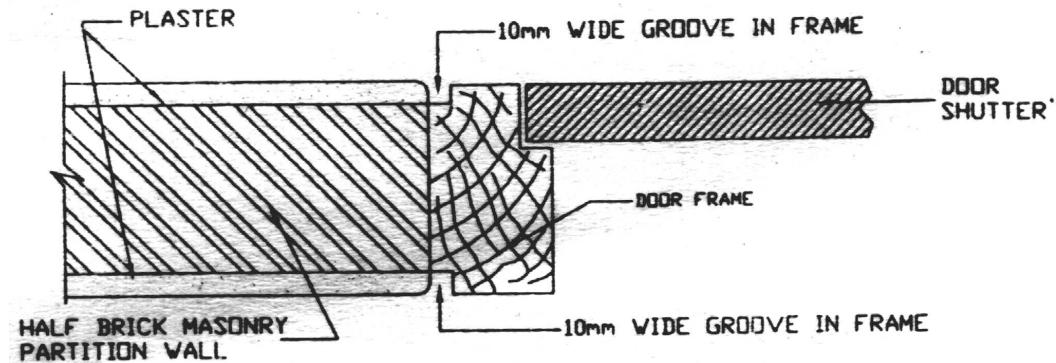


Figure 38 : Arrangement showing fixing of door frame flush with wall surface.

#### 4.4 CRACKS IN CONCRETE AND TERRAZZO FLOORS

Cracks in the floors can be avoided to large extent by taking preventive measure as elaborated in chapter – 3. Inspite of these precautions some times cracks develops in floor as under:

- (i) **Crazing** : Inspite of the precautions, sometimes the floors develop very fine cracks of map pattern known as crazing. These cracks appear soon after construction and are due to use of excessive water in the concrete / terrazzo mix, poor grading of aggregates, quick drying after laying, or inadequate curing.

There is no effective remedy for such cracks once they appear. The affected portion has to be replaced when it becomes unserviceable.

- (ii) **Corner Cracks**: Corner cracks in panels of concrete flooring occur because of curling up of corners due to differential shrinkage between the top and bottom of the slab. When load comes on the floor, curled up corners give way and develop cracks due to tension on the top.

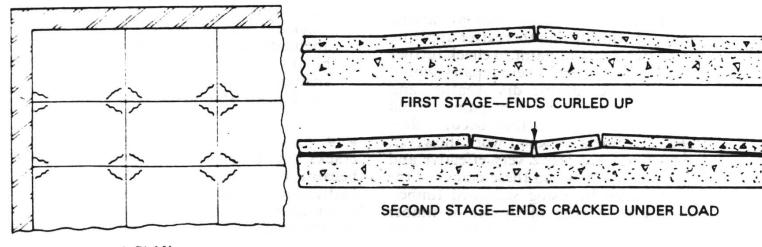


Figure – 39 : Corner cracks in panels of concrete flooring

Differential shrinkage in floor panels occurs due to use of excessive water in concrete or excessive trowelling, and fines working up to the top during the process of tamping and trowelling. There is no effective remedy against such cracking; the affected portion when it becomes unserviceable has to be replaced.

- (iii) **Cracking of floor in deep filling:** Sometimes it is necessary to construct a building on a site, which is low, and deep filling (more than 1 m) is required under the floors in the plinth. If this filling is not well compacted, in course of time moisture or water from some source, for example, heavy rains or floods, leaky water supply mains, etc. may find its way to the filled up soil. That may cause settlement of soil and cracks in floors.

**For prevention of such cracks,** soil used for filling should be free from organic matter, brickbats and debris. Filling should be done in layers not exceeding 25 cm in thickness and each layer should be watered and well rammed.

When a floor is required to take heavy loads as in grain godowns, warehouses industrial buildings, it is necessary to do filling in 25 to 30 cm layers with soil containing optimum moisture content. Every layer of soil should be compacted to 95 percent proctor density with the help of road milers. Specifications for flooring should also be for heavy duty loading.

#### 4.5 Cracks in roof terrace

Cracks in roof terrace generally result in leakage of rainwater through roof and are a matter of common occurrence. As terrace is very much exposed to weather, cracking occurs along the parapets at the junction and also at intermediate sections in long stretches. The main cause of cracking being the thermal and moisture movements.

