Building Technology

SUGAM STATIONARY SUPPLIERS & PHOTOCOPY SERVICE

PH. NO:- 9841599592 (NCIT COLLEGE)

2018

Building Technology (2-0-2)

Evaluation:

	Theory	Practical	Total
Sessional	30	20	50
Final	50	-	50
Total	80	20	100

Course Objectives:

The main objective of this course is to make students familiar with building components, building services and finishing works. After completing this course students will also be able to prepare complete drawings of a building.

Course Contents:

1. **Foundations and Basements** (3 hrs)
   - 1.1 Types of foundations
   - 1.2 Some common problems with existing foundations
   - 1.3 Retaining properties and water proofing of basement
   - 1.4 Earthquake effects on foundations
   - 1.5 Damp-proof courses

2. **Masonry** (3 hrs)
   - 2.1 Brick and Block masonry
   - 2.2 Bonds in brick work
   - 2.3 Types of brick walls
   - 2.4 Stone masonry
   - 2.5 Classification of stone masonry
   - 2.6 Composite masonry

3. **Floors, Vertical Transportation and Roof** (4 hrs)
   - 3.1 Floors and its types
   - 3.2 Different means of vertical transportation
   - 3.3 Elements of staircase
   - 3.4 Types of staircases
   - 3.5 Relationship between rise and tread in stairs
   - 3.6 Types of roofs- shapes, material
   - 3.7 Single and double timber roof: their types, comparative advantages and some construction details
   - 3.8 Roof trusses
   - 3.9 Roof coverings

4. **Openings** (2 hrs)
   - 4.1 Doors: types and details
   - 4.2 Windows: types and details
   - 4.3 Ventilators: types and details

4.4 Hardwares for doors, windows and ventilators

4.5 Arch and Lintels (3 hrs)

5. **Joints**
   - 5.1 Types of joints: construction and expansion joints
   - 5.2 Treatment and detailing of joints at the roof level
   - 5.3 Treatment and detailing of joints at the floor level
   - 5.4 Treatment and joints in external walls
   - 5.5 Treatment and joints in Shear wall (3 hrs)

6. **Temporary Construction**
   - 6.1 Scaffolding: single and double scaffolds
   - 6.2 Formwork for excavations and trenches
   - 6.3 Formworks for reinforced concrete construction
   - 6.4 Shoring: horizontal, slant and vertical shores (3 hrs)

7. **Cladding and External Finishing**
   - 7.1 Cladding for load bearing and framed structures
   - 7.2 Brick and stone facing
   - 7.3 Cladding in concrete panels and their construction details
   - 7.4 Plastering, punning and pointing
   - 7.5 Properties and application of paints (2 hrs)

8. **Internal Finishing**
   - 8.1 Partitions: types, functions and methods of construction
   - 8.2 Mobile partitions
   - 8.3 Suspended and false ceilings: types, functions and methods of construction (5 hrs)

9. **Water Supply and Drainage**
   - 9.1 Mains of water supply: storage and distribution system
   - 9.2 Hot water supply
   - 9.3 Drainage of sewage and waste
   - 9.4 Rainwater pipes and gutters
   - 9.5 Septic tanks
   - 9.6 Rainwater harvesting (2 hrs)

10. **Electrical Services**
    - 10.1 Residential and commercial requirements
    - 10.2 General principles
    - 10.3 Wiring system
    - 10.4 Trunkings, busbars and ducts for electrical distribution
    - 10.5 Safety precautions
    - 10.6 Intake structures and provisions

Practical Works:

1. Plans, elevations and sections of a building
2. Trench plan and footing detail
3. Doors and window detail
4. Details of basements and shear wall
5. Construction details of roof
6. Water supply and drainage system

Note: The drawings for the practical works shall be produced with free-hand as well as CAD Tool

Text Books:

1. Chudley, R. (1987). *Construction Technology*. England: Longman Group UK Ltd.
2. Punmia, B.C., Jain, Ashok K. & Jain, Arun K. (2008). *Building Construction*. New Delhi: Laxmi Publications (P) Ltd.

References:

1. Reid, E. *Understanding Buildings*. MIT Press.
2. Olin, H.B. *Construction Principles, Methods and Materials*.
3. Ching, F.D.K. *Building Construction Illustrated*.
4. Kumar, S. (2010). *Building Construction*. New Delhi: Standard Publishers Distributors.
5. Singh G. (2010). *Building Construction*. New Delhi: Standard Book House.

1) Spread footings

It is the base of the structure transmitting the load to the soil, which is large in width in order to distribute the load over wider area. Spread footing supports either a column or wall.

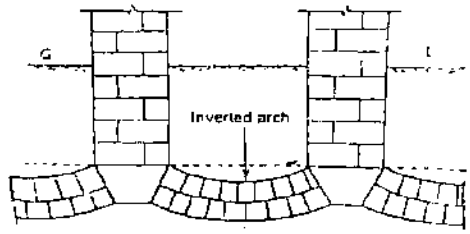


Fig. Inverted arch footing.

Types of spread footings

a) Strip footing
b) Pad or isolated or independent footing
c) Grillage foundation.

a) Strip footing

A spread footing provided for a continuous wall is called strip footing. The shape & size of strip footing depends upon the material used and the magnitude of super imposed load; e.g. brick masonry walls, stone masonry walls, RCC walls, light loads, heavy loads etc. Strip footings may be as follows:

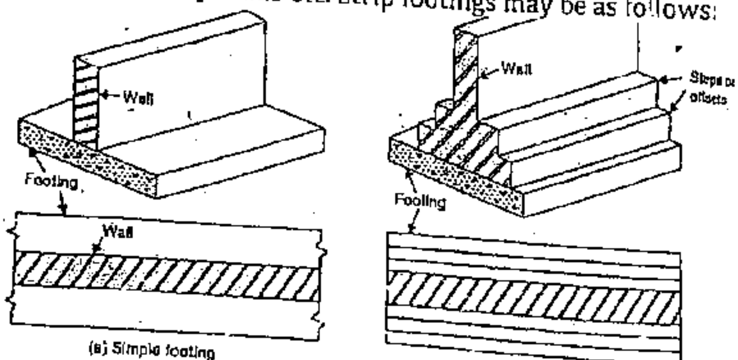
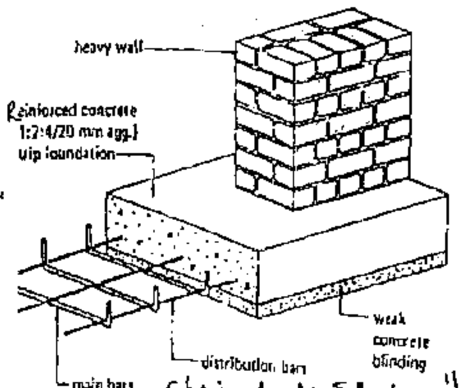


FIG. . SPREAD FOOTING FOR WALLS : STRIP FOOTING.

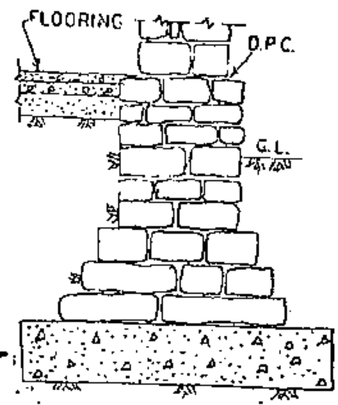
Fig: Strip footing for brick masonry walls



Strip footing for heavily loaded brick masonry wall.

Strip footing for brick masonry walls:

- Consists of several courses of brick which is usually twice the breadth of wall above.
- Increase base width by offsetting 5cm on either side of the wall.
- Depth of each course= 10cm thick.
- Bottom course are made equal to 20cm thick.



Strip footing for stone masonry walls:

- A bed of lean concrete of uniform thickness is first spread over the entire length of the wall.
- Depth of each course not less than 15 cm thick.
- Offset of each layer 10 to 15 cm thick.
- In no case, depth of concrete bed should never be less than its projection the wall base.

Fig: Strip footing for stone masonry walls

Note: - Both the brick masonry walls or stone masonry walls have either simple or stepped footing.

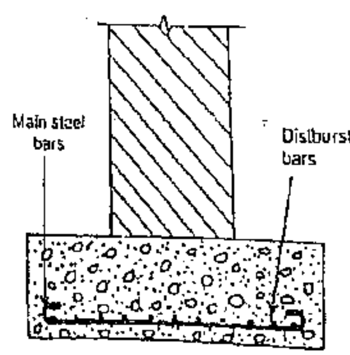
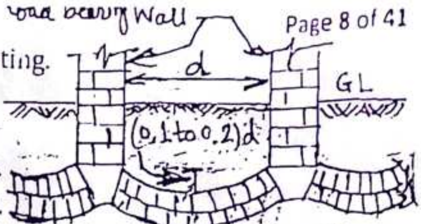


Fig. R.C.C. footing for wall.

Reinforced Cement Concrete (RCC) footing (for heavy loads):

- Used where the walls are subjected to heavy loading and the bearing capacity of soil is low.
- 7 to 8 cm thick PCC (plain cement concrete) is provided below the reinforced concrete footing.

- Main objective is reducing volume of masonry in footing.



Inverted Arch footing **(for walls with heavy load):**

- Was used in multi-storied buildings in ancient times.
- Out dated, with advent of R.CC construction practice.
- The main advantage is that in soft soils the depth of foundation is greatly reduced.

b) Pad or isolated or independent footings

A spread footing provided for a single column is called pad or isolated or independent footing. A pad footing is provided under a column to distribute the concentrated loads in the forms of uniformly distributed load on the soil below. Its shapes may be square, rectangular or circular etc.

Types of pad footings according to their shape and construction practice

i) Simple pad footing
ii) Stepped pad footing
iii) Sloped pad footing
iv) Eccentrically loaded footing

Pad footings can be made with brick, stone or RCC. Simple, Stepped and Sloped differ to each other only in construction practice but all of them are symmetrical in both the axes. Thus, they are helpful in transferring the concentric loading. But, eccentrically loaded footing is the special case, provided to transfer the eccentric loads of the superstructure. It is not symmetrical in the both axes.

Types of pad footings according to materials used

Brick pillar footing

- Square footing is the simplest & most economical
- Area of base is calculated by dividing the total load to which the column is subjected to, by the safe bearing capacity of soil.

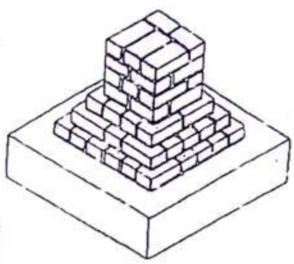


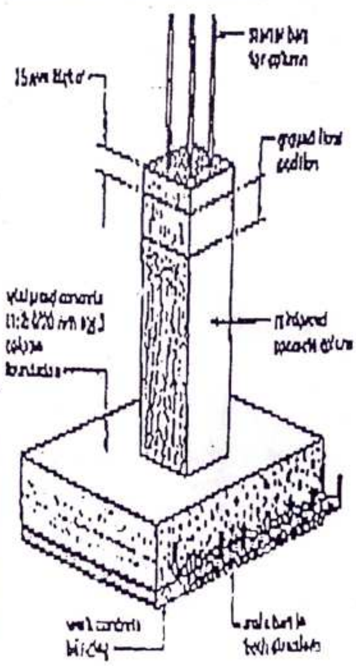
Fig: Simple pad footing for brick pillar

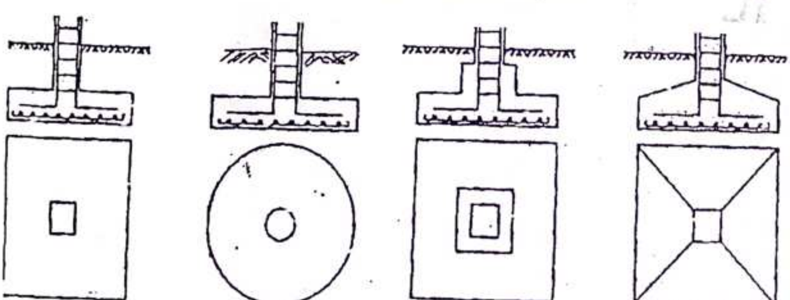
Stone pillar footing

- Similar in construction as brick pillar except the offset and thickness of each course is slightly bigger.

R.C.C column footing

- Used against the low bending strength, the footing constructed with bricks, stones or PCC require considerable depth to be safe to carry heavy loads.
- Depth of PCC footing can be appreciably reduced by providing R/F at its base to take up tensile loads.
- Footing is reinforced both ways by means of steel placed right angles to one another at equal distance apart.





(a) Square footing (b) Circular footing (c) Square footing with pedestal (d) Sloped footing

Reinforced Concrete Pad Footings for RCC columns

A building has two basic parts:

1. ***Sub-structure or foundation*** - It is the part of building located below the ground level which transmits the load of super- structure to the supporting soil
2. ***Super-structure*** - It is the part of building constructed above the ground level to serve the purpose of its intended use

1. FOUNDATION AND BASEMENTS

<u>Foundation</u>: Foundation is the lowest part of a structure which provides a base for the super structure. It includes the portion of structure below the ground level as well as the concrete blocks, piles, raft, grillage, etc. provided to transmit the loads (dead and live loads) of the structure to the sub-soil.

<u>Basements</u>: It is a floor structure constructed to provide one (shallow) or more floors (deep) in a building that are either completely or partially below the ground level.

Functions of foundation are as follows:

- To transmit the all super imposed loads (wind, snow, vibration, dead and live loads) of the structure to the soil below or to distribute the weight of the structure over large area so as to avoid over loading of the soil beneath.
- To distribute the load evenly and thus prevent unequal settlement.
- To provide a levelled hard surface for building operation and for supper structure to be built over it.
- To take the structure deep enough into the ground and thus increase its stability, preventing overturning and lateral movement of supporting materials

Characteristics: The foundation that has the following characteristics is preferred (Conditions to be fulfilled by a good foundation).

1. Wide enough section to distribute weight over larger base area within safe bearing capacity
2. Evenly loaded condition that prevents unequal settlement
3. Deep enough preventing overturning and increasing stability

<u>Architectural view of foundation</u>

1. Climate and its effects
2. People and their requirements
3. Materials and methods of construction
4. Regulations and bye-laws of sanctioning authority

1.1 Types of foundations

Foundations can be broadly classified on: **(1.1.1) Shallow foundation and (1.1.2) Deep foundation**

1.1.1 Shallow foundation

When the foundation is placed immediately beneath the lowest part of the super structure, then it is called as shallow foundation. The depth of the shallow foundation is equal to or less than its width. The main object of such foundation is to distribute the structure's loads over a wide horizontal area at shallow depth below the GL. It is adopted when a good bearing stratum is available near the ground surface. It is laid after open excavation of soil in the ground so any foundations which have depth even greater than its width but are constructed by way of open excavation are also considered as shallow foundation. The portion of the shallow foundation, constructed with brick work, stone masonry or concrete under the base of wall or column to distribute the load over a larger area is termed as **footing.**

Types of shallow foundation:

1) Spread footings
2) Combined footings
3) Strap footing, and
4) Mat or raft foundation

Introduction

- A building may be defined as a permanent or semi-permanent structure used by human beings to protect themselves from natural calamities (disasters) like heat of sun, rain, snowfall, storm and wild animals as well as from thieves etc.
- A building is a relatively permanent enclosed structure constructed over a plot of land consisting of walls, floors, doors, windows, openings and roofs to provide a covered space for different activities as living, entertaining, manufacturing and storing etc. A building is composed of interrelated systems and assemblies that work together to contribute to the building's proper functioning.
- **Building technology** is the application of scientific knowledge including the use of machineries and equipment for practical purpose of constructing a building. The term **"building technology," means the knowledge of the technical processes and methods of assembling buildings.**
- The method adopted for construction and choice of materials to be used in the building depends upon a number of factors like character of a occupancy (use), location of site, climate, local materials and funds available.
- Normally all buildings are constructed according to the drawings and specifications prepared by the architects. Each city has prescribed building byelaws to which building must conform. The building byelaws lay down norms like minimum front, side and rear setbacks (the projection which creates problem to progress), minimum height and area of habitable rooms, kitchen, bath, minimum area of windows, width of staircase etc. which are required to be followed by the architect in involving the design of the building.
- Apart from respecting building byelaws, the building design should ensure optimum utilization of built up space(i.e. area under circulation should be minimum), thermal comfort, proper ventilation, desirable illumination and acoustical characteristics and it should satisfy the functional requirement of people who live and work in the building.

Types of building

Depending upon the character of occupancy or the type of use different type of buildings has been classified in the following groups as:

Group – A : Residential buildings
Group – B : Educational buildings
Group – C : Institutional buildings
Group – D : Assembly buildings
Group – E : Business buildings
Group – F : Mercantile buildings
Group – G : Industrial buildings
Group – H : storage buildings
Group – I : Hazardous buildings

Eccentrically loaded footings (for walls or columns)

As for as possible, the foundation should be so shaped and proportioned that the centers of gravity (CG) of the imposed loads coincide with the CG of the supporting area of base. However, when the walls or columns are to be placed closed to the property lines, the required supporting area base cannot be placed concentrically with the imposed load & there is certain distance between CG's, which is called eccentricity and the foundation designed in such condition is called eccentrically loaded foundation.

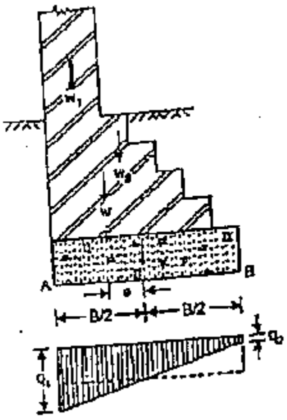
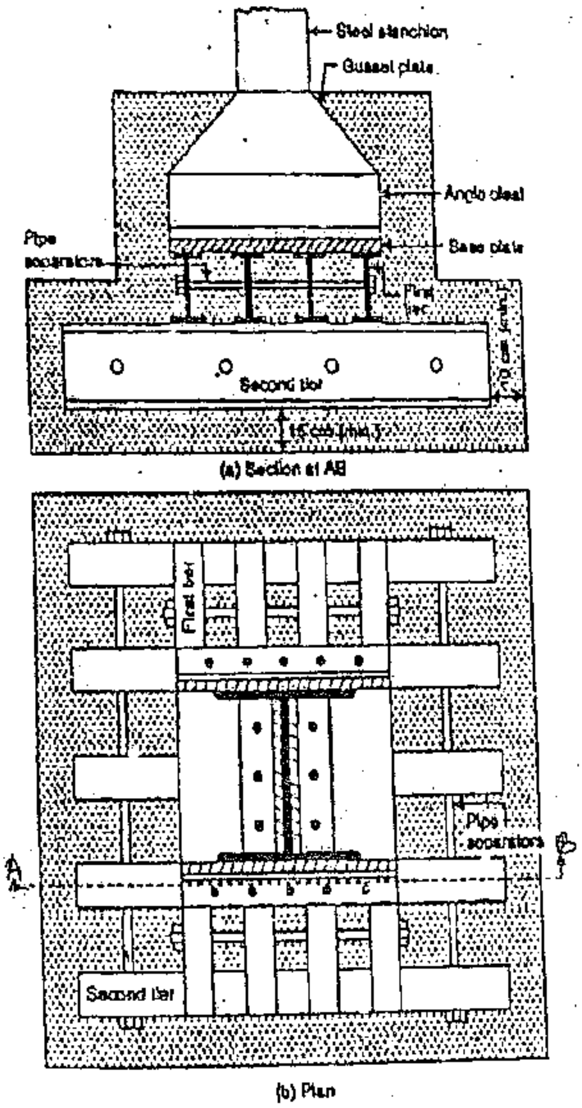


FIG. - 7. ECCENTRIC LOADING.

c) Grillage foundation

- Used when heavy structural loads from columns, piers are required to be transferred to a soil of low bearing capacity.
- Avoids deep excavation & provides necessary area at the base to reduce intensity of pressure within safe bearing capacity of soil.
- Depth of foundation is limited to 1 to 1.5 m



1. TYPICAL GRILLAGE FOUNDATION FOR STEEL STANCHION

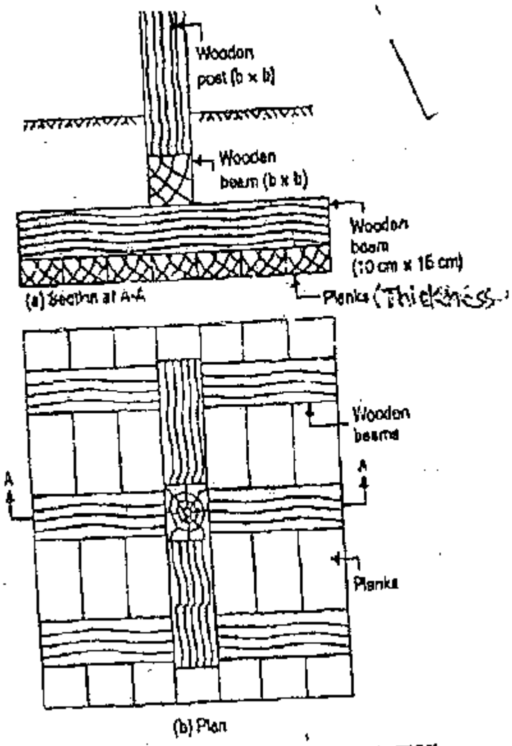
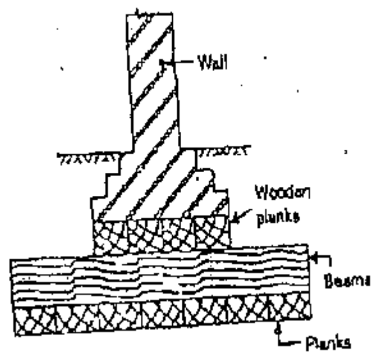


FIG. 3.12. TIMBER GRILLAGE FOUNDATION FOR WOODEN POST.

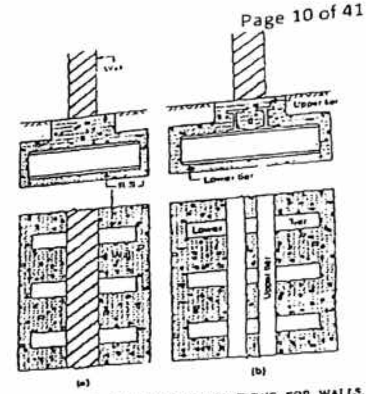


3.1 TIMBER GRILLAGE FOUNDATION FOR MASONRY WALL

Types of Grillage foundation
i) Steel grillage foundation for column
ii) Timber grillage foundation for column
(i) Steel grillage foundation for column and wall

i) Steel grillage foundation for column:

- Consists of steel beams also known as grillage beams, which are provided in single or double tiers.
- In double grillage tier, the top tier is laid at right angle to bottom one.
- The grillage beams are embedded in concrete. Generally minimum clearance of 8 cm is kept between the grillage beams so that concrete can be easily poured and properly compacted.



. 3.11. STEEL GRILLAGE FOUNDATIONS FOR WALLS.

ii) Timber grillage foundation for column:

- Used where soil encountered is soft & permanently water logged area so that steel may corrode due to sub-soil water.
- Use timber planks & tier instead of steel.
- No concrete is embedded between the timber joist, however bottom concrete is replaced by timber plate form constructed by timber planks.

2) Combined footings

A combined footing is the one which supports two columns. It may be rectangular or trapezoidal in plan. The CG of the footing should coincide with CG of the combined loads of the columns. When the column nearer to the property line has to carry heavy loads, the trapezoidal Section is provided in order to coincide the CG of loads & footings. Combined footing is provided when - Columns are much closed so that the footings overlap.

- When the end column is near the property line for avoiding eccentric loading case.
- When bearing capacity is less so that the individual require more area; i.e. more than 50 % of the whole area.

Types of combined footing
a) Rectangular Combined footing (Plan → Rectangular)
b) Trapezoidal Combined footing (Plan → Trapezoidal)
c) Combined Wall-Column footing (Single footing for both wall & column).

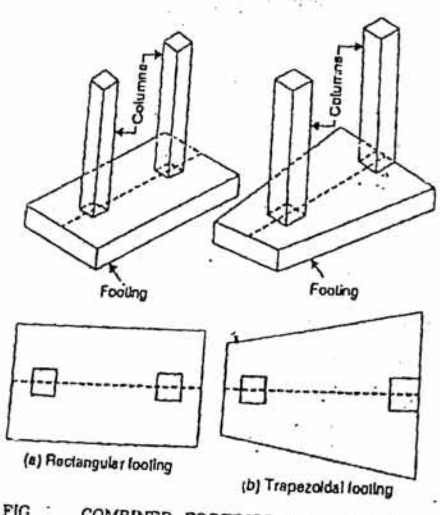


FIG. . COMBINED FOOTINGS FOR COLUMNS.

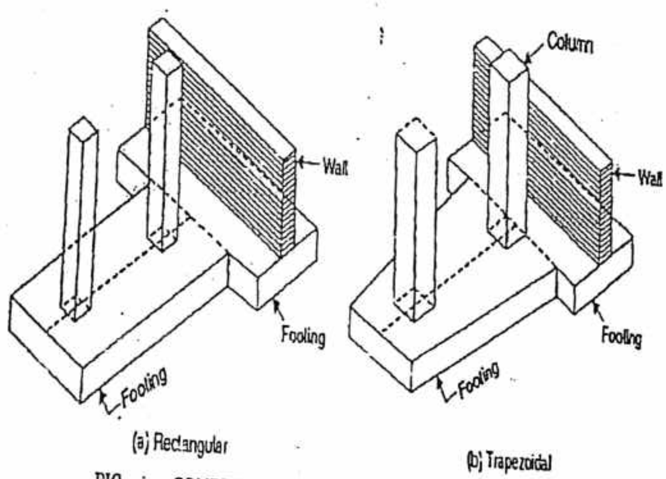


FIG. . COMBINED FOOTINGS FOR COLUMNS AND WALL.

3) Strap footing

If the independent footing of the two columns is connected by a beam, then it is called as Strap footing. The strap footing is provided when columns are placed in large distance such that trapezoidal footing becomes quiet narrow, with high bending moment. The strap beam, assumed to be infinitely stiff, serves to transfer the column loads on to the soil with equal and uniform soil pressure under both footings.

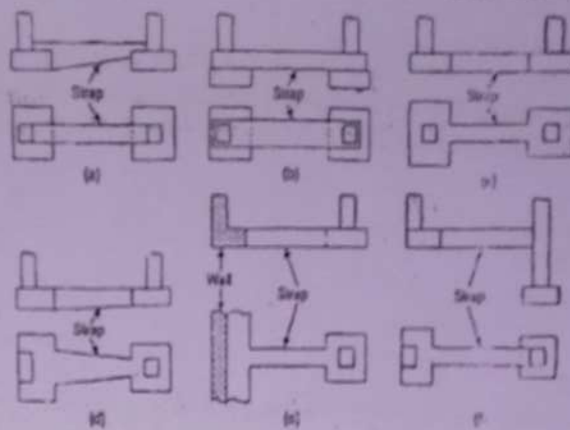


FIG. 1.1 COMMON ARRANGEMENTS OF STRAP FOOTINGS

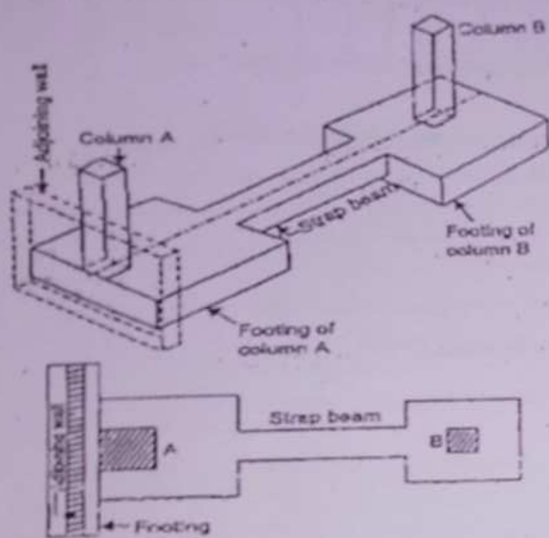


FIG. 5.7. STRAP FOOTING.

4) Raft or Mat foundation

- Provided when bearing capacity of soil is very low and building loads is heavy where the soil mass contains compressible soil and having chances of differential settlement.
- Consists of thick RCC slab covering the slab covering the entire area of the bottom of the structure.
- Reinforced in two layers (running at right angles to each other) both near bottom and top face of the slab.

Types of Raft foundation

a) Flat plate type
b) Flat plate thickened under columns
c) Flat plate with pedestals
d) Two way beam and slab type
e) Cellular type
f) Basement wall as rigid frame

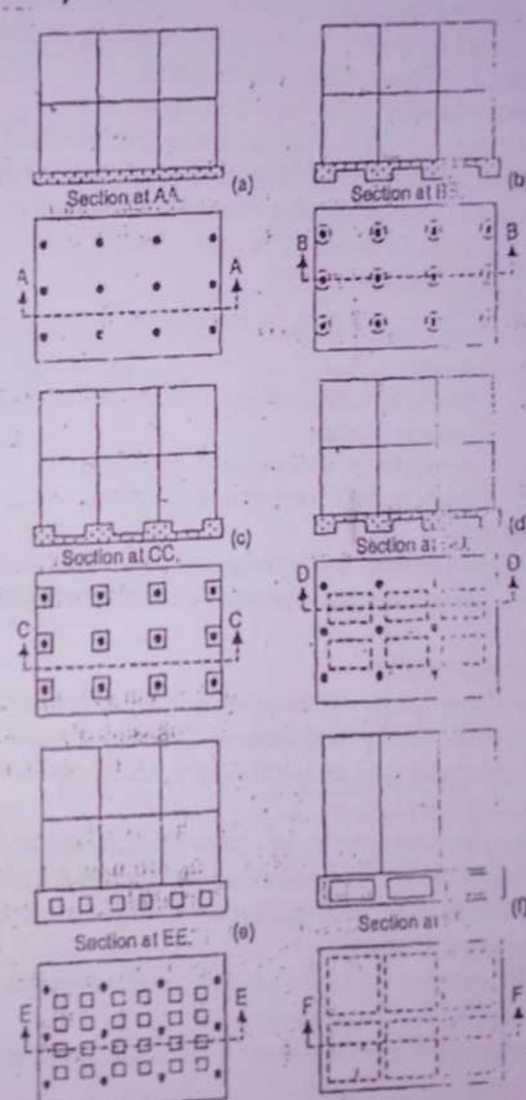


FIG. 1.5. COMMON TYPES OF RAFT FOUNDATION

1.1.2 Deep foundation

Deep foundations are those in which the depth of foundation is very large in comparison to its width. In general, ***depth of foundation ranges between twice its widths to several meters.*** ***The purpose of deep foundation is to attain bearing stratum deep inside*** the ground in case of weak soil.

Types of deep foundation:-

1) Pile foundation
2) Pier foundation, and
3) Caisson or well foundation

1) Pile foundation

- It is defined as column inserted into the ground to transmit the structural loads to the lower level/ deep enough level of soil.
- Driven into the ground either vertically or with some inclination. It is used individually or in cluster (placed in group) form
- It is the most commonly used than pier and caisson or well foundation and it is preferred in:
    - i) Heavier load and the top soil have poor bearing capacity.
    - ii) Necessary to ensure stability & durability.
    - iii) High water table level or large fluctuation of it.
    - iv) Canal or deep drainage lines exist near the foundation.
    - v) Compressible, water logged or made up type soil exists.
    - vi) For bridges, in order to keep foundation deep enough to the scour depth.
    - vii) Raft or grillage foundations are not possible

Classification of piles

(A) Classification of piles based on their function

a) End bearing pile
- Penetrates through the soft soil & their bottom rest on a hard stratum.
- Acts as column.
- Actually do not support the load, but acts as a medium to transmit the load from foundation to hard stratum.

b) Friction pile
- Provided when loose soil extends to a greater depth.
- Frictional resistance developed on the sides of pile counter act the load coming on the piles.

c) Compaction piles
- Provided when the foundation is to be made on loose granular soil
- Increase the bearing capacity of soil by compaction.
- Sometimes, pile tube is driven out & filled with sand forming a sand pile.

d) Tension or uplift piles
- Provided where the structure is subjected to uplift due to hydrostatic pressure or due to overturning moment. e.g. Transmission tower foundation etc.

e) Anchor piles: Provided for anchorage against horizontal pull and thrust.

f) Fender piles & dolphins
- Provided in order to protect the concrete deck or other front structure from the abrasion or impact from ships.

g) Batter pile: Piles driven at an inclination in order to resist large horizontal or inclined forces.

h) Sheet pile: The tree types of sheet piles are: ***Concrete*** sheet pile, ***Timber*** sheet pile and ***steel*** sheet pile
- Functions as retaining wall. Commonly used as bulkheads or as impervious cut off to reduce seepage & uplift under hydrostatic structure

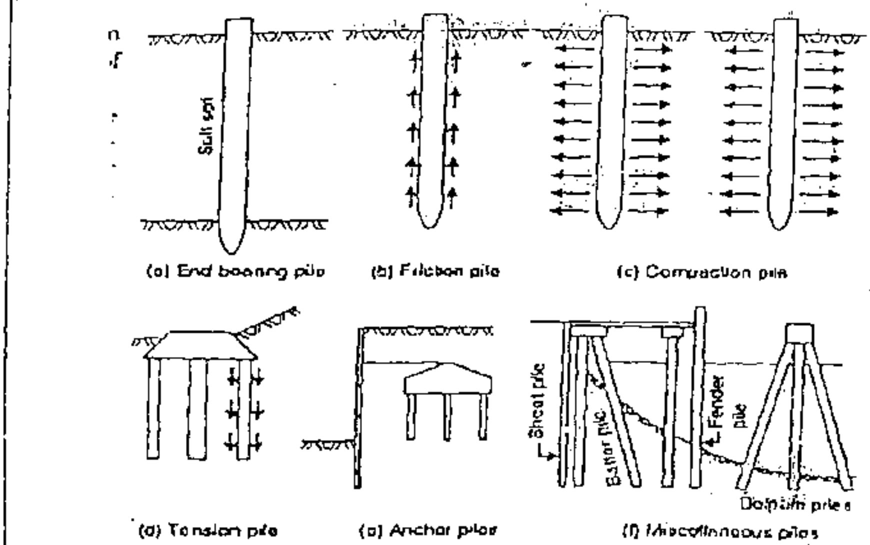
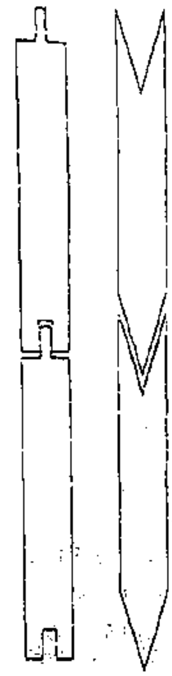


FIG. . CLASSIFICATION OF PILES BASED ON FUNCTION.



PRE-CAST R.C.C. SHEET PILES

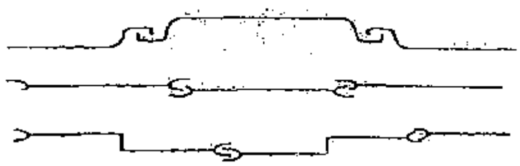


FIG. . STEEL SHEET PILES.

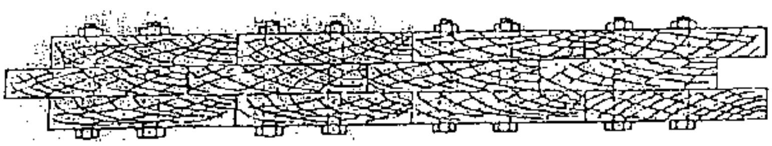


Fig. . Wake-field joint timber pile.

Fig. . Different forms of steel sheet piles.

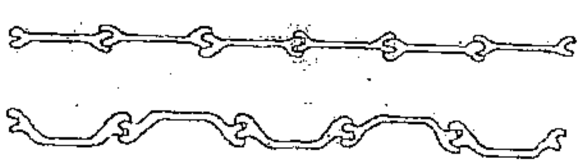


Fig. . Steel sheet piles connected with clutches.

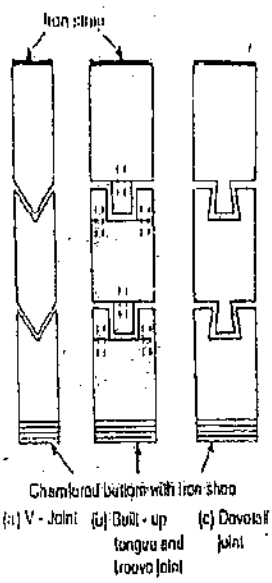
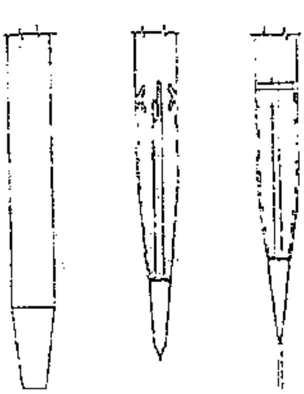


FIG. . TIMBER SHEET PILES.

- Function of sheet piles:
  - to enclose a site
  - to retain the side of trench
  - to make water tight enclose for retaining structure
  - to protect river banks
  - to prevent seepage below dams
  - to confine the soil to increase its bearing capacity
  - to protect against sea erosion of the banks of sea
  - to protect foundation from scouring

Different types of Timber pile shoes→



B) Classification of piles based on materials composition.

1. Timber piles
2. Concrete piles
   (i) Precast concrete piles
   (ii) Cast in situ concrete piles
      (a) Driven cast in situ concrete piles
         - Cased driven piles
         - Uncased driven piles
      (b) Bored cast in situ concrete piles
         - Bored & pressure piles
         - Bored & under reamed piles
         - Bored compaction piles
3. Steel piles
   i) H piles or H-beam piles ii) Pipe piles (Steel tube piles) iii) Sheet piles
   iv) Box piles v) Screw piles vi) Disc piles
4. Composite piles
   i) Concrete & timber composite piles
   ii) Concrete & steel composite piles

1. Timber piles

- Are made from timber
- Circular or square in cross-section
- At bottom, a cast-iron shoe & at top steel plate known as pile cap is provided.

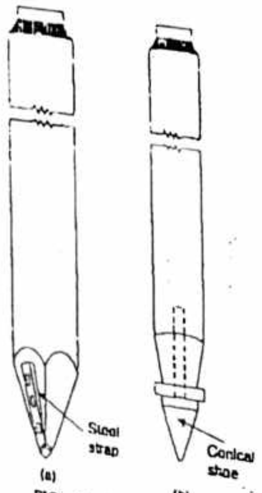


FIG. 4.18. TIMBER PILES.

Advantages

- Cheaper and economical
- Easily stored and transported
- Driven very rapidly
- Elastic property bears lateral forces

Disadvantages

- Possibility of decay
- Cannot driven in hard soil, rock etc
- Low bearing capacity & lesser Strength
- Cannot be made very long
- Easily damaged by over driving

Concrete piles

(i) Pre-cast concrete piles

- Defined as a reinforced concrete pile which are casted & cured in a factory and then transported to the site for driving.
- Dia. Normally varies from 35cm to 65cm and the length from 4.50 m to 30m
- Circular, square, rectangular or octagonal in cross-section.

Advantages of Pre-cast concrete piles

- Durable even in water
- Material required is easily available and greater bearing capacity
- Cast to any shape, size and length
- Monolithically bonded to pile cap & steel shoe

Disadvantages of Pre-cast concrete piles

- Costlier
- Cannot driven rapidly
- Qualified technical supervision and heavy driving machines required
- Must be reinforced

(ii) Cast-in-situ concrete piles

- Casted in situ
- A bore hole is dug into the ground by inserting a casing & the bore is then filled with cement concrete after placing reinforcement.
- May be cased or uncase when casing is driven out, then it is called uncased type whereas when the casing is left, then it is called cased type.

(ii) Cast-in-situ concrete piles

(a) Driven cast-in-situ concrete piles:

They may be - Driven Cased cast-in-situ concrete piles
& Driven Uncased cast-in-situ concrete piles

Cased cast in situ concrete piles

The shell or casing is driven into intimate (close) contact with the surrounding soil and remains in position to maintain driving resistance and protect the concrete filling during the placing of other adjacent piles and during the initial setting period.

Types of cased driven cast in situ concrete *piles*

a) Raymond piles

i) Raymond standard concrete pile
ii) Raymond step-taper concrete pile

i) Raymond standard concrete pile

- Primarily friction pile
- 6-12cm long
- Tapered 1 in 30
- Top Ø 40 to 60 cm & bottom end Ø 20 to 30 cm
- Pile consist of thin corrugated steel shell closed at bottom
- Steel is reinforced with spirally wound hard drawn wire on 8cm pitch
- The shell is closed at bottom with steel boot
- Shell is driven with a collapsible steel *mandrel or core* in it having the same tapering
- Mandrel is mechanically collapsed and withdrawn, leaving the shell inside the ground
- The shell is inspected with flash lit or drop light, concrete is gradually filled up to the top

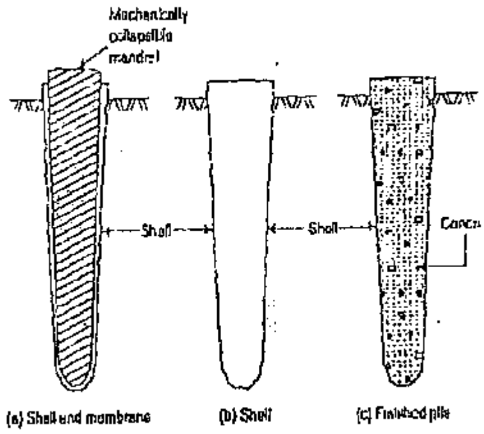


FIG. 4.2. STAGES IN RAYMOND STANDARD PILE CONSTRUCTION

ii) Raymond step-taper pile

- Either friction or end bearing and can be driven in any type of soil
- Maximum depth 36m, bottom most shell made of heavier gauge and closed by flat steel plate welded to the boot ring
- Joints between sections of shell are screw connected
- Increase in diameter 2.5cm to each successive shell
- The pile has the advantage of on the job length flexibility, internal inspection after being driven, and a steel shell left in place to maintain driving resistance and protect a fresh concrete filling

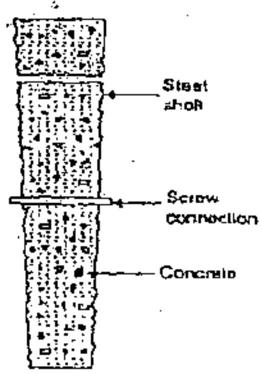


FIG. 4.3. RAYMOND STEP-TAPER PILE.