Remedial measures for these cracks are enlarging and cleaning the cracks and filling them with mastic compound so as to seal the cracks without hindering future movement. If these cracks are repaired with cement mortar, in course of time cracks will reappear and no useful purpose will be served.

Cracks at junction of roof terrace and parapets could be **prevented/minimized** by adopting special junction arrangement.

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## Chapter - 5

### PROVISION OF MOVEMENT JOINT IN STRUCTURES

Movement joints in structure are introduced so that unduly high stresses are not created in any part of a structure and to avoid unsightly cracks. When the joints permits expansion as well as contraction it is termed as **expansion joint**, when it allows only contraction it is termed as **control joint**, and when the joint permits sliding movement of one component over another it is termed as **slip joint**.

**Expansion joint** : It consists of pre-plan break in the continuity of structure or a component with a gap of 6 to 40 mm wide, the gap in some cases is filled with a flexible material with gets compressed under expansive force & stretched under a pulling force. To avoid possibility of rainwater penetrating through the joint, water bar, sealant or a protective cover is provided on the joint.

**Control joint** : It consists of straight butt joint without any bond at the interface, formed by laying concrete in alternate panels or by providing a strips of a materials which do not develop much bond with concrete i.e. glass, aluminium, plastic in grid form.

Dummy joint is another form of control joint consisting of a weaken section of the member at the joint (2/3 of the total thickness of member). It is provided either by leaving a groove at the time of laying of concrete or by mechanically forming a groove after laying of concrete.

**Slip joint** : It is intended to provide sliding movement of one component over another in a plane at right angles to the plane of another with minimum restraint at the interface. It is formed by applying a layer of plaster on one of the surface and finishing it smooth before casting of another, or by adopting any other approved suitable method.

#### 5.1 GENERAL GUIDE FOR PROVISION OF MOVEMENT JOINTS IN BUILDINGS

S. No. (1)	Particulars (2)	Movement joint and other measures (3)
(i)	<b>Load bearing structure</b> <ul style="list-style-type: none"> <li>a) Building with flat roof having cross walls at intervals as in residences, hostels, hospitals, office buildings, business premises, schools etc.</li> </ul>	<p>Provide vertical expansion joints 20 to 40 mm wide, 25 to 40 meter apart. For this purpose, introduce twin walls or a wall and a beam or twin beams at the expansion joints. Joints should start from DPC level and should be through walls as well as floors, roof and parapet. In RCC roof slab, provide additional expansion joints such that length of a slab does not exceed 15 to 20 meter. It is necessary to locate some expansion joints at change of direction and at sections of substantial change in height of a building, concealing the joints in recesses where feasible. When blocks of buildings such as residential flats are built in continuous rows, expansion joints should be provided at junctions of blocks as shown in figure 41d.</p>