) Mc Arthur cased pile

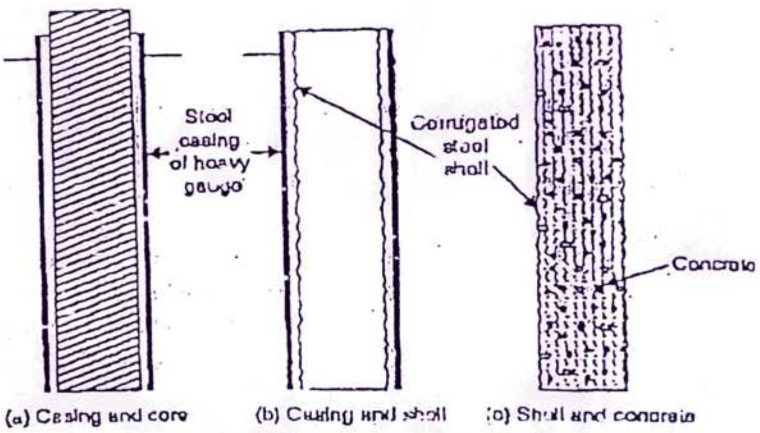


FIG. 4.4 STAGES IN Mc-ARTHUR CASED PILE.

- Driving of piles uses an additional steel casing of heavier gauge with a central core as shown in figure (a)
- After reaching a desired depth, the central core is withdrawn and a corrugated shell of uniform dia. is inserted as a casing
- Concrete is filled in the shell gradually compacting it and withdrawing the steel casing.
- The completed pile as shown in fig(c) contains concrete core and the outer corrugated shell which works as both end & friction bearing pile

c) Union metal mono tube pile

- Mon tube pile uses the tapered fluted steel shell without mandrel.
- The shell may be driven with hammer of comparable size those used for wooden piles, the shell after inspection is filled with concrete and excess length of the shell, if any, is cut.
- Suitable for a wide variety of soil conditions and required depth
- Such piles are both end and friction bearing

d) Swage piles

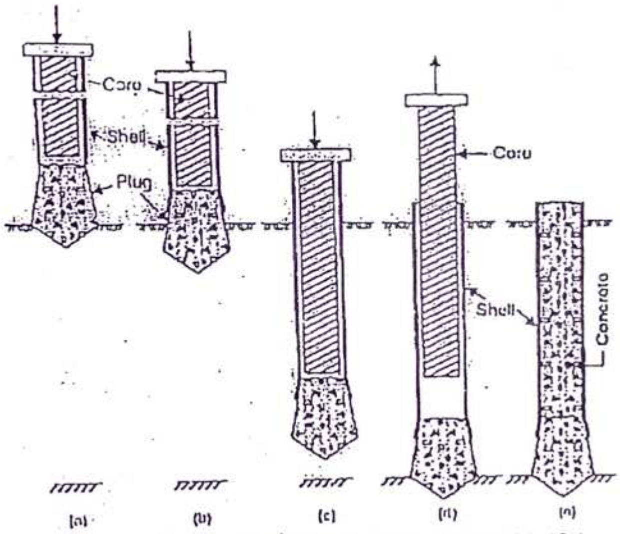


FIG. 4.5. STAGES IN SWAGE PILE CONSTRUCTION

- These piles are used with advantage in very hard soil & where it is designed to leave water tight shell for some time before filling the concrete.
- In first stage (Fig. a) a thin steel pile (known as shell) is placed on a precast concrete plug, and a steel core, which is not long enough to reach the plug is inserted in the shell
- In the second stage (Fig. b), as the pipe is driven over the plug until the core reaches the plug, the pipe is *swaged out* by the taper of the plug, thus forming a water tight joint
- In third stage (Fig. c), the pipe is driven to specified depth. The driving force is practically all exerted by the core on the plug and the pipe pulled down rather than driven.
- In fourth stage (Fig. d), after the pipe has reached the desired depth, the core is removed and the pipe left open until it is desired to fill it
- In final stage (Fig. e), the steel casing is removed and so created hole is concreted.

c) Western button-bottom pile

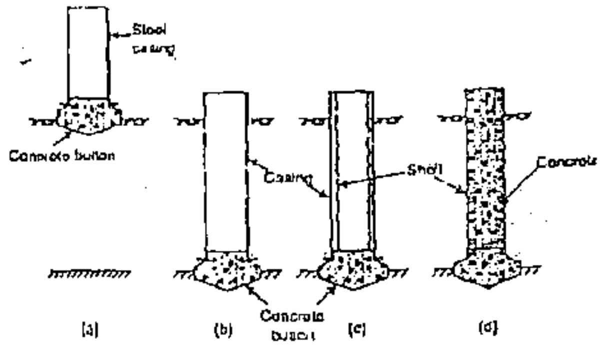


FIG. 4.6. STAGES IN BUTTON BOTTOM PILE CONSTUCTION.

- These piles are used where increase in end bearing area is desired
- The pile uses a concrete plug of the shape of a button of which the diameter is 25mm arger than the steel pipe. The concrete button enlarges the hole in the soil during driving. Due to this, the side friction is reduced temporarily
- These piles have been used up to length of about 23m & for load up to 50 tons.
- In first stage (Fig. a) a steel pipe with 12mm thick wall and reinforced base of cast steel, is set over the concrete button.
- In the second stage (Fig. b), the pipe and the button are driven to a specified depth.
- In the third stage (Fig. c), a corrugated steel shell is inserted in the pipe, resting on the button. A steel plate with a bolt hole in it is welded on the bottom of the shell, before lowering it, so that the hole may fit over the central bolt in button bottom. The nut may be tightened with the help of a long socket wrench.
- In the fourth stage (Fig. d), the casing is withdrawn, leaving the button in place, and the shell filled with concrete. Reinforcement may be used if necessary.

<u>*Uncased cast- in- situ concrete piles*</u>

These piles do not use casing, and hence they are cheaper. However, great skill is required in their construction. These piles are used only where it is certain that neither soil nor water will fall into the hole, or squeeze into and reduce the size of the hole left after withdrawing a driven mandrel or shell before concreting, and also where adjacent piles will not damage the green concrete.

The following are the common types of uncased cast in situ piles:

a) Simplex piles
b) Franki piles
c) Vibro-piles
d) Padestal piles

a) Simplex piles:

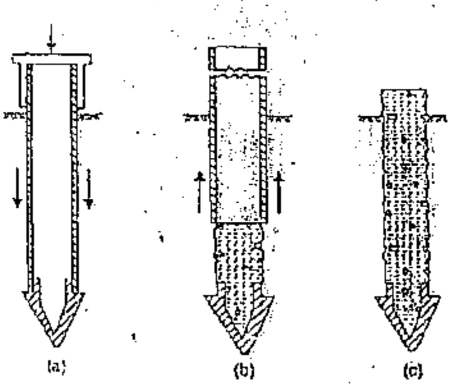


FIG. 4.7. SIMPLEX STANDARD PILE

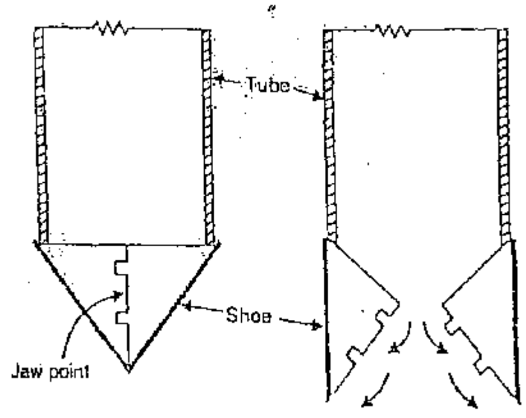


FIG. 4.8. ALLIGATOR JAW POINT.

Procedure of constructing the Simplex pile is as follows:

- A steel tube fitted with a cast iron shoe is driven in to the ground up to the required depth as shown in Fig.(a)
- Reinforcement, if necessary is, is put inside the tube. Concrete is then poured into the tube, and the tube slowly withdrawn, without concrete being tamped, leaving behind the cast iron shoe as shown in Fig.(b)
- Fig(c) shows a completed process and such pile is known as Simplex standard pile
  In the above method, the cast iron shoe remains behind, and a new shoe has to be used for each pile. But sometimes if soil is form enough to stand, the cast iron shoe is provided with alligator jaw point as shown in figure above which is hinged to the shell and it is withdrawn together with the shell (pipe).

b) Franki piles:

These piles have enlarged base of mush-room shape, which gives the effect of a spread footing. These piles are best suited to granular soil as well as where bearing stratum of limited thickness can be reached at reasonable depth.

Construction procedure is as follows;

- Heavy removable pipe shell is set vertically on the ground with help of leads as shown in fig. (a) and a charge of dry concrete or gravel is formed.
- A diesel operated drop hammer of 20 to 30 kN weight is driven on the concrete. This results in the formation of a dense plug that penetrates the ground and drags the tube with it as shown in fig.(b)
- When the tube reaches to the desired depth, the tube is held in position by cables (leads) and the hammer is applied to the concrete, forcing it down and outward.
- This results enlargement of the base into the mushroom shape. If required a fresh charge of semi dry concrete is put to enlarge the bulb as shown in fig.(c)
- The shaft is filled by introducing successive charges of concrete, ramming , and withdrawing gradually about 300 mm at a time as shown in fig(d)
- Reinforced cage can be installed, if desired, after enlarging base has been formed, the hammers goes inside the cage of reinforcement.

The diameters of Franki piles vary from 50 cm to 60 cm, while the enlarged base may have a diameter of about 90 cm or more. The pile has a carrying capacity of 60 tonnes (600 kN) to 90 tonnes (900 kN).

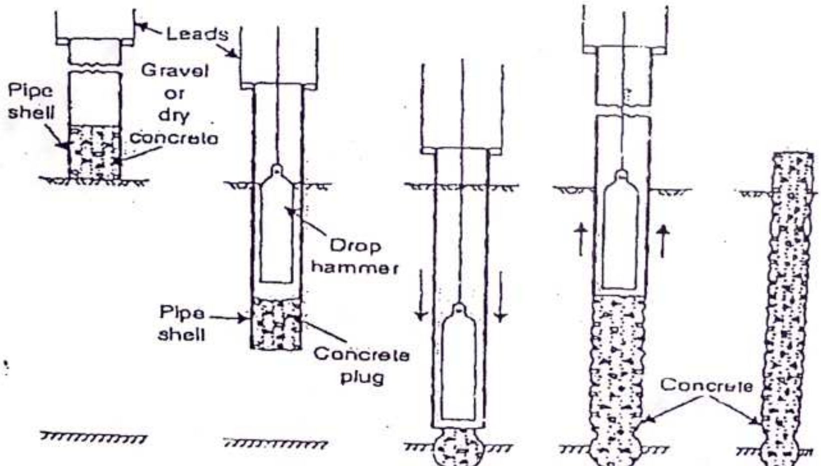


FIG. 4.9. STAGES IN THE FORMATION OF FRANKI PILE.

a) Vibro piles:

These piles are used in soft sub-soil. Bothe *'standard'* and *'expanded'* piles are formed by the vibro-process. Vibro pile are formed by driving a steel tube and shoe, filling with concrete, and extracting the tube, using upward extracting and downward tamping blows alternatively.

Procedure for *Standard vibro- piles*:

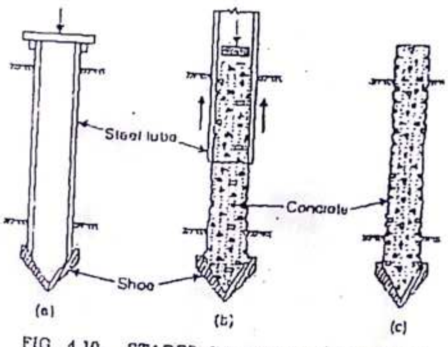


FIG. 4.10. STAGES IN THE FORMATION OF STANDARD VIBRO-PILES

- Constructed in sizes of 35, 45 and 50 cm Ø with length > 25m, the larger for loads of 60 to 70 tonnes
- Steel tub, fitted with cast iron shoe(but not fixed) is driven in the ground by 20 to 25 kN hammer, operated by steam or compressed air, delivering up to 40 blows per minute with a stroke of 1.4 m.
- After driving the desired depth extracted links, are fitted to the hammer and top of the tube fig.(a)
- Concrete is filled(usually 1:2:4 mix) as shown in fig.(b)
- The withdrawal of the tube and the ramming of concrete are affected by hammer operating at 80 blows per minute.
- Each up-stroke results in 4 cm withdrawal of the tube (leaving the shoe behind) while concrete is consolidated in each downward blow
- If required reinforcement cage consisting of 6 bars of 12 to 24 mm Ø with 4 to 6 mm Ø binder @ 150 to 200 mm pitch may be inserted after stage-1 (fig-a)

Procedure for *Vibro- expanded piles*:

- This piles are used where the desired driving resistance is not obtained at reasonable depth due to low bearing capacity and in such case its bearing capacity is increased by enlarging its diameter at the bottom
- Tube fitted with conical shoe is driven and a charge of concrete is filled up to some depth
- The tube is completely with drawn, leaving behind the shoe and the concrete over it
- The tub now fitted with a flat shoe, is again lowered in the hole until it reaches the deposited concrete fig. (d)
- Tube is further driven down into the concrete resulting in the formation of bulged end fig.(e)

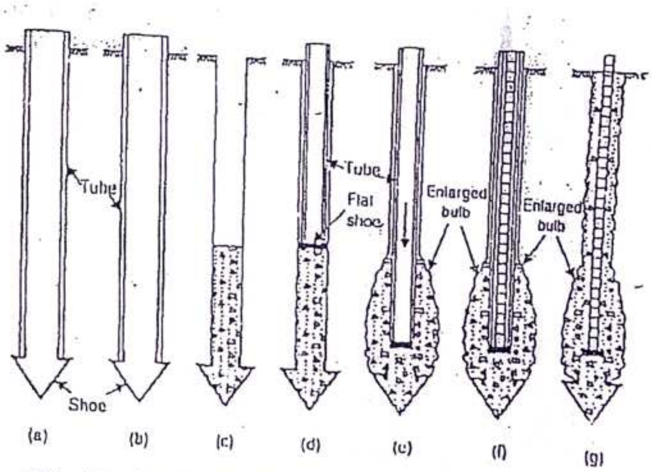


FIG. 4.11. STAGES IN FORMING VIBRO-EXPANDED PILE.

- The reinforcement cage is lowered in the tube so that it rest on the flat shoe about 1 to 2 m above the conical shoe fig (f)
- The tube is now filled with concrete, and the pile is completed by succession of upward extracting and downward consolidating blows, as in vibro-piles

d) Mc Arthur Padestal piles:

The pile is used where thin bearing stratum is reached with reasonable depth. The pedestal of the pipe gives the effect of spread footing on this comparatively thin bearing. The pile uses a steel tube and a steel core, the lower end of the core being flush with the bottom of the casing and end made flat.

Procedure for ***Mc Arthur Padestal piles***:

- The core and casing are driven together into the ground
- The core is taken out, and a charge of concrete is placed in the tube
- The core is replaced in the casing till it rests on the top of the poured concrete. While maintaining a pressure of the core and the hammer on the concrete, the casing is pulled up by 0.5 to 1 m as shown in fig.(c)
- The charge of concrete is rammed out resulting the formation of a pedestal fig. (d)
- The core is removed, the casing is filled with concrete , and core is replaced in contact with concrete (fig. e)
- The casing is pulled up while maintaining the pressure of the core and on the concrete. The finished pile is shown in fig. (f)

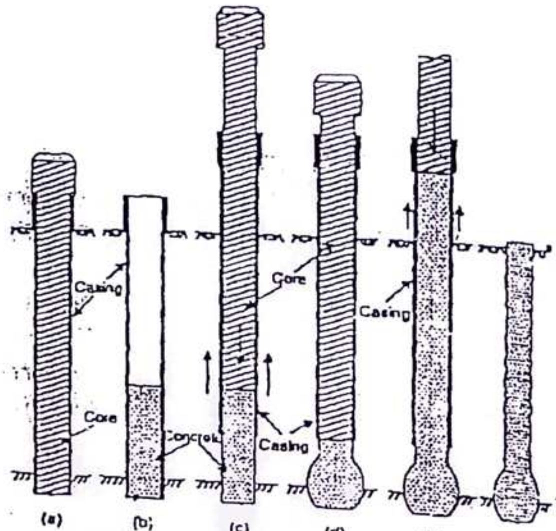


FIG. 4.12 STAGES IN THE FORMATION OF Mc-ARTHUR PADESTAL PILES.

Bored piles

Bored piles are those which are forced by forming a bore hole in the ground and then converting it, either with the help of casing tube or without a casing tube. Bored piles have advantage over the driven piles, in those location and situations where vibration and noise caused by driving of piles are to be avoided or the strata of adequate bearing capacity is so deep that they are difficult to reach by driven pies.

Bored piles are of following three types:

i) Pressure piles

ii) Under- reamed Piles, and

iii) Bored compaction piles

i) Pressure piles

- Formed with the help of casing tube, boring auger and compressed air equipment.
- Especially suitable for those congested site where heavy vibration & noise are not permissible and where heavy pile driving machine cannot move.

Stage of construction

- First a steel tube of 1.2 to 1.8 m long and 400 mm Ø is sunk in the ground and bore hole inside it is excavated by boring tool such as auger etc.

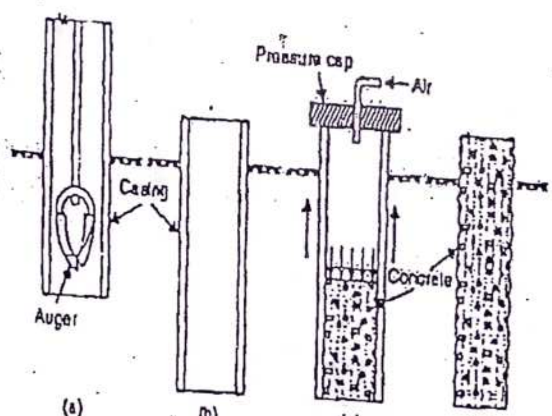


FIG. 4.13. STAGES IN THE CONSTRUCTION OF PRESSURE PILE

- Further same size of steel tube are screwed successively and sunk in the ground, as boring proceeds, till the required depth is reached. The bored soil is continuously taken out. At the end, boring tool is taken out and the hole is cleaned as in fig. (b)
- Concrete is charged in the tube, cap is tightened & air is compressed and simultaneously the tube in exerted out.
- Repeat the process until the concreting comes to the ground level.
- These piles are formed in three sizes: 340 mm Ø(by using 300 mm Ø tubes), 440 mm Ø(by using 400 mm Ø tubes) and 500 mm Ø(by using 460 mm Ø tubes), up to a length of 25 m.

ii) Under reamed piles

- Under reamed piles are bored *cast- in-situ* concrete piles having one or more *bulbs* formed by enlarging the bore hole for the pipe stem by an under-reaming tools.
- These piles may have only one bulb known as single under reamed pile and more than one bulb known as multi-under reamed pile.
- Diameter of the pipe varies 20 to 50cm and the diameter of the bulb varies from 2-3 times diameter of the piles.
- Length 3 to 8m
- Vertically spacing between the bulbs 1.25 to 1.5 times the dia. of bulb.
- Effective to obtain adequate capacity for downward, upward or lateral loads and movements in black cotton soil and loose soils

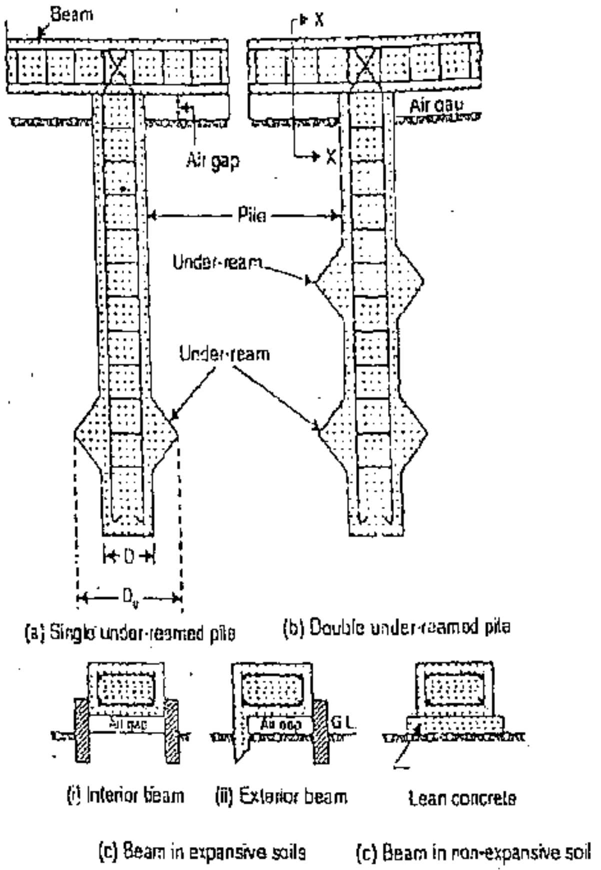


FIG. 4.26. DETAILS OF UNDER-REAMED PILE FOUNDATIONS

Construction procedure

- A vertical bore hole is prepared with the help of casing to the required depth and under reaming tool is used for enlarging the base. The tool consists of two set of collapsible blade and bucket at the bottom for collecting the excavated soil. And, when the bucket is full, then it is withdrawn and the collected soil is removed by opening the bottom lid.
- Casing tube is filled with concrete and compacted properly and casing is withdrawn for one meter height and then concreting is done for 1m height.
- Continue the process till the full length of pile is concreted.

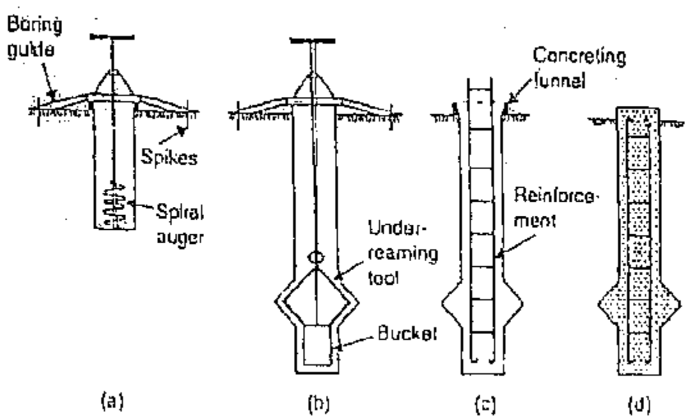


FIG. 4.25. STAGES IN THE CONSTRUCTION OF UNDER-REAMED PILE.

iii) Bored compaction pile

- Modification of under reamed pile. Combines both bored and driven pile
- Same as under reamed except there is the addition of reinforced cage.
- Load bearing capacity is increased by 1.5 to 2.0 times over normal under-reamed piles.

Construction procedure

- Prepare hole with help of spiral augur, using guides and then under-ream it with the help of under-reaming tool and fill the pile with concrete without reinforcement cage.

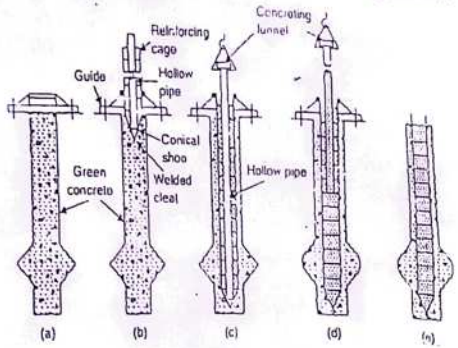


FIG. 4.27 CONSTRUCTION OF BORED COMPACTION PILE

- Place reinforcement cage, enclosing a hollow driving pipe (funnel) on top of freshly laid concrete.
- Drive the assembly into the fresh concrete with mechanical winches (about 5 kN). After driving through the full depth of concrete, fill concrete in the hallow drive pipe or concreting funnel & the funnel is gradually withdrawn leaving the cage and concrete behind.

3) Steel piles

A steel pile may be a rolled section, a fabricated shape or a piece of sheet pile. Two or more sections of sheet piles may be connected together in a box shape and driven as one pile.

Types of steel piles

Metal piles were used since 1838 in the form of cast iron pipes or solid iron shafts with disks or screw flanges penetrating only short distances. But, now-a-days, the following types are more common in use namely in other word, viz

i) H – piles (H - beam pile)
ii) Box - piles
iii) Tube piles or steel pipe piles
iv) Screw piles
v) Disc piles

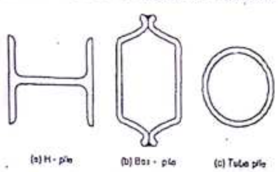


FIG. 4.16. STEEL PILES.

H-beam piles

- Bears the shape of alphabet 'H'
- Suitable where it is desired to penetrate to rock or through hand material with least recourse to jetting, coring etc., because they have very small soil displacement and very much suitable for those structures in which pile extend above ground level and continue as columns. For the super-structure.
- It can with stand large impact stresses developed during hard driving.
- They are used as long piles with high bearing capacity.

Box piles

- They are rectangular, octagonal or other shape in form and filled with concrete.
- Generally used to support a wharf or other sea structures where deep water, silt and sliding banks are present.
- Driven with closed or with open bottom.
- They may be filled with concrete if open bottom.

Steel Tube piles

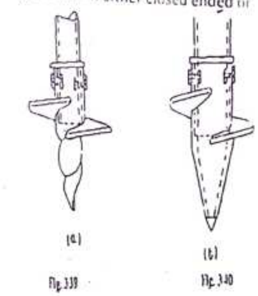
- Are made up with seamless or welded pipes which may be driven either closed ended or open ended.
- If open bottom, concreting is done.
- Their circular shape makes ease in handling & driving.

Advantages of steel piles

- Easily lengthen by welding.
- Can resist lateral forces.
- Bears high bearing capacity.
- Can resist impact stresses.
- Useful in hard or rocky strata, etc

Disadvantages of steel piles

- May corrode (affect by corrosion)
- Expansive
- Heavy, may create difficulty in handling, etc.



Different forms of screw piles

4) Composite pile

A composite pile is formed when it is a combination of either bored pile and a driven pile or a pile of two different materials. They are suitable where the upper part of a pile is to project above the water table. They prove economical as they permit the utilization of the great corrosion resistance property of one material with cheapness or strength of the other. They may be

i).Timber + concrete, or
ii) Steel & concrete

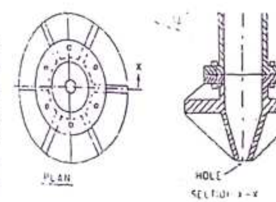


Fig. 341
Disc pile

i) Timber & concrete combined piles: They are used in water logged or in water bodies where timber is used below the permanent or lowest water level while concrete piles usually cast in situ is formed above it. Such that the advantages of both types pile get combined. It also reduces the cost of construction.

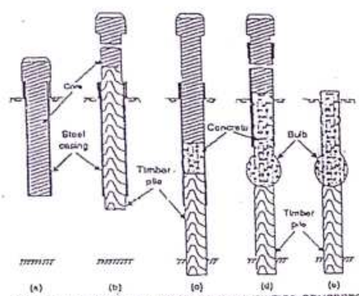


FIG. 4.17. STAGES IN FORMATION OF TIMBER-CONCRETE COMPOSITE PILE.

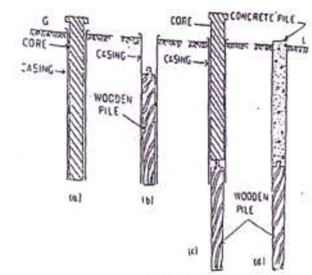


Fig. 334 to 337
Different stages in the construction of composite pile

ii) Steel and concrete composite piles: They are used where the required length of pile is greater than that available for the cast in situ type pile. Steel is used in lower part and concrete is casted above it. This combination is mostly used where satisfactory penetration of the pile into rock is required for heavy loads.

Selection of type of piles: It depends upon the following factors

- Nature of structure
- Loading of structure
- Ground water table
- Length of pile required
- Availability of material
- Factor causing determination of piles
- Cost of piles

Methods of pile driving

1. Drop hammer method
2. Steam hammer method
3. Water jet method
4. Pile driving by boring method

1.1.2 *Pier foundation*

A *Pier foundation* consists of a cylindrical column of large diameter to support and transfer large super-imposed loads to the firm strata below. The difference between *pile foundation and pier foundation* lies in the method of construction. Though pile foundations transfer the load through friction and/or bearing, pier foundations transfer the load only through bearing. Generally, pier foundation is shallower in depth than the pile foundation. Pier foundation is preferred in a location where the top strata consists of decomposed rock overlying a strata of sound rock. In such a condition, it becomes difficult to drive the bearing piles through decomposed rock. In the case of stiff clays, which offer large resistance to the driving of a bearing pile, pier foundation can be conveniently constructed.

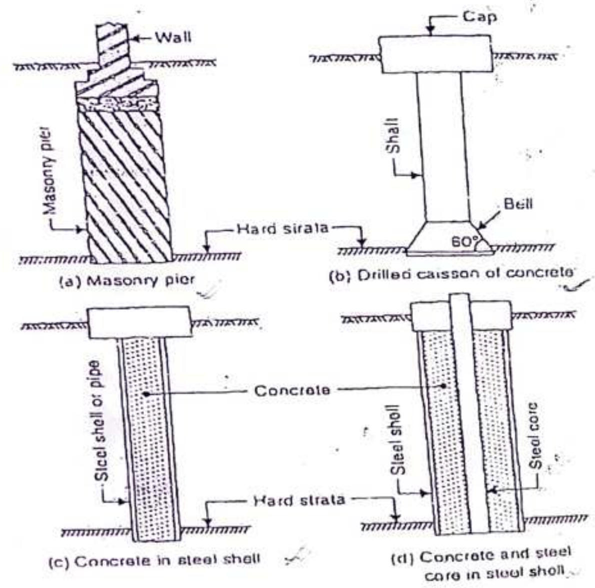


FIG. 2.9. PIER FOUNDATIONS

Pier foundations may be of the following types :

(*i*) Masonry or concrete pier

(*ii*) Drilled caissons.

These are shown in Fig 2.9.

When a good bearing stratum exists upto 5 m below ground level, brick, masonry

or concrete foundation piers in *excavated pits* may be used [Fig. 2.9 (*a*)]. The size and spacing of the piers depends upon the depth of hard bed, nature of overlying soil and super-imposed loads.

The terms *drilled caissons, foundation pier* or *sub-pier* are interchangeably used by engineers to denote a cylindrical foundation. A *drilled caisson* is largly a compressed member subjected to an axial load at the top and reaction at the bottom. Drilled caissons are generally drilled with the mechanical means. Drilled caissons may be of three types (*i*) concrete caisson with enlarged bottom [Fig. 2.9 (*b*)], (*ii*) caisson of steel pipe with concrete filled in the pipe [Fig. 2.9 (c) and (*iii*) caisson with concrete and steel core in steel pipe [Fig. 2.9 (*d*)].

2. **Pier foundation with arches.** Fig 3.32 shows a typical pier foundation for a wall carrying heavy loads. Piers are dug at regular interval and filled with cement concrete. The piers may rest on good bearing strata. These piers are be connected by concrete or masonry arch, over which the wall may constructed. If required, a concrete beam may be provided over the arch if the arch is constructed of masonry. The arches are constructed with a gap above the ground level. This gap would permit free vertical movement of soil during swelling and shrinkage operations.

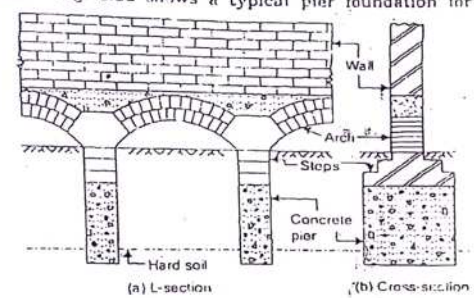


FIG. 3.32. PIER FOUNDATIONS WITH ARCH.

1.1.3) Well foundations (caissons)

The caisson is a structure used for the purpose of placing a foundation in correct position under water. It is a member with hallow portion which after installing in position by any means is filled with concrete or other material.

Caissons are of flowing three types. viz.

a) Box caissons
b) Open caissons, and
c) Pneumatic caissons

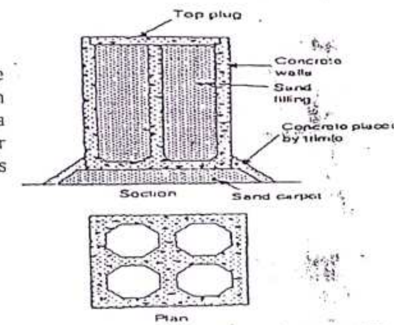


FIG. 4.33 BOX CAISSON (CONCRETE).

a) Box caissons

A box caisson is open at top and closed at the bottom. It is a strong water tight vessel built of timber, reinforcement concrete or steel. These types of caissons are suitable where bearing stratum is available at shallow depth and where loads are not heavy. Caissons is built on land and then launched and floated to pier site where it is sunk in position. Then, it is filled with suitable material and top is sealed.

b)Open caissons or wells

The open caissons are open both at top & bottom. They are built up of timber, metal, RCC or masonry. They are used on sandy or soft bearing strata liable to scour and where no firm bed is available for large depth below the surface.

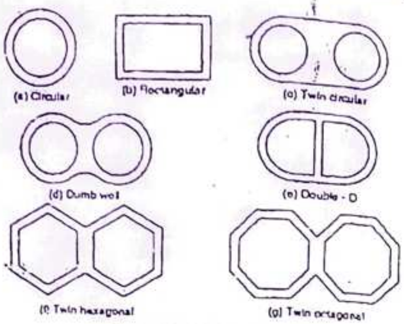


FIG. 4.34. SHAPES OF WELLS.

Shapes of the well may be

- Circular
- Rectangular
- Twin circular
- Dumb well
- Double – D
- Twin hexagonal
- Twin octagonal

Construction method of open caissons:

The cutting edge is placed at the bottom of the pit. Above the cutting edge wall reinforcement is suitably tied up and the caisson walls are then concerted in lift to a suitable height. When the freshly laid concrete has gained sufficient strength, sinking operation is started. The caisson sinks due to its own weight, when the soil from the space inside is removed by using clam shell. As sinking proceeds additional action of the caisson walls are successively casted When caisson is sunk to the required depth its base is plugged by providing concrete seal.

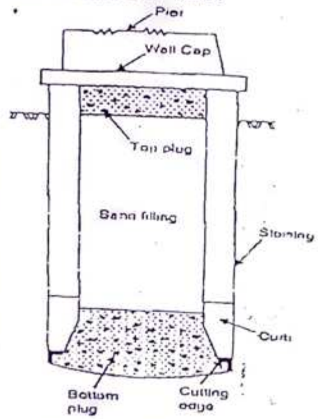


FIG. 4.35. SECTION OF A WELL FOUNDATION

c) Pneumatic caisson

A pneumatic caisson is open at bottom & closed at top containing air or operated by air or gas under pressure. This is useful at locations where it is not possible to adopt wells. Here, compressed air is used to remove water from the working chamber and the foundation work is carried out in dry condition.

Dangers encountered in caisson construction:

Caisson disease is so named since it appeared in construction workers when left the compressed atmosphere of the caisson and rapidly re-entered to normal atmospheric conditions. It is caused by the same process as decompression sickness in divers. Many workers were either killed or permanently injured by caisson disease during the construction of caisson foundation for Brooklyn Bridge in Washington (USA).

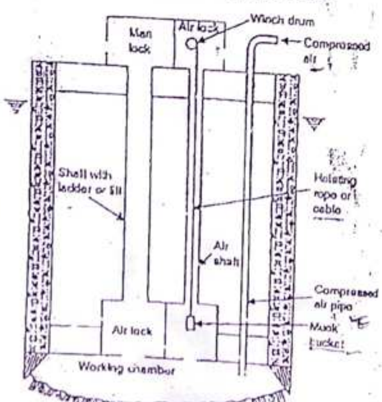


FIG. 4.36. SECTIONS OF A PNEUMATIC CAISSON.

Design constants for shallow foundation

a) Depth of foundation (D_f)

Depth of foundation depends upon the nature of sub-soil and magnitude of the load on the structure. Anyway, the foundation must be carried out below.

i) Depth of frost penetration

ii) High volume changes in soil due to moisture fluctuation.

iii) Unconsolidated materials like mud, garbage and other made up ground.

iv) Weakened by roots hole, cavity produced by animals, worms, etc. & rain water scouring.

v) Generally below minimum depth of 500 mm form the natural ground level

Although, sub-soil exploration is most essential for any important structures or buildings, we can calculate the minimum depth of foundation by using Rankin's formula.

$D_f = P_0/\gamma * [(1-\sin\emptyset)/(1+\sin\emptyset)]^2$

Where,

D_f = minimum depth of foundation (m)

P_0 = safe bearing capacity of soil (KN/m^2)

γ = Unit weight of soil (KN/m^3)

$\emptyset$ = Angle of repose of the soil or angle of internal friction.

b) Depth of concrete bed (d)

It is calculated by using the formula;

$d = 5/6 * t$

Or,

$d = \sqrt{(3px^2/M_r)}$

Where,

t = thickness of wall.

d = depth of concrete block in cm.

x = projection of concrete block on either side of the lowermost course of wall footing in cm.

M_r = safe modulus of rupture of concrete mix used in kN/mm^2

P = net upward soil pressure in KN/m^2

The value of x should vary between 100 to 150 mm. The plane of greatest shear in concrete block across at an angle is 45°.

Note: - The modulus of rupture of various grade of concrete mix shown in table below

S.N	Type of concrete	M_r = KN/mm^2	M_r = KN/m^2
1	Pure lime and surkhi		
2	Lime concrete	0.155	155
3	M_7(1:4:8)	0.246	246
4	M_{10}(1:3:6)	0.352	352
5	M_{15}(1:2:4)	0.527	527

Note: - The Angle of internal friction of various soils has been shown in table below

S.N	Type of soil	Angle of internal friction
1	Loose earth	30° to 45°
2	Compact earth	50°
3	Dray sand	25° to 35°
4	Moist sand	30° to 45°
5	Wet sand	15° to 30°
5	Clays	25° to 45°
5	Gravel	30° to 40°

c) Width of footing or breadth of concrete bed (B).

It is calculated by

B = W/p_o

Where,

B = width of footing in meter.

W = total load including self-weight of footing in KN/m.

p_o = safe bearing capacity of the soil in kN/m² = SBC

d) Minimum width of concrete bed block.

B_{min} = 2t + 2x

Where, t = thickness of wall.

X = offset of concrete block.

v) Draw sketch of the foundation section with the calculated sizes.

Numerical1: - Design wall footing which is rest on sandy soil with angle of internal friction (repose) 30° and safe bearing capacity (SBC) 15t/m². The unit weight of soil is 1600 Kg/m³; wall thickness is taken as 30 cm and total load per unit length of the soil wall is 12.47 t/m.

Solution.

Given;

Angle of repose (Ø) = 30°

Safe bearing capacity of soil; SBC (p_o) = *15t/m²= 15000* Kg/m²

Unit weight of soil (γ) = 1600Kg/m³

Wall thickness (t) = 30 cm

Total load per unit length of soil (w) = 12.4766 t/m = 12476.60 kg/m

Now,

1) To find the depth of foundation (D_f);

D_f = P_o/γ*[(1-sinØ)/ (1+sinØ)]²

= 15000/1600* [(1-sin30°)/ (1+sin30°)]²

= 9.375x0.111

= 1.04 m

≈105 cm

Let's take the minimum depth of foundation = 105 cm

2) To find the depth of concrete bed (d)

We have; d = 5/5* wall thickness

= 5/6*30

= 25 cm

Alternatively, Depth of concrete bed block, d = √(3p x²/M_r) .... (1)

x = Projection of concrete bed block on either side of the lowermost course of wall footing in cm. (The value of x is generally taken equal or greater than 15 cm)

M_r = Safe modulus of rupture of concrete mix used in kN/mm²

P = net upward soil pressure in kN/m²

Let's assume the grade of concrete be M_{10} (1:3:6).

Therefore, M_r= 3.520 kN/m² = 352x1000 N/m² = 352x1000/9.81 kg/m² = 35881.75 kg/m²

(Since, 1kg = 9.8066 N)

Therefore, d = √ (3 x 15000 x (0.15)²/35881.75) = 0.16 m =16 cm

So adopt, d = 16 cm means provide depth of concrete bed = 16 cm

3) To find width of footing or breadth of concrete bed (B):

We have, B = W/p_o

B = W/p_o

= 12476.6 kg/m / 15000 kg/m²

= 0.83 m

= 83 cm

Therefore, the required width of the concrete bed (B) = 83 cm

4) Again, assume the offset of the concrete block, x = 15 cm in order to find the minimum width of concrete bed block

Thus, the minimum width of foundation required (B_{min}) = 2t + 2x

= 2x30+2x15

= 90 cm, which is greater than 83 cm

Therefore, adopt the width of bed block (B_{min}) = 90 cm

5) Draw sketch of the foundation section with calculated sizes:

Numerical 2: Design a foundation for 35 cm wall 3 m long if load carrying on the wall is 30 ton and if it is built on a soil with its ultimate bearing capacity of 30 ton/m². Assume the factor of safety = 3.0

Solution:

Given:

Width of wall (t) = 35 cm

Load on wall = 30 ton

Ultimate bearing capacity of soil (UBC) = 30 ton/m²

Factor of safety (F) = 3

Length of wall = 3 m

Now,

Total load per unit length of wall (W) = Total load/ length of wall

= 30 / 3 ton/m

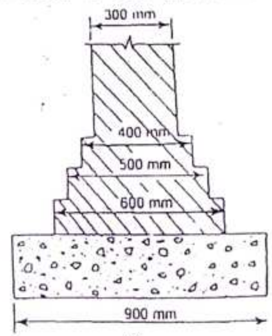
= 10 ton/m

And, safe bearing capacity of soil (SBC) = UBC/F

= 30/3 ton/m²

= 10 ton/m²

Here, angle of repose and unit weight of soil is not given. That means we could not find the minimum depth of the foundation. Hence, proceed from step 2.



(b)

1) To find the depth of concrete bed (d)

We have, d = 5/6 * the wall thickness

= 5/6*35

= 29.17 cm

≈ 30 cm

2) To find the width of concrete bed (B)

B = W/p_o

= 10/10 m

= 1 m

Let's assume offset of the concrete block, x = 15 cm.

Therefore, the minimum width of the concrete block; B_{min}

= 2t + 2x

= 2(35+15)

= 100 cm.

Thus, provide the width of the concrete block, B = 100 cm.

Since, the angle of repose and unit weight of the soil is not given, that means we could not be able to calculate the depth of foundation theoretically, thus provide the minimum depth of footing equals to width of the concrete bed, i.e. 100 cm.

Basement

A basement is one (shallow) or more floors (deep) of a building that are either completely or partially below the ground floor. The supporting and partitioning walls in basements are mostly constructed with rich mix of reinforced cement concrete having adequate thickness and act as load bearing walls. The basement walls are provided with doors and openings. Floor slabs and walls are monolithically constructed with R.C.C to resist dampness from earth soil. Basement construction including its operation cost is expensive and it's difficult to construct where ground water table is high. A mat foundation having a basement floor has been shown in figure below.

Waterproofing is the formation of an impervious barrier that is designed to prevent water entering or escaping from various sections of building structures in basement floors. The design and the construction procedures required to complete basement waterproofing are more important than waterproofing the basement itself. As the cost and availability of real estate increases in urban areas, basements are becoming more and more common in new structures such as high rise buildings, commercial complexes etc. Basements can provide space for most commercial activities, storage, archives, plant rooms or car parking. In residential buildings, they provide valuable additional space, which can be efficiently heated and is particularly useful for leisure activities with different games rooms, storage and parking without increasing the height of the building. Basements are required for underground metro and railway stations apart from commercial activities. Basement waterproofing installers are highly specialized in new constructions and normally do not deal with landscape, demolition, excavation, underground utilities, backfill, compaction and a variety of other tasks which come into play during a basement waterproofing repair job. The term "basement waterproofing" is intended to encompass the topic of moisture protection and protection from all undesirable liquids and gases as applied to a variety of existing below-grade structures. It requires special damp proofing or water proofing techniques, drainage systems, lighting, ventilation etc. in basement floor.

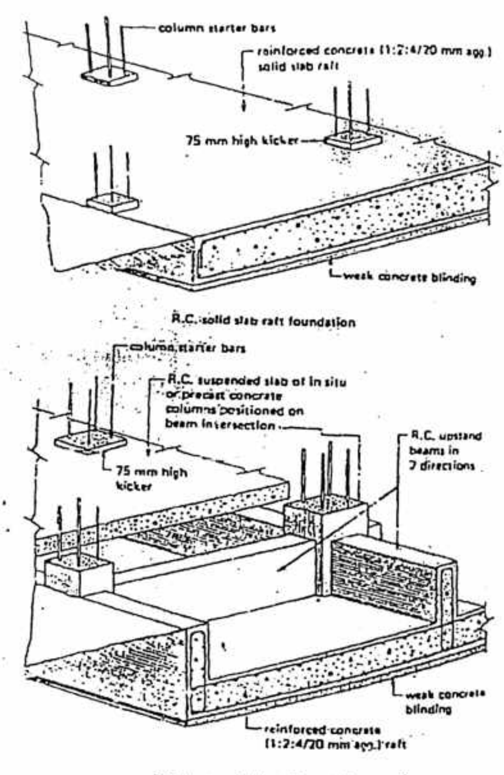


Fig 11.10 R.C. raft foundations

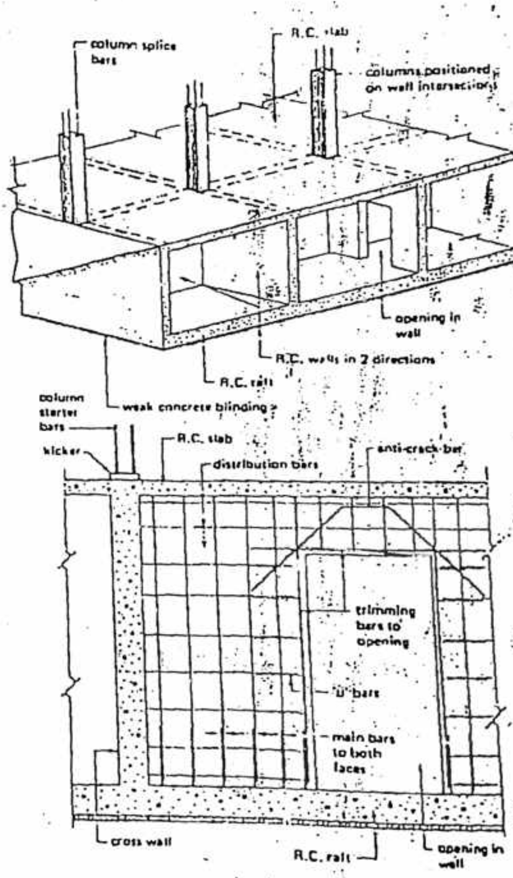


Fig. 11.11 Typical cellular raft details with basement

1.2 Some common problems with existing foundations

Not everything that we do for buildings is for appearances. The appearance and the beauty of building are contributed by long-term FUNCTIONING and durability of the building which is possible only till the existing foundation is properly functioning. The basic function of a foundation is to transmit all the loads (dead, live and other loads) to the subsoil on which it rests in such a way that (a) settlements are within permissible limits, without causing cracks in the super structure and (b) soil does not fail in shear. Since, the foundation remains below the ground level, the signs of failure of foundations are not noticeable, till it has already affected the building.

Therefore, the existing foundation of a structure is always facing with problems as mentioned below:

1) Settlement of sub-soil below the foundation that may be normal within limits but if there is some existing damage that needs to be addressed (talked)
2) Unequal settlement of subsoil which is unsafe and ultimately lead to failure of foundation and collapse of the structure. In this case, the issues will be that the existing foundation is repairable or not.

(3) Many foundations are damaged due to water. When rain collects on a roof because of poor drainage, it can drip into a home and basement. Water from plumbing leaks, sprinkler systems and other sources can also seep into a home if it isn't directed away from the foundation. The accumulation of water inside a structure will not only cause breading of germs, decay and damage of wooden supports, enter small cracks and eat away at the foundation.

Causes of foundation settlement

1. Consolidation of soil particles
2. Reduction of moisture content
3. Heaving (lift or drag with great effort) of soil due to pressure
4. General earth movement due to earthquakes, vibration or factors)

Effect of unequal settlements

1. Stress in building
2. Distortion of structure fabrics
3. Failure of structure

Prevention of unequal settlement

1. Proper foundation design
2. Proper soil investigation
3. Proper supervision and construction as per design
4. Use of proper construction materials as specified by architect and designers

Causes of foundation failure

1. Unequal settlement of soil
2. Unequal settlement of masonry
3. Unequal load distribution
4. Horizontal movement of soil adjoining structure
5. Lateral pressure tending overturn
6. Shrinkage due to withdrawal of moisture from soil
7. Atmospheric action
8. Lateral escape of soil below foundation
9. Nearby building construction
10. Trees etc.

Suitability of different types of foundation is selected according to:

1. Total load of building
2. Nature and bearing capacity of soil

A good foundation is judged by:

1. Location (whether the building is located on hard or rocky stratum or in soft soil or in high ground water table, near river, stream, landslide area, and area affecting by frequent vibrations etc.)
2. Suitability of foundation (determined by the total load of the structure and bearing capacity of soil)
3. Settlements (land prepared by filling earth or old hardened surface etc.)

A good foundation depends on:

1. Heavy load
2. Poor bearing capacity of sub-soil
3. High water table or marshland
4. Cost consideration

Foundation in black cotton soil

One of the common problems with existing foundation is caused due to presence of black cotton soils. Black cotton soil and other expansive soils have typical characteristics of shrinkage and swelling due to moisture movement through them. During rainy season, moisture penetrates into these soils due to which they swell. Black cotton soil has their grains which are more or less in the form of platelets or sheets (just like leaf of book) and their grains are not round. When moisture enters between the platelets under some hydrostatic pressure, the particles separate out resulting in increase in the volume, which is known as swelling. If the footing is constructed over it, high swelling pressure is induced which results serve cracks in the structure.

Black cotton soil is:

- Good for agriculture and bad for structure
- High shrinkage value due to change in in moisture content
- Volume varies as 20 – 30 % of original volume
- Develops vary wide and deep cracks due to excessive shrinkage
- Very week in saturation
- Problematic for foundation

Precautions for foundations in black cotton soil.

1. Limit the load on the soil to 5.5 ton/m^2.
2. Take minimum depth of foundation = 1.5m.
3. Provide reinforcement concrete ties or bands all around the main walls of the building.
4. If possible remove the layer of black cotton soil (If the total depth of layer is 1 to 1.5m thick).
5. Make wider trench and fill either sides of the foundation by sand.
6. Compact the bed level enough.
7. Foundation should be constructed in dry season.
8. Raft foundation can be the solution.
9. Tie – beam in plinth is important

Types of foundations suitable in black cotton soil

- Strip or pad foundation
- Pier foundation
- Under reamed pile foundation
- Raft or mat of foundation

3. Under-reamed pile foundations.

1. **Strip or pad foundation.** For medium loads, strip foundation (for walls) and pad foundation (for columns) may be provided, along with special design features discussed above. Fig. 3.31 shows some typical sections of shallow footings suitable for black cotton and other expansive soils.

Section of Fig. 3.31 (*a*) is suitable when the soil, though expansive, has little swelling pressure. A 60 cm thick layer of cohesionless sand is placed below the foundation concrete, and is compacted. Sand is also filled around the footing. When the soil swells, the sand grains would yield by moving up, thus relieving the swelling pressure. When the soil shrinks, the sand layer would expand, but there will be no discontinuity in the soil support. Sand fill should also be used below flooring. Section of Fig. 3.31 (*b*) is suitable where the swelling pressures are relatively high. The alternate layers of mooram (or ballast) and sand act as a spring which can compress or expand along with the sub-soil movements. It will, thus absorb all the movements, thus keeping the footing free from these effects. If the soil is soft and has poor bearing capacity, a 30 cm thick layer of ballast and mooram should first be rammed into the soil. Over the top of it, a min. of 30 cm thick layer of coarse grained sand may be placed. In all the three cases, the foundation concrete may be done in rigid cement concrete, and if possible, it may contain nominal reinforcement. Fig. 3.31 (*d*) shows a section which may be used for soils of high swelling pressure, and having high shrinkage properties. After compacting the base of the tranch, 25 to 30 cm wide strips of concrete, 25 to 30 cm thick, may first be laid and compacted. After the strip concrete is cured, the space between the two is filled with sand. The space between the two strips of concrete (i.e. width of sand fill) may be kept equal to width of the bottom course of masonry. On the top of this, the foundation concrete layer, preferably of reinforced concrete is laid. The sides of the masonry footings is filled with sand as usual. In addition to this, 80 mm dia. pipes spaced at 1.5 to 2 m etc. are placed through masonry and concrete bed, so as to reach the bottom sand fill a shown, and sand is filled in the pipe. A plug may be placed on the top of the pipe, to facilitate the inspection from time to time, and to pour fresh sand if required.

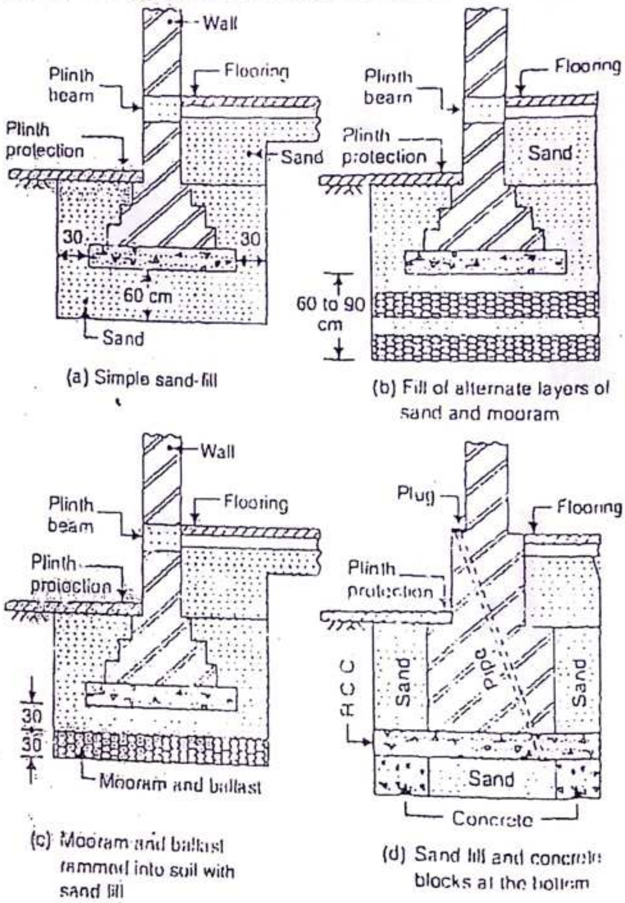


FIG. 3.31. STRIP FOOTING WITH SPECIAL TREATMENT

Suitability of different types of foundation

Foundation is the lowest part of a structure which provides a base for the super structure so that the load coming over it is to be transmitted safely to the underlying hard strata. They can be of various types. That means we can provide different types of foundation depending upon the nature of load intended to come over it and the underlying strata or soil where we are going to rest any structure. Hence, some foundations and their suitability can be explained as follows:

- If the building is residential then we can provide any types of shallow foundation depending upon the nature of ground such as spread footing, independent footing (most common), mat foundation etc.
- If we are going to cover whole the area including the boundary line, the eccentrically loaded footing is best suited.
- If the wall is load bearing type, then we have to provide wall footing that may be stone or brick masonry depending upon what materials we are going to use/available.
- If the bearing capacity of soil is low or very low combined or mat foundation will be the solution.
- If the bearing capacity is low, we may have required providing the combined footing and if the load on column is not uniform the trapezoidal combined footing may be the solution.
- If the ground is water logged in shallow depth timber grillage foundation is the best one.
- Similarly, if the structures load is heavy and if hard stratum is quite below, and then we have to provide the deep foundation or caissons. Among the pile foundation, if there is soft soil but presence of hard stratum below it, then end bearing pile is best where as if the loose bed of soil extends to greater depth then we have to provide the friction piles.
- If the structure to be constructed is by the side of water bodies, anchor or uplift piles have to be provided. Timber piles are the best solution below the water bodies for greater depth.
- If the soil is very loose we can provide under reamed piles and if the soil is hard and upcoming load is heavy then steel piles is best suited.
- If we have to pass greater depth at water bodies or in water logged area the composite piles having timber portion at bottom and concrete pile above it is the solution.

1.3 Retaining properties and water proofing of basement

The construction of basement walls have their retaining properties like a retaining wall since they are subjected with lateral and overturning pressure exerted by the earth pressure and sub-surface water pressure. Basically, in basement floors underground water is applying pressure to the floor or walls of basement and trying to get in however, it depends on the structure. These pressures should be considered while designing the basement structure.

Very simply, from a waterproofing perspective, basements fall into three categories:-

A. **Non Waterproof Masonry Structures** - include brick or cement concrete block work and stone masonry walls. MOST OLDER STYLE DOMESTIC PROPERTIES FALL INTO THE TYPE A CATEGORY.

B. **Integrally Waterproof Structures** – which includes reinforced concrete where the walls and floor are tied together to water tight (for example Mat foundation) but there also may be some defects during construction hence it also fails and occurs dampness through concrete.

MANY MODERN BASEMENT STRUCTURES FALL INTO THE TYPE B CATEGORY - AND FAIL.

C. **Drained Cavity Structures** - Many civil engineering structures involving deep basements are constructed in the drained cavity format. The outer earth retaining walls are often very wet, maybe even running with water, but the inner wall is kept dry by virtue of the 'drained cavity' in-between. Thus Type A masonry structure can often be converted to a Type C 'i.e. Drained Cavity' Structure by the installation of a drained cavity membrane together with drainage channels and sump and pump.

Basically there are TWO distinct approaches for water proofing of basement -

1) Applying a 'Tanking System' this will be a coating of some sort bonded to the walls and floor to create an inside out 'tank' A tank where the water is on the outside
2) Converting the structure to a Type C 'Drained Cavity' Structure by the installation of a drained cavity membrane together with drainage channels, sump and pump

Methods to make water proofing of basement (horizontal & vertical DPC)

The following treatments are generally adopted for water proofing of basement:

1. Treatments to foundations against gravitational water.

- This is done by air drains (width=20 to 30cm) constructed parallel to the external wall.
- The outer wall of the drain is kept above the ground to check the entry of surface water.
- A R.C.C roof slab is provided.
- Openings with gratings are provided at regular interval, for the passage of air and usual
- DPC are provided horizontally.

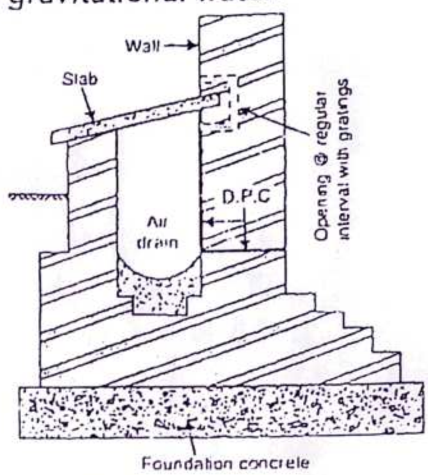


FIG. 21.1. AIR DRAIN.

2. Treatment to basements

Treatment to basement is generally done by:

a. Providing foundation drain & DPC
b. Providing R.C.C raft & wall slab
c. Asphalt tanking

a. Providing foundation drain & D.P.C

When basement rests on soil which are not properly drained, then floor as well as wall receive water continuously oozing out (slowly seep out). In such case, a trench all around the perimeter of the building is excavated up to foundation level and a drain pipe with perforated surface is laid and filling the trench by gravel. And sometimes, if the magnitude of oozing out, water is more, cross drain may also require. Finally, the water is collected into the catch drain and is pumped out or drained naturally as per the site condition. In addition to this horizontal & vertical DPC are provided in wall as well as foundation

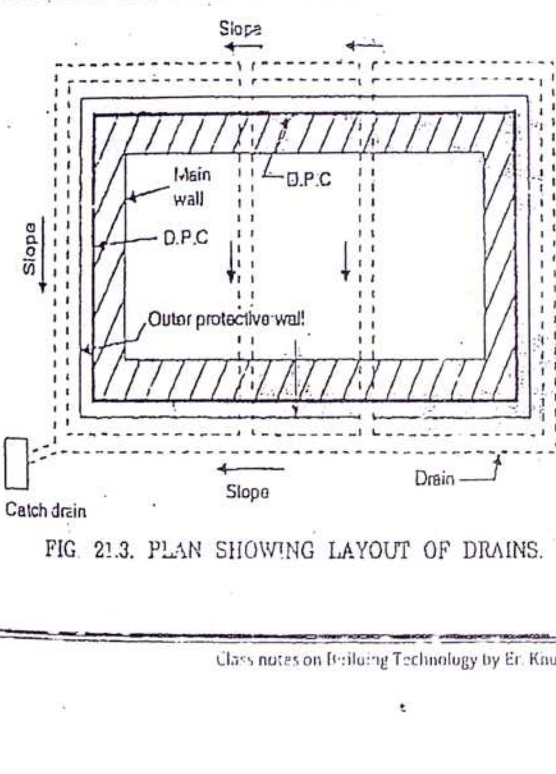


FIG. 21.3. PLAN SHOWING LAYOUT OF DRAINS.

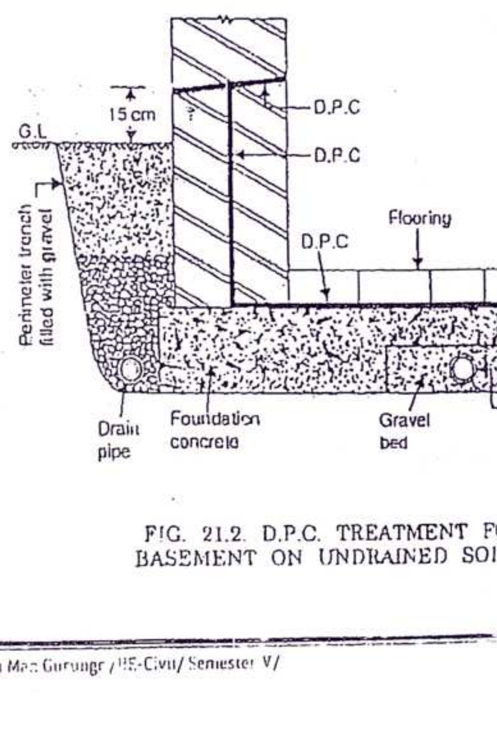


FIG. 21.2. D.P.C. TREATMENT F(BASEMENT ON UNDRAINED SOI

b. Provision of RCC raft & wall slab

When the underground water pressure is more, then; only the drainage system cannot solve the problem. In such a case R.C.C slab is provided both horizontally & vertically. In horizontal course, PCC band is placed first and then DPC is provided. Above this band, directly RCC slab is casted or in some cases, flat brick soling is provided between the DPC band and the RCC slab. in vertical course first of all, half brick wall, DPC band and RCC wall is provided side by side ensuring the brick wall at the outer side.

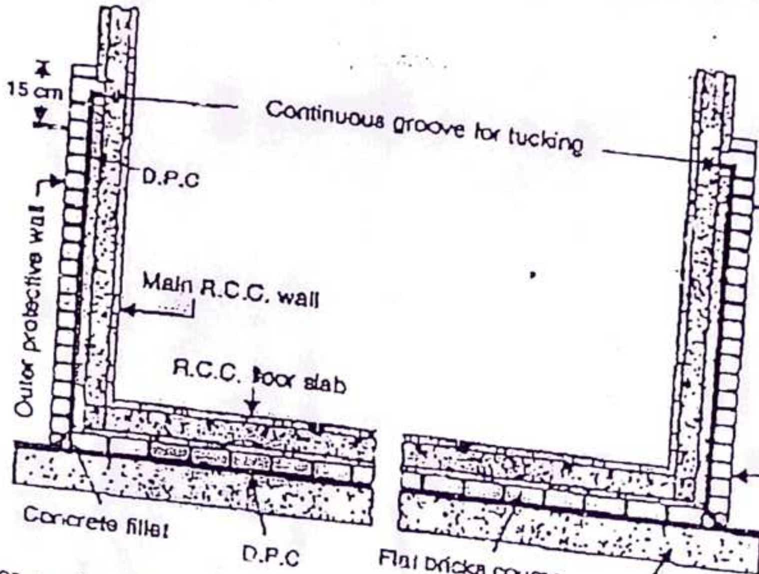


FIG. 21.4. D.P.C. TREATMENT FOR BASEMENT IN DAMP SOIL.

c. Asphalt tanking

This is same as provision of RCC slab (raft) and wall slab except in this case masonry wall is provided in place of side wall slab & floor concrete bed instead of RCC raft. Thus treatment is done when the underground water pressure is not very high. The DPC band is provided in the form of asphaltic layer of 30 mm thick in three coats over the entire area of the basement floor and then extending it in the form of vertical DPC on the external faces of the basements walls.

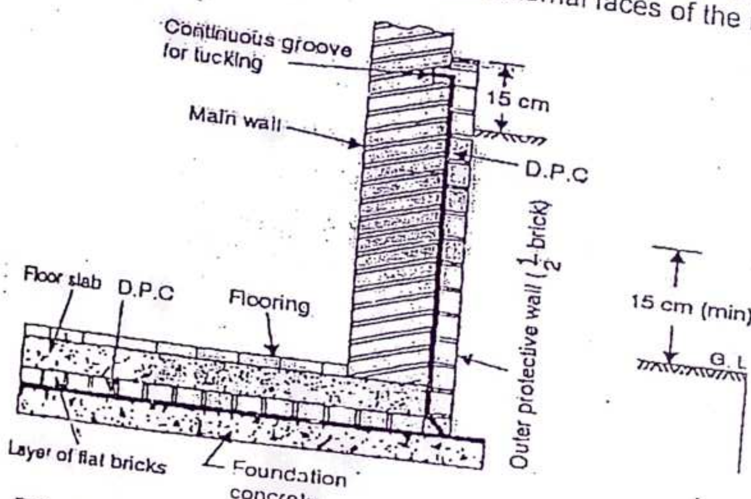


FIG. 21.5. ASPHALT TANKING FOR BASEMENT.

1.5 Damp proof course

It is a water repellent membrane (course) applied between the source of dampness and the part of building adjacent to it. One of the basic requirements of a building is that it should be dry or free from moisture travelling through walls, roofs or floors. Dampness is the presence of hygroscopic or gravitational moisture. Dampness gives rise to unhygienic conditions apart from reduction in strength of structural components of the building. Absorption of moisture by the building material is one of the chief causes of dampness. On account of granular nature of materials, moisture finds an easy access through the voids and this aided by capillary action assists the moisture to travel in different directions. Sometimes, faulty design, bad workmanship, or by use of poor materials in construction, moisture may find its way to interior of the building either through the foundation and plinth, walls, chhajja or floors and roofs.

Effects of dampness:

1. Creates unhealthy living and working condition.
2. Causes efflorescence on building surface, which may disintegrate bricks, stones, tiles etc.
3. May cause softening and crumbling of plaster.
4. The wall decoration is damaged which is very difficult and costly to repair.
5. May cause unsightly patches on walls, ceiling etc.
6. The flooring gets loosened due to reduction in adhesion.
7. Timber fittings such as door, window, etc which is in contact with damp walls, floors etc get deteriorated.
8. Electrical fittings get deteriorated giving rise to leakage of electricity and consequent danger of short circuiting.
10. Floor coverings get damaged or cannot be used.
11. It promotes and accelerates the growth of termites.
12. Dampness causes rusting and corrosion of metal fittings attached to the walls, floors and ceilings.
13. Dampness along with darkness breeds germs of dangerous diseases like tuberculosis, rheumatism (disease causing in joints) etc.

Sources of Dampness

The following are the sources/causes of dampness in building.

1. Moisture rising up the walls from ground.
2. Rain travel from wall tops.
3. Rain beating against external walls.
4. Condensation.
6. Miscellaneous causes of dampness:
   i. Poor drainage
   ii. Imperfect orientation of rooms or building
   iii. Imperfect roof slope
   iv. Defective construction
   v. Absorption of water from defective rain water pipes.
   vi. Leakages from pipe and pipe fittings both in inside and outside of wall

Remedial measures to prevent Dampness.

The following methods are generally used for protecting the building from dampness.

1. Use of damp proofing course (DPC) or membrane damp proofing

This consist of introducing a water repellent membrane of damp proof course between the source of dampness and the part of building adjacent to it. DPC may consist of flexible materials such as bitumen, mastic asphalt (a gum from the bark of a Mediterranean tree used in making varnish and chewing gum and mixed mastic with asphalt), plastic or polythene sheets, cement concrete etc. It may be provided horizontally or vertically. Asphalt is a dark tar, like substance used in road surfacing or water proofing of building Bitumen is a black sticky substance obtained naturally from petroleum which is used for road surfacing.

The following general principles should be kept in mind while providing DPC.

1. The DPC should cover full thickness of wall excluding rendering (service).
2. The mortar bed supporting DPC should be leveled and even and should be free from projections, so that DPC is not damaged.
3. DPC should be so laid that of a continuous projection is provided.
4. At junctions and corners of walls, the horizontal DPC should be laid continuous.
5. When a horizontal DPC is continued to a vertical face, a cement concrete fillet of 7.5cm radius should be provided at junction.
6. DPC should not be kept exposed on the wall surface otherwise it may get damaged

2. Use of integral damp proofing

This consists of adding certain water proofing compounds to the concrete mix, so that it becomes impermeable. The water proofing compounds may be in three forms.

a. Compounds made from chalk, talc, fullers earth, which may fill the voids of concrete under the mechanical action principle.
b. Compounds like alkaline silicates, aluminum, sulphate, and calcium chlorides etc. which react chemically with concrete to produce water proofing concrete.
c. Compounds like soap, petroleum, oils, fatty acid compounds such as stearates of calcium, sodium ammonia etc. work on water repulsion principle. When these are mixed with concrete, the concrete becomes water repellent.

3. Surface treatment

The surface treatment consists in filling up the pores of the materials exposed to moisture by providing a thin layer of water repellent material over the surface. Many surface treatments like pointing, plastering, painting, distempering etc. are given to the exposed surface and also to the internal surfaces. The generally using water proofing compounds are sodium or potassium silicates, Aluminium or Zinc sulphates, coal, tar bitumen, waxes, fats etc. It should be noted that surface treatment is effective only when the moisture is superficial and is not under pressure.

4. Cavity wall construction

This is an effective method of damp prevention. A cavity wall consists of two parallel walls or leaves of masonry separated by a continuous space or cavity. It consists of three parts. viz;

a) Outer wall – 10cm thick.
b) The cavity – 5 to 8cm thick.
c) The inner wall – minimum 10cm thick.

5. Guniting

This method consists of providing an impervious layer of rich cement mortar over the exposed surfaces for water proofing or over pipes, cistern etc. for resisting the water

6. Pressure grouting

This consists of forming cement grout under pressure into cracks, voids, fissures etc present in the structural components of the building or in ground. This method is quite effective in checking the seepage of raised ground water through foundations and sub-structure of building.

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Requirements of damp proofing materials

1) Imperviousness

It should not permit any moisture movement or penetration through it.

2) Durable

It should have life span equal to the life span of building.

3) Strong

It should be strong enough to resist super-imposed loads on it.

4) Flexibility

It should be flexible enough to accommodate the structural movements without any fracture.

The material should be such that leak-proof jointing is possible.

The material should remain steady in its position when once applied.

5) Cheap and easily available

It should not be costly and easily availablr.

Materials used for damp proofing

1. Flexible / Non – rigid materials (hot bitumen).

e.g. Bitumen felts, metal sheets of lead, cupper, polythene sheet etc.

2. Semi – rigid materials

Mastic asphalt, combination of materials like sand, asphalt and mineral fillers etc.

3. Rigid materials

Bricks, stones, slates, cement mortar, cement concrete etc.

4. Grout

Cement slurry and acrylic based chemicals, polymers etc.

1.4 Earthquake effects on foundations

Earthquakes are most destructive forces that nature releases on earth. They not only cause a loss of life and property but also shake the moral of the people. Vibrations of earth surface caused by waves coming from source of disturbances inside the earth are called earthquakes. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests etc.

Epicentre, Hypocentre and earthquake *wave*:

The point inside the earth mass where slipping or fracture begins is termed as ***Focus*** or ***hypocentre*** and the point just above the focus on the earth surface is termed as ***epicentre.*** The position of hypocentre is determined with help of seismograph records which indicate the arrival times of different types of energy waves. Compressional waves which are also termed as longitudinal or ***primary (P) waves*** travel the fastest (traveling at about 8km. per second or 18,000 mph) and arrive first. It has the form of a sound wave that, as it spreads out, alternately pushes and pulls at the ground material). The shear or transverse or ***secondary (S) waves*** shears the rock sideways at right angles to the direction of travel. The third type is a surface wave called the ***Love (L) wave*** that is similar to a secondary (S) wave with no vertical displacement. The fourth type of wave, also a surface wave, is known as the ***Rayleigh (R)*** waves; in this the disturbed material moves both vertically and horizontally in a vertical plane pointing in the direction in which the waves are traveling. Of the two surface waves, ***Love waves*** generally travel faster than ***Rayleigh.***

Earthquake causes ground motion in any direction i.e. ***horizontally, vertically*** and in ***all directions*** radiating from the epicentre by which structures are influenced with ***inertial forces.*** It is therefore, essential to ensure ***(i) stability, (ii) strength and (iii) serviceability with acceptable levels of safety by way of suitable design and detailing.*** The intensity and duration etc. of seismic ground vibration depends upon the ***magnitude*** of the earthquake, its ***depth of focus, distance from epicentre, characteristics of path through which seismic waves travel and soil strata on which the structure stands.*** The random earthquake ground motion which causes the structure to vibrate can be resolved in any three mutually perpendicular directions (i.e. X, Y and Z axis). But the usual direction of ground vibration is horizontal.

Basic deference between *Magnitude* and *Intensity:*

Magnitude of an earthquake is a measure of its size which is released by the faulty rupture and is measured by single value (Richter scale) for a given earthquake. Earthquake of ***a given magnitude*** causes ***different shaking intensities at different locations*** and therefore the damage induced in the ***building at these locations is different.*** Intensity of an earthquake is an indicator of the severity of shaking generated at given location which is much higher near epicentre than farther away

General Effects Due to Earthquake

Direct Effects

- Ground failures (or instabilities due to ground failures)
- Surface faulting surface or fault rupture)
- Vibration of soil (or effects of seismic waves)
- Ground cracking
- Liquefaction
- Ground lurching (swaying)
- Differential settlement
- Lateral spreading
- Landslides
- Vibrations transmitted from the ground to the structure.

Indirect effects/Consequential Phenomena

- Tsunamis
- Changes
- Landslides
- Floods
- Fires

The seismic effect or damage that usually concerns the structural engineer, and which is taken into account by code seismic-resistant design provisions, is the vibration of the structure in response to ground shaking at its foundation.

Effect of earthquakes on the foundation may be as follows:

1) Development of shear stress in weak earthquake and shear failure in case of strong earth quake at any parts of foundation due to unequal settlement of sub-soil.
2) Overturning and sliding effects of foundation in severe cases.
3) In the case of strong earthquake and stable foundation shear failure may occur at columns between the sub-structure and super-structure (near the plinth level).
4) Formation of cracks and failure of plinth beams, tie beams, strap beams and combined footings as well as slabs of basement floors due to horizontal movement and tensile stress development.
5) In strong shaking, change in ground water table and sub-soil condition, formation of caves and voids under building thus reduction in bearing capacity of soil and stability of foundation.
6) In very strong earthquake, in some cases foundation as a whole part of the building including super-structure may be punched or sunk below the ground level.

Earthquake Magnitude Scale

Richter Magnitude scale	Earthquake Effects	Estimated Number Each Year
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicentre.	One every 5 to 10 years

Earthquake Magnitude Classes

Earthquakes are also classified in categories ranging from minor to great, depending on their magnitude.

Class	Magnitude
Great	8 or more
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 -3.9

Richter magnitude scale

The ***Richter magnitude scale*** (often shortened to ***Richter scale***) was developed to assign a single number to quantify the energy that is released during ***an earthquake***.

The scale is a ***base-10 logarithmic scale***. The magnitude is defined as the logarithm of the ratio of the ***amplitude*** of waves measured by a ***seismograph*** to an arbitrary small amplitude. An earthquake that measures 5.0 on the Richter scale has a shaking amplitude 10 times larger than one that measures 4.0, and corresponds to a 31.6 times larger release of energy!!!

Since the mid-20th century, the use of the Richter magnitude scale has largely been replaced by the ***moment magnitude scale (MMS)*** in many countries. However, the Richter scale is still widely used in ***Russia*** and ***other CIS*** countries. Earthquake measurements under the moment magnitude scale in the ***United States***—3.5 and up, on the MMS scale—are still usually incorrectly referred to as being quoted on the Richter scale by the general public, as well as the media, due to their familiarity with the Richter scale as compared to the MMS.

Chapter-2, Masonry

Masonry may be defined as the construction of building units bonded together with mortar. The blocks of materials such as brick, stone, concrete, hollow block etc. is cemented together with some form of mortar usually in horizontal course is known as masonry wall or simply the masonry. The masonry wall is built up of individual blocks of materials bonded together with mortar. It may be either brick masonry or stone masonry or concrete block masonry (hollow) or reinforced brick masonry or composite masonry. Masonry is generally a highly durable form of construction. The durability of the overall masonry construction is significantly affected by the materials used, the quality of the mortar and workmanship and the pattern in which the units are assembled. The selection of the type of material for the masonry is made by keeping in view the requirements of strength, durability, water proofing, thermal insulation, sound insulation, fire resistance and economy etc.

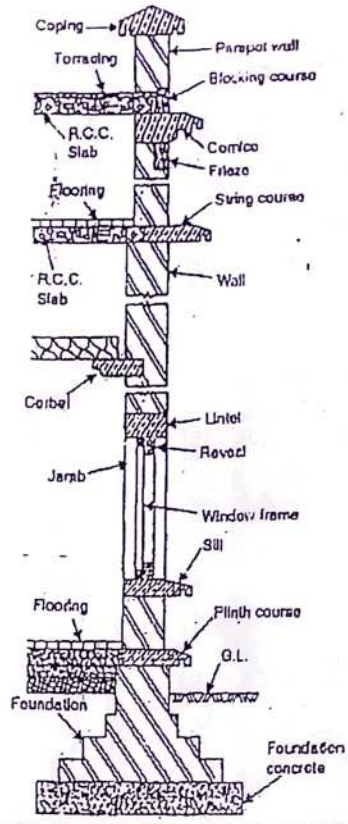


FIG. 6.6. SECTION THROUGH A WALL.

Functions of masonry wall

Wall is one of the most essential components of a building. The primary function of a wall is to enclose or divided space of the building to make it more functional and useful.

Functions of wall

- It provides privacy.
- Its helps to enclose or divide space of the building.
- It affords security.
- It gives protection against heat, cold, sun and rain.
- It may provide support to floor and roofs etc.

Types of Masonry walls

A) According to their function masonry walls may be divided in to following three categories:

1. Load bearing wall
   a) External wall (Enclosing wall)
   b) Internal wall (Divide wall)
2. Non-load bearing wall
   a) External wall (Enclosing wall)
   b) Internal wall (Divide wall)
3. Retaining walls

1. Load bearing wall

A wall designed to carry super imposed loads of floors and roof is known as load bearing wall. Such wall has continuous foundation (strip foundation) to carry the entire imposed load including their self-weight.

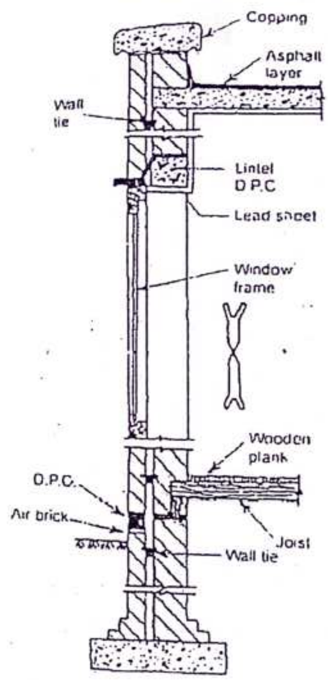


Fig. 9.3. *Section of cavity wall and ties.*

2. Non-load bearing wall

They are not designed to carry super imposed load of the structure. They carry only their own weight. They generally serve as divide or partition wall. It is provided to serve as screen for privacy and to keep out wind and weather. The loads from floors and roof in this case are borne by either brick pier or by a system of RCC or steel beam and column frames. Non-load bearing walls are also known as panel wall, curtain wall or filler wall.

3. Retaining walls

This is a type of wall built to resist the pressure of earth, granular material or liquid filled behind it after it is built.

According to the materials used masonry walls may be divided as follows:

1. Brick masonry walls
2. Stone masonry walls
3. Reinforced brick masonry walls
4. Composite masonry walls
5. Hollow concrete block masonry walls

2.1 Brick masonry and block masonry

2.1.1 *Brick masonry*

The construction of brick unit bonded together with mortar is termed as brick masonry. The strength of brick masonry depends upon the types of mortar used, the quality and strength of bricks and method of bonding adopted in construction. Generally cement mortar is used for works of permanent nature where strength is of vital importance, lime mortar for general construction purpose and mud mortar for works of temporary nature. Brick masonry is widely employed in the construction of building components such as walls, portions of footings, stair column, floors, arches etc.

Advantages of brick masonry

- All the brick has uniform shape and size hence they can be laid easily in any definite pattern.
- They are light in weight and small in size, hence, they can be easily handled.
- They do not need any dressing.
- The art of brick laying can be understood very easily and even unskilled masons can do it.
- They are easily available.
- Ornamental works can be easily done with bricks
- Light partition walls and filler walls can be easily constructed.

Types of brick:

i) Traditional brick

ii) Modular bricks

i) Traditional bricks: Those are traditional bricks which have not been standardised in size
- The dimensions of traditional brick vary from place to place. Their length varies from 20 to 25 cm; width varies from 10 to 13 cm and thickness from 5 to 7.5 cm.
- The commonly adopted nominal size of traditional brick is 23 cm x 11.4 cm x 7.6 cm approximately

ii) Modular bricks: Modular bricks conform to the size laid down by Bureau of Indian standard Institution, India.
- Any brick which is of the same uniform size as laid down by BIS is known as the modular brick
- The nominal size of modular brick is 20 cm x 10 cm x 10 cm while the actual size of brick is 19 cm x 9 cm x 9 cm. Nominal size includes the mortar thickness.