	b) Buildings of ware house type or factory buildings with flat roof having no or very few cross walls.	Provide vertical expansion joints 20 to 40 mm wide at 20 to 30 meter intervals with twin beams at the joints. In case pillars or columns are provided in a building to support the beams, it will be necessary to provide twin pillars/columns at the joints. If walls are panel walls between columns which supports roof beams, vertical expansion joint should be provided 25 to 40 meter apart as in (I)a above.
	c) Buildings of ware house type or factory buildings having sloping roof with sheets or tiles on trusses.	For expansion of walls in the longitudinal direction, expansion joint should be provided as in i (b) with either twin trusses at the joints or single truss on one side of the joint and slotted holes in purlins resting over the truss, to allow for movement in the longitudinal direction. No joints are required in roofing sheets and other purlins since slide play in bolt holes is enough to take care of thermal movements in these items. For steel trusses with riveted joints, no provision for movement of trusses in the transverse direction for spans up to 15 meter is necessary as slight play in riveted joints allows for necessary movements. For spans between 15 & 25 meter in case of riveted trusses and spans up to 25 meter in case of welded trusses, one end of the truss should be fixed and the other end should have slotted holes with a slip joint at the support to allow for transverse movement. Trusses exceeding 25 meter in length should have roller and rocker bearing arrangement.
	d) RCC roof slab having adequate thermal insulation on top.	In hot and dry regions like north India where variation in temperature are more than $15^{\circ}\text{C}$ , provide expansion joints in slabs 20 to 25 mm wide and 15 to 20 meter apart. Where variations in temperature less than $15^{\circ}\text{C}$ , additional joints apart from those of i (a) are not needed.
	e) RCC roof slab having no or very little thermal insulation or protective cover on top.	Provide expansion joints in slab 10 to 15 meter apart.
	f) Supports for RCC slabs exceeding 4 to 6 meter length.	Provide slip joint between the slab and the bearing wall, keeping a gap of about 12 mm width between slab and brick cover (Fig. 18,23 & para 3.4.9).
ii	<b>RCC framed structures</b> a) RCC framed structure	Provide vertical expansion joints 25 to 40 mm wide at 30 to 45 m interval. Joints should be provided by introducing twin columns and twin beams, twin columns having combined footing. It is necessary to locate some expansion joints at change of direction and at sections of substantial change in height of a building concealing the joints in recesses, where feasible (fig. 41). Roof slab should have adequate thermal insulation on top.
	b) Panel walls for cladding.	Provide a horizontal expansion joint about 10 mm in width between the top of panel and soffit of beam. This gap may be filled up with mastic compound finished with some sealant or filled with weak mortar up to a depth of 3 cm. on the external face and left open on the internal face. If structurally necessary, lateral restraint to the panel at the top should be provided by using telescopic anchorage. (fig. 36)

		In case of panels longer than 5 to 8 meter, either provide a groove in the plaster at the junction of RCC column and brick panel, or fix a 10 cm wide strip of metal mesh or lathing over the junction before plastering. The reinforced strip of plaster can accommodate differential movement elastically, without cracking, to some extent.
	c) Masonry partitions	Provide horizontal expansion joints as in (ii) (b).
iii	<b>Junction between old and new structures</b>	Provide vertical slip joints or expansion joints, depending upon the length of the old new portions; make suitable arrangement for preventing seepage of rain water in to the joint from top and sides.
iv	<b>Long masonry compound walls</b>	Provide vertical expansion joints 5 to 10 mm wide at 5 to 8 meter interval from grade level up wards ; also provide expansion joints at changes of direction; provide additional control joints in coping stones mid way.
v	<b>Concrete pavements</b>	Provide expansion joints 20-25 mm wide at 25 to 40 meter interval together with control joints at 5 to 8 meter interval, depending on thickness of pavements extent of temperature variation anticipated, and local conditions. Thinner the pavement, closer the spacing of control and expansion joint. Joints are needed both in longitudinal and transverse direction. In the transverse direction, a spacing of 3 to 5 meter for control joint is generally adopted, depending upon the size of construction equipment available; control joints normally functions as construction joint as well. As far as possible, panel should be squarish in shape- length to breadth ratio should not exceed 1.5. Incidence of shrinkage cracking in panels, which are rectangular in shape, is comparatively more than that of square panel.
Vi	<b>Misc. components/ locations</b> a) RCC sun-shades	Provide expansion joints 5 to 8 mm wide and 4 to 6 meter apart; joint should be only in the exposed portion, i.e. projected portion; some joints should in variably be located at change of direction, reinforcement should not be continued through the joint. It is not necessary to fill the joint with any jointing material.
	b) RCC facia	Provide expansion joint as in vi (a).
	c) RCC balcony	Provide vertical expansion joints 8 to 12 mm wide and 6 to 9 meter apart, with water bar, filled with mastic compound.
	d) RCC railling	Provide expansion joint 5 to 8 mm wide 6 to 9 meter apart.
	e) Open varandah with RCC slab floors/roof	Provide vertical expansion joints in slabs (parallel to the span) 10 to 15 mm wide and 6 to 9 meter apart; joints should be located at the centre of supporting pillars; joints may be filled with mastic compound and V-grooved at the bottom and suitable arrangement made at the top to prevent leakage of water through the joint. (fig. 43)
	f) Brick tiling over mud phuska for roofing terracing.	Brick tiles should be laid with joints 8 to 10 mm wide, grouted with mortar. 1 cement : 1 lime : 6 sand; no expansion joints are required.
	g) Lime concrete terrace over roof slab.	Provide 10 to 15 mm wide dummy joints, 4 to 6 m apart; fill the joints with some mastic compound.

	h) Pre-cast concrete slabs over lime concrete terracing.	Size of slabs should be 0.6 to 0.75 meter square and these should be laid in lime mortar with 10 mm wide expansion joints. 4 to 6 meter apart in both direction; joints should be filled with some mastic compound.
	i) Concrete/terrazo flooring.	Provide control joints 1 to 2 meter apart; alternatively, provide strips of glass, aluminium or some plastic material at 0.75 to 1.20 meter interval in both directions; joints strips are required mainly to prevent shrinkage cracks. When laying floor over an RCC structural slabs, ensure good bond (roughening it by hacking if necessary) and priming with cement slurry. Alternatively provide a lime concrete base course 5 to 7.5 cm thick over the structural slab.
	j) Plaster work.	Joints in brick masonry should be raked to 10 mm depth while mortar is green. Plastering should be done after masonry has been cured and dried.  At the junction of wall & ceiling provide a groove in plaster about 10 mm in width as shown in figure 18. When plastering over long masonry walls, abutting RCC columns, either give a vertical groove in plaster at the junction or embed in plaster over the junction a 10 cm wide strip of metal mesh or lathing as in item (ii) (b).  Sometimes longitudinal cracks occurred in plaster along conduits/pipes embedded in chases in masonry. To avoid these cracks, conduits/pipes should be placed at least 15 mm below the wall surface and embedded up to wall surface in concrete 1:2:3, cement, sand, coarse aggregate using well graded coarse sand and 6 mm and down graded coarse aggregate. Concrete surface should be finished rough and plastered over after 7 days or more at the time of general plastering of the wall.

### Note

- i) For more detail "Code of practice for design and installation of joints in building" IS-3414 : 1968 shall be referred.
- ii) For seismic zones III, IV & V, expansion joints have to be much wider for which IS:4326-1976 "Code of practice for earthquake resistant design and construction of building (revised) should be referred.

### 5.2 Some typical expansion joint arrangements

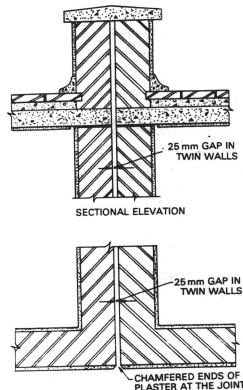


Figure 40 : Expansion joint in slabs supported on twin walls.

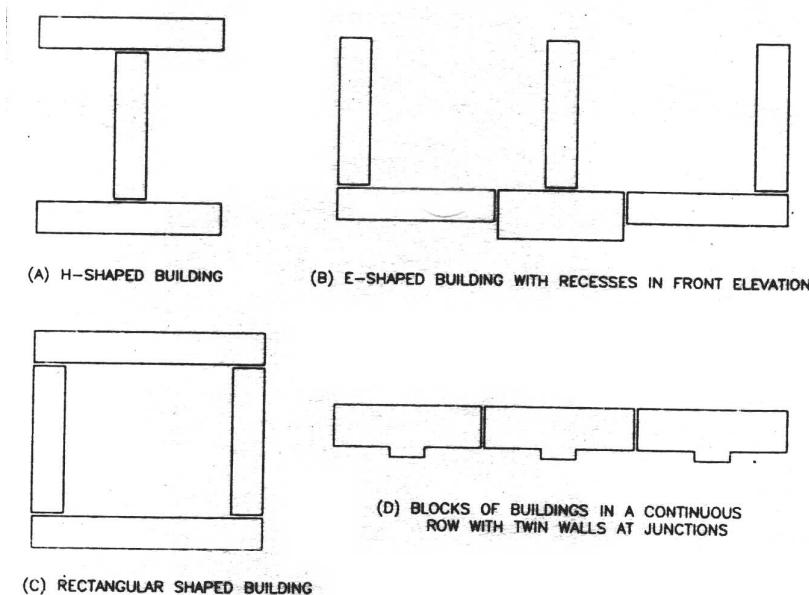


Figure 41 : Location of expansion joint at change of direction, in recesses and at junction of blocks