General principles to be observed in brick masonry construction (important for exam)

The strength of masonry work depends upon the materials used, nature of workmanship and supervision. The following points should be observed in the construction of brick masonry:

1. Use bricks of good quality with uniform colour, well burnt, with exact shape and size.
2. Before using the bricks in masonry, they should be soaked in water for 2 hours so that bricks do not absorb water from the mortar. A good brick should absorb < 20% water of its own weight.
3. Bricks should be laid with the frog pointing upward.

4. Construction of brick wall should start from the end or corner.
5. Brick courses should be perfectly horizontal.
6. Verticality of the wall should be ensured by frequently checking with plumb-bob. Battered surfaces, if any should be properly checked with the help of wooden template and plumb bob.
7. Mortar used should be as per specification.
8. Whenever work is stopped brick masonry should be left with toothed end.
9. When it is required to raise new construction over the old or dry one, it should be well cleaned and wetted before starting the construction.
10. Use of brick bats should be avoided.
11. It is found that with an average winter - summer temperature differences of about 100°F, a brick masonry wall expands by about 10mm in every 30 m length of the wall. Hence it is desirable to provide minimum of 18 mm wide expansion joints after 30 m to 45 m length of wall.
12. Walls should be raised uniformly. In no case difference between adjoining walls be more than 1 m. In a day no wall should be raised by more than 1.5 m.
13. Quoins used to form the jambs for windows, doors and other openings should be of the full height of the course.
14. To get proper key for plastering or pointing, the face joints should be raked to a depth of 10 to 15 mm, when the mortar is green. If plastering or pointing is not to be provided, face joints should be stuck flush and finished neatly.
15. Holdfasts for doors and windows and pipes should be embedded in brick masonry with cement mortar or concrete, at the time of constructing the wall itself.
16. Brick masonry should be regularly cured for 2 weeks.
17. For carrying out brick work at higher levels, only single scaffolding should be used.
18. Plastering should be done after about 28 days of completion of brick masonry. This permits adequate time for the shrinkage in masonry and concrete to take place before plastering operation is carried out.

Advantages of Brick Masonry over Stone Masonry:

1. Since shape and size of bricks are uniform, it do not need skilled labour for the construction.
2. Bricks are light in weight and hence handling them is easy.
3. Bricks are easily available around cities and their transportation cost is less because their weight is less. Stones are to be brought from quarries which are located only a few places.
4. It is possible to use all types of mortar in brick masonry. For unimportant buildings even mud mortar can be used.
5. Thinner walls can be constructed with bricks but it is not so with stones.
6. It is easy to form openings for doors and windows.
7. Dead load of brick masonry is less.
8. In brick masonry mortar joints are thin and hence construction cost is reduced considerably.
9. Brick masonry has better fire and weather resistance compared to stone masonry.

Disadvantages *of Brick Masonry over Stone Masonry*:

1. Strength of brick masonry is less than that of stone masonry.
2. Durability of brick masonry is less.
3. Brick masonry needs plastering and plastered surface needs colour washing. Stone masonry doesn't need them and hence maintenance cost is more in brick masonry.
4. Brick masonry absorbs water and there is possibility of dampness. There is no such problem in stone masonry.
5. More architectural effects can be given in stone masonry compared to that in brick masonry.
6. Stone masonry gives massive appearance and hence monumental buildings are built in stone masonry

2.1.1 *Block masonry (Concrete or cement-concrete masonry)*

Block masonry uses cement concrete blocks, either hollow or solid, for wall construction, with or without stone facing. A hollow unit is defined as that unit which has core-void area greater than 25 % of the gross area. Depending upon the shape and size various types of concrete masonry units are manufactured and they can be grouped in two heads:

(i) Regular concrete blocks:
They are manufactured from dense aggregates and used in load bearing walls.

(ii) Hollow concrete blocks:

- They may be used both for load bearing and non-load bearing walls.
- *Concrete association of India* recommends, the face thickness of the hollow blocks should be at least 5 cm, and the net area should be 55 to 60 % of the gross area.
  Recommended size of hollow concrete blocks are: 39 cm x 19 cm x 30 cm
  39 cm x 19 cm x 20 cm
  39 cm x 19 cm x 10 cm
- Mix ratio consists of 60 % fine (i.e. sand) and 40% course aggregate of 6 to 12mm size, with a combined fineness modulus of 2.9 to 3.6. The cement-aggregate mix is 1:6 proportion
- The strength of block must be > 3 N/mm^2
- Common surface finishing of blocks are obtained by varying the mix proportions and using appropriate size of aggregates
- Except common surface finishing of blocks, other types of surface finishing are: Rough finish, glazed finish, slumped finish, specially faced finish like marble finish and colour finish.

General principles to be observed in cement concrete block masonry construction

The construction principles which should be followed for a sound block masonry construction are as follows:

1. Blocks are applied in dry condition and should not be drenched in water before use.
2. Blocks of successive course should be so laid that the vertical joints are staggered.
3. The mortar to be used for the work should be of proper quality and proportion.
4. The thickness of mortar joints should be 5 to 10mm thick and should be uniform. The mortar used should not be stronger than the concrete mix used for manufacture of blocks. Generally gauged mortar (cement-lime-sand) of mix proportion 1:1:10 is used.
5. All the courses should be laid truly horizontal and all the vertical joints should be truly vertical.
6. Vertical surfaces of the wall should be constructed perfectly in plumb.
7. Curing of finished masonry work should be kept wet for at least seven days.
8. The blocks used for external walls should have water absorption < 10 % and it is should be < 15 % for internal walls.
9. Concrete blocks have high thermal expansion due to which walls cracks at corners so to minimise the cracks, solid concrete blocks or hollow blocks filled with concrete should be used at the junction of walls.
10. Double scaffolding should be adopted to carry out the block masonry construction at higher level.

Advantages of hollow concrete block masonry

- Construction work is very easy and rapid since the size of concrete blocks is bigger than that of brick which is always regular in size and shape requiring no dressing work.
- They are light in weight which can be easily handled.
- Because of their lightness, the load transferred to the foundations much less than the stone masonry.
- There is great saving in material for hollow concrete block construction.
- Because of hollow space, the resulting wall has better insulating properties against sound, heat and dampness.
- Thinner walls can be easily constructed, resulting in increase in floor area.
- Blocks can withstand the atmospheric action, and do not require plaster or any other covering or facia work.

Some technical terms used in brick, block and stone masonries:

Stretcher: A stretcher is the longer face of the brick.

Header: A header is the shorter face of the brick.

Lap: Lap is the horizontal distance between the vertical joints of successive brick courses.

Perpend: It is an imaginary vertical line which includes the vertical joint separating two adjoining bricks.

Bed: Bed is the lower surface of the brick when laid flat.

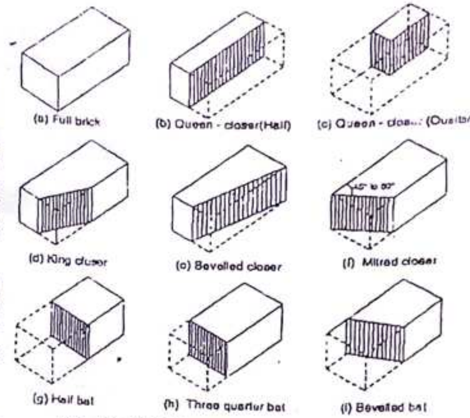


FIG. 6.3. VARIOUS FORMS OF BRICK PORTIONS.

Half Bat: It is the portion of the brick cut across the width. If the length of the brick is equal to the half the length of the original brick is called half bat.

Three-quarter bat: It has length equal to the three-quarter of the length of a full brick.

King closer: It is a portion of a brick which is so cut that the width of one its end is half that of a full brick, while the width at the other end is equal to the full width.

Queen closer: It is a portion of a brick obtained by cutting a brick length wise into two portions. When a queen-closer is cut into two pieces, it is then called as queen closer-quarter.

Frog or kick: A frog is an indentation in the face of the brick to form a key for holding the mortar.

Racking back: It is the termination of a wall in a stepped fashion.

Toothing: It is the termination of a wall in such a fashion that each alternate course at the end projects in order to provide adequate bond if the wall is continued horizontally at a later stage.

2.2 Bonds in brickwork

Bonding is a process or assuming bricks and mortars to tie them together in a mass of brick work. It is the interlacement of bricks, formed when they lay (or project beyond) those immediately below or above theme. It is the method of arranging the bricks in courses so that individual units are tied together and the vertical joints of the successive course do not lie in same vertical line. Bonds of various types are distinguished by their elevation or face appearance.

Depending upon the type of bond used, the following are the types of brick masonries.

1. Stretcher bond
2. Header bond
3. English bond
4. Flemish bond: a) Single Flemish bond
   b) Double Flemish bond
5. Garden wall bond
6. Facing bond
7. Dutch bond
8. Racking bond: a) Herring bone bond
   b) Diagonal bond
9. Zigzag bond
10. Brick on edge bond or silver lock's bond or soldier's course
11. English cross bond
12. Rat trap bond
13. Quetta bond
14. Broken bond or bonds between columns
15. Reversed bond

1. Stretcher bond

All the bricks are laid with their stretchers on the direction of the face of the wall. At every alternate course, the wall is started with half bat in order to avoid the continuous perpend in successive layer. This bond is used or possibie only when the wall thickness is equal to the half-length of the brick such as partition walls, division walls and half-brick skins of hollow or cavity walls etc.

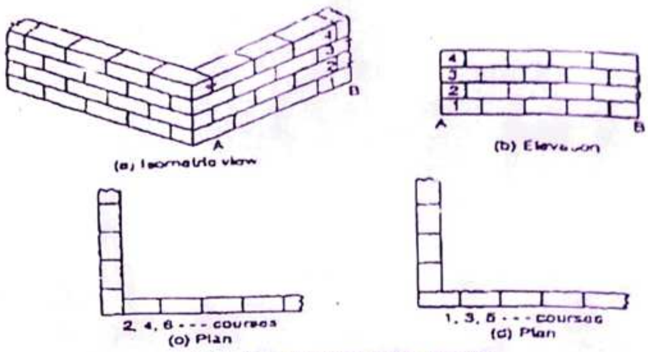


FIG. 6.4. STRETCHER BOND.

2. Header bond

All the bricks are laid with their header facing towards the face of the wall. The width of the brick are thus along the direction of the wall. Three-quarter bricks are used as quoins in each alternate layer in order to avoid the continuous perpend. It is used for one brick thick wall. This bond does not have strength to transmit pressure in the direction of length of the wall. It is unsuitable in load bearing walls.

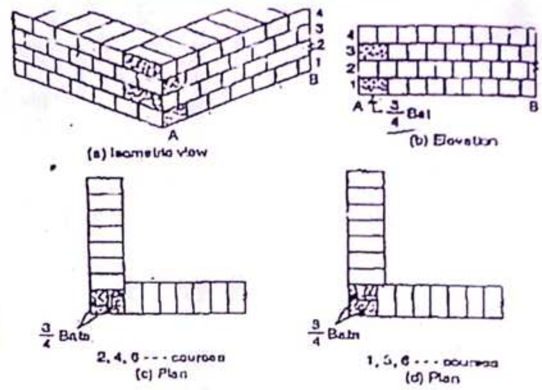


FIG. 6.5. HEADER BOND

3. English bond

This bond consists of alternate courses of headers and stretchers. In this bond, vertical joint of each header courses come over each other, similarly, the vertical joints of the stretcher courses also come over each other. In order to break the vertical joints in the successive courses, it is essential to use queen closer after the first header in header course. This type of bond is the most common type bond used, for all wall thicknesses. This type of bond is considered to be the strongest bond.

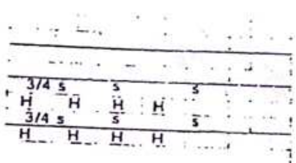
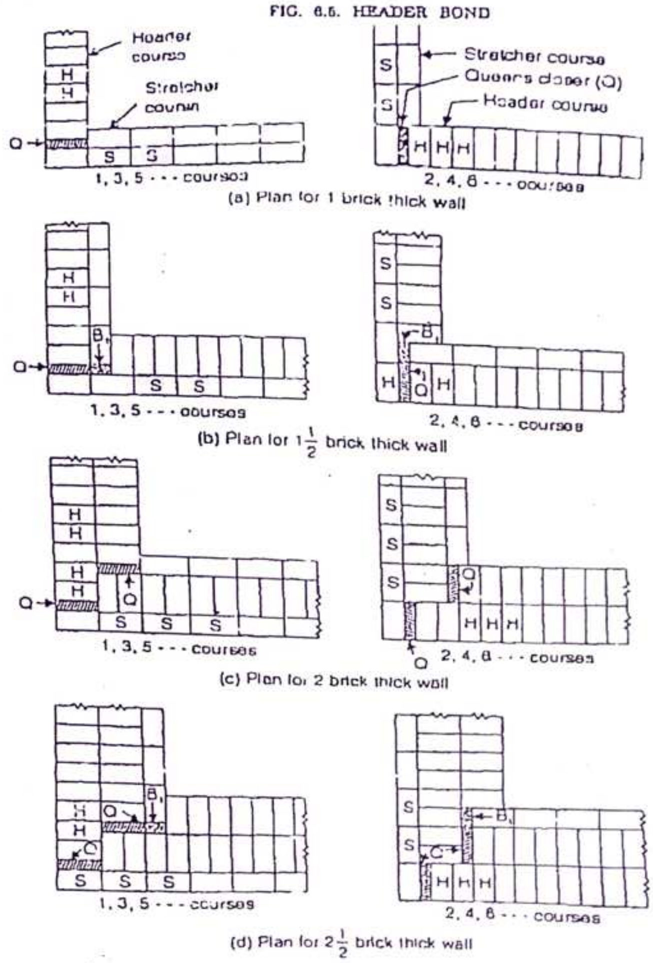


Fig. ELEVATION O F ENGLISH BOND



Walls of various thicknesses in English bond

4. Flemish bond

In this bond, each course is comprised of alternate headers and stretchers. Every alternate course starts with a header at the corner. Queen closers are placed next to the queen header in alternate courses to develop the face lap. They are of two types:

a. Single Flemish bond

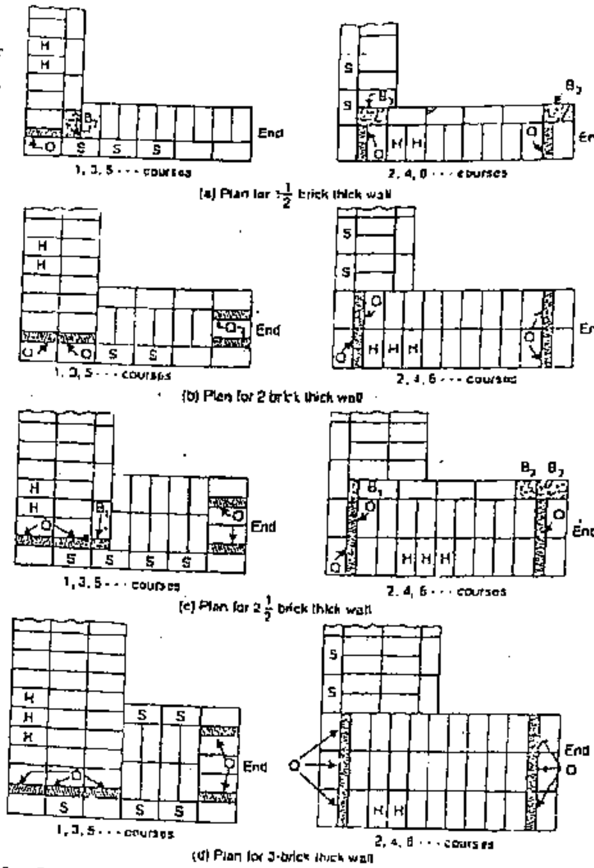
b. Double Flemish bond

a) Single Flemish bond

Single Flemish bond is comprised with double Flemish bond facing and English bond backing and hearting in each course. This bond thus uses the strength of English bond and appearance of Flemish bond. This type of bond is only possible when the wall thickness is more than 1½bricks.

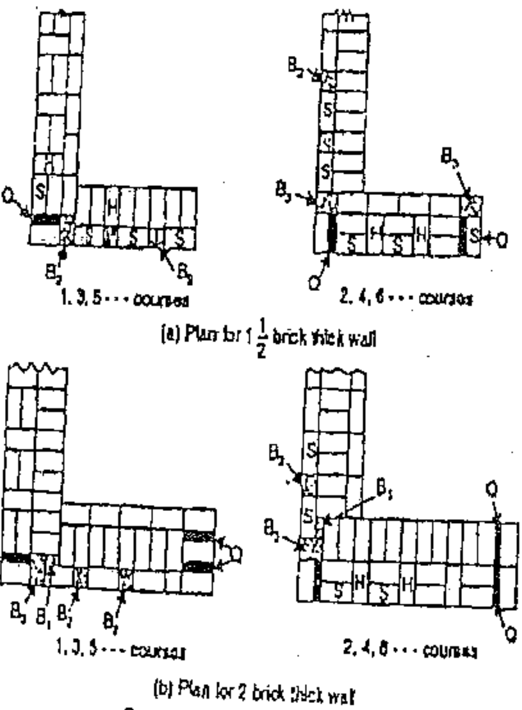
b) Double Flemish bond

Each course presents the same appearance both in front and back face as well. Alternate headers and stretchers are laid in each course; as a result of which, double Flemish bond presents better appearance than English bond. Brick bats are used in case of walls having thickness equivalent to odd number of half bricks. The queen closer is used next to the quoin header in alternate-course.



S - STRETCHER FACING ; H - HEADER FACING ; Q - QUEENS CLOSER ,
$B_1 = \frac{1}{4}$ BAT ; $B_2 = \frac{1}{2}$ BAT , $B_3 = \frac{3}{4}$ BAT

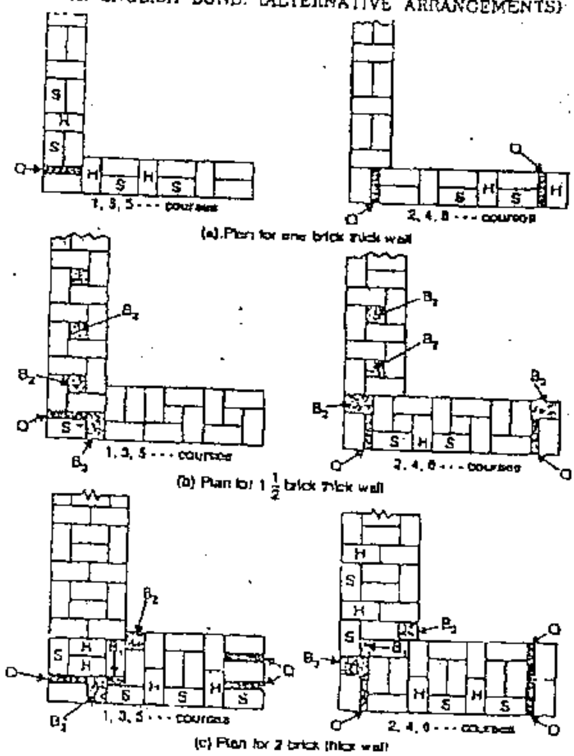
FIG. 6.8. ENGLISH BOND. (ALTERNATIVE ARRANGEMENTS)



S = stretcher ; O = Queen's closer

B_2 = HALF BAT ; $B_3 = \frac{3}{4}$ BRICK ; B_1 = QUARTER BAT

FIG. 6.11. SINGLE FLEMISH BOND.



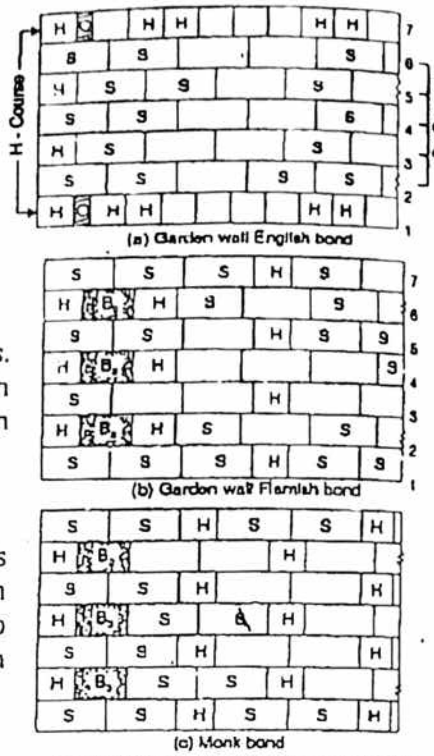
S - STRETCHER ; H - HEADER ; Q - QUEENS CLOSER ;
B_2 = HALF BAT ; $B_3 = \frac{3}{4}$ BRICK ; B_1 = QUARTER BAT

FIG. 6.10. DOUBLE FLEMISH BOND.

5. Garden wall bond

This type of bond is used for the construction of garden walls, compound walls where the thickness of the wall is one brick thick and height does not exceed two meters. They are of three types:

a. Garden wall in English bond.
b. Garden wall in Flemish bond.
c. Garden wall in Monk bond.


(a) Garden wall English bond

(b) Garden wall Flemish bond

(c) Monk bond

S = Stretcher ; H = Header ; B_3 = 3/4 Brick bats

FIG. 5.17 GARDEN WALL BONDS.

Garden wall in English bond.

Header course are provided only after 3 to 5 stretcher courses. In each header courses, a queen closer is placed next to quoin header to provide necessary lap. In stretcher courses, quoin headers are placed in alternate course.

Garden wall in Flemish bond

Each course contains one header after 3 to 5 stretchers continuously placed, through the length of the course. Each alternate course contains three-quarter brick placed next to the quoin header and a header lay over the middle of each central stretcher.

Garden wall in Monk bond

This is special type of garden wall Flemish bond in which each course contains one header after two successive stretchers. Every alternate course contains a quoin header followed by a ¾ brick bat. Due to this, the header rests over the joint between two successive stretchers.

6. Facing bond

This bond is used where bricks of different thickness are to be used in the facing and backing of the wall. In this bond, a header course is provided after several stretcher courses. Since the thickness of bricks are different in facing and backing, the vertical distance between the successive header courses is kept equal to the least common multiple of the thickness of backing and facing bricks. Thus if nominal thickness of facing bricks is 10 cm and that of backing bricks is 9 cm, then the header course is to be provided at a vertical interval of 90 cm.

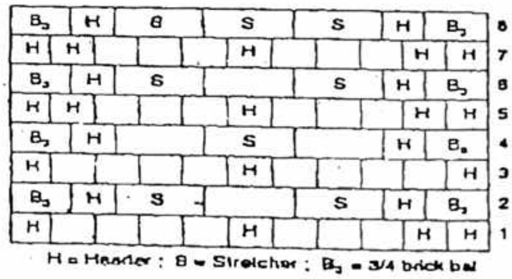

H = Header : S = Stretcher : B_3 = 3/4 brick bat

FIG. 6.14. DUTCH BOND.

7. Dutch bond

In this type of bond, alternate course are headers and stretchers like English bond. In stretcher course ¾ brick are sued as quoin header and a header is placed next to the ¾ brick in every alternate stretcher course. This is the modified form of English bon d.

8. Racking bond

This bond is used in thick walls. In this type of bond, the bonding bricks are kept at an inclination to the direction of the wall. Due to this the longitudinal stability of the wall built in English bond is very much increased.

two types .

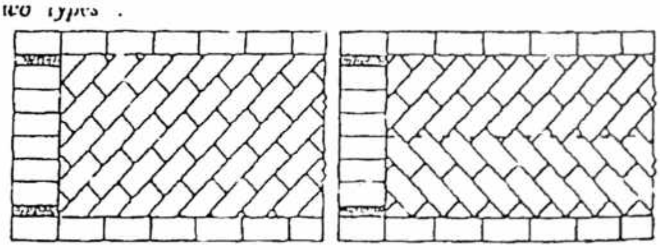

(a) Diagonal bond (b) Herring - bone bond

FIG. 6.16. RAKING BONDS.

Types of racking bond: a. Diagonal bond
b. Herring bone bond

a. Diagonal bond

In this bond, brick are arranged at 45° in such a way that extreme corners of the series remain in contact with the external line of stretchers. Brick cut to triangular shapes and of suitable sizes are packed in the small triangular spaces at the ends. This bond is best suited in walls which are 2 to 4 bricks thick. The bond is introduced at regular vertical interval, generally at every 5th or 7th course. In every alternate course of the bond, the direction of the bond, the direction of the bricks are reversed.

b. Herring bone bond

This bond is best suited in walls which are thicker than 4 bricks thick. Bricks are arranged at 45° in two opposite directions from the centre of the wall thickness. The bond is introduced in the wall at regular interval. In every alternate course, the direction of bricks is reversed. This bond is generally used for ornamental finish to the face works and for brick flooring.

9. Zigzag bond

This bond is similar to herring bond except that the bricks are laid in zigzag fashion. This bond is commonly used for making ornamental panels in brick flooring.

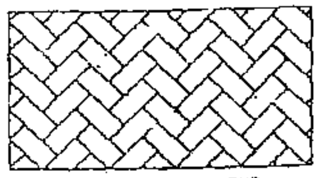


FIG. 8.16 ZIG-ZAG BOND.

10. Brick on edge bond (Silver lock's bond or soldier's course)

This type of bond uses stretcher bricks on edges instead of bed. This bond is weak in strength, but is economical. Hence it is used for garden walls, compound walls etc. Bricks are kept standing vertically on end. The bricks are arranged as headers and stretchers min such a manner that the headers are placed on bed and stretchers are placed on edge thus forming a continuous cavity. Due to this, the bond consumes less number of bricks.

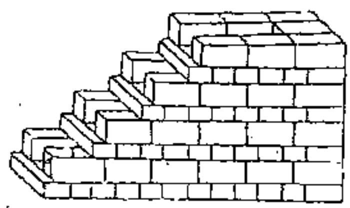
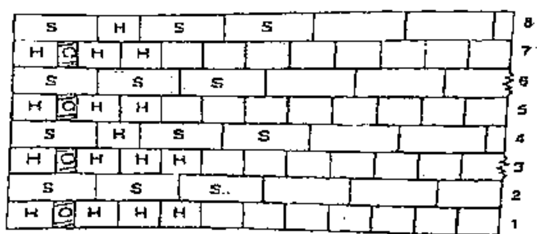


Fig. 8.12. *Silverlock's bond.*

11. English cross bond:

This is a modification of English bond, used to improve the appearance of the wall. This bond combines the requirements of beauty and strength. Special features of bond are as follows:

- Alternate courses of headers and stretchers are provided as in English bond.
- Queen closers are placed next to the quoin headers.
- A header is introduced next to the quoin stretcher in every alternate stretcher course.

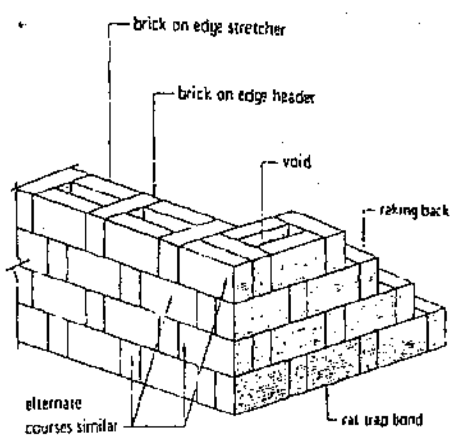


H = Header ; S = Stretcher ; Q = Quoin's closer

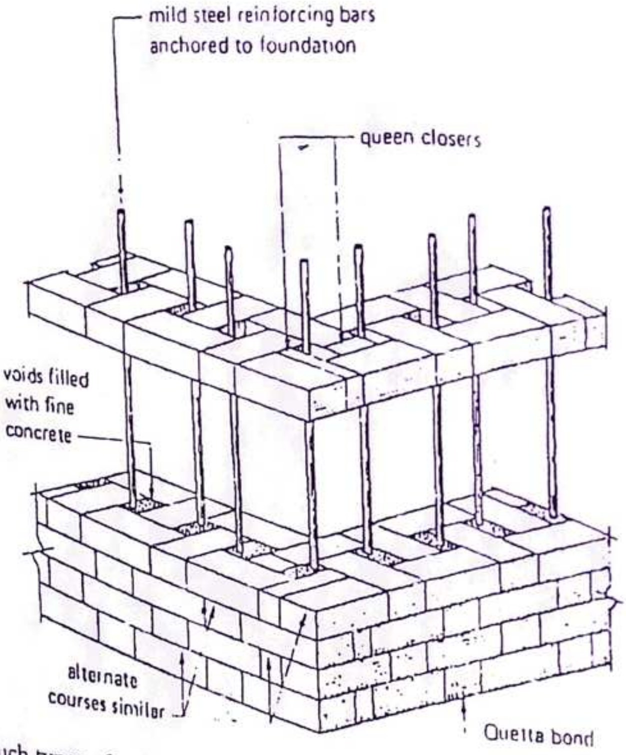
FIG. 8.12. ENGLISH CROSS BOND

12. Rat- trap bond wall

This is brick on edge bond and gives a saving on materials and loadings, suitable as baking wall to a cladding such as tile hanging. This bond is weak due to formation of cavity in central portion of the wall. This bond is used for garden walls, partition walls, veranda wall, parapet wall etc.



Rat - trap bond wall is a cavity wall construction with added advantage of thermal comfort and reduction in the quantity of bricks required for masonry work. By adopting this method of bonding of brick masonry compared to traditional English or Flemish bond masonry, it is possible to reduce in the material cost of bricks by 25% and about 10to 15% in the masonry cost. By adopting rat-trap bond method one can create aesthetically pleasing wall surface and plastering can be avoided.



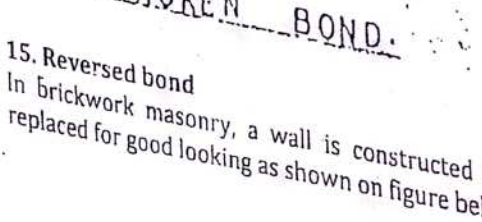
13. Quetta bond

Walls constructed with this bond is costly due formation of cavity inside the wall for reinforced cement concrete and with brick facing as shown on figure at right side⇒

Quetta bond is constructed with one and half brick thick wall for added strength. Such types of wall are constructed for retaining walls, dam walls, wall for water reservoirs and to construct walls in prisons etc.

14. Broken bond

Sometimes the length of wall to be constructed is not equal with the sum of total length formed by adding the total length of headers and stretchers and in such case, the bond is adjusted by using the ¾ bat in the wall as shown in figure bellow. The bond formed in such way on brick masonry is known as broken bond.

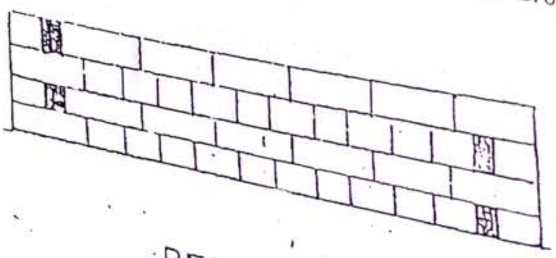


BROKEN BOND.

Another type of broken bond

15. Reversed bond

In brickwork masonry, a wall is constructed in reversed bond when broken bond is to be replaced for good looking as shown on figure bellow.



REVERSED BOND.

2.3 Types of brick wall

A wall is one of the most essential components of a building. The bricks which are used for buildings are obtained by moulding clay in rectangular blocks of uniform size and then by drying these blocks. They are of uniform size, light in weight and require no lifting appliances. The bricks are of various sizes. The actual size of a modular brick is 19 cm × 9 cm × 9 cm. With mortar thickness size of such a brick becomes 20 cm × 10 cm × 10 cm and it is known as the nominal size of the modular bricks. Brick masonry can support a great amount of weight but has no flexibility. Common bricks must have a minimum compressive strength of 50 kg/m^2 and the average water absorption should not be more than 20 per cent by weight. Brick masonry may require structural reinforcement such as steel beams, rigid insulation boards, and fiberglass bats. Brickwork creates an impression of solidity and permanence. Bricks are nearly maintenance free; never need painted or stained, and resists damage from wind, fire, and water. Brick masonry also provides a noise barrier and thermal insulation. Buildings made of brick masonry generally stay cooler in summer and warmer in winter. According to their function as well as construction, brick masonry walls may be categorised as follows:

a) **Load bearing brick wall:** The walls which are designed to carry supper imposed-loads in addition to their own weight are called load bearing walls and they may be further sub-divided in to:

1) ***Solid brick wall:*** It is constructed in rich cement mortar to carry super-imposed loads of the structure
2) ***Cavity-wall:*** A cavity walls consist of two 'skins' separated by a hollow space (cavity). The skins are commonly masonry such as brick or concrete block. The cavity wall is constructed for damp proofing, sound proofing and heat insulating purposes, it also carry the weight of the super imposed load.
3) ***Faced wall:*** A masonry wall in which the facing and backing are bonded with two different types of bricks or when the wall is bonded by bricks in one face and the next face with some other materials like stone or blocks and the wall so constructed exerts a common action under loading is called as brick faced wall. Usually the brick having good quality is used in facing which do not need plastering and the wall constructed is also called as a composite wall.
4) ***Veneer or Thin Brick wall:*** A veneered wall or thin brick wall is a layer of brick applied to the outer surfaces of buildings for decorative purposes only. Brick veneers do not add support to a structure nor do they strengthen it. The bricks used for veneers are usually hollow and thinner than building bricks. Masonry veneer walls consist of a single non-structural external layer of masonry work, typically brick, backed by an air space. Stone veneer is used as a protective and decorative covering for exterior or interior horizontal walls and surfaces.

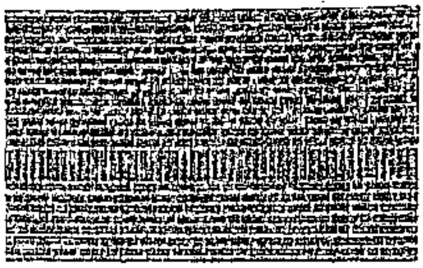


Fig- Brick veneered wall

b) ***Non-load bearing brick wall:*** The brick walls which are designed to carry self-load only are called non-load bearing brick wall, and they may be further sub-divided in to:

1) ***Brick curtain wall:*** "Curtain wall" refers to any cladding system that is "hung" externally from the structural frame and self-supporting wall carrying no other vertical loads but subjected to lateral loads like wind load. On the other hand, it is most often associated with gridded systems of metal mullions and rails (mostly aluminium) and glass. But if, instead of aluminium or metal and glass, the wall is constructed using the bricks, then the wall is known as brick curtain wall.
2) ***Brick Panel wall:*** It is also the external non-load bearing wall commonly related to framed structure.
3) ***Brick partition walls:*** It is a thin internal wall which is constructed to divide the space within the building into rooms. It may be load bearing or non-load bearing. A load bearing partition wall is known as internal wall and it does not carry any external load.
4) ***Brick separating walls:*** A wall separating different occupancy within the same building is called separating wall.
5) ***Brick party wall:*** A brick wall separating the adjoining ~~adjoinig~~ building is called party wall i.e. compound wall.

c) ***According to the mortars*** used during the construction of walls, brick masonry walls may also be catagorised as follows:

1) ***Dry brick masonry wall:*** Brick wall is constructed without using any mortar.
2) ***Brick wall in mud mortar:*** In this type of brickwork, mud is used to fill up the joints. The mud is prepared by intimately mixing sand and clay. The thickness of the mortar joints is 12 mm. This

type of brickwork is adopted in cases of low-cost construction and the maximum height up to which a wall can be constructed in this type of *brickwork is 4 m.*

3) ***Brick wall in cement mortar:*** Cement, sand and water is mixed in required proportion to construct the brick wall
4) ***Brick wall in lime mortar:*** Lime is used instead of cement and water is added in required proportion to construct the brick wall.
5) ***Brick wall in cement-lime mortar or gauged mortar or composite mortar:*** – The brick wall is constructed in gauged or composite mortar which is prepared by mixing cement lime and sand and water in required proportions
6) ***Brick wall in lime - surkhi mortar:*** – The brick wall is constructed in lime - surkhi mortar which is prepared by mixing lime, surkhi (fine powder prepared by grinding broken brick ballast in to fine powder) and water.

d) ***According to the composition of bricks,*** their use and finishing appereances, brick masonry walls may also be catagorised as follows:

1) ***Building or Common brick wall***

   Common brick masonry is used in construction and is cored with two rows of holes to save on material and lessen the weight. Building bricks are made of clay and usually come in colours ranging from orange to brown. The most common colour is red.
2) ***Slipper wall:*** It is constructed to raise the height of timber ground floors which is suspended above the ground floor for protection of timber floor from dampness.
3) ***Honey combed brick wall:*** It is constructed in sleeper walls for free air circulation.
4) ***Firebrick wall:*** It is a wall constructed by using heat resistant clay bricks and they are used for fireplaces, furnaces, and boiler room etc.
5) ***Glazed Brick wall:*** Glazed bricks have a ceramic surface on one side that makes it easy to sanitize and clean. This type of brick masonry is used in hospitals and laboratories.
6) ***Patio Brick wall:*** Patio bricks are similar to building bricks except they have a smoother surface. These bricks come also in many colours, shapes, and sizes.
7) ***Brick tile wall***: It is usually used for interior walls and is made from clay. Brick tile masonry comes in a wide array of rich colours and multiple sizes for ease in pattern design.

e) ***According to the combination of bricks*** with other materials brick masonry may be catagorised as follows:

1) ***Brick-stone composite masonry***
2) ***Brick and concrete block composite masonry***
3) ***Reinforced brick masonry***

f) ***According to purpose of wall,*** brick masonry may be categorised as

1) ***Brick shear wall***
2) ***Brick buttress walls***
3) ***Brick retaining wall***
4) ***Brick parapet walls (self-standing walls)***
5) ***Brick garden walls (self-standing walls)***
6) ***Brick compound walls or brick fencing walls***

g) ***According to the structure and finishing of brick,*** brick masonry walls may be categorised as:

1) ***Hollow brick walls***
1) ***Solid brick walls***
2) ***Air-brick wall***
3) ***Sand faced brick walls***
4) ***Rustic brick wall***
5) ***Rolled brick walls***
6) ***Drag faced brick walls***
7) ***Rumbled brick wall***
8) ***Handmade brick walls***

2.4 Stone masonry

The construction of stones (as building unit) bonded together with mortar is termed as stone masonry, where stone are available in abundance in nature. On cutting and dressing to the proper shape they provide an economical material for the construction of various building components such as walls, columns, footings, arches, lintels etc. stone masonry being more stronger, durable and weather resistant as compared to brick masonry, it is also used in construction of piers, decks, dams and other marine structures.

2.5 Classification of stone masonry

Depending upon the arrangement of stones in the construction degree of refinement used in shaping the stone and finishing adopted, stone masonry can be classified as:

(A) Rubble masonry

(B) Ashlar masonry

a. Ashlar fine tooled
b. Ashlar rough tooled
c. Ashlar rock, rustic or quarry faced
d. Ashlar chamfered
e. Ashlar block in course
f. Ashlar facing etc

Fig: Flint walling or Flint Rubble masonry

(A) Rubble masonry

In such masonry, the blocks of stone that are used are either undressed or comparatively rough dressed. The masonry has wide joints, since stones of irregular sizes are used.

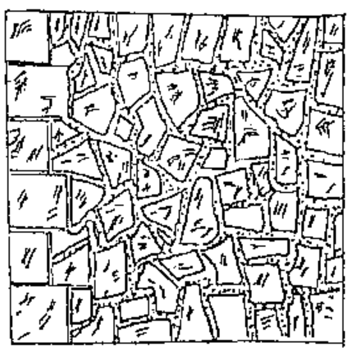
They can be classified as:

1. RANDOM RUBBLE MASONRY
i. Uncoursed
ii. Built to courses

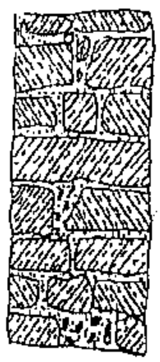
2. SQUARE RUBBLE MASONRY
i. Uncoursed
ii. Built to courses
iii. Regular coursed

3. DRY RUBBLE MASONRY

4. MISCELLANEOUS TYPES
i. Polygonal walling
ii. Flint walling etc.



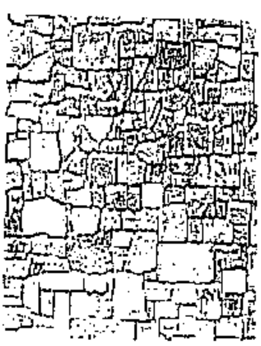
ELEVATION



SECTION

FIG: RANDOM RUBBLE MASONRY: UNCOURSED

1. RANDOM RUBBLE MASONRY



(i) Random rubble masonry : Uncoursed

This is the cheapest, roughest and poorest form of stone masonry. The stone used in this type of masonry has wide variation in their shape and size and are directly obtained from quarry. The stones are carefully laid so as to break joints; chips of stones are used into the hearting. The quoins are chiselled or hammer dressed and is laid as header and stretcher alternatively

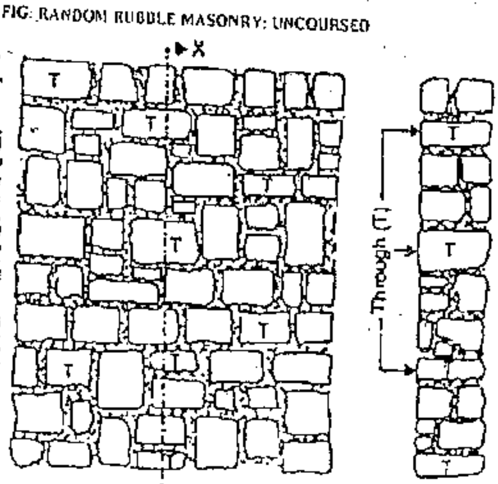


FIG. 5.14. RANDOM RUBBLE : UNCOURSED.