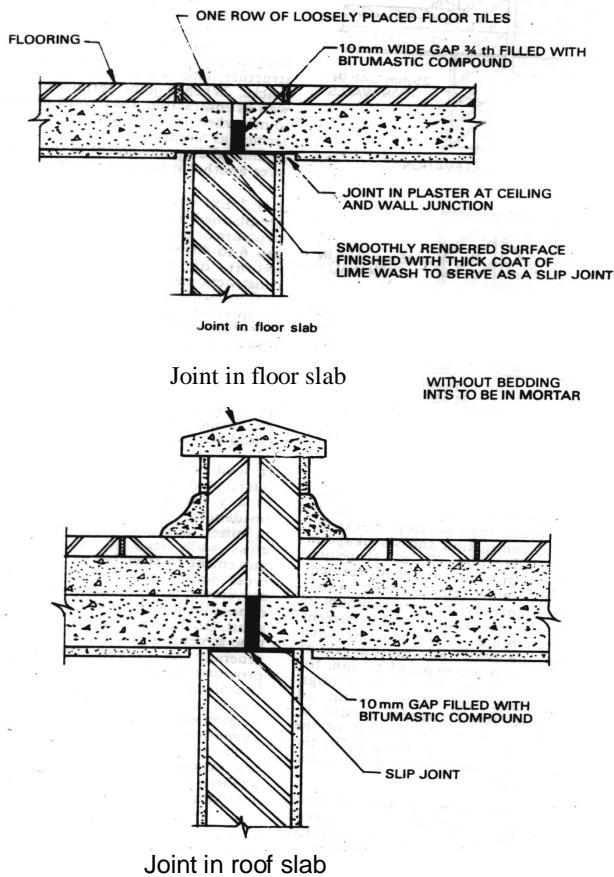


Figure 42 : Expansion joint in RCC slabs supported on intermediate walls.

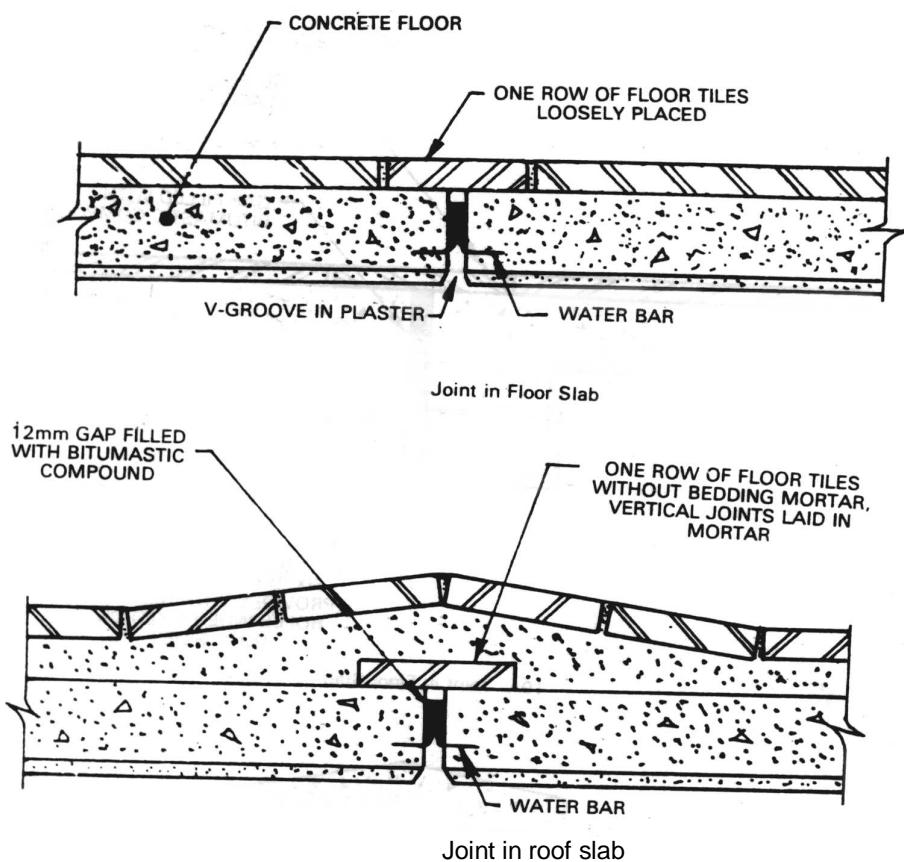


Figure 43 : Expansion joint in RCC slab of long open varandahs supported on twin walls.

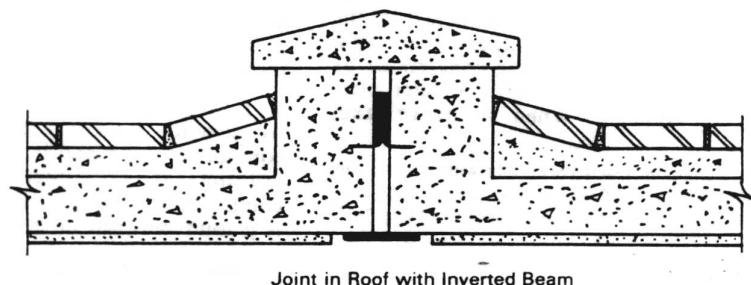
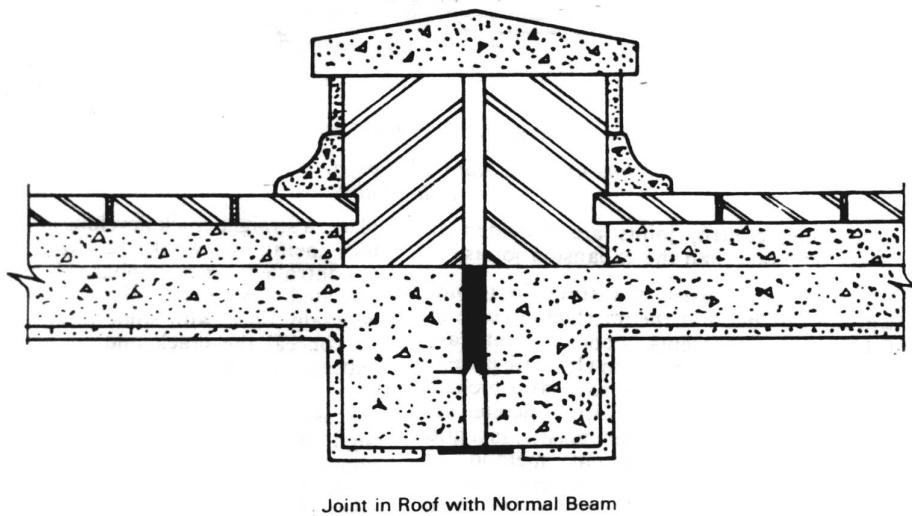
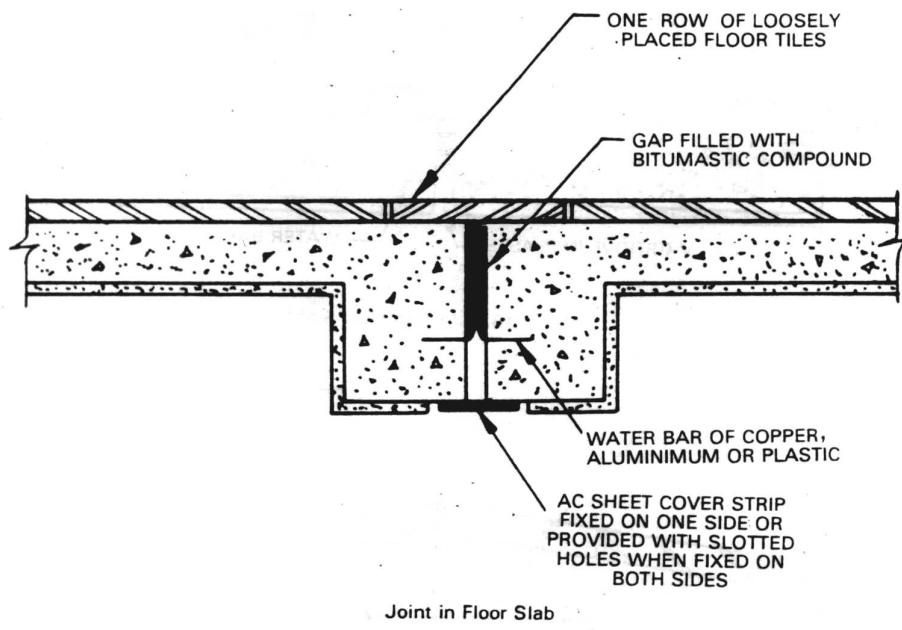


Figure 44 : Expansion joint in RCC slab with twin beams (Continued).