(ii) Random rubble masonry : Built to courses

The method of construction is the same as above except that the work is roughly levelled up to from courses varying from 30to45cm thick. All the courses are not of the same height. For the construction of this type of masonry, quoins are built first line is stretched between the tops of quoins. The intervening walling is then brought up to this level by using different size stones.

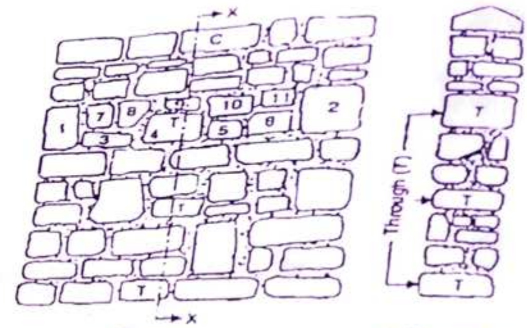


FIG. 6.15. RANDOM RUBBLE : BUILT TO COURSES

2. SQUARE RUBBLE MASONRY

(i) Square rubble: Uncoursed square rubble masonry (square-snacked rubble)

*This masonry uses stones having straight bed and sides. The stones are usually squared and brought to hammer dressed or straight cut finish. They are arranged on face in several irregular patterns and sometimes such course is known as **square-snacked rubble.***

R=riser (a large stone or through stone)

L=leveller (thinner stone)

S= sneck (small stone)

R, L and S are arranged in a pattern having their depth (size) in ratio of 3:2:1 respectively

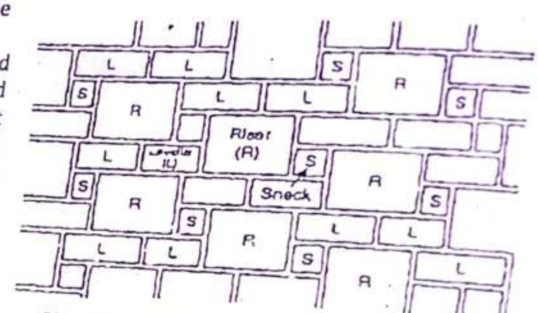


FIG. 6.16. UNCOURSED SQUARE RUBBLE.

(ii) Square rubble: Built to courses square rubble masonry

This type of masonry also uses the same stones as used for uncoursed square rubble. But the work is levelled up to courses of varying depth. The courses are of different height. T= through stone

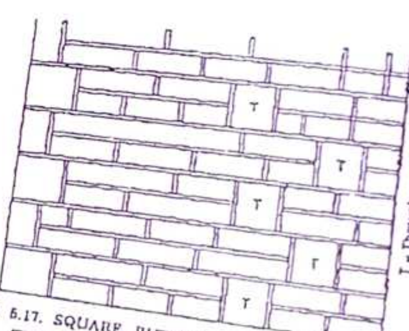
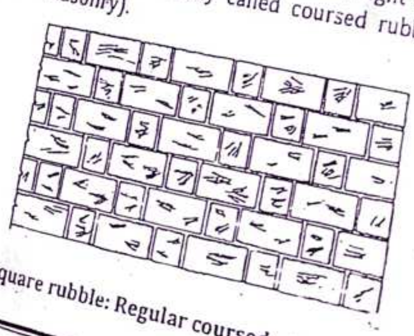


FIG. 6.17. SQUARE RUBBLE : BUILT TO COURSES.

(iii) Square rubble: Regular coursed (Coursed rubble masonry)

In these types of masonry, the wall consists of various courses of varying height, but the height of stones in one particular course is the same. When the height of the courses is equal, it is usually called coursed rubble masonry (CR masonry).



Square rubble: Regular coursed rubble masonry (1st class)

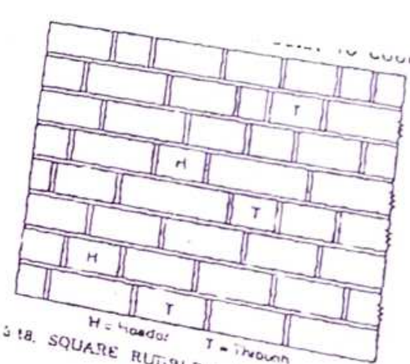


FIG. 6.18. SQUARE RUBBLE : REGULAR COURSED.

3. DRY RUBBLE MASONRY:

It is made to courses in which mortar is not used in the joints. This type of construction is the cheapest and requires more skill in construction. This may be used for non-load bearing walls such as compound wall.

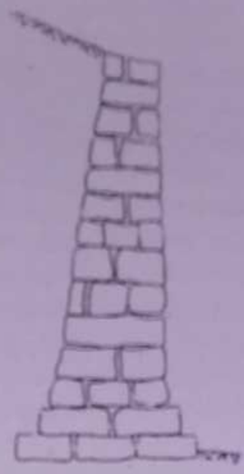


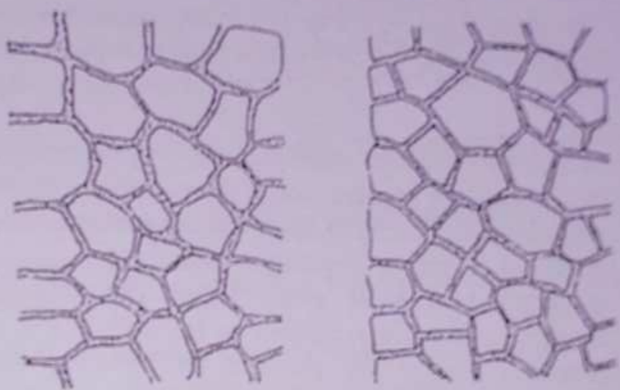
Fig. 7.10: Dry rubble masonry

Fig. 5.60
Dry stone retaining wall

4) MISCELLANEOUS TYPES OF RUBBLE MASONRY:

(i) Polygonal walling (Polygonal rubble masonry)

In these types of masonry, stones are hammer finished on face to an irregular polygonal shape. These stones are bedded in position to show face joints running irregularly in all direction.



(a) Rough picked (b) Close picked

FIG. 5.19. POLYGONAL RUBBLE MASONRY.

(ii) Flint walling or flint rubble masonry

The stones used in this masonry are flints or cobbles, which vary in width and thickness from 7.5 to 15cm and in length 15 to 30cm. These are irregularly shaped nodules of silica. The stones are extremely hard, but are brittle. Therefore, may break easily. The face arrangement of the cobbles may be either coursed or uncoursed or built to course.

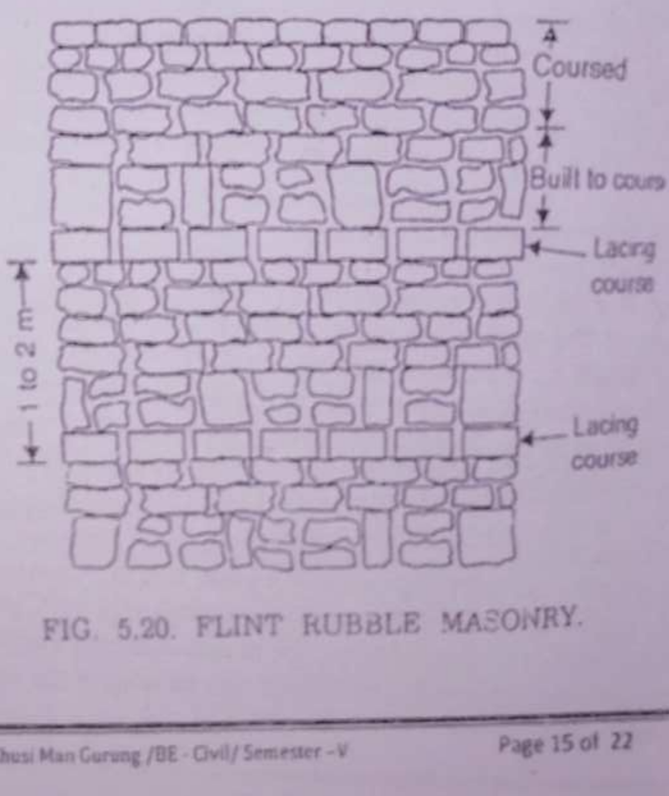


FIG. 5.20. FLINT RUBBLE MASONRY.

(B) Ashlar masonry

This masonry consists of blocks of accurately dressed stone with extremely fine bed and end joints. The block may be either square or rectangular shaped. The height of stone varies from 25 to 30cm. the height of the block in each course is kept equal but it is not necessary to keep all courses of the same height. Ashlar masonry is of following types:

i. Ashlar fine tooled.
ii. Ashlar rough tooled
iii. Ashlar rock, rustic or quarry faced.
iv. Ashlar chamfered.
v. Ashlar block in course.
vi. Ashlar facing.

(i) Ashlars fine tooled

This is the finest type of stone masonry. Each stone is cut to regular and required size and shape so as to have all sides rectangular, so that the stone gives perfectly horizontal and vertical joints with adjoining stone. The beds, joints and faces are chisel dressed, such that all waviness and unevenness is completely removed and a fairly smooth surface is obtained. The thickness of courses is generally not less than 15cm. And width of the stone is not kept less than its height. Headers & stretchers are placed alternately. The thickness of mortar joints is equal or less than 5 mm.

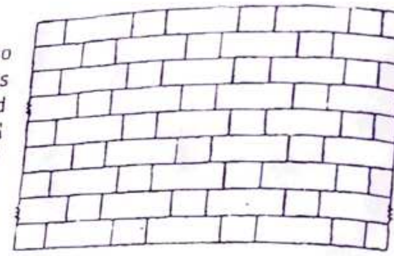
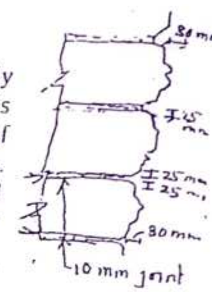


FIG. 5.21. FINE TOOLED ASHLAR MASONRY.

(ii) Ashlar rough tooled (Bastard ashlar)

In this type of masonry, the beds and sides of each stone block are finely chisel dresses just in the same manner as for ashlar fine but the exposed face is dressed by rough tooling. A strip about 25 mm wide and made by means of chisel is provided around the perimeter of the rough dressed face of each stone. The mortar thickness should not be more than 6mm & projection on exposed face is limited to 3mm.



(iii) Ashlar rock faced (rustic or quarry faced)

In this type of masonry, the exposed face of the stone is not dressed but is kept as such so as to give rock, facing. However, a strip of about 25mm wide, made by means of chisel is provided around the perimeter of exposed face of every stone. The projections on the exposed face (known as bushing) exceeding 80mm in height are removed by light hammering. The height of each block may vary from 15to30cm. The mortar thickness is limited to 10mm.

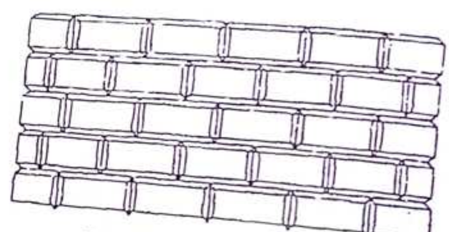


FIG. 5.22 ASHLAR CHAMFERED.

(iv) Ashlar chamfered

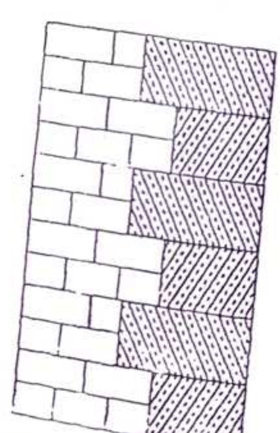
This is special form of rock-faced ashlar masonry in which the strip provided around the perimeter of the exposed face is chamfered or bevelled at an angle of 45° by means of chisel to a depth of 25mm. Due to this a groove is formed in between adjacent blocks of stone. And bushing more than 8mm is removed by hammer.

(v) Ashlar block in course

This type of masonry is intermediate between rubble and ashlar masonry. The faces of each stone are hammer dressed, and height of block is kept. The same in any course though it is not necessary to keep uniform height for the entire course. The vertical joints are not as straight and as fine as in ashlar masonry. The height of each course may vary from 15 to 30 cm. This type of masonry is used in heavy works such as retaining walls, bridges etc.

(vi) Ashlar facing

This type of masonry is provided along with brick or concrete block masonry to give better appearance. The sides and bed of each block are properly dressed so as to make them true to shape. The exposed faces of the stone are rough tooled and chamfered. The backing of the wall may be made in brick masonry.



5.23. ASHLAR FACING MASONRY.

Procedure to construct stone masonry (supervision) - 'Important for exam'

The following points should be kept in mind for supervising the stone masonry work

1. The stone used should be strong, tough, hard and should conform the specification of work. It should be free from defects like cracks, cavity, veins etc.
2. Each stone block should be well watered (watered) and cleaned before use.
3. All the stone should be laid on their natural bed.
4. Stones to be used should be properly dressed as per the type of masonry.
5. Proper bond should be maintained. Formation of vertical joints should be avoided.
6. No tensile stresses should be allowed to develop in the masonry.
7. Masonry work should be raised uniform, so that the non-uniform distribution of load on foundation is avoided. However, where it is not possible & where one part of wall has to be kept behind, the wall should be raked back at an angle of 45°or less.
8. Broken stones, small pieces and chips should not be used for facing and backing. However, these may be used in hearting for proper packing with mortar.
9. The facing and backing of wall should be well bound by through stones. The through stone should be laid staggered in the successive courses. The centre to centre distance between them should not exceed 1.5m.
10. The mortar to be used for the work should be of proper quality and proportion.
11. Quoins used to from the jambs for windows, doors and other openings should be of the full height of the course. The breadth and length of the quoin should at least be 1.5 times and twice its depth respectively.
12. Vertical surfaces of the wall should be constructed perfectly in plumb. They should be frequently checked.
13. Battered surfaces, if any should be properly checked with the help of wooden template and plumb bob.
14. When it is required to raise new construction over the old or dry one, it should be well cleaned and wetted before starting the construction.
15. Double scaffolding should be adopted to carry out the stone masonry construction at higher level.
16. The exposed joints of the masonry should be properly pointed by cement mortar or lime mortar by raking them first up to a depth of about 2cm.
17. After the construction is over, the whole work should be cured at least for 2 to 3 weeks.

Comparisons between stone masonry and Brick masonry

The stone masonry and brick masonry can be compared with respect to their various properties in tubular form.

S.N	Description	Stone masonry	Brick masonry
1	Uses	Construction of piers, dams, marine structures, residential building etc.	Generally used for building purposes.
2	Strength	Bears high crushing strength	It has less crushing strength
3	Durability	More durable	Less durable as compared to stone masonry
4	Appearance	Colour improves the appearance; no treatment required	Generally requires plastering
5	Source	Natural	Artificial
6	Cost	High	Low
7	Availability	Easily not available	Easily available
8	Bond	It requires a great deal of time and extra labour in maintaining proper bond	Regular shape and sizes results in quick construction of good bond
9	Construction	Skilled manpower required	Ordinary mason can also perform
10	Casting	Not convenient	Conveniently casted into any shape
11	Handling	Not easy	Easy in handling
12	Fire resistance	less	More
13	Damp proofing	No danger	Cause disintegration

Choosing wall thickness height to length ratio.

The thickness of brick wall depends upon the following.

- The anticipated load to come on the wall.
- The overall height of wall.
- The overall height of wall.
- The height between the floors.
- The length of wall between piers, buttresses, cross wall etc.
- Strength of brick masonry (brick, mortar, bonding)

Let the total load coming on wall due to different types of load be 'P', A= area of wall, p= allowable comp. strength of the brick, L= length of wall, t= thickness of wall

Now,

Area (A) = Total load (P)/ permissible strength of brick (p)

Or, $A = P/p$

Or, $L \times t = P/p$

$\therefore t = P/p * L$

For unit length; i.e., $L = 1$, then $T = P/p$

- The length of wall is the length measured between cross wall.
- The thickness of wall should not be less than1/6 the storey height.
- For basement walls, the thickness should not be less than 1/3 the height of retained soil above basement level nor should it be less than the thickness of wall at ground floor plus 10cm.

Slenderness ratio: The slenderness ratio of wall is the ratio of its effective height divided by the effective thickness of or the effective length divided by the effective thickness, whichever is is less. It depends upon length of wall, height of wall, thickness of wall and support conditions etc/ The slenderness ratio should not be more than 20. If the slenderness ratio is < 20 then it creates stress problem and when > 20, it creates stability problem. The limiting value of slenderness ratio should be such that wall should fail under stress.

$$\text{Slenderness ratio} = \frac{\text{Effective length}}{\text{Effective thickness}} \quad \text{or} \quad \frac{\text{Effective height}}{\text{Effective thickness}} \quad \text{not} > 20$$

Note: The c/c spacing of expansion joints should be 40m and minimum thickness of expansion joint should be 20mm.

The height of parapet wall varies from 60 to 90 cm but general kept 75 cm.

2.6 Composite masonry

Walls constructed with different types of materials and different classes of masonry at facing and backing is known as composite masonry. Generally superior material or superior type of masonry is used in the construction of facing whereas backing of the wall which is not exposed may be constructed with inferior materials or inferior type of masonry. The composite masonry may be adopted due to two reasons:

i. Improvement of appearance of wall, etc.,
ii. Use of available materials, to obtain optimum economy

To prevent splitting and unequal settlement of the walls of all type of composite masonry, following preventive measures should be taken during construction:

i. Backing and facing portions should be constructed simultaneously.
ii. Both facing and backing should be carried in rich mortar.
iii. Adequate through stone should be used.
iv. Provide metal cramp, lead plugs, dowels etc. to keep facing and backing binded together.

Types of composite masonry

1) Stone composite masonry
2) Brick-stone composite masonry
3) Cement concrete masonry
4) Hollow clay tile masonry
5) Reinforced brick masonry
6) Glass block masonry

1. *Stone composite masonry*
It consist of ashlar masonry facing and rubble masonry backing as shown in Fig. 7.1⟹

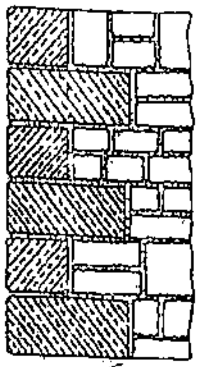
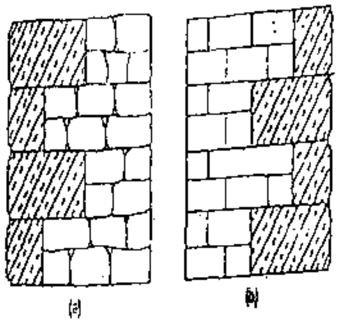


FIG. 7.1.



(a) Ashlar stone facing over rubble stone masonry.
(b) Brick masonry facing over ashlar backing.

2. *Brick-stone composite masonry*
Brick-stone composite masonry can be simultaneously used in three forms of composite masonry: a) Brick backed ashlar masonry
b) Brick-backed stone slab facing
c) Rubble-backed brick masonry

Fig 7.2 *(a) shows brick-backed ashlar masonry.*

The ashlar may be rough tooled. It is preferable to use the height of ashlar as a multiple of brick thickness plus masonry joints; so that coursed masonry is obtained. Cement mortar is used for construction. Bricks should be laid in proper bond. Alternate courses of ashlar may be headers. Under each projecting course of ashlar, header bricks should be used.

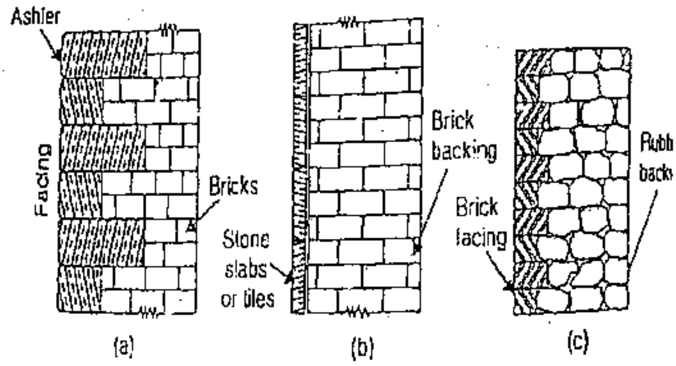
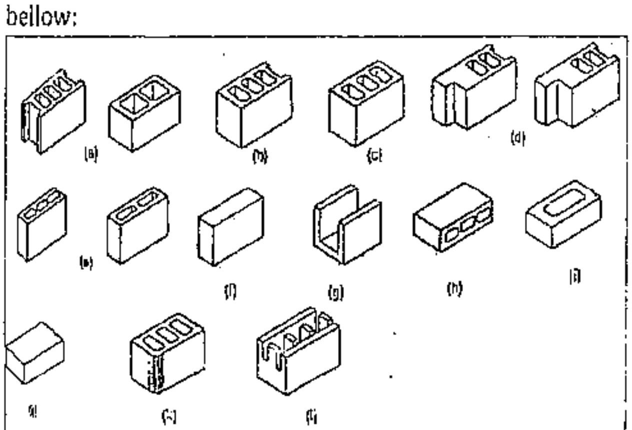


FIG. 7.2. BRICK-STONE COMPOSITE MASONRY.

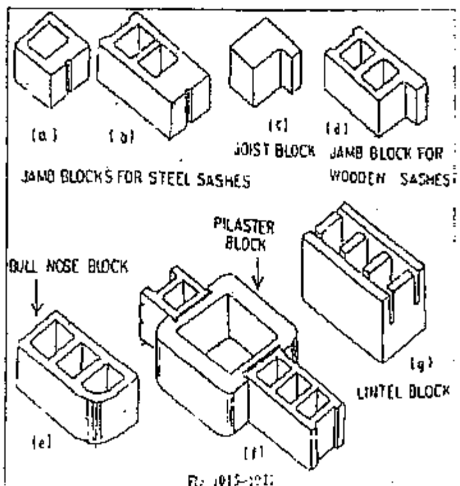
Fig 7.2 *(b) shows the facing of stone slabs or stone tiles.*
The backing consists of bricks laid in courses with proper bond. This type of construction is generally adopted for marble stone tiles. If stone slabs are used they are fine dressed, and are used in big panels. It is preferable to use metal cramps to connect the facing and backing masonry of the wall.

Fig 7.2 *(c) shows the rubble-backed brick masonry.* It is generally used at locations where rubble stone is available in large quantities, but ashlar is not available. In that case the facing of the wall may be done in bricks laid in courses. Each alternate brick course consists of brick quoin header.

3. *Cement concrete masonry*
Cement concrete masonry has been already explained above (on Para 2.1.1 brick and block masonry) in detail. As earlier stated above, either hollow or solid concrete blocks are used for composite masonry wall construction with stone facing. Cement concrete blocks may be used in form of pre-cast hollow concrete block, plain concrete or reinforced cement concrete. The blocks can be manufactured in various shapes and sizes as per actual requirements as shown in figures bellow:



(a) STRETCHER BLOCKS (b) CORNER BLOCK (c) DOUBLE CORNER OR PILLAR BLOCK (d) JAMB BLOCKS (e) PARTITION BLOCKS (f) SOLID BLOCK (g) BEAM OR LINTEL BLOCK (h) FLOOR BLOCK (i) FROGGED BRICK BLOCK (j) SOLID BRICK BLOCK (k) BULL NOSE BLOCK (l) LINTEL BLOCK
FIG. 7.3. CONCRETE MASONRY BLOCKS.



Specially shaped hollow concrete blocks for jambs, lintels, corners, etc.

4. Hollow clay tile masonry

Hollow clay blocks (or clay tiles) are made of selected clay earth, which is dried and burned. The clay block is used to build foundations, walls, partitions, floors and other structural members. They are quite strong and light even though the thickness is relatively thin. These tiles are fire proof, sound proof, thermal insulated, resistant to termite and decay caused by the contact of moisture or chemicals. They are manufactured in various shapes and sizes as shown in figure bellow with different grades of load bearing such as: Load bearing (LB), Extra Load bearing (L.B.X.). These tiles may have grooves on one or more faces which is used only for where plaster is to be done: otherwise smooth tiles should be used. The load bearing main walls and partition walls should be constructed in 1:6 (cement, lime, sand), and non-load bearing main walls and partition walls are constructed in 1:2:9 mixes. Clay blocks should be dipped in water before use.

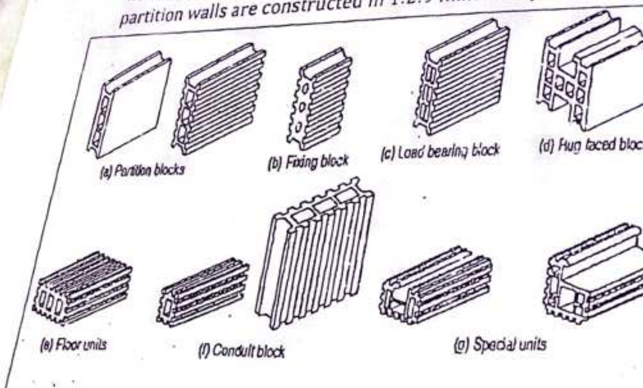


FIG. 7.4. CLAY BLOCK UNITS.

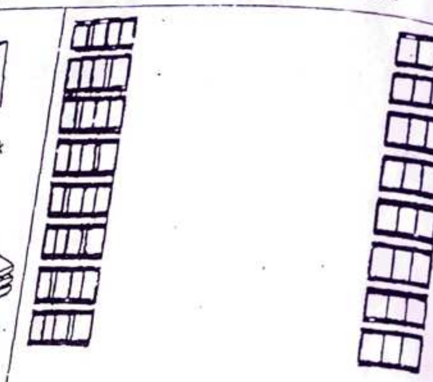


Fig. 10.22–10.13

Sectional elevation of different thickness of load bearing tile walls

5. Reinforced brick masonry

Reinforced brick masonry is the one which is strengthened by the provision of mild steel flats, hoop iron, expanded mesh or bars. These reinforcements are laid either horizontally or vertically with rich cement mortar (usually 1:3) and first class bricks having high compressive strength. There should be sufficient mortar cover to avoid corrosion for reinforcement.

Reinforced brick masonry is adopted in the following cases:

1. When the brick work has to bear tensile and shear stresses
2. When it is required to increase the longitudinal bond between the bricks
3. When the brick work is supported on soil which is susceptible to large settlement
4. When brickwork is supposed to act as a beam or lintel over openings
5. When the brick work is to resist lateral loads such as retaining walls etc.
6. When the brick work is subjected to heavy compressive loads e.g. a brick pillar
7. When the brick work is constructed in seismic areas.

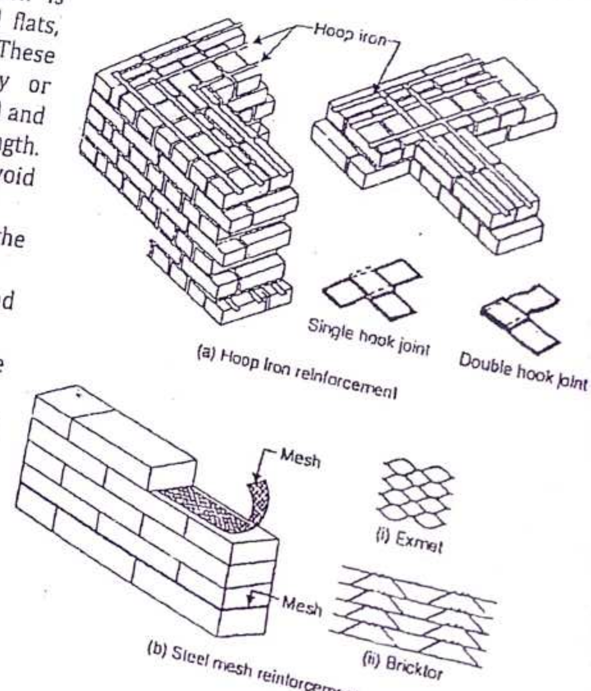


FIG. 7.5 HORIZONTAL REINFORCEMENT IN WALLS.

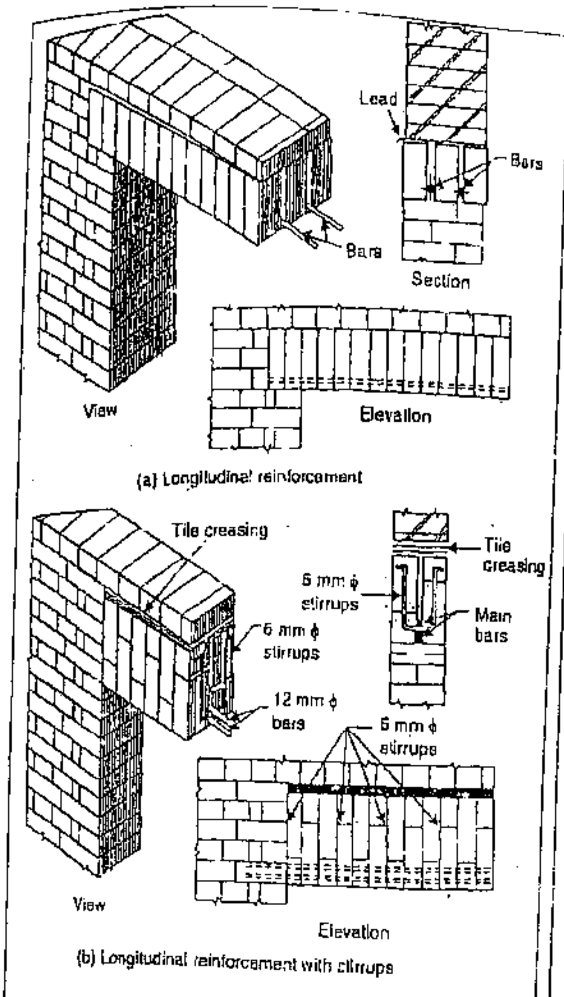


FIG. 7.6. REINFORCED BRICK WORK LINTELS.

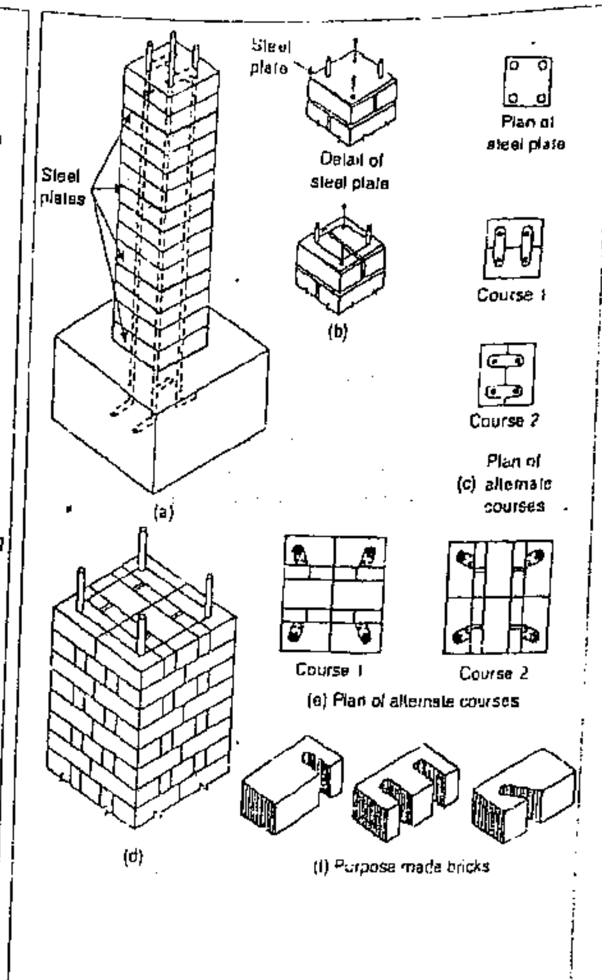


FIG. 7.7. REINFORCED BRICK WORK PIERS.

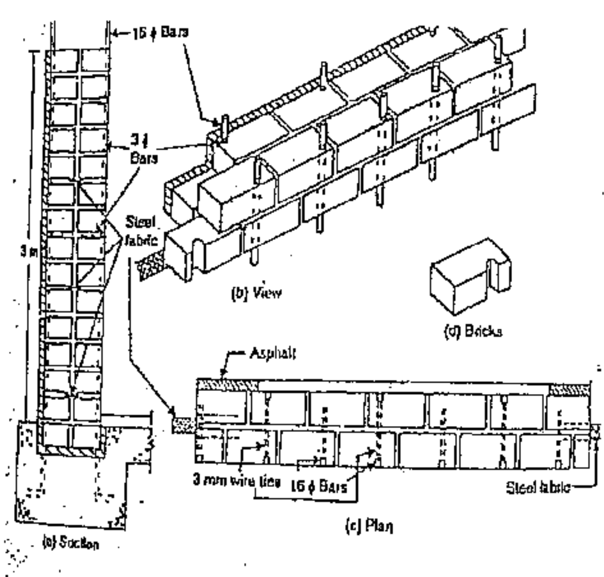
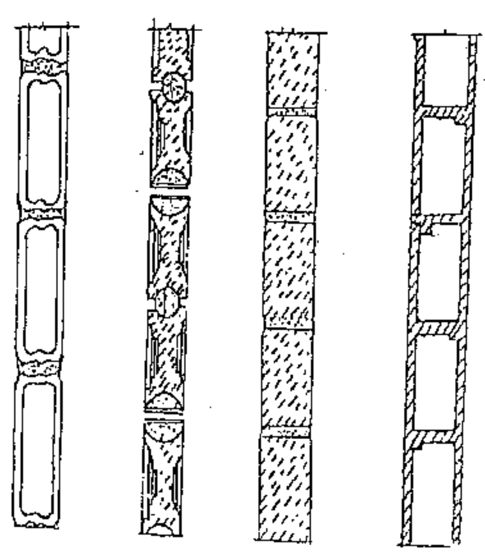


FIG. 7.8. REINFORCED BRICK WORK RETAINING WALLS.



Figs. 1024–1027

Sections of different types of glass block masonry

6. Glass block masonry

Glass blocks are made from structural glass annealed to withstand the stresses it is expected to bear. The blocks may be hollow or solid. The glass blocks are used in 1:1:4 (cement + lime + sand). The horizontal joints should be reinforced with galvanised expanded metal strips.

The construction of glass block masonry should be done in such a way that there is complete freedom of movement of the panel within the frame work. Provision for thermal expansion of glass bricks is made along jambs and heads of each panel. The panels should be properly anchored at sills, jambs and head. Following are the advantages of glass-block masonry:

1. It is non-porous, impervious, and non-absorbent of moisture
2. The light getting in these block panels is diffused and may be given any desired tinge of colour, pleasing to eyes.
3. Can be easily cleaned since its surface is smooth and it does not catch dirt.
4. Low condensation action on its surface which is important in cold countries for certain manufacturing industries where high humidity has to be maintained within the building.
5. It has great heat insulating and good sound proofing properties.
6. It is considered more sanitary.
7. If used on external walls, window openings are not required as sufficient light is admitted through blocks themselves. They also obstruct clear visibility from outside and thus provide good privacy conditions.

   Glass walls are not built to resist any load other than their own load.

Chapter 3 Floor, Vertical Transportation and Roof

3.1 Floors and its types

Introduction

Floors are the horizontal elements of a building which divide the building into different levels for the purpose of creating more accommodation within a restricted space one above the other and provide support for the occupants, furniture and equipment etc. of a building. A floor system may be composed of linear beams or joist overlaid with a plane of sheathing or it may be an almost homogeneous material

Requirement of floor

A floor must satisfy the following requirements.

a) Adequate strength and stability
b) Adequate fire resistance
c) Sound insulation
d) Damp resistance, and
e) Thermal resistance

Components of a floor: A floor is composed of two essential components or parts:

a) Sub floor or base course or floor base:
It is a structural component provided to support the floor covering. It imparts strength and stability to the floor covering and all other super imposed loads. The object of floor base is to give proper support to the covering so that it does not settle, and to provide damp resistance and thermal insulation

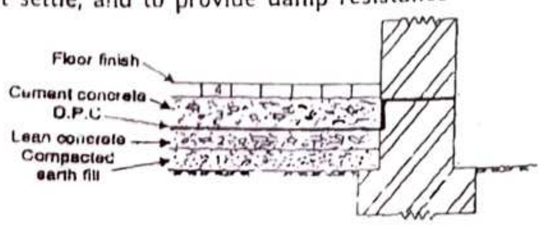


FIG. 11.1. SOLID GROUND FLOOK

b) Floor covering or flooring or floor finishes.
They are the covering over the sub-floor and are meant to provide a hard, clean, smooth, impervious, durable and attractive surface to the floor.

Types of floors

According to the structure of building, floors may be

1) Ground floor
2) Basement floor
3) Upper floor

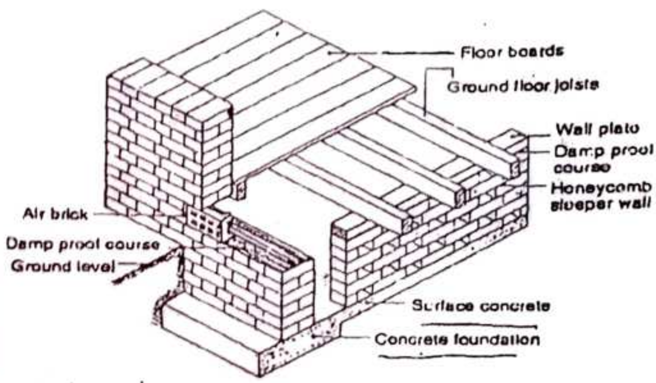


FIG. 11.2. SUSPENDED TIMBER GROUND FLOOR

1) Ground floor

The bottom floor near the natural surrounding ground level is termed as ground floor or the floor of building immediately above ground is known as ground floor.

Two types of ground floor

a) Solid ground floor
b) Suspended ground floor

a) Solid ground floor

There is no gap between ground level and plinth level (ground floor level). The gap between ground level and plinth level are completely filled with solid materials.

Materials used for sub-floor or base course or floor base of solid ground floor are:

i. Cement concrete
ii. Lime concrete
iii. Stones
iv. Bricks
v. Wooden blocks (for wooden flooring only)

b) Suspended ground floor

Suspended ground floor is a timber floor that is not touching the ground level and it is suspended above the ground There is always certain air gap between the ground level and plinth level in such floor. Ventilations are provided in the wall to keep the air circulation so that the floor becomes dry. Suspended ground floors are usually constructed in dancing hall, stage, auditorium etc.

2). Basement floor

A floor when provided for the accommodation below the natural ground level is termed as basement floor.

A basement floor is similar to ground floor except its location.

3) Upper floor

All other floor above the ground floor are termed as upper floor (timber upper floor, flag stone flooring resting on steel joist, stone patty floors, R.C.C., etc.)

The materials used for floor finish or floor covering or flooring are as follows:

1. Mud and Muram
2. Bricks
3. Flag stones
4. Concrete
5. Terrazzo
6. Mosaic
7. Tiles
8. Marble
9. Granolithic finish
10. Wood or timber
11. Asphalt
12. Rubber
13. Linoleum flooring
14. Cork
15. Glass
16. Plastic or PVC

Selection of flooring materials depends upon following factors:

1. Initial cost
2. Appearance
3. Cleanliness
4. Durability
5. Damp resistance
6. Sound insulation
7. Thermal insulation
8. Fire resistance
9. Smoothness
10. Hardness
11. Maintenance

1. Mud and muram flooring

They are used only in low cost housing.

Mud flooring

- Cheap, hard, fairly impervious, easy to construct and maintain
- It has cool thermal insulation property due to which it remains cool in summer and fairly warm in winter.
- 25 cm thick selected moist earth is speeded (spread) and is then rammed well to get a compacted thickness of 15 cm.
- To prevent cracks due to drying, small quantity of chopped straw is mixed in moist earth.
- Sometimes cow-dung is mixed with moist earth and thin paint of cement cow dung (1:2 to 1:3) is also applied.

Muram flooring

- It is a form of disintegrated rock with binding material; the flooring has practically the same properties as that of mud flooring.
- 15 cm thick layer of muram is laid over prepared sub grade, over it, 2.5 cm thick layer of powder muram (fine muram) is spread and water is sprinkled over it and then rammed well.
- After dry hard surface is formed, it is rubbed with thin pasta of cow-dung and rammed again for two days during morning hours.

2. Brick flooring

- Used in cheap construction, especially where good bricks are available.
- This type of flooring is especially suited to ware-houses, stores, go downs etc.
- Well burnt and uniformed shape bricks are either laid on edge or on flat arranged in herring bone fashion or set at right angles to the walls or at any other pattern for good looking.
- They may be laid in either one or double course with P.C.C concrete bed beneath it.

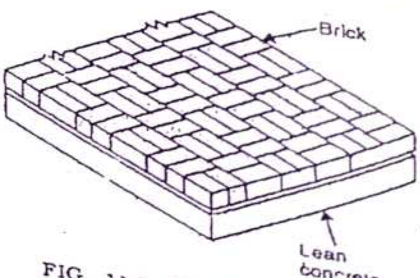


FIG. 11.3. BRICK FLOORING.

3. Flag stones

- Flagstone is any laminated sand stone available in 2cm to 4cm thickness, in the form of stone slabs of square (30cmx30cm, 45x45cm or 60cmx60cm) or rectangular size (45x60cm).
- The sub-soil is properly compacted, over which 10 to 15cm thick lime/lean cement concrete is laid.
- Then 20 to 25 cm thick layer of bed mortar is spread over the concrete bed and flag stones are laid over. This type of work is also called paving.
- The laying of stone slabs is started from two opposite corners by stretching a string.
- The joints between the stone slabs are raked out to a depth of 15 to 20 cm and then flush pointed with 1:3 cement mortars.
- Proper slope is given to the surface for drainage and the work is cured for at least one week by sprinkling water.

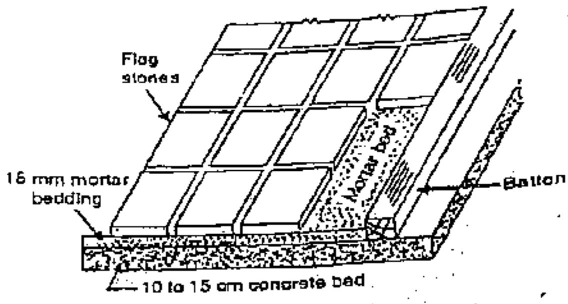


FIG. 11.4. FLAG STONE FLOORING.

4. Concrete flooring

- Commonly used in any kinds of building as they are moderately cheap, quite durable and easy to construct.
- It consists of two components viz. base concrete & topping or wearing surface.
- The two components of the floor can be constructed either monolithically or non-monolithically. When the floor is laid monolithically, good bond between the two components is obtained resulting in smaller over all thickness.
- When it is done monolithically we observe the following three disadvantages:

i. The topping is damaged during subsequent operations

ii. Hair cracks are developed because of the settlement of freshly laid base course which hasn't set.

iii. Work progress is slow because the workman has to wait at least till the initial setting of the base course.

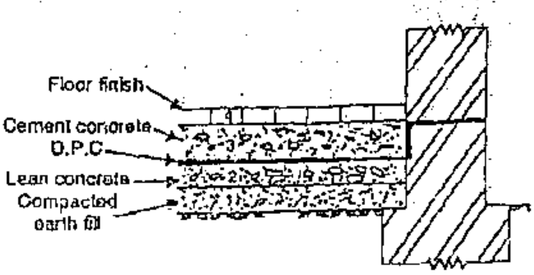


FIG. 11.1. SOLID GROUND FLOOR.

Hence in most of the cases non-monolithic construction is preferred.

- The base course consists of 7.5 to 10cm thick either in lean cement concrete bed (1:3:6 to 1:5:10) or lime sand (1 lime : 1 surkhi: 1 sand) and 60% coarse aggregate of 40 mm nominal size.
- When the base course (concrete) is hardened, its surface is brushed with stiff broom, cleaned thoroughly and is wetted the previous night and excess water to drain.
- The topping is then laid in square or rectangular panels by use of either glass or plain asbestos strips or by use of wooden battens set on mortar bed.
- The topping layer usually consists of cement concrete (1:2:4) generally 4cm thick. Prior to laying the concrete in the panel, a coat of neat cement slurry is applied. Glass or battens should have depth equal to thickness of topping. Steel trowel is used for finishing the top surface. Dusting of the surface with neat cement and then troweling results in smooth finish. The surface is then properly cured for a period of 7 to 14 days.

Terrazzo flooring (chips of polished stone set in concrete)

- It is very decorative and has good wearing properties which are widely used in all types of building.
- Terrazzo is a specially prepared thin concrete surface containing whit or grey cement and marble chips (of different colours) in proportion to 1:1¼ to 1:2. Marble chips may vary from 3mm to 6mm size. Colour can be mixed to white cement to set desired tint.
- The terrazzo flooring is done over the sub-base course (about 7.5cm thick P.C.C, generally 1:3:6 ratio) and has overall thickness of 40mm (cement concrete layer 1:2:4=34mm & terrazzo topping=6mm).
- Before laying the flooring the entire area is divided into suitable panels of pre-determined size and shape. For this, aluminium or glass scrip are used. The strips have the same height as the thickness of flooring (i.e. 40mm). The strips are jointed to the sub-base course with the help of cement mortar and their tops are perfectly set to level and line. Alternate panels are filled.

- The sub-base course is cleaned thoroughly & wetted. The wetted surface of the sub-base course is smeared with cement slurry. Concrete grade of 1:2:4 i.e. base course is then laid in alternate panels levelled and finished to rough surface when the surface is hardened, the terrazzo mix (cement + marble chips + water) is laid and finishes to the level surface. Additional marble chips may be added during temping and rolling operation, so that at least 80% of the finished surface show exposed marble chips. The surface is then floated and trowelled and left to dry for 12 to 20hrs. After that, the surface is cured properly for 2-3 days.
- The first grinding is done, preferably by machine, using coarse grade (no. 60) carborundum stones, using plenty of water. The ground is then scrabbled & cleaned. Cement grout of cream-like consistency, of the same colour is then applied on the surface so that pores & holes etc are filled. The surface is cured for 7days.
- The second grinding is done with carborubdum stones of fine grade (no.120). The surface is scrabbed and cleaned thoroughly and cement grout is again applied. The surface is cured for 4 to 6 days.
- The final grinding is done with carborundum stones of N 320. The surface is thoroughly scrabbed & cleaned using plenty of water. The floor is then washed with dilute oxalic acid solution.
- Finally the surface is polished with polishing machines the wheels of which are fitted with felt or hessian bows, to get fine shine. Wax polish is also applied with the help of the polishing, to get final glossy surface.

6. Mosaic flooring (small pieces of coloured stone or glass)

- Mosaic flooring is made of small pieces of broken tiles of china glazed or cement or marble, arranged in different pattern. These pieces are cut to desired shapes and sizes.
- Generally a concrete base (PCC 1:3:6, thickness 7.5cm) is prepared and over it 5 to 8cm thick lime surkhi mortar is spread and levelled.
- Thin 3 mm thick cementing material in the form of paste of two parts of slaked lime, one part of powdered marble and one part of pozzolona material is spread and is left to dry for about 4hrs.
- Thereafter, small pieces of broken tiles or marble pieces of different colours are arranged in definite patterns and hammered into the cementing layer. The surface is gently rolled by stone roller of 30cm dia. and 40 to 60cm long, sprinkling water over the surface, so that cementing material comes up through the joints and an even surface is obtained. The surface is allowed to dry for 1 day & is there after rubbed with a pumice stone fitted with a long wooden handle to get smooth and polish surface. The floor is allowed to dry for two weeks before use.

7. Tile flooring

- It is constructed from square, hexagonal or other shapes made of clay (pottery), cement concrete or terrazzo having different sizes and thickness.
- Used as an alternative to terrazzo flooring, especially where the floor is to be laid quickly.
- The method of laying tiled flooring is similar to that for flag stone flooring except that greater care is required.
- Over the concrete base, a 25 to 30 mm thick layer of lime mortar 1:3 (1 lime: 3 sand or surkhi) is spread as bedding which is allowed to harden for 12 to 24 hours. Before laying the tiles, neat cement slurry is spread over the bedding mortar and also a thin paste of cement is applied on the bottom side of the tile, then tiles are laid flat, gently pressing them into the bedding mortar with the wooden mallet, till levelled surface is obtained.
- On the next day, the joints between the adjacent tiles are cleaned of loose mortar etc. to depth of 5 mm, using wire brush, and then grouted with cement slurry if the same colour shades as that of tiles. The flooring is cured at least for 7 days.

8. Marble flooring

- It is superior type of flooring used in kitchen, bathrooms, corridors, stairs and hospitals, temples etc. and especially preferable where extra cleanliness is required.
- Over the base course of P.C.C, about 75mm thick, it may be laid in different sizes, usually in rectangular or any shapes of floor surface. Over the base course, 20mm thick bedding mortar of generally 1:4 c/m is spread under the area of each individual slabs. The marble slab is then laid over it, gently pressed with wooden mallet and levelled. The marble is then again lifted up and fresh mortar is added to the hollows of the bedding mortar.
- The mortar is allowed to harden slightly; cement slurry is spread over it and the marble slabs are again laid. It is gently pressed with wooden mallet so that the cement pastes oozes out from the joint which should be as thin as possible (paper thick). The oozed out cement is cleaned with cloth. The paved area is properly cured for about one week and polished with polishing machine before use.

9. *Timber flooring*

Timber flooring is used for carpentry halls, dancing halls, auditoriums, etc. They are quiet costlier. However in hilly areas, where timber is cheaply and readily available and where temperature drops very low, timber flooring is done. One of the major problems in timber flooring is the damp proofing for which a D.P.C band below it is required.

Timber flooring may be either for ground floor or for upper floors. The timber flooring for ground floor may be suspended type or solid type as mentioned below:

Solid type timber floor (fully supported on ground)

When the dampness problem is not of major concern then timber flooring may be supported on the ground all along as shown in Fig. 11.6. Then, such type of flooring is called solid type of flooring (timber). First of all, base concrete is first laid in 15 to 20cm thickness. Over it, a layer of mastic asphalt is applied. Wooden block flooring is then laid over it. Wooden blocks are short but thick (with sizes 20x8cm to 30 x 8cm and thickness 2 to 4 cm) and are laid in suitable design.

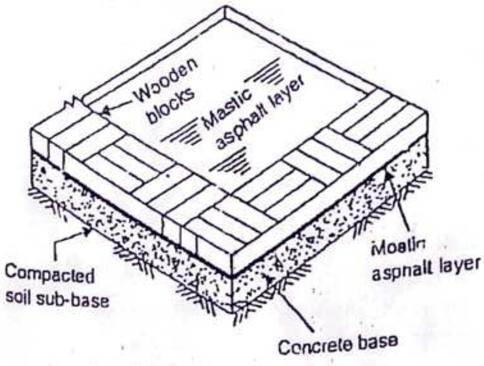


FIG. 11.6. WOODEN BLOCK-FLOORING

Suspended type timber floor (Supported above the ground)

In this type of flooring, there is a hollow space blow the floor which is kept dry and well-ventilated by providing air bricks in the outer walls and voids in the sleeper walls. The flooring consists of boarding supported on bridging or floor joists of timber, which are nailed to the wall plates at their ends. Spacer walls are known as sleeper wall are spaced from 1.80 m to 2.00 m. They are generally provided when there is considerable dampness.

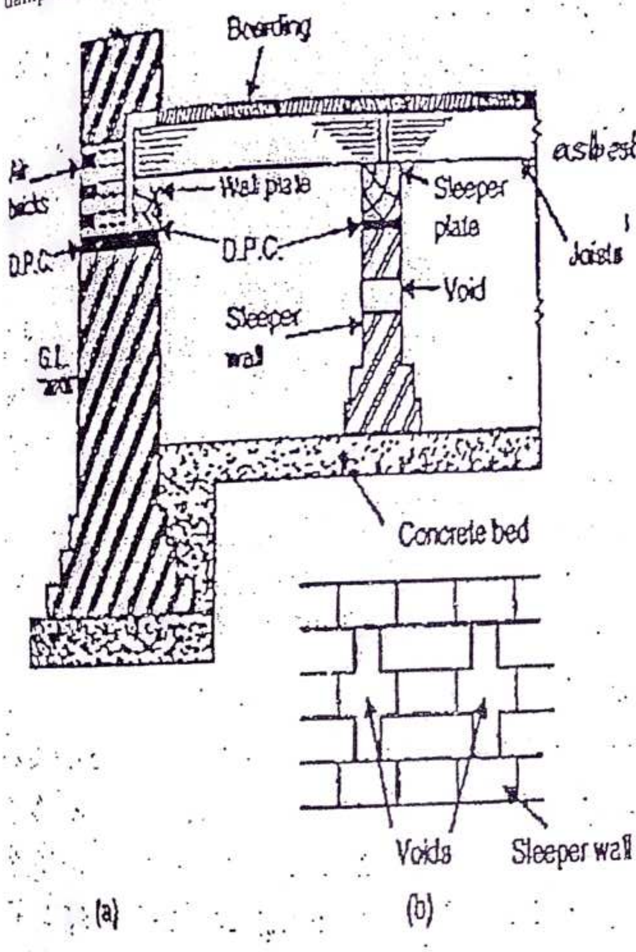
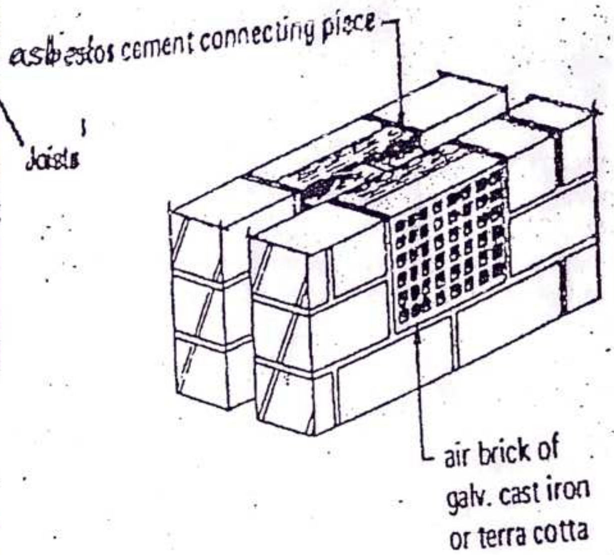


FIG. 11.5. SUPPORTED TYPE TIMBER FLOOR



Typical Air Brick Detail

iii. *Timber construction for upper floors*

Though, timber floor has quite light in weight, they possess poor resistance to fire and sound insulation. They are quite costly, thus they are used where timber is cheaply available.

Timber floors are basically of three types.

a) Single joist timber floor
b) Double joist timber floor
c) Framed or triple joist timber floor

a) *Single joist timber:*

This is the simplest type of timber floor used for residential buildings, where spans are short or moderate (say up to 4m) and loads are comparatively lighter. The floor consists of wooden of wooden joist (also called bridging joists) spaced 30 to 40cm a part and supported on end walls, over which timber planking or boarding is fixed. The width of joist are kept 5 to 8cm wide and depth is determined by thumb rule.

Depth (cm) = 4 x span in meters ± 5cm

The joists are supported on wall plates 10x7cm to 12x7cm. A space about 5cm is kept at the ends for air circulation. When the span is more than 2.5m, it becomes essential to support the timber joist by providing herring bone strutting at the mid span. Strut size 5x3cm to 5x5cm. The ends of the joist are nailed, logged or notched to the wall plates.

b) *Double joist timber flooring:*

This type of flooring is stronger and is used for spans between 3.5 to 7.5 metres. The bridging joists are supported on intermediate wooden supports, called binders. Thus, the loads of bridging joists are first transferred to the binders and the to the end wall in the form of highly concentrated loads. This is a disadvantage of this type of flooring. Also, the overall depth of the flooring is increased. Because of the intermediate supports, the bridging joists are of smaller sections, and are spaced at 30 cm centers. The spacing of the binders is kept 2 to 3.5 m and they rest on stone or wooden bearing templates which are not less than 0.75 to 2.5 m in length. In order to reduce the overall depth of the floor, bridging joists are cogged to the binders, with the depth of sinking equal one third depth of bridging girders and bearing not less than 2.5 cm. Alternatively the ends of their bridging girders are cut and thy are jointed with the help of filler provided along the two sides of the binder.

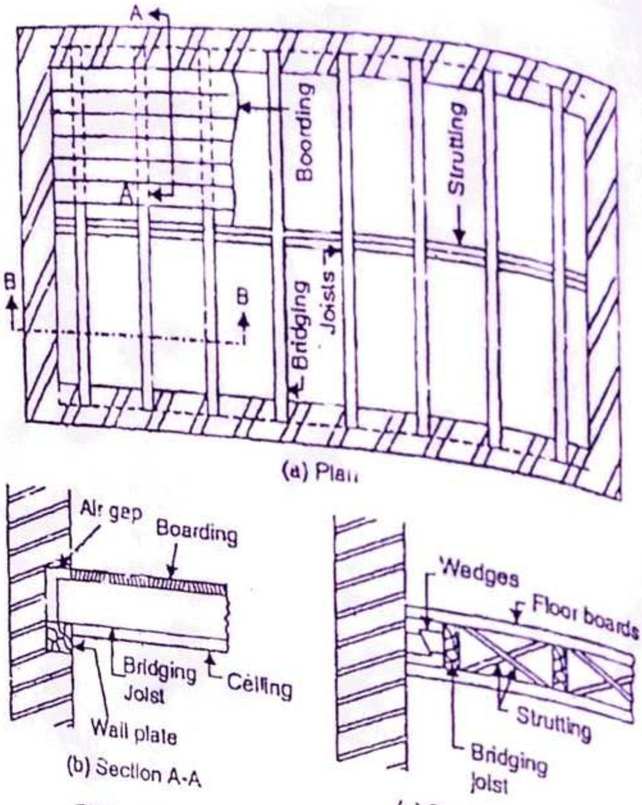


FIG. 12.11. SINGLE JOISTS TIMBER FLOORING.

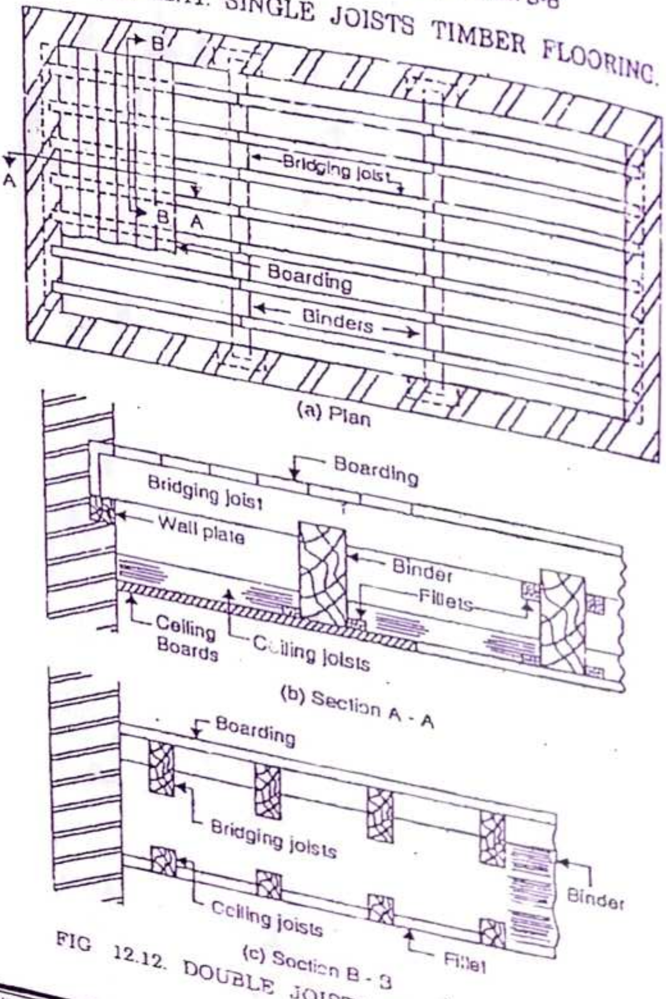


FIG 12.12. DOUBLE JOISTS TIMBER FLOORING.

c) **Framed or triple joist timber flooring:** This type of floor is suitable for spans greater than 7.50m, in which intermediate supports, known as girders are provided for the binders. There are four elements of flooring viz floor boards, bridging joist, binders & girders. The bridging joists support the floor boards. The binders are staggered and connected to girders by tusk & tenon joists to increase the rigidity of the floor and to decrease the overall depth of floor.

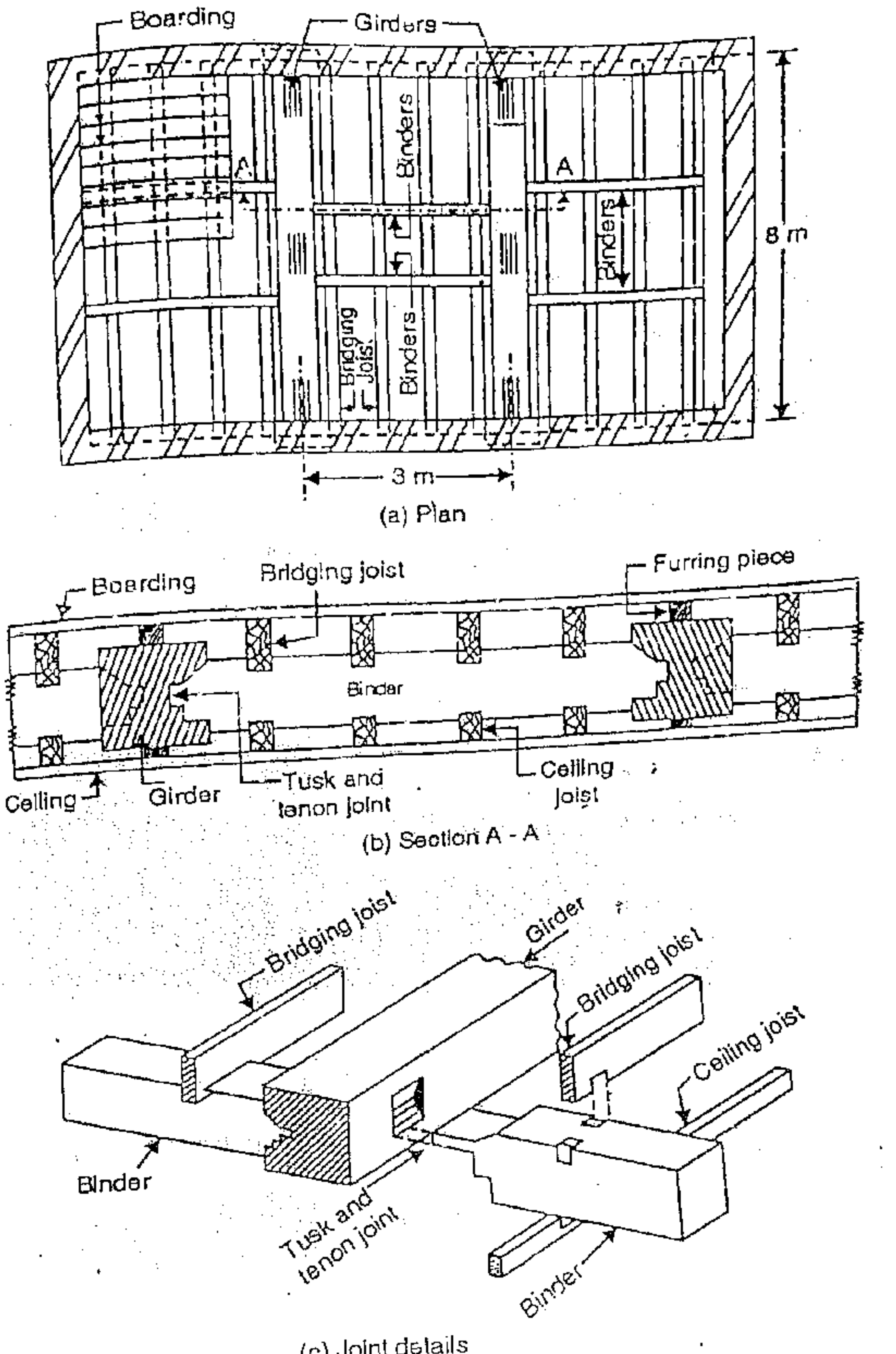


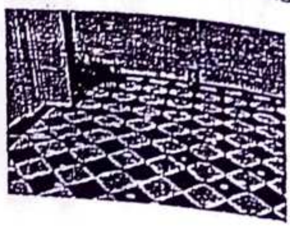
FIG. 12.13. FRAMED OR TRIPLE JOISTS TIMBER FLOORING

10. Granolithic finish (flooring):
Such types of flooring have very hard finishing so they are used in industrial buildings. Granolithic finishing consists of rich concrete made with very hard and tough quality coarse aggregate (granite, basalt, quartzite etc.). The concrete mix proportion varies from 1:1:2 to 1:1:3 and for heavy duty floor in public buildings 1:2:3. The thickness of finish may be minimum 25 mm when laid monolithically with top concrete, and 35 mm when laid over hardened surface. But in public buildings the thickness of granolithic finish may also be 13mm to 20mm using small size aggregate. If exceptionally hard surface is required sand may be replaced by fine aggregate of crushed granite or abrasive grit may be sprinkled uniformly over the surface (@ 1.5 to 2.5 kg/m^2.) during floating operation.

11. Asphalt flooring

- It is dustless, elastic, durable, waterproof, acid proof and attractive in appearance.

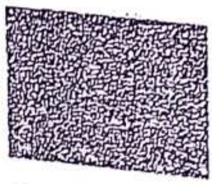
Fig.- Asphalt flooring⇒



- Procedure of construction:
  - Clean sharp sand or grit is mixed to melted asphalt (molten mass) in proportion of 2:1 (two part cement and 1 part asphalt)
  - The compost is poured on th previously prepared concrete bed by means of iron ladle
  - Uniform thickness (13mm to 25mm)
- Before the layer becomes hard very fine sand in small quantity is shifted over it and the surface is well rubbed
- Used in breweries, dairies, shops, swimming pool etc.
- Asphalt flooring is of 4 types:
  - I. Asphalt mastic flooring
  - II. Asphalt tiles flooring
  - III. Asphaltic mosaic
  - IV. Acid proof mastic asphalt

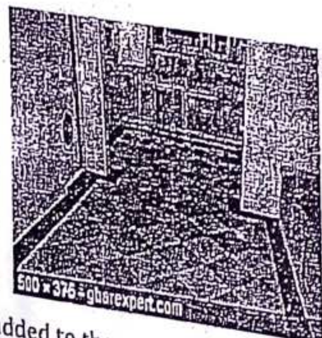
12. Rubber flooring

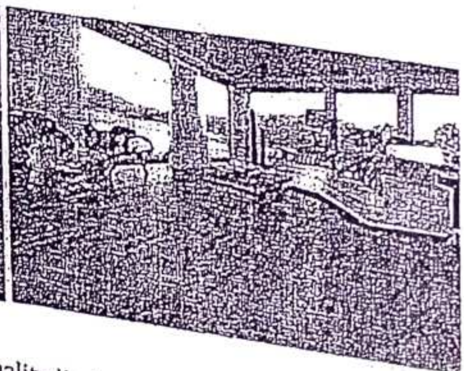
Fig. - Rubber flooring⇒



- Consists of sheets or tiles of rubber in various patterns and colour with thickness varying from 3 to 10 mm
- Sheets or tiles are fixed to concrete base
- Resilient (strong) and noise proof
- Used in hospitals, X-ray room, radio station etc.

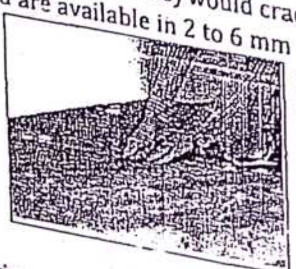
13. Linoleum flooring ⇒

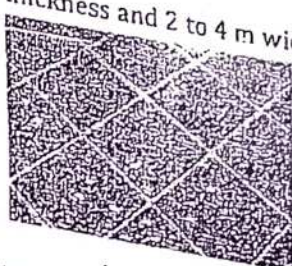




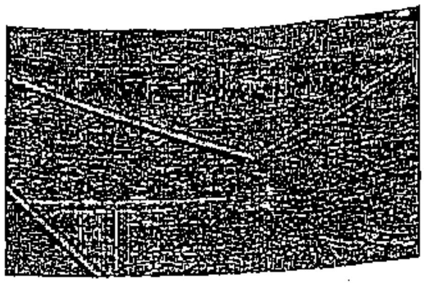
Linoleum is a floor covering available in rolls and made by mixing renewable materials such as solidified linseed oil or oxidized linseed oil (linoxyn) in gum, pine resins, pigments, ground cork dust, wood flour, and other mineral fillers such as calcium carbonate, most commonly on a burlap or canvas backing; pigments are often added to the materials.

- Linoleum is available in both cheaper and good quality. Good quality linoleum is sufficiently flexible to be used in buildings in which more rigid material (such as ceramic tile) would crack.
- The linoleum sheets are either plain or printed and are available in 2 to 6 mm thickness and 2 to 4 m wide rolls and linoleum tiles are also available.
- They can be fixed (or glued) to the concrete base or wood floor, in different patterns.
- Linoleum coverings are attractive, resilient, durable and cheap and cleaned easily, however, it is subjected to rotting when kept wet so they cannot be used in kitchen and bathrooms but can be used in bed rooms.
- Linoleum is used in break dancing as an alternative to cardboard as it provides a large, slick and durable surface.





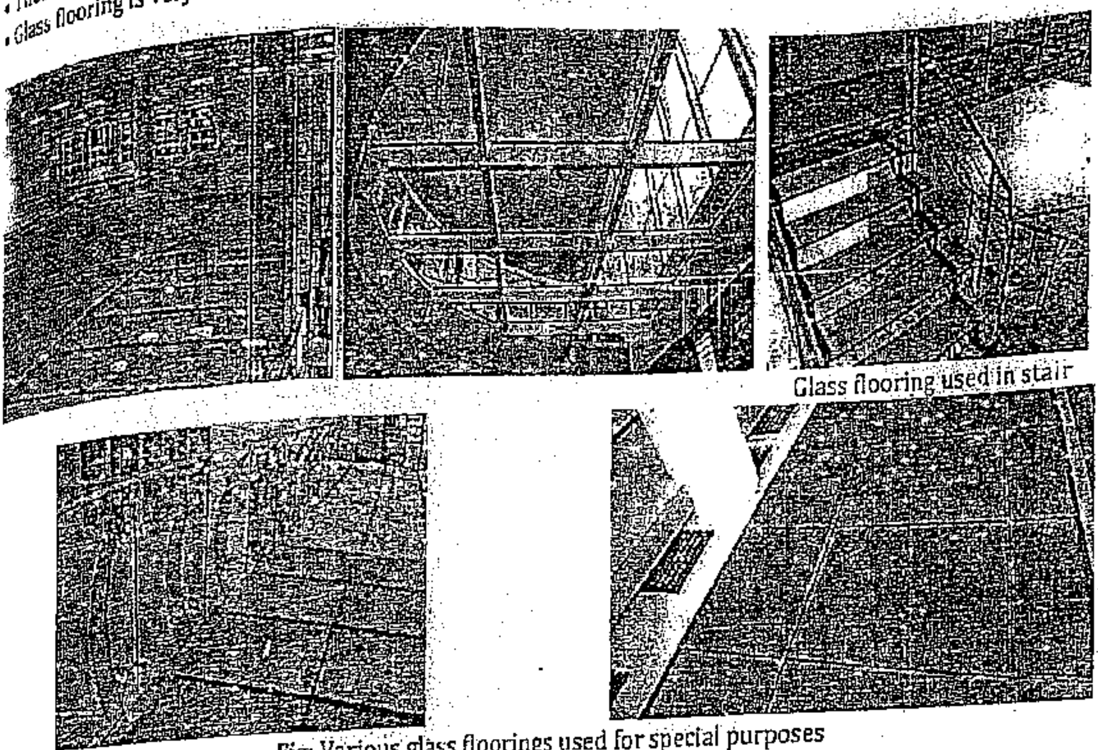
14. Cork flooring



- It is perfectly noiseless and used libraries, theatres and galleries etc.
- Available in the form of cork carpet or cork tiles and fixed to concrete base
- Used in church, libraries, theatres etc.

15. Glass flooring

- It is a flooring for special purpose
- Used in circumstances where it is desired to transmit light from upper floor to lower floors, and specially to admit light at the basement from upper floor
- Structural glass is available in the form of tiles or slabs in various thickness 12 to 30 mm.
- These are fixed in closely spaced frame so that glass and frame can sustain anticipated (expected) loads.
- Glass flooring is very costly so it is not commonly used.

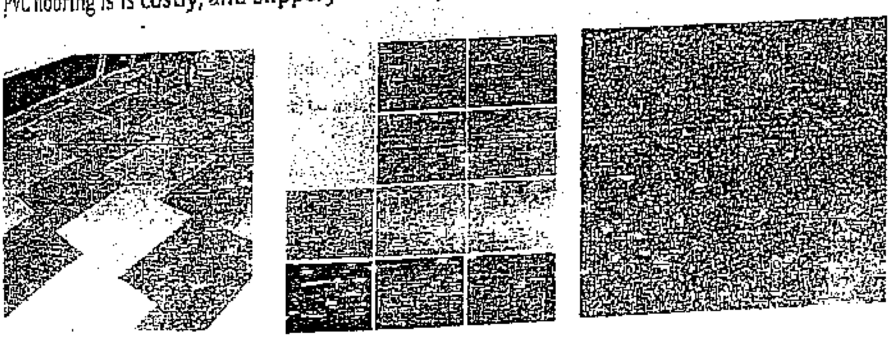


Glass flooring used in stair

Fig: Various glass floorings used for special purposes

16. Plastic or PVC flooring:

- It is of plastic materials, called Poly-Vinyl-Chloride (PVC), fabricated in the form of tiles of different sizes and colour shades as shown in figure below.
- Widely used in all residential as well as non-residential buildings. The tiles are laid on concrete base.
- Specified adhesive is applied on the base concrete as well as on backside of tiles and the tile is laid when it is sufficiently set (approximately within 30 minutes).
- PVC flooring is is costly, and slippery and easily damaged when in contact with burning objects.



3.2 Different means of vertical transportation:

A building comprises of various spaces and floors which are connected with the help of connectors.

Connectors are of two basic types:

I. Horizontal connector (passage, corridor, hall-way, foyer, lobby etc.)
II. Vertical connector (stairs, elevators, escalators, ramps etc.)

Stairs, ramps, elevators, lift and escalators are different means of vertical transportation.

Stair: A stair may be defined as a vertical means of transportation which connects two different spaces placed at two different levels inside a building. Stair is needed wherever the different in level is present. Stair is used for the purpose of ascendance anddescedence inside a building and this is one of the best used building elements used during hazards as an escape.

A space where stair is accommodated is said to be staircase. In earlier days, staircases were designed with heavy decoration and demonstrated as a sign of prosperity but now trend of this decoration has been changed and staircase are constructed in a simple way giving priority for economical design and safety to users. The space which spaces the stairs is said as stair well too.

Lift / Elevator: For most people residing in urban cities, elevators have become an integral part of their daily life. Simply stated, an elevator is a hoisting or lowering mechanism, designed to carry passengers or freight, and is equipped with a car and platform that typically moves in fixed guides and serves two or more landings. The elevators can be broadly classified as either electric traction type or hydraulic type.

Traction elevators: Such types of elevators consist of an elevator car and counterweight attached to opposite ends of hoist ropes. The hoist ropes pass over a driving machine that raises and lowers the car. Traction elevators run on load-bearing rails in the elevator hoist way. Traction elevators are most often used in mid-rise and high-rise buildings with five or more floors.

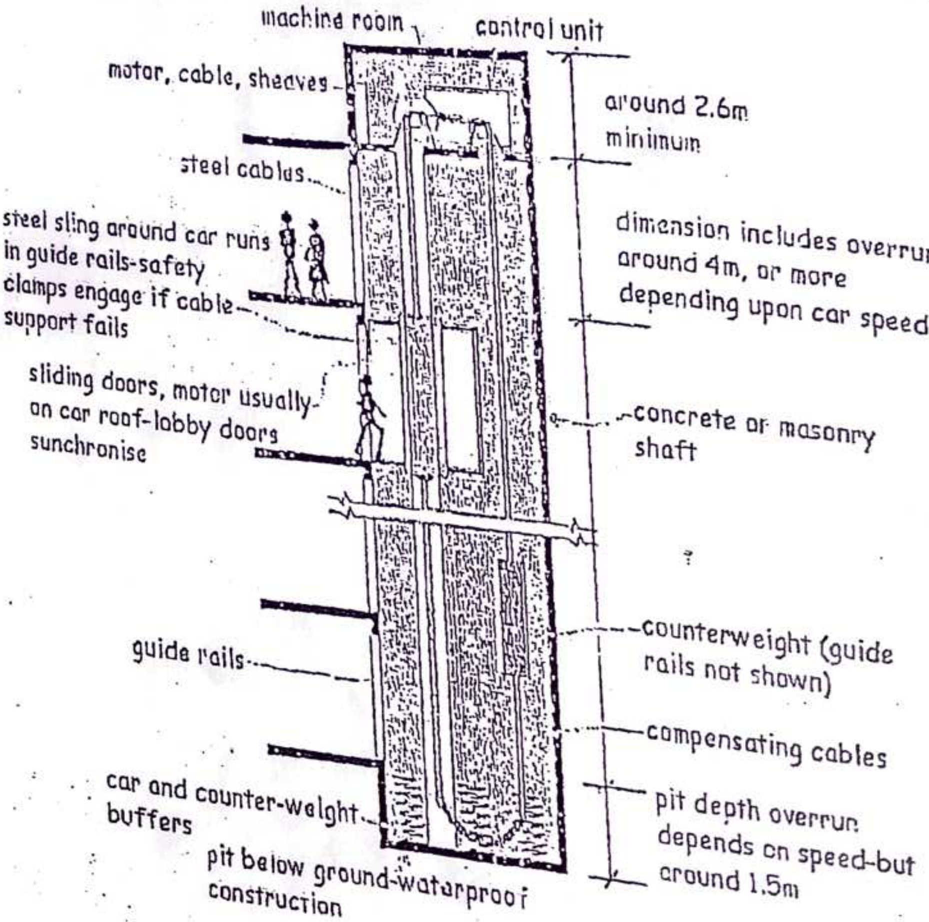
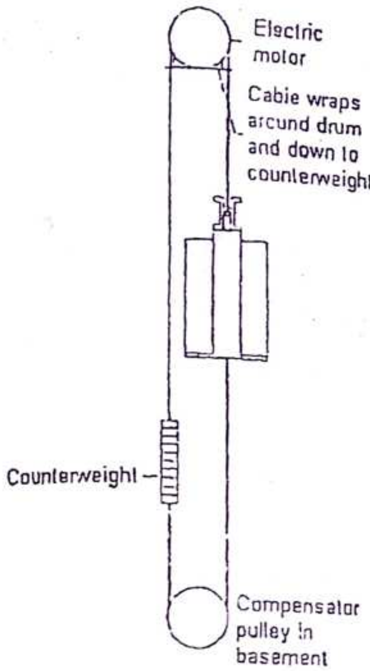
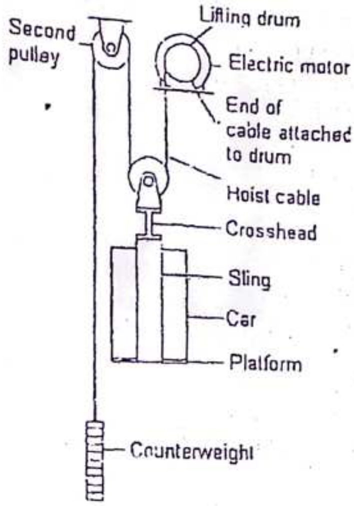


Fig Traction elevator/lift

Hydraulic elevators: Hydraulic elevators are raised by forcing pressurized oil through a valve into a steel cylinder located above ground or underground. The hydraulic elevators consist of the pressure forces, a piston to rise or lifting the elevator platform and a car enclosure mounted on it. The car is lowered by opening the valve and allowing the weight of the car to force oil from the cylinder in a controlled manner. When the valve is closed the car is stopped. Since the weight of hydraulic elevator cars is borne by the piston, there is no need for a structural framework or load-bearing rails. Hydraulic elevators are commonly found in low-rise buildings with two to five floors.



Traction Drum Arrangement



Lifting Drum Arrangement

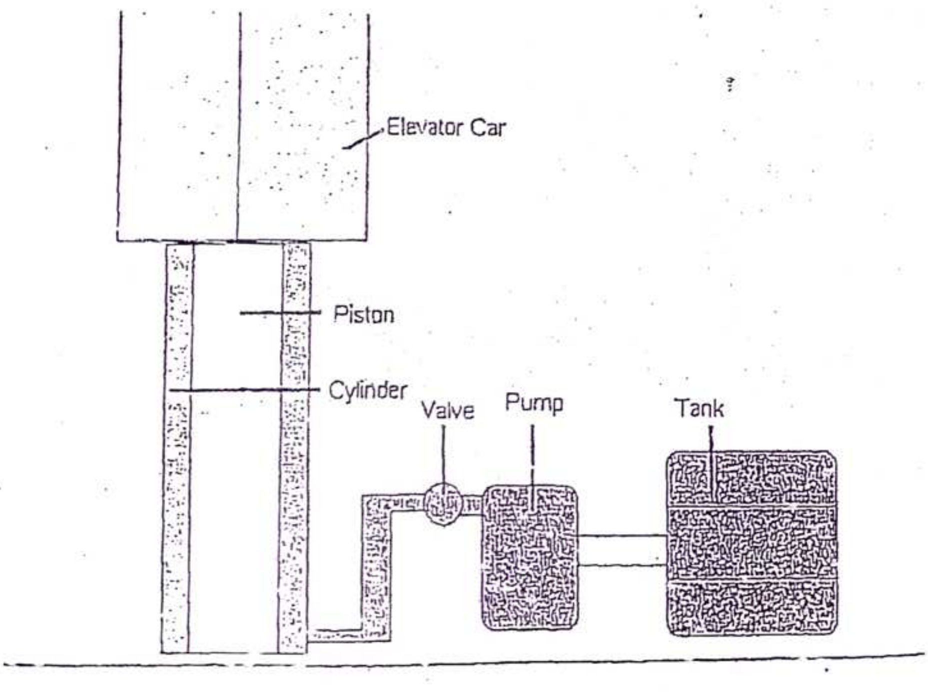


Fig.Hydraulic Elevator

Types of lifts:

i. *Passenger lift*
ii. *Goods or service lift*
iii. *Open lift*

Terminologies used in lift:

Call indicator, Car body work, Suspension rope, Lift well, Machine room

A lift should be provided in all buildings as prescribed hereunder:

(i) In case of Building having height more than 13.00m, lift shall be provided.

(ii) Lift shall be provided at the rate of one lift for 20 tenements of all the floors or part thereof for residential buildings and at the rate of one lift per 1000.00 m² or part thereof of built-up area for non-residential buildings. The tenement and built-up area on ground floor and two upper floors shall be excluded in computing the above requirement. Lift shall be provided from ground floor and shall have minimum capacity of six persons. On the basis of detailed calculations based on the relevant provisions of National Building Code, the number of lifts can be varied.

(iii) Not withstanding anything contained in the Development Control Regulations in case of building with 21 meters or more in height at least two lifts shall be provided.

Escalators: The other mode of vertical building transportation is "Escalator". It can be described as moving stairs typically used to carry large number of people at high volumes through a limited number of floors. These are commonly used in high density areas or where sudden traffic surges are expected at times; for example at discharge times from offices, railways, underground stations, airport terminals, theatres, shopping malls and departmental stores. In such applications, escalators will provide shorter travel time than elevators because elevator cars are limited in size and passengers have to wait longer for the service.

Ramps: Ramps – both external and internal – connect different levels and are essential for wheelchair users and useful for others such as parents with pushchairs, shoppers with trolleys and some older people. They need to be designed and detailed with care if they are to have real practical value.

Disabled people who are not wheelchair users and some older people, find ramps – particularly long ones – inconvenient or difficult, and prefer to use steps. Therefore ramp should always be associated with steps in close proximity, which should also be carefully designed.

Ramps may be of three types:

(1) Ramps for pedestrians:

(a) General:- the provisions applicable to stairway shall generally apply to ramps. A ramp in a hospital shall not be less than 2.25 m wide in addition to satisfy the fire fighting requirements.

(b) Slope:- A ramp shall have slope of not more than 1:10 and it shall be of non-slippery material.

(c)Handrail:- A hand rail shall be provided on both sides of the ramp

(2) Ramps for handicapped people:

The provision of the ramp with a hand rail to every public building on ground floor only as compulsory for handicapped people as per the revised National Building Code.

(3) Ramps for basement or storied parking:

For parking spaces in a basement and upper floors at least two ramps of adequate width and slope shall be provided preferably at the opposite and such ramps may be permitted in the side and rear marginal open spaces after leaving sufficient space for movement of fire fighting equipment.

Stair[illegible]

A stair[illegible] is a set of steps leading from one floor to the other. It is provided to afford the means of ascent and descent between the various floors of a building. The room or enclosure of the building in which the stair is located is known as stair case. The opening or space occupied by the stair is known as stair way. In a residential building, it should be centrally located to provide easy access to all the rooms. In public building, it should be located near the entrance. In large building there can be more than one stairs. Stair may be of timber, bricks, stones, steel or R.C.C.

1.8.3 Elements of staircase

The section of a stairc... and its elements has been shown below in the figure. The technical terms associated with the design and construction of stairs is defined as below:

1. Step: It is a portion of stair which permits ascent or descent. It is comprised of a tread & a riser. A stair is composed of a set of steps.
2. Tread: It is the upper horizontal portion of a step upon which the foot is placed while ascending or descending.
3. Riser: It is the vertical portion of a step providing a support to the tread.
4. Flight: This is the unbroken series of steps between the landings.
5. Landing: It is the level platform at the top & bottom of a flight between the floors. It facilitates change of direction and provides an opportunity for taking rest during the use of stair.

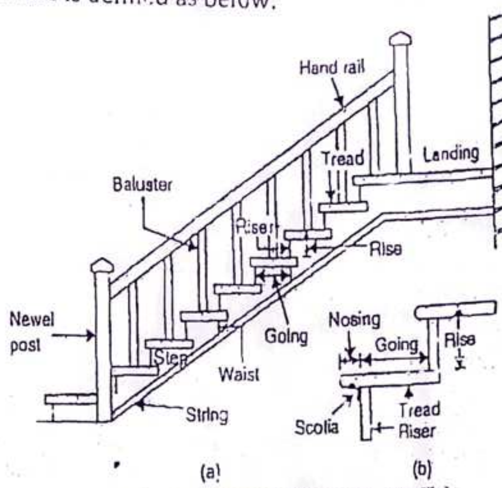


FIG. 14.1 TERMS USED IN STAIRS.

6. Rise: It is the vertical distance between two successive tread faces.
7. Going: It is the horizontal distance between two successive riser faces.
8. Nosing: It is the projecting part of the tread beyond the face of the riser. It is generally rounded off from architectural considerations.
9. Scotia: It is a moulding provided under the nosing to improve the elevation of step and provide strength to the nosing.
10. Soffit: It is the underside surface of a stair.
11. Run: It is the total length of stairs in a horizontal plane, including landings.
12. Waist: The thickness of RCC slab over which steps of RCC rest, is known as waist.

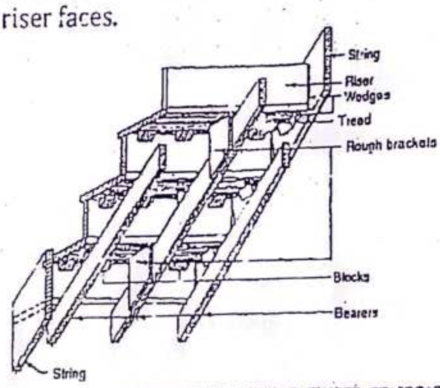


FIG. 14.12. CONSTRUCTION OF A SIMPLE TIMBER STAIRCAS

13. Walking line: It is the approximate line on the stair, adopted by the people during use of the stair. This line is located about 40 cm from the centre of the hand rail.
14. Line of nosing: It is an imaginary line parallel to strings and tangential to the nosing.
15. Strings or stringers: These are the sloping members which support the steps and run in a stair. They run along the slope of the stair.
16. Pitch of slope: It is an imaginary line connecting the nosing of all tread in one flight. Pitch or slope is the angle made by the line with the horizontal or it is the angle which the line of nosing of the stair makes with the horizontal.
17. Newell post: It is a vertical member which is placed at the ends of flight to connect the ends of strings and hand rail.
18. Baluster: It is a vertical infill member of wood or metal supporting the hand rail between the string and handrail.
19. Balustrade: It is a row of balusters which is surmounted (overcome) by a hand rail to provide protection for the user.
20. Handrail: It is a rounded or moulded member of wood or metal following generally the contour of the nosing line and fixed on the top of balusters.
21. Head room: or Headway! It is the minimum clear vertical distance between the tread and overhead structure i.e. ceiling or soffit of the flight or ceiling of landing
22. Stairway / Stair well: The space where the stair is housed.
23. Newel: Post forming the junction of flights with landing or carrying the lower end of strings.
24. Header: It is the horizontal structural member supporting stair stringers or landings.

25. Spandrel: It is the triangular framing under the outside string of an open string stair.

Ideal requirements of stair

Stair is the means of ascent and descent between various floors of a building. Hence, in order to provide easy, quick and safe mode of communication between the floors, a stair should satisfy the following requirements.

1. **Location**
   a. It should be located as to provide easy access to the occupants of the building
   b. It should be so located that it is well lighted and ventilated directly from the exterior.
   c. It should be so located as to have approaches convenient and specious.

   Note: - Centre location for residential & near entrance point to the public building is preferable.
2. **Width of stair**
   It should be wide enough to carry the user without much crowd or inconvenience. It depends upon its location and type of the building 90cm to 120cm for residential & 120cm to 150cm for public building is sufficient width of stair.
3. **Length of flight**
   From comfort point of view, the nos. of steps should be not more than 12 and not less than 3. For public buildings, the maximum number of treads in one flight is limited to 9.
4. **Pitch of stair:** The pitch of stair should match with the French theory, according to which "the average labour of moving vertically is about twite that of moving horizontally, if the average human stride is taken as 23 inches. If the rise and going are measured in inch units, the best pitch of the stair is that inclination which by twicing the rise and adding the going equals 23. When measured in cm units, a comfortable slope is achieved when twice rise plus going is equal to 60 approximately. Pitch should however is limited to 30^0 to 45^0
5. **Head room**
   The clear distance between the tread and soffit of the flight immediately above the tread should not be less than 2.1 to 2.3m.
6. **Balustrade**
   Open well stair should always be provided with balustrade to provide safety to the users. Wide stair should have hand rail on both sides.
7. **Step dimension**
   The rise and going should be of such dimension as to provide comfort to the users. Their proportion should be such as to provide desirable pitch of the stair. The going should not be less than 25cm & the rise should be 10cm to 15 cm. The width of landing should not be less than that of the width of stair.
8. **Materials of construction**
   The materials used for the construction should be such as to provide sufficient strength & free resistance fire resistance is most essential for the stair.

Types of steps: Steps in a stairs may be of following types:

1. **Flier step:** Steps of uniform width and rectangular shape in plan as shown in Fig. 14.2(a).
2. **Bull nose step:** Provided at bottom of the flight, projects in front of newel post as shown in Fig. 14.2(a)
3. **Round ended step:** Semi-circular shape projects out from the stringer, Fig. 14.2(b)
4. **Splayed step:** Provided at the beginning of the flight near newel post, Fig.14.2(c)
5. **Commode step:** It has curved tread and riser as shown in Fig. 14.2(d)
6. **Dancing step:** Dancing or balancing steps are the winders which do not radiate from a common centre as shown in Fig. 14.2(e)
7. **Winder:** Winders are tapering steps, such as those which radiate from a point usually situated at the centre of a newel as shown in Fig. 14.2(f).

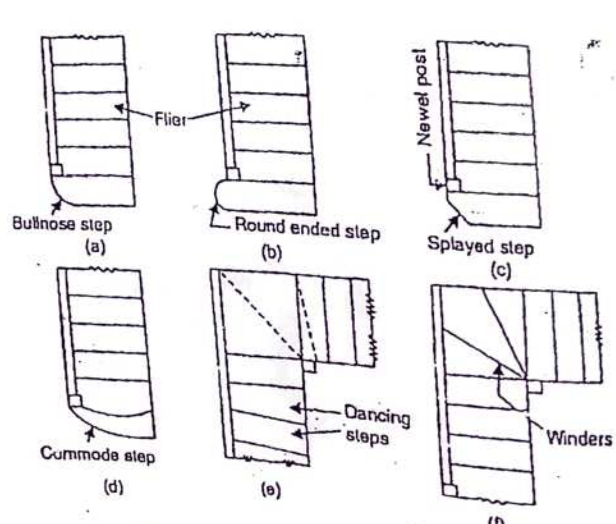


FIG. 14.2 VARIOUS TYPES OF STEPS.

3.4 Types of staircases

Staircases may be classified according to the materials used and configuration they have.

Classification based on material of construction

(1) *Timber staircase*

(2) *Masonry staircase:*

i. Brick masonry staircase
ii. Stone masonry staircase
iii. Pre-cast concrete masonry staircase

(3) *Reinforced concrete masonry staircase*

(4) *Steel staircase or metallic stairs*

Classification based on shape or configuration of staircase

(1) *Straight staircase*

(2) *Turning staircase:*

(i) *Quarter turn staircase*
(ii) *Half turn staircase (dog legged & open well or open newel stair)*
(iii) *Three-quarter turn staircase*
(iv) *Bifurcated staircase*

Each type of turning stairs may have of following three types:

a. *Newel stairs*
b. *Well or open-newel stairs and*
c. *Geometrical stairs*

(3) *Continuous staircase:*

i. Circular
ii. Spiral
iii. Helical etc.

Classification based on shape or configuration of staircase:

(1) Straight staircase

When stair runs straight between the two floors, it is called straight stair. It is used for small houses where there are restrictions for available widths. The stair may consist of either one single flight or more than one flight.

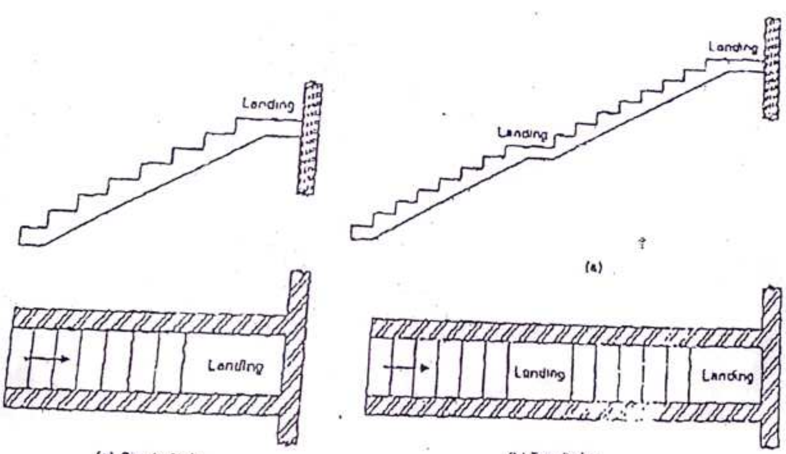


FIG. 14.3. STRAIGHT STAIRS.

(2) Turning staircase:

(i) Quarter turn stair

A quarter turn stair is the one which changes its direction to the left or the right, the turn being affected either by introducing a quarter space landing or by providing winders. Winders are the steps in trapezoidal shapes formed at change of direction of a stair.

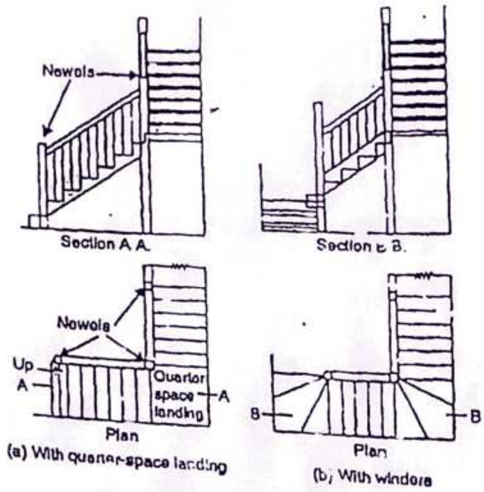


Fig: Newel quarter turn stair

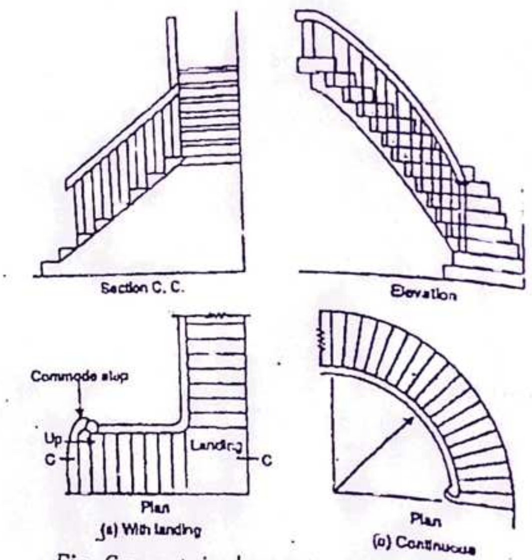


Fig: Geometrical quarter turn stair

Types of quarter turn stair may be as follows:

a. Newel quarter turn stair

These stairs have the conspicuous (clearly visible) newel posts at the beginning and end of each flight. Winders may or may not be provided at landing.

b. Geometrical quarter turn stair

The stringer as well as the hand rail is continuous without newel post at the landing.

(ii) Half turn stairs

Half turn stair has its direction reversed or changed for 180°. These types of stairs are more common. Such types of stair are of following three types:

a. Dog-legged or newel half turn stairs
b. Open newel half turn stair
c. Geometrical half turn stair.

a. Dog legged or newel half turn stair

When there is no space or less than 15cm between the two strings, then the stair is called dog legged half turn stair. It is also known as newel half turn stair because it has newel posts provided at the beginning and end of each flight. These may be of with winders or without winders at landing.

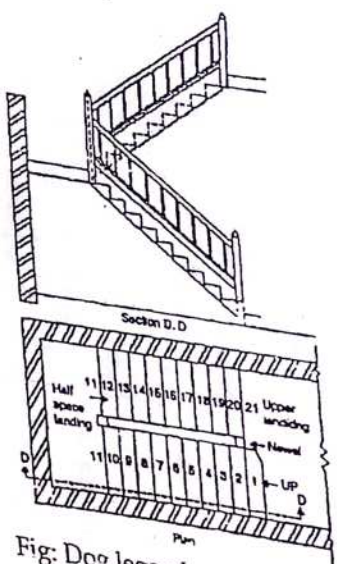


Fig: Dog legged or newel half turn stair

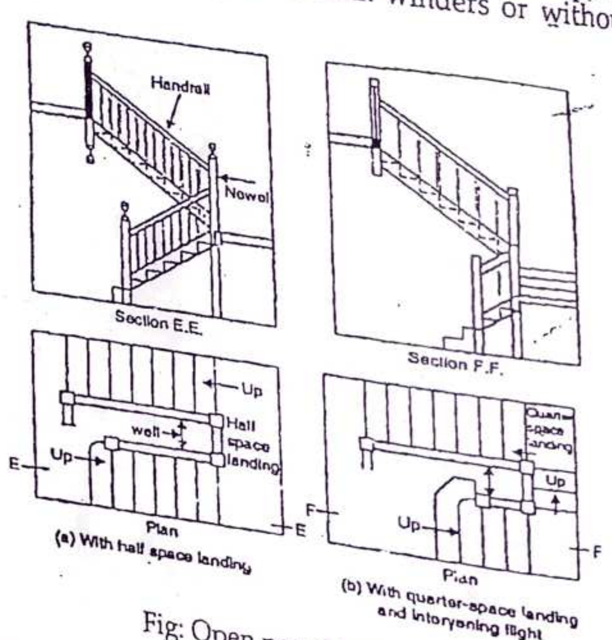


Fig: Open newel half turn stair

b. Open newel half turn stair
These stairs are similar to dog legged half turn stair except the space between the two strings. The spaces between the strings vary from 15cm to 100cm. When the space left is more, a small flight containing two to four steps may be introduced at the turn, between the two quarter space landings.

c. Geometrical half turns stairs
When the strings and the hand rails are continuous without any intervening newel post, such type of stair is called geometrical half turn stair. These may be either with half space landing or without landing.

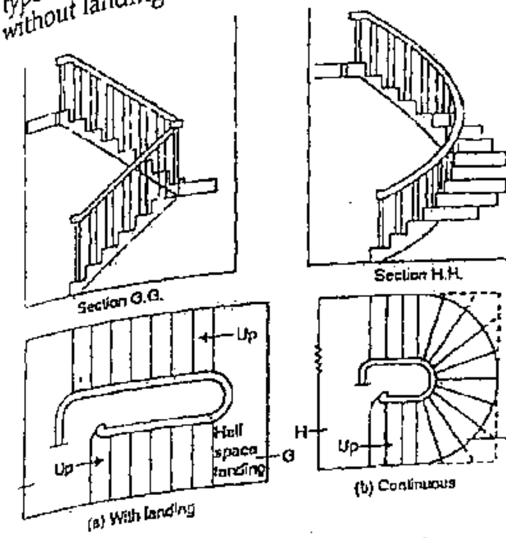


Fig: Geometrical half turns stairs

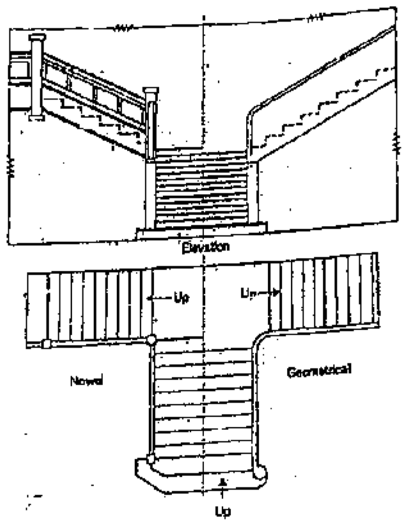
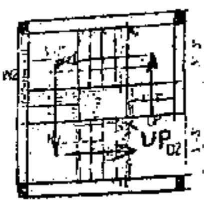


Fig: Bifurcated stairs

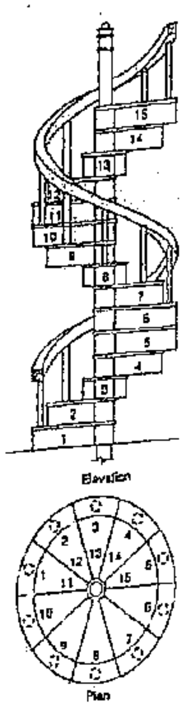
(iii) Three quarter turn stair
A three quarter turn stair has its direction changed three times with its upper flight crossing the bottom one. It may be either newel type or open newel type. Such type of stair is used when the length of the stair room is limited and when the vertical distance between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

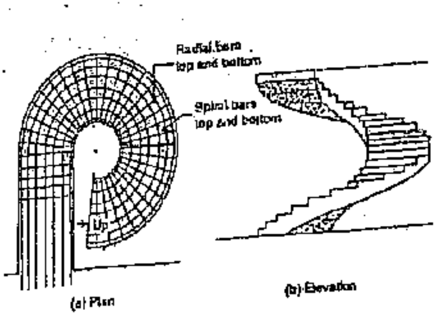
Three quarter turn stair⟹



(iv) Bifurcated stairs
This type of stair has a wider flight at the bottom which bifurcates into two narrower flights one turning to the left and the other to the right, at the landing. It may be newel type with a newel post or of geometrical type with continuous stringer & hand rail.

3. Continuous stairs
Continuous stairs are those which do neither have any landing nor any intermediate newel post. They are, therefore geometrical in shape e.g. *circular, spiral* or *helical shapes*. Continuous type of stairs is usually made either of R.C.C or metal and is employed at a location where there are space limitations. Such types of stair are also used as emergency stair and are provided at back side of a building. As all steps are winders, such stair is therefore not comfortable.





3.5 *Relationship between rise and tread in stair:*

For comfortable ascent and descent, the raise and tread of a step in stair should be well proportioned according to the following thumb rules

(i) (2 x Rise in cm) + (Going in cm) = 60 ⟹ $2R + T = 60$ (in cm)

(ii) (Rise in cm) + (Going in cm) = 40 to 45 ⟹ $R + T = 40$ to 45 (in cm)

(iii) (Rise in cm x Going in cm) = 400 to 450 ⟹ $R * T = 400$ to 450 (in cm)

(iv) Adopt Riser = 14 cm and Tread T = 30cm as standard; then for every 20mm subtracted from going, add 10 mm to the rise. Thus, other combinations for rise and going would be 15 cm x 28 cm, 16 cm x 26 cm, 17 cmx 24 cm.

(v) For hospital, office buildings etc. the comfortable size of steps is 10 cm x 30 cm while for residential buildings the common size of step is 16 cm x 26 cm

(vi) Pitch of stair is generally limited from 30^0 to 45^0

Dimensions for stair design (as per IS Code)

Type of Building	Riser in (mm)			Tread in (mm)			Slope of stair		Unobstructed width of stair
	Min.	Opt.	Max.	Min.	Opt.	Max.	Opt.	Max.	Min. (mm)
Residential	100	175	190	225	250	350	35^0	40^0	800
Semi-public (Factory, office, school, shop)	100	165	190	250	275	350	31^0	38^0	1000
Public (cinema, hall, theatre, hospitals)	100	150	180	280	300	350	27^0	33^0	1000 to 1200 (1200 for hospitals)

Design of a stair can be preceded in following steps:

1) Given the level difference between two floors (ceiling height +thickness of floor slab).
2) Assume the types of building, type of stair and accordingly the size of riser (R).
3) Find the number of riser (NR) = Level difference /Size of riser
4) Find the number of treads by NT = NR - 1
5) Assume the size of tread (T)
6) Assume the width of the stair
7) Consider the size of landing (L) equal to width of stair
8) Assume the entry space (E), generally equal to landing
9) Find the total length of stair = (NT * T) + L + E
10) Adjust the size of riser and tread if required

Exercises for staircase design:

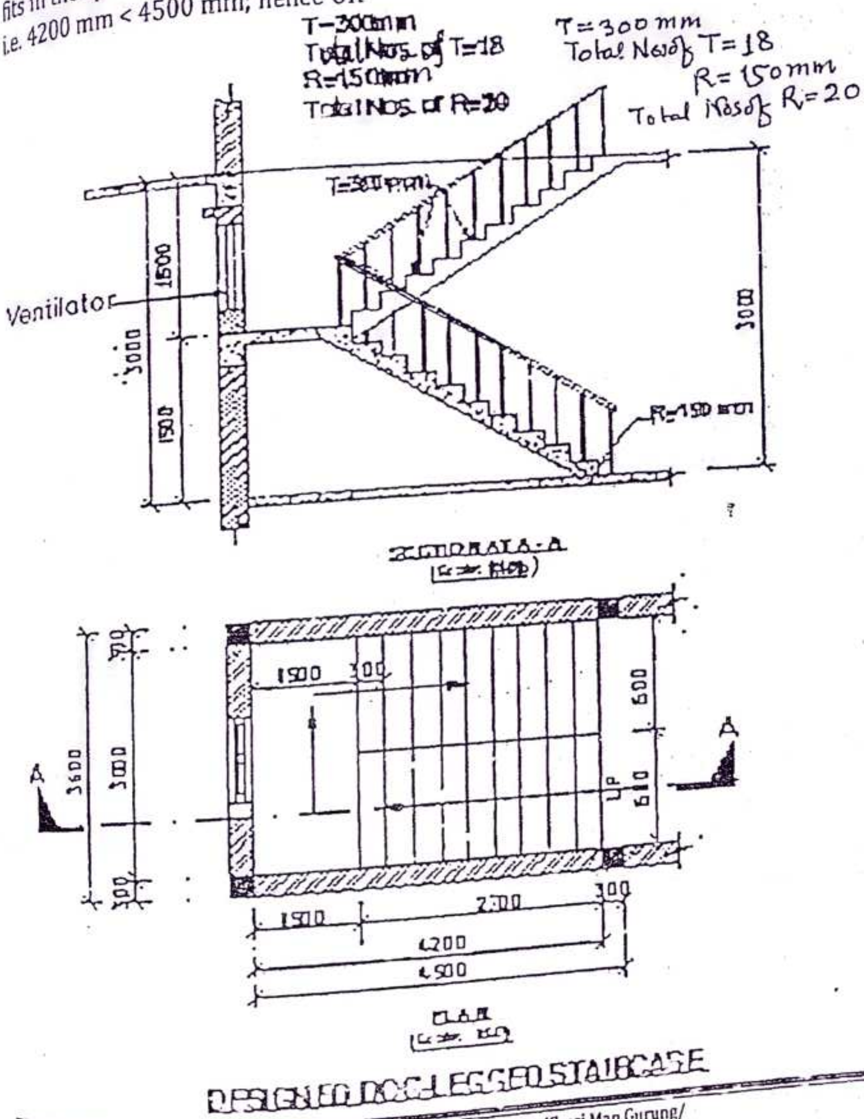
1) Design a dog-legged stair case for a residential building in a stair well of 4.5 m x 3.0 m and vertical span between two floors is 3.00 m. assume the necessary data. Draw a neat sketch to support your design.

Solution:

1) Floor height = 3.00 m = 3000 mm (given)
2) Assuming the height of riser (R) = 150 mm
3) Nos. of risers (NR) = Floor height or Level Difference/Size or Height of riser
   = 3000/150 = 20 Nos.

Nos. of flight in dog-legged stair = 2 nos.
Nos. of riser in a flights = total nos. of riser / 2 = 10 Nos.

4) Nos. of tread in a flight = Nos. of riser in a flight – 1 = 10 – 1 = 9 Nos.
5) Width of tread or size of tread (T) = 600 - 2R
   = 600 – 2 · 150 = 300 mm
6) Width of stair = Space given as in stair well or width of stair well / 2 = 3000/2 = 1500 mm
7) Width of landing = Width of stair = 1500 mm
8) Total length of stair = T * nos. of T in a flight + width of landing = 300 * 9 + 1500
   = 4200 mm, this easily fits in the space (4.50 m) since the total calculated length of stair is < length of stair well, i.e. 4200 mm < 4500 mm; hence OK



DESIGNED DOG-LEGGED STAIRCASE

Problem: Design a stair in Administration building having staircase size 5000 mm x 3520 mm with a floor height of 3.35 m. Draw plan and elevation as well.

Solution:

Step 1: Find first the height of each flight

Try first the dog legged type stair

Thus, the height of each flight = $\frac{\text{floor height}}{2} = \frac{3.35}{2} = 1.675$ m $= 167.50$ cm

Step 2: Find nos. of riser in each flight

Let's try tread (T) 30 cm & riser (R) = 15 cm,

Therefore, nos. of riser in each flight = $\frac{\text{Height of each flight}}{\text{Height of riser}} = \frac{167.50}{15} = 11.16$

Say nos. of riser in each flight = 11

Now, calculate the height of riser

Actual riser = $\frac{\text{Height of each flight}}{\text{Nos. of riser}} = \frac{167.50}{11} = 15.22$ cm

Step 3: Find nos. of treads

Nos. of treads = Nos. of riser – 1 = 11 – 1 = 10 nos.

Step 4: Find nos.

Assume the flight width and check whether the calculated size can be accommodated in the given staircase or not

Say width of flight = 150 cm

Check for width = Flight width x 2

= 150 x 2

= 300 cm < 352 cm, OK

Therefore, gap available in between the flight = 352 – 2 x 150

= 52 cm

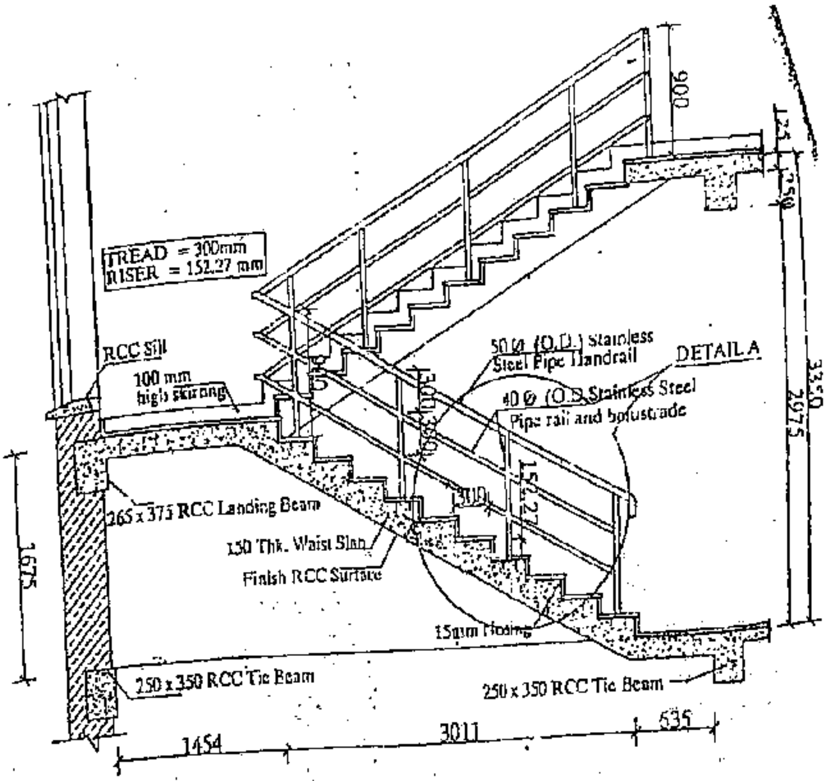
Check for length,

The total length of stair = landing width + nos. of tread x tread width

= 150 + 10 x 30 = 450 cm

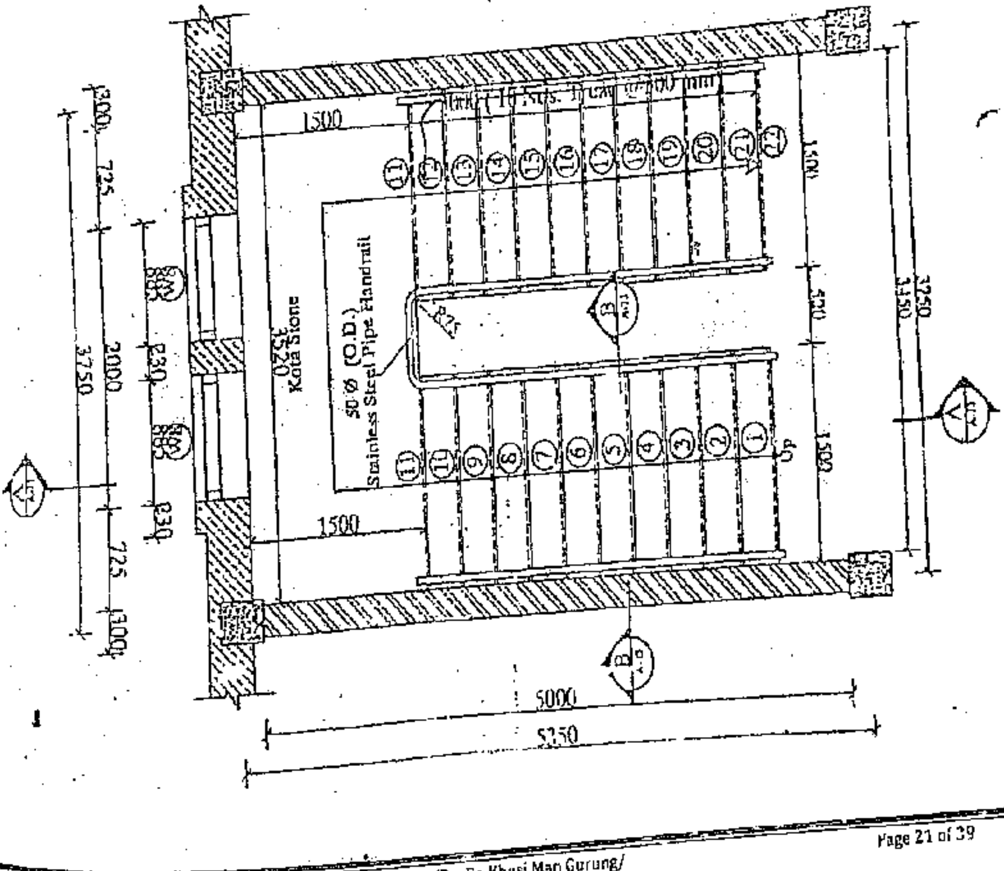
Therefore, space available for circulation in front of stair = 500 – 450 = 50 cm, OK

(See fig on the next page)



STAIRCASE SECTION A-A

Scale - 1:50



1.6 Types of roofs - shape, material

Introduction

A roof is the uppermost part of a building which is supported on structural members and covered with a roofing material. The main function of roof is to enclose the space of the building and to protect it from the damaging effects of the weather elements such as rain, wind, heat, snow etc. The structural element may be trusses, beams, slabs etc. The roofing materials or roof coverings may be A.C. sheets, tiles, slats, slab etc. Roof and roof coverings receive rain & snow more directly and in much greater quantity than walls. It must, therefore, provide a positive barrier to the entry of rain and rigorous (strong) weather proofing is most important. The structural component must have adequate strength and stability. A roof must have thermal insulation, fire resistance & sound insulation.

The functions of any roof are:

1. To keep out rain, wind, snow and dust.
2. To prevent excessive heat loss in winter
3. To keep the interior of the building cool in summer.
4. It is designed to accommodate all stresses encountered.
5. It is designed to accept movement due to changes in temperature and moisture content.
6. It is designed for strength and stability of building.
7. It is designed for durability and free from maintenance.
8. It is designed to provide resistance to the passage of sound.
9. It provides safety for occupants
10. It has aesthetic beauty

Requirements of a roof: To be a good roof, it should have the following properties (requirements)

1. **Adequate strength**

It should have adequate strength to carry the super imposed load (dead loads & live loads)

2. **Effective protection**

It should effectively protect the building against rain, sun, window etc and it should be durable against adverse effects of such agencies

3. **Water proof**

It should be water proof and should have efficient drainage arrangement.

4. **Thermal insulation**

It should have adequate thermal insulation.

5. **Fire resistance**

It should be fire resistant.

6. **Sound insulation**

It should provide insulation against external sounds.

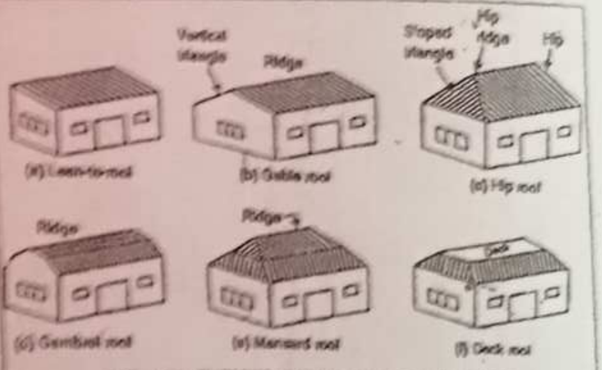


FIG. 15.1. VARIOUS FORMS OF SLOPING ROOFS

Types of roofs or classification of roof

Types of roofs may be as follows:

1. Pitched or sloped roof
2. Flat roof
3. Shelled roof
4. Domed roof

1. Pitched or sloped roof:

A roof with sloping surface is known as a pitched roof. Pitched roofs are considered suitable for buildings in coastal regions or in areas where rainfall and snowfall is very heavy. Normally the sloped roof has the slope from 1 in 3 to 1:1 or 1:1½. The pitch of the roof is determined by the types of coverings and the basic form of roof is governed by the load and span. Pitched roofs are basically of the following forms or shape:

a. Lean to roof
b. Gable roof
c. Hip roof
d. Gambrel roof
e. Mansard or curb roof
f. Derk roof

Materials used for pitched roofs may be Thatch, Wood singles, Slates, Tiles, G.I. and A.C. sheets etc.

2. *Flat roof or Terraced roof*

Flat roofs are considered suitable for buildings in plains or in hot regions where rainfall is scanty. These roofs are either horizontal or practically horizontal with slope less than 1 in 10. Even a flat roof has to have some slope at top so that rain water can be drained off easily and rapidly. Generally, reinforced cement concrete is used for flat roof construction.

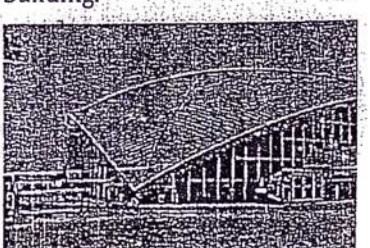
Advantages of flat roofs:

1. The roof can be used as terrace for playing, gathering, sleeping and for celebrating functions.
2. Construction and maintenance is easier.
3. They can be easily made fire proof in comparison to pitched roof.
4. They avoid the encluser of triangular space. Due to this, the architectural appearance of the building is very much improved.
5. Flat roofs have better insulating properties'
6. They require lesser area of roofing materials than pitched roof.
7. They are more stable against high winds.
8. They do not require false ceiling, which is essential in pitched roofs.
9. Flat roofs are proved to be overall economical
10. In multi-storeyed buildings, flat roof is the only choice, since overhead water tanks and other services are located on the terrace.

Disadvantages of flat roofs:

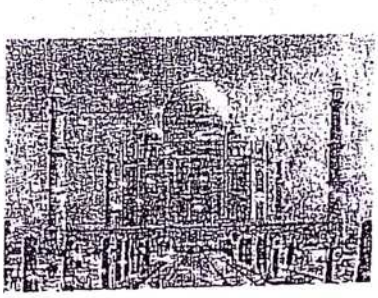
1. The span of flat roof is restricted, unless intermediate columns are introduced. Pitched roofs can be used over large spans without any intermediate columns.
2. The self-weight of flat roof is very high. Due to this, the sizes of beams, columns, foundations and other structural members are heavy.
3. It is very difficult to rectify leak in flat roof.
4. The speed of flat roof construction is much slower than the pitched roof.
5. The initial cost of flat roof is more than the pitched roof
6. They are unsuitable at places of heavy rainfall and snowfall especially highly unsuitable to hilly areas.
7. They are highly vulnerable to heavy temperature variations, especially in tropic, due to which cracks are developed on the surface. These cracks may lead to water penetration later, if not repaired in time.
8. The flat roof exposes the entire building to the weather agencies, while the projecting elements (such as eaves etc.) of pitched roof provide some protection to the building.

3. Shelled roof⟹



This is the type of roof that has thin section. It may be constructed in curved surface such as parabola, hyperbola, cylindrical shape or segment of curve. Shelled or Curved roofs have their top surface curved to give architectural effects.

4. Domed roof⟹

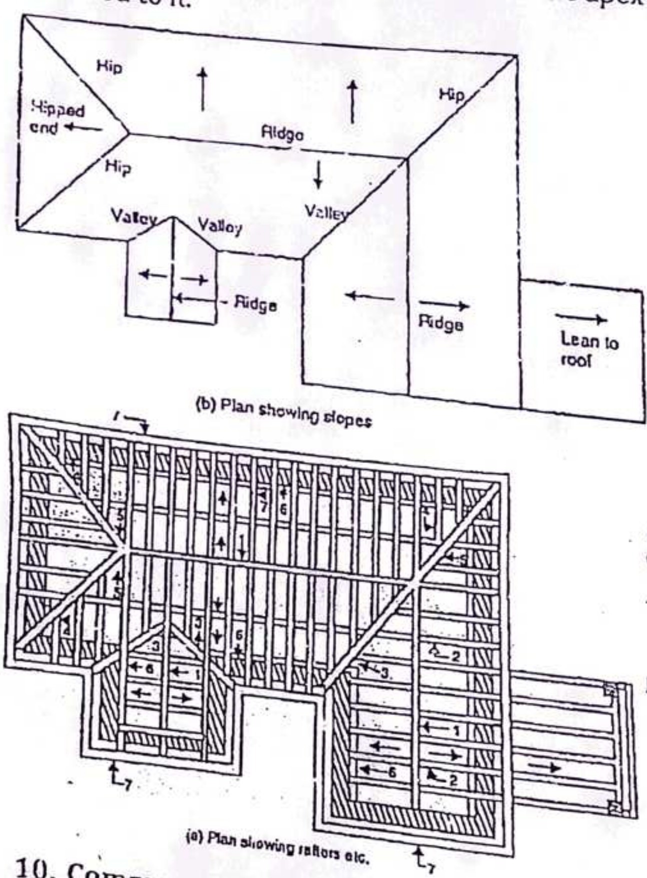


This is the curved roof having the roof area more than semicircle. Therefore dome has largest roof area compared to all types of roofs. This can be constructed by the use of R.C.C. or arch technology. Care must be taken in construction as it requires high skill.

The selection of the type of roof depends upon the shape or plan of the building. climatic conditions of the area and type of constructional materials.

Technical terms of roof:

1. **Span:** The clear distance between the supports of an arch, beam or roof truss.
2. **Rise of roof:** It is the vertical distance between the top of the ridge and the wall plate.
3. **Pitch:** It is the inclination of the side of a roof to the horizontal plane. It is expressed either in terms of degrees or (angle) or as a ratio of rise to span.
4. **Ridge:** It is defined as the apex line of the sloping roof. It is thus the apex of the angle formed by the termination of the inclined surfaces at the top of a slope.
5. **Hip:** It is the ridge formed by the intersection of two sloping surfaces. Where the exterior angle is greater than 180º.
6. Hip rafters: These are the slopping rafters which forms the hip of sloped roof. They run diagonally from ridge to the corners of the walls to support to support roof coverings. They receive the ends of the purlins ends of jack rafters.
7. **Valley:** It is a reverse of a hip. It is formed by the intersection of two roofs surfaces where making an essential angle less than 180º.
8. **Valley rafters:** These are the slopping rafters which run diagonally from the ridge to the eves for supporting valley gutters. They receive the ends of the purines and ends of jack rafters on both sides.
9. **Ridge piece, ridge beam or ridge board:** It is the horizontal wooden member, in the form of abeam or board, which is provided at the apex of a roof truss. It supports the common rafters fixed to it.



(b) Plan showing slopes

(a) Plan showing rafters etc.

1-Ridge
2-Common rafters
3-Valley rafters
4-Jack rafters
5-Hip rafters
6-Wall plate
7-Eaves board

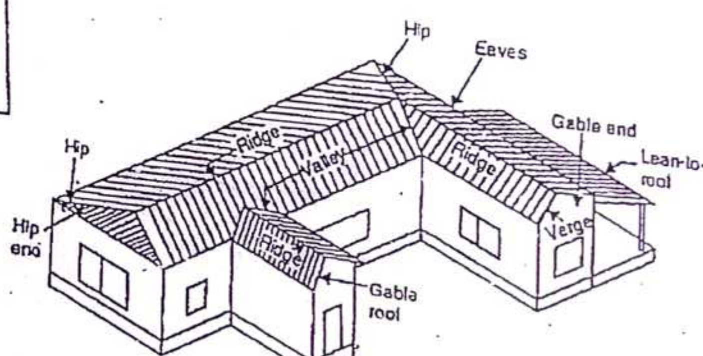


FIG. 15.2. VIEW OF A BUILDING WITH BASIC SLOPING ROOFS.

10. **Common rafters or spars:** These are inclined wooden members running from the ridge to the eaves. They are bevelled against the ridge beam at the head and are fixed to purlins at intermediate points. They support the battens or boarding to support the roof coverings. Depending upon the roof coverings the rafters are spaced from 30 cm to 45 cm centre to centre.
11. **Jack rafter:** These are the rafters shorter in length which run from heap or valley to the eaves.
12. **Battens:** These are the wooden members fixed on rafter to provide support to the roof coverings: slates, tiles etc.

13. Boarding: They act similar to battens and are nailed to common rafter i.e. support the roofing materials above.
14. Cleats: These are small pieces of wood fixed on rafter to prevent purlin to slide down.
15. Wall plates: These are long wooden members, which are provided on the top of the stone or brick wall, for the purpose of fixing the feet of the common rafters. These are embedded from sides and bottom in masonry of the wall, almost at the centres of their thickness. Wall plate actually connects the wall to the roof.
16. Post plate: This is similar to a wall plate except that they run continuous, parallel to the face of wall, over the top of the posts, and supports rafters at their feet
17. Template: It is the bedding block provided at the end of truss.
18. Dragon ties: It is the tie placed across the corners and over the wall plates and helps to provide resistance to the truss of a hip rafter.
19. Ceiling joist: It is the wooden member that functions as tie to the feed of the rafters and provides support to the ceiling boards on the undersides and any cistern housed within the roof void.
20. Purlins: These are horizontal wooden or steel members, used to support common rafters of a roof when the span is large. Purlins are supported on trusses or walls.
21. Struts: These are the compressive members that transfer load of purlin to a suitable load bearing support within the span of roof.
22. Eaves: The lower edge of the inclined roof surface is called eaves. From the lower edge (eaves), the rain water from the roof surface drops down.
23. Eaves board or facia board: It is a wooden plank or board fixed to the feet of the common rafters at the eaves. It is usually 25 mm thick and 25 mm wide. The end of lower most roof covering material rest upon it. The eaves gutter, if any, can also be secured against it.
24. Verge: It is the edge of roof coverings, slates, CGI sheets or tiles on the roof.
25. Truss: A roof which is a frame work, usually of triangles, designed to support the roof coverings or ceiling over rooms.

3.7 Single and double timber roof: their types, comparative advantages and some construction details

A roof with sloping surface is known as a pitched roof. Pitched roofs are basically of the following forms

(a) Single roof
- i. Lean to roof or veranda roof
- ii. Couple roof
- iii. Couple-close roof
- iv. Collar beam roof or collar tie roof

(b) **Double or purlin roof**

(a) Single roof:

Single consists of only rafters which are supported at the ridge and at the eaves (above the wall) to support roofing materials. Such roofs are used only when the span is limited to 5.00 meters, otherwise the size of the rafters will be uneconomical. Single roofs are of four types:

- i. Lean to roof or verandah roof
- ii. Couple roof
- iii. Couple-close roof
- iv. Collar beam roof or collar tie roof

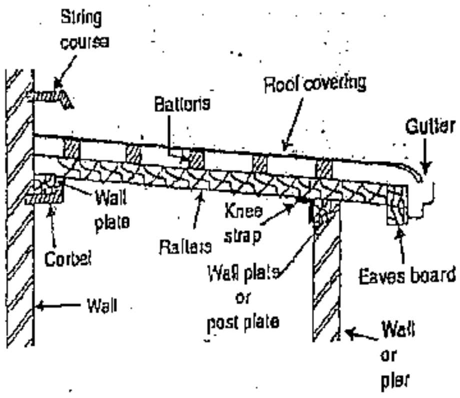
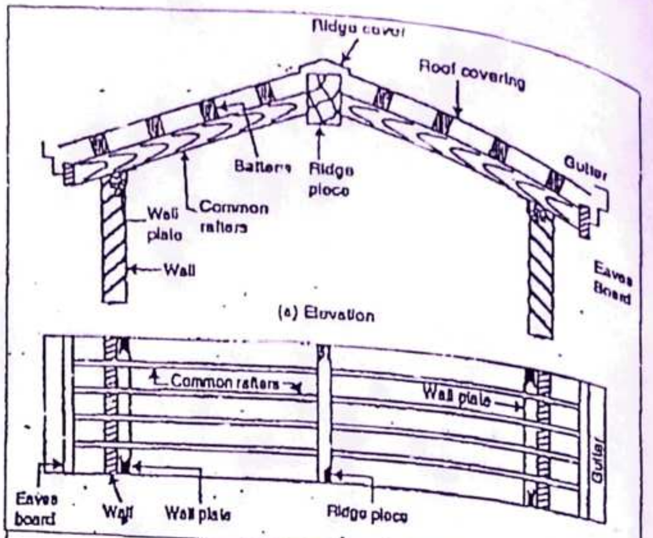


FIG. 15.4. LEAN-TO-ROOF

(i) *Lean to roof*

This is the simplest type of sloping roof in which rafters slope to one side only. The wall to one side of room is made higher than other side in order to make it slope to one side. A wooden wall plate is supported by corbel (steel or stone), which are provided 1cm c/c. Over the wall plate across the two cross wall, a wooden member known as rafter is fixed which has slope ± 30°. The rafter is nailed at wooden wall plate at their upper end and the lower end is notched & nailed to the wall plate. Sometimes, iron knee straps & bolts are used to connect the rafter to the post plate. Eaves board, batten, roof coverings are fixed as shown in fig above. The maximum span of such type of roof is **2.50m** & is useful for **sheds,** out houses attached to main building, verandah etc.



(ii) Couple roof⟹
This type of roof is formed by couple or pair of rafters which slope to both the sides of the ridge of the roof. The upper ends of each pair of rafter is nailed to common ridge piece or ridge beam and their lower ends are notched & nailed to the wooden wall plates embedded in the masonry on the top of the outer wall. Such type of roof can be used up to span of **3.60m.**

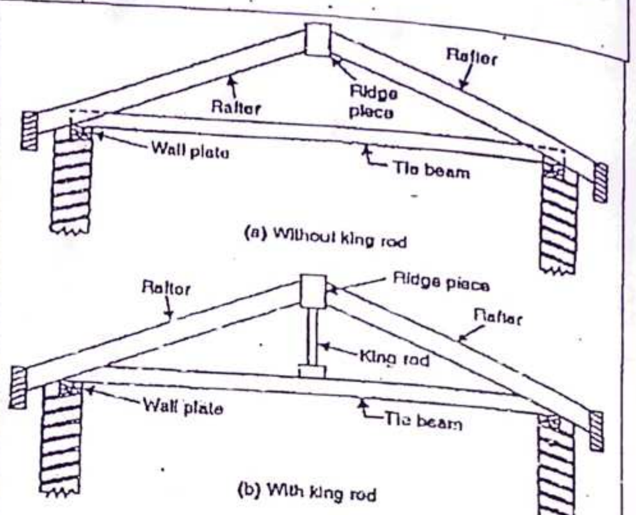


FIG. 15.6. CLOSE COUPLE ROOF.

(iii) Couple close roof⟹
When the common rafter or simply the rafter is joined at the top of wall plate by a tie beam as shown in fig, then a couple roofs becomes couple close roof. Due to this such type of roof can be used to a greater span than the previous one i.e. up to **4.20m.** King post may or may not be used. The use of tie beam reduces the tendency of roof from spreading out.

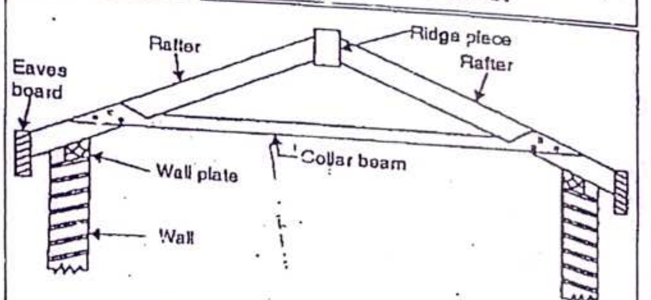


FIG. 15.7. COLLAR BEAM ROOF.

(iv) Collar beam roof or collar tie roof⟹
When the span goes on increasing, the use of couple close roof becomes ineffective because of bending of tie beam. Hence the position of tie beam is lifted towards the ridge beam i.e. one third to one half of the vertical height from wall plate to the ridge. Thus, the beam provided is called as collar beam when there is use of collar beam in a roof, and then it is collar beam roof. This roof is suitable for spans up to **5.0m.**

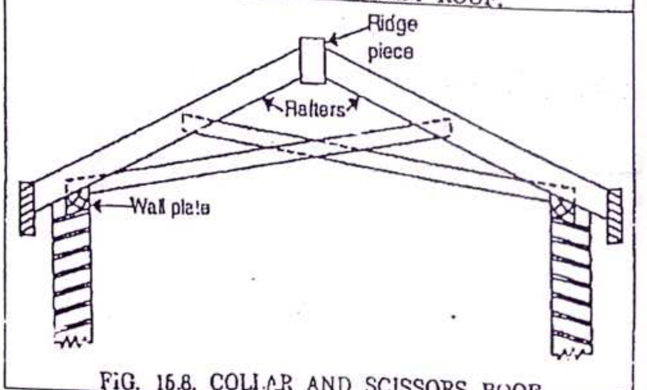


FIG. 15.8. COLLAR AND SCISSORS ROOF

(v) Collar & scissors roof⟹
It is similar to the collar beam roof; except that two collar beams crossing each other to have an appearance of scissors is provided. This roof is suitable for spans up to 5.0m.

(b) Double roof or purlin roof

Double or purlin roof consists of rafter and purlin, in which purlin give intermediate support to the rafter and are supported on the walls. The use of purlin reduces the size of rafter. Such type of roof can also be called as rafter & purlin roof which is suitable for *spans up to 5.0m*. The rafter is generally provided (40 to 60cm c/c. Each rafter is supported at three points viz.

i) at the bottom, on the wall through wall plate

ii) at the top, by the ridge beam

iii) at center by purlin for larger roofs, two or more purlins may be provided to support each rafter.

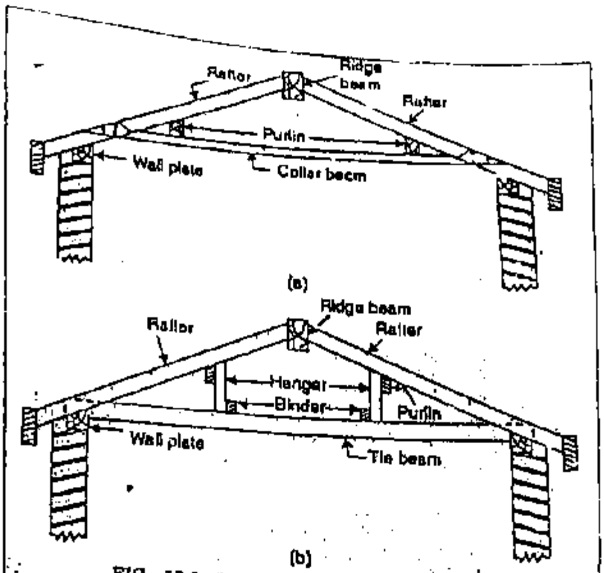


FIG. 15.9. RAFTER AND PURLIN ROOF.

3.8 Roof trusses

Roof truss is used when the span exceeds 5m and where there are no inside walls to support purlin. Center to center span is generally limited to 3m for wooden trusses. In this system roof consists of three elements:

(a) Rafter (to support the roofing materials)

(b) Purlin (to give intermediate support to the rafter)

(c) Trusses (to support the ends of purlin).

Roof constructed with such arrangement is also known as *Triple membered* or *framed roof or trussed roof*. The trusses span in the same direction in which the couple of rafter run.

There are various types of roof trusses in common use which are:

a) King post truss
b) Queen post truss
c) Combination of King post and Queen post truss
d) Mansard truss
e) Truncated truss
f) Belfast truss
g) Composite truss
h) Steel truss

a) King post truss

A king post truss consists of following components:

a) Lower tie beam
b) Two inclined principle rafter
c) Two struts
d) King post

- Spacing of king post is limited to 3 m c/c
- Truss is suitable for span varying 5 to 8 m
- Lower horizontal tie beam receives the ends of the principle rafters and prevents the wall from spreading out to thrust
- The struts connected to the tie beam and the principle rafters in the inclined direction prevents the sagging of principle rafter
- Ridge beam is provided at the apex of the roof to provide end support to the common rafter
- The trusses are supported in wall plates

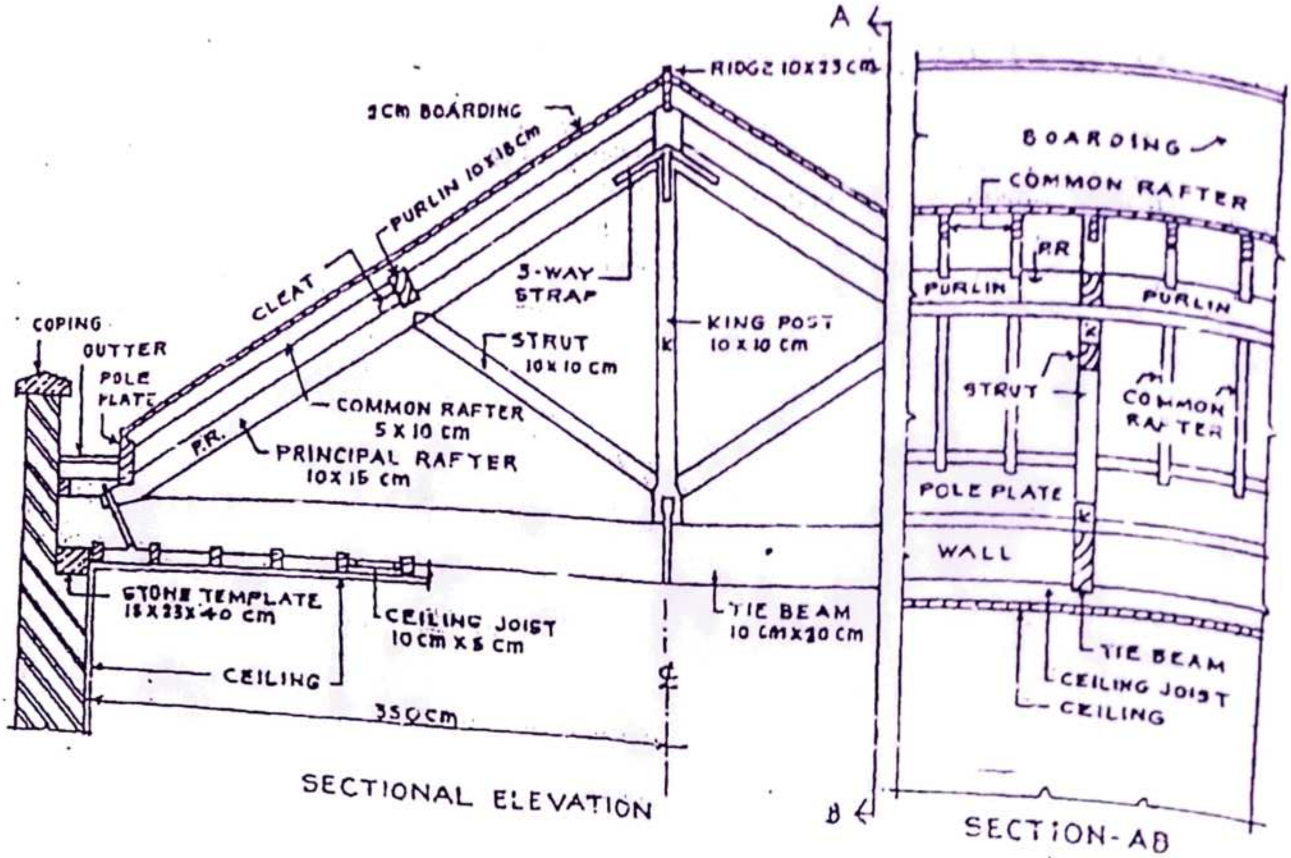


Fig: King post truss

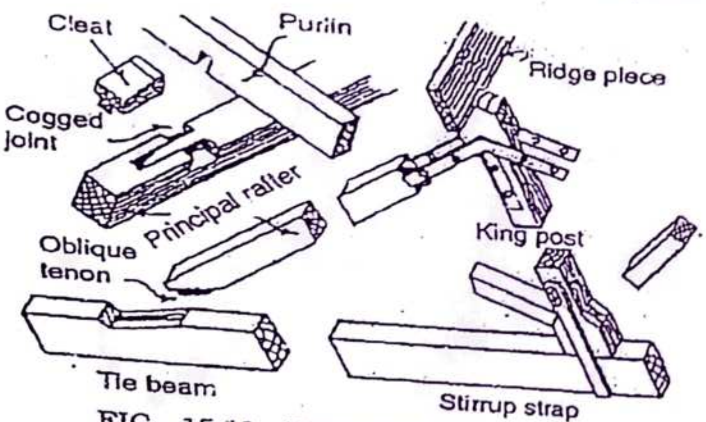


FIG. 15.11. DETAILS OF JOINTS IN KING-POST TRUSS.

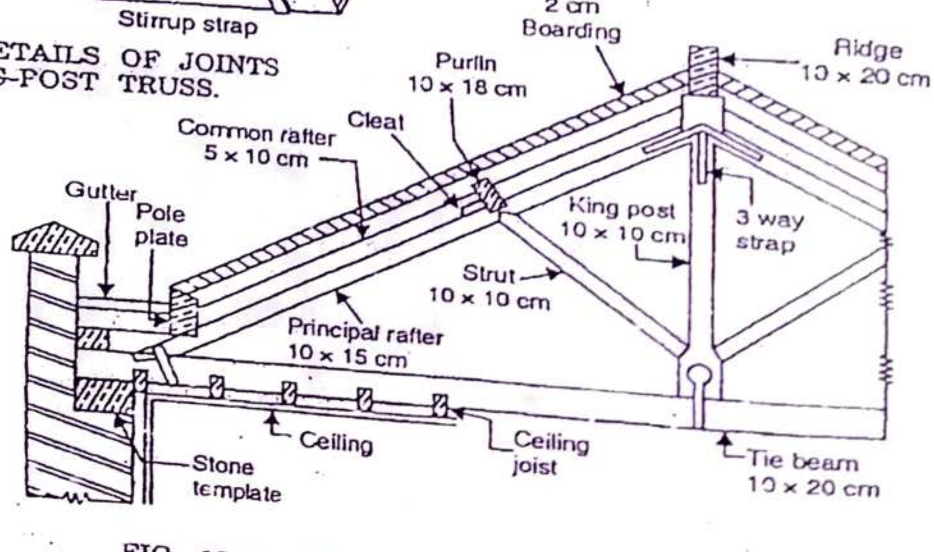
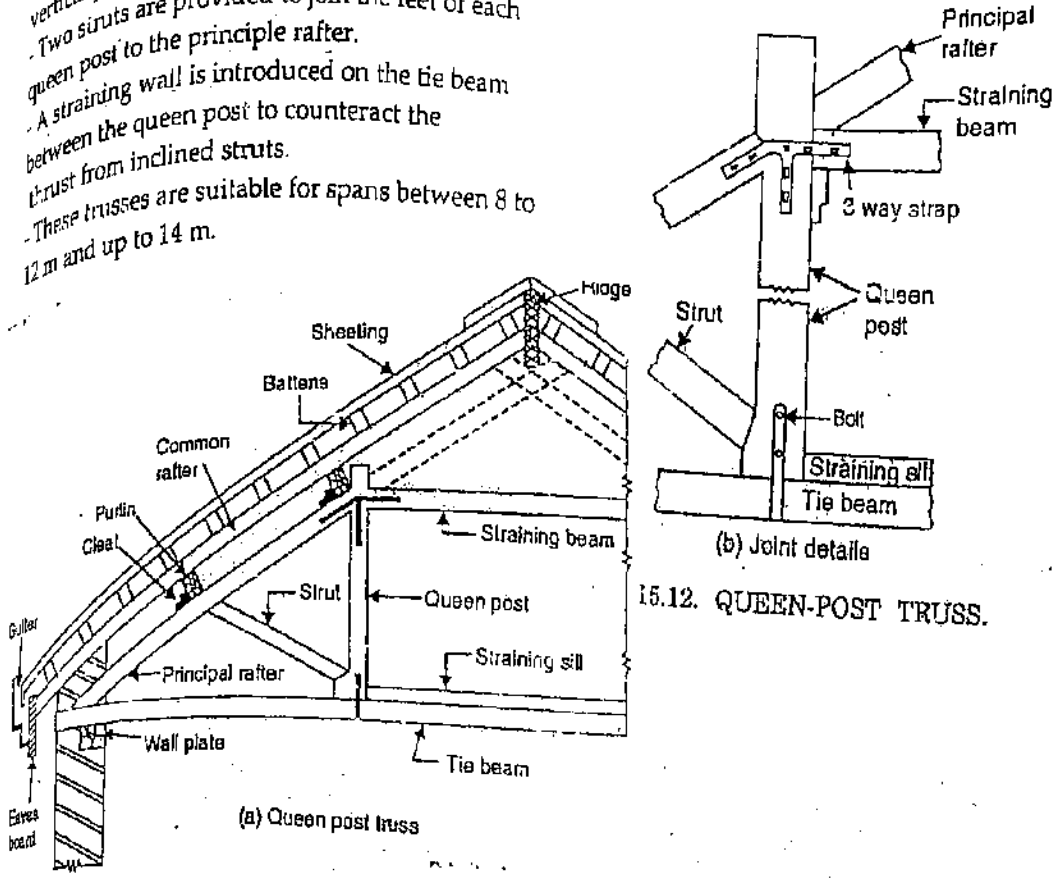


FIG. 15.10. KING-POST TRUSS (SPAN 7 m.)

b) Queen post truss

- A queen post truss differs from kingpost truss in having two vertical posts rather than one. The vertical posts are known as queen post.
- Two struts are provided to join the feet of each queen post to the principle rafter.
- A straining wall is introduced on the tie beam between the queen post to counteract the thrust from inclined struts.
- These trusses are suitable for spans between 8 to 12 m and up to 14 m.



15.12. QUEEN-POST TRUSS.

c) Combination of King-post and Queen-post trusses:

For greater spans the queen-post truss can be strengthened one or more upright member called princess-post to each side. Figures shown below in fig.(a) and (b) shows resulting combination of King-post and queen-post trusses, which are suitable up to 18.00 m span.

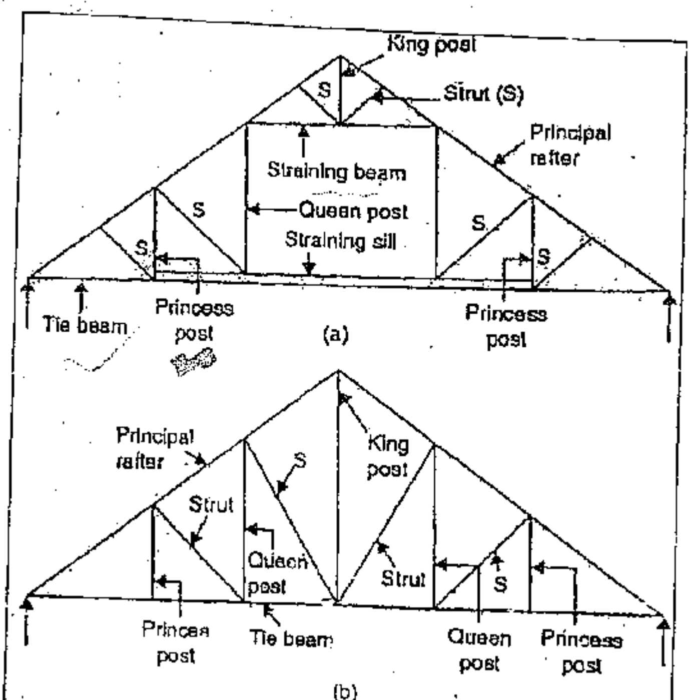


FIG. 15.13. COMBINATION OF KING-POST AND QUEEN-POST TRUSSES.

d) Mansard truss

This post is combination of King-post and Queen-post trusses designed by Francois Mansard, a French architect. It is a two storey truss, with upper portion consisting of King-post truss and the lower portion of queen-post truss. It has become obsolete because of its odd shape.

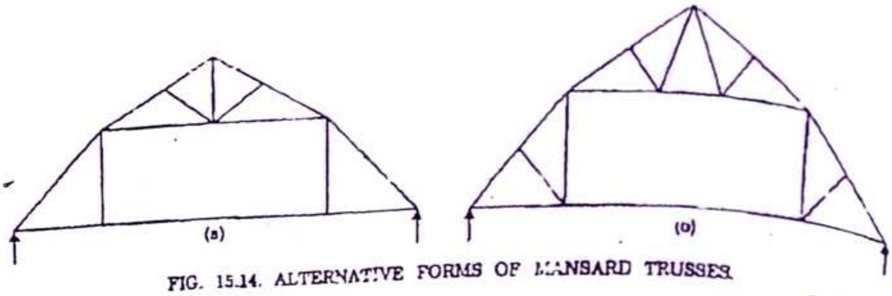


FIG. 15.14. ALTERNATIVE FORMS OF MANSARD TRUSSES

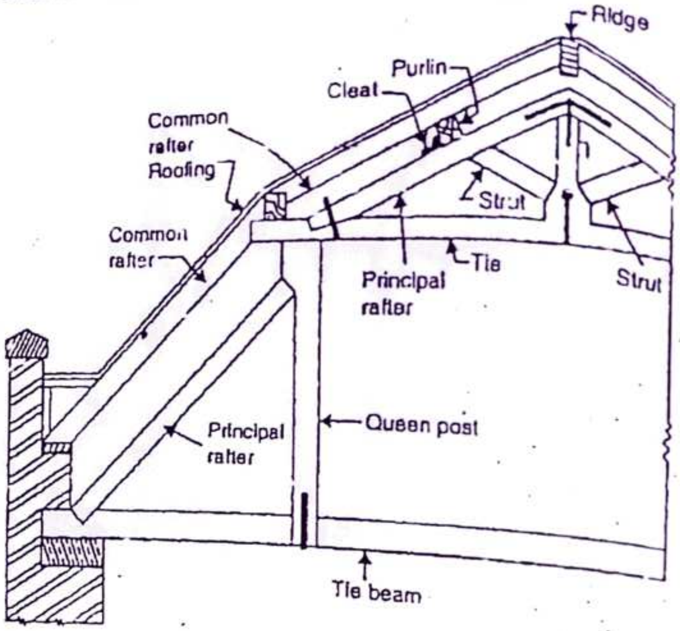


FIG. 15.15. DETAILS OF MANSARD TRUSS.

e) Truncated truss

A truncated truss is similar to Mansard truss, except that its top is formed flat with a gentle slope

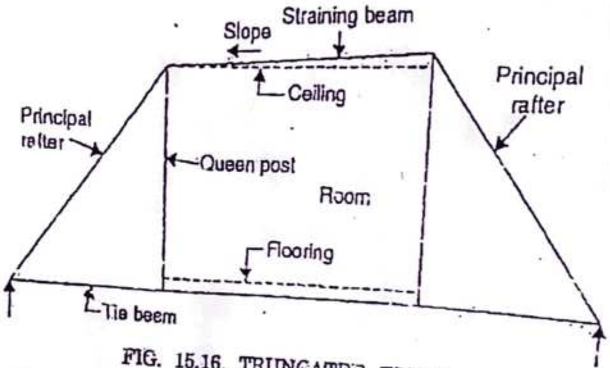


FIG. 15.16. TRUNCATED TRUSS.

f) Belfast truss or bow-string truss⟹

This truss, in the form of bow, consists of thin section of timber with its top chord curved. If the roof covering is light, this roof truss can be used up to 30.00 m span. The roof truss is also known as latticed roof truss

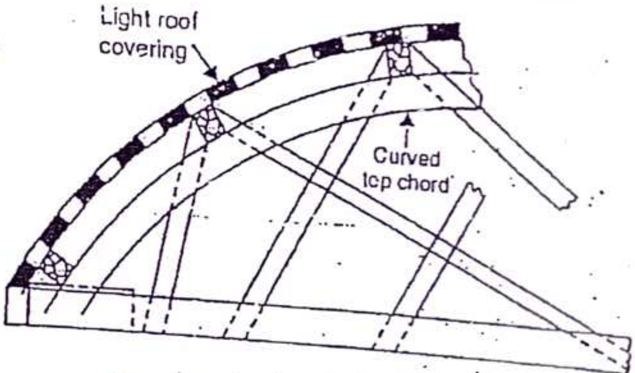
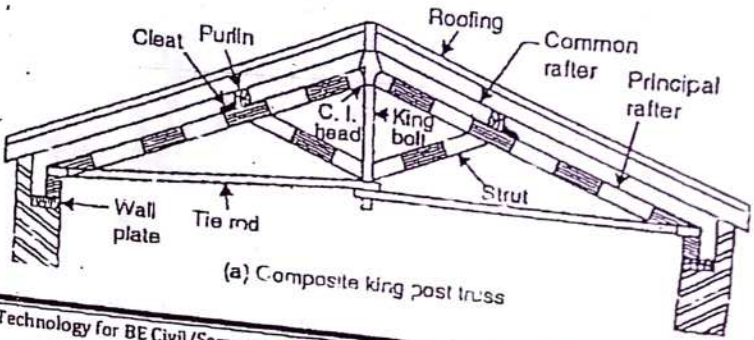


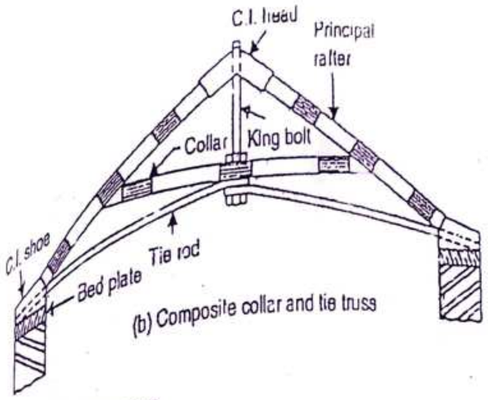
FIG. 15.17. BEL-FAST TRUSS.

g) Composite trusses

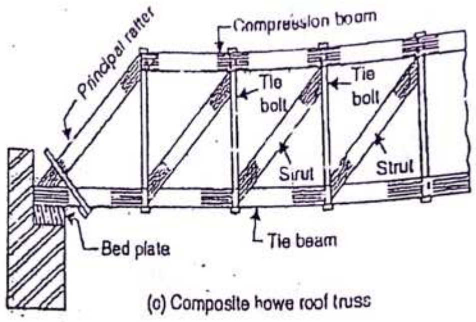
Roof truss made of two materials such as timber and steel, are known as composite roof trusses. The tension members are made of steel and compressive members are made of timber. Special fittings are required to at the junction of steel and timber members. The following figures show some common types of composite roof trusses, using fittings such as C.I head, C.I. shoe, steel angle bolts and straps etc.



(a) Composite king post truss



(b) Composite collar and tie truss



(c) Composite howe roof truss

h) Steel trusses

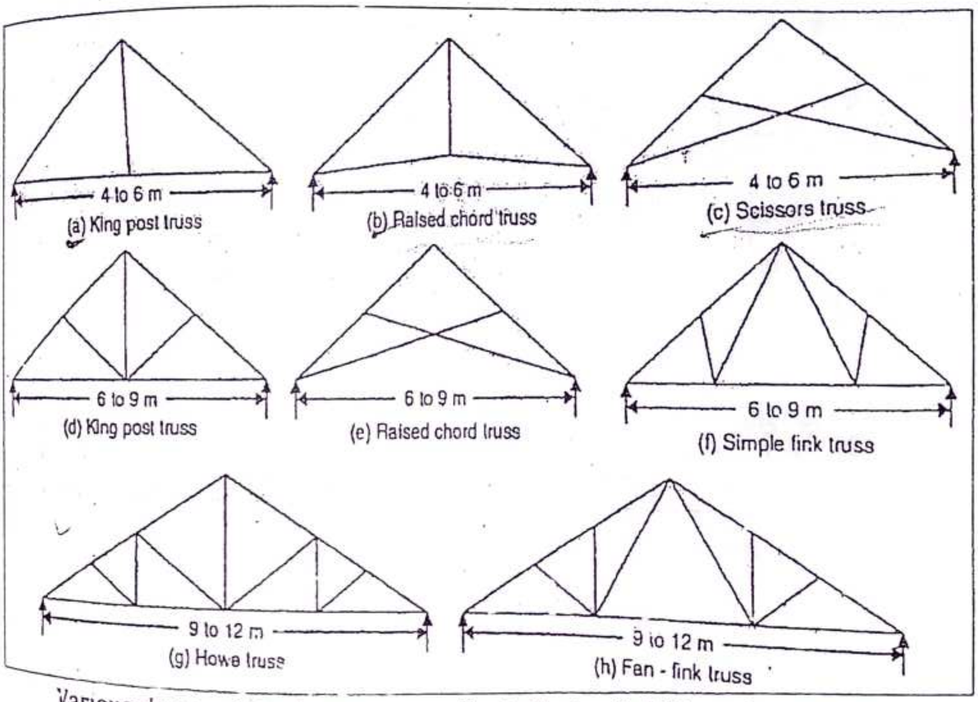
Steel trusses are more commonly used for used for all spans - small or large, since they are:

1. Economical
2. Easy to construct or fabricate
3. Fire-proof
4. More rigid
5. Permanent
6. Antifungal and termite proof

Steel trusses are fabricated from rolled steel structural members such as channels, angles, T-sections and plates. Most of the roof trusses are fabricated from angle-sections because they can resist effectively both tension and as well as compression and their joint is easy to construct.

Steel trusses may be categorised as follows:

i. Open trusses
ii. North light trusses
iii. Bow string trusses
iv. Arched rib trusses
v. Solid arched trusses



Various shapes of steel trusses according to their suitability and span ranges

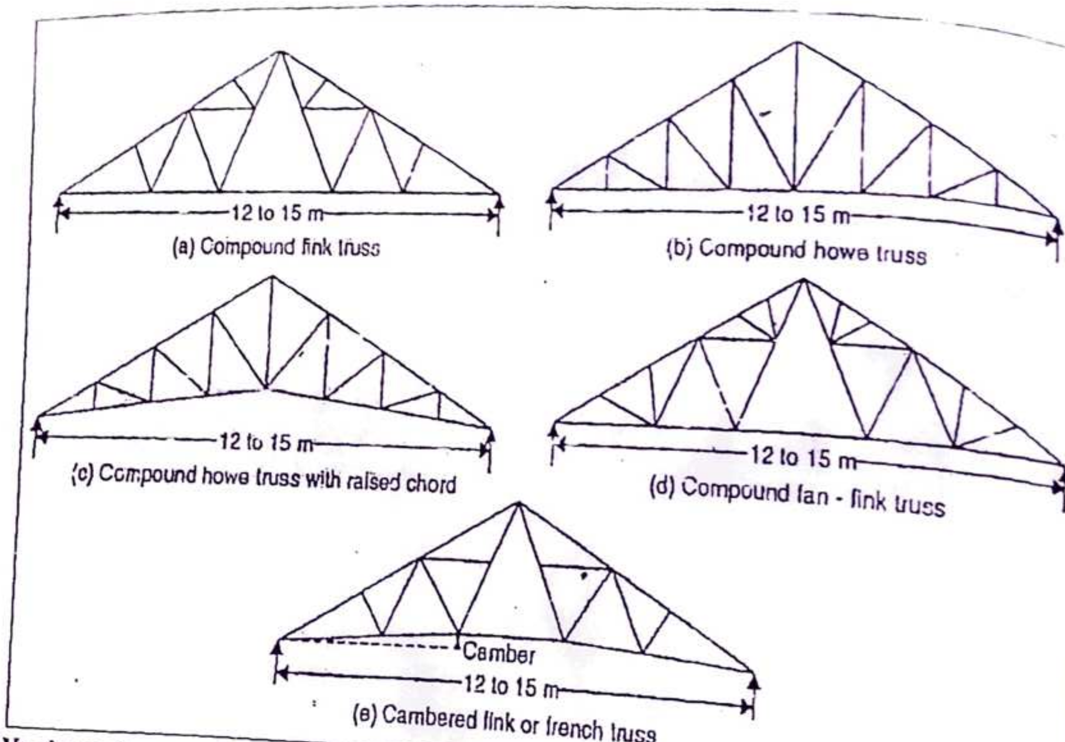


Fig.-(a) Various shapes of steel trusses according to their suitability and span ranges

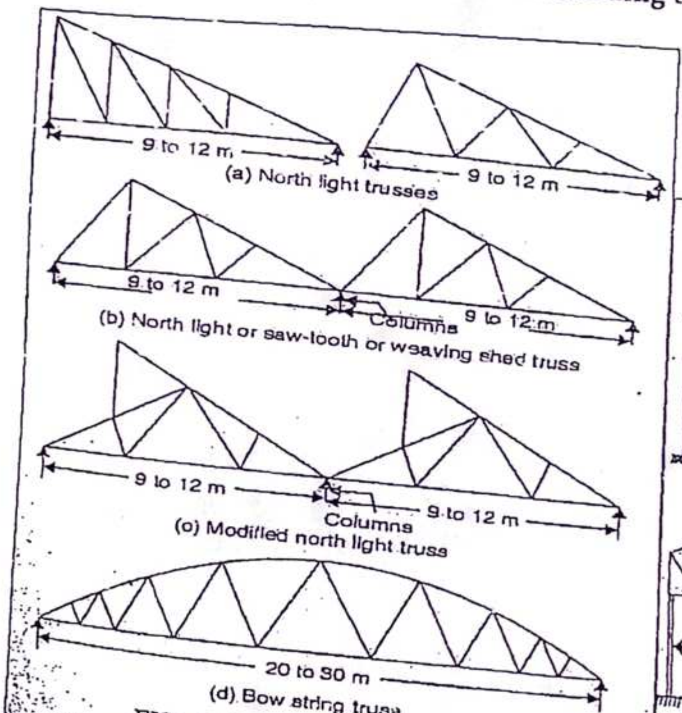


FIG. 15.21. STEEL TRUSSES.

Fig.-(b) various shapes of steel trusses according to their suitability and span ranges

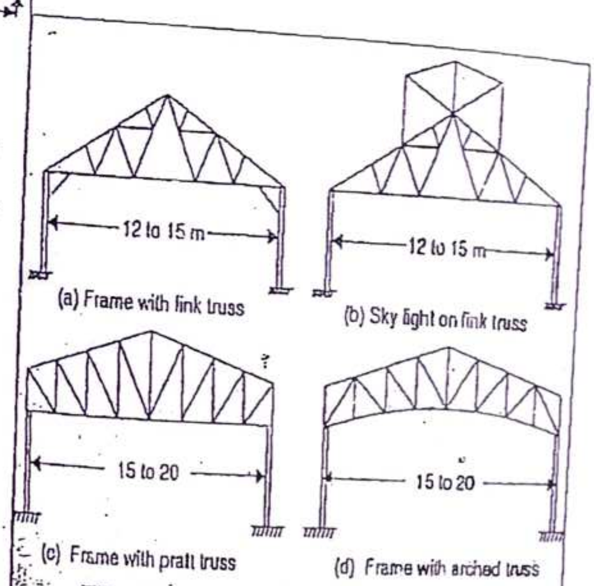


FIG. 15.22. INDUSTRIAL BUILDING BENTS.

Fig.-(c) various shapes of industrial steel bents according to their suitability and span

Industrial Building bents: These building bents, employed in big factories or mills, consist of a roof truss supported on steel stanchions. The asbestos corrugated and trafford cement sheets are commonly used as the roof covering materials. These bents are transversely braced as shown in fig. (c) above on right side

Details of steel roof trusses:

Steel roof trusses are commonly fabricated from angle sections and plates