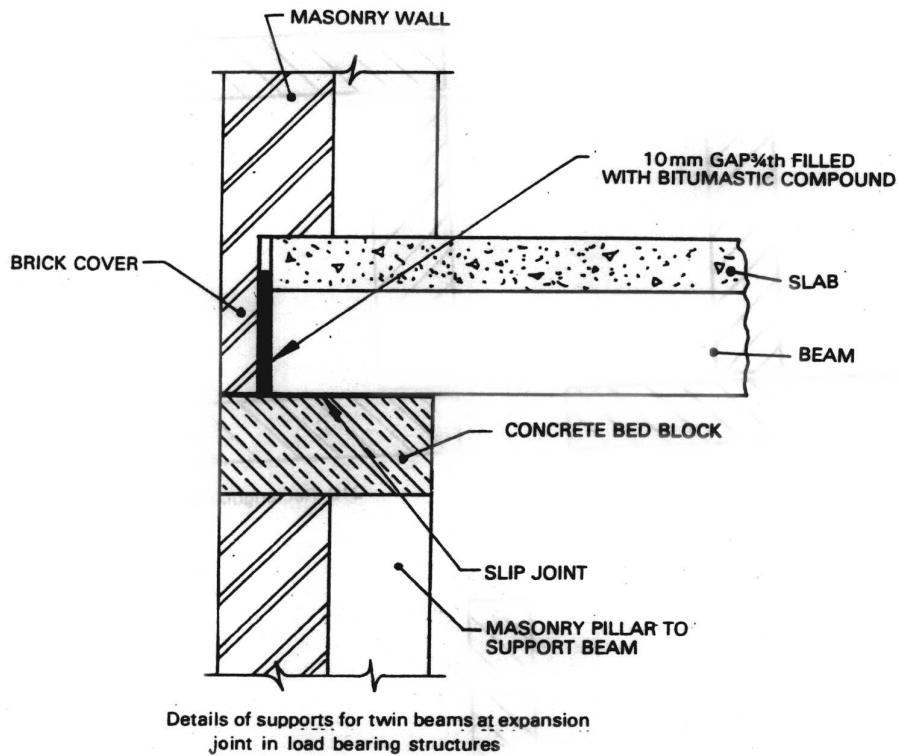


Figure 45 : Expansion joints in RCC slabs with twin beams.

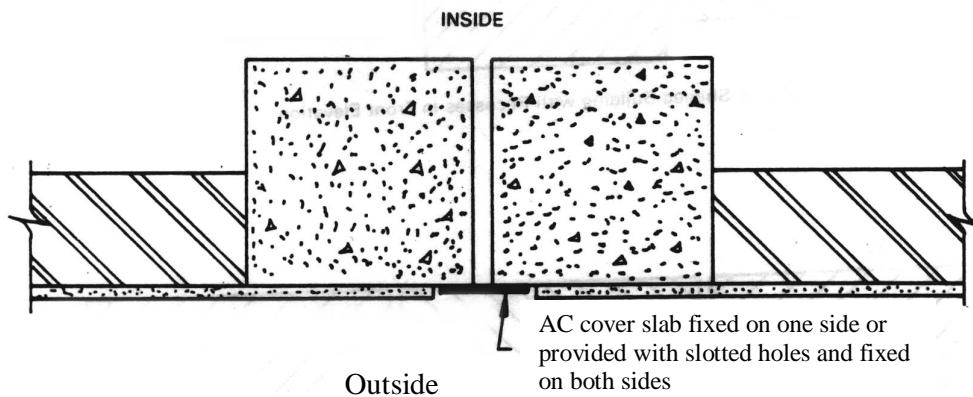


Figure 46 : Expansion joint in columns of framed structure.

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# NOTES

## **OUR OBJECTIVE**

To upgrade Maintenance Technologies and Methodologies and achieve improvement in productivity and performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability, and Utilisation.

*If you have any suggestion & comments, please write to us :*

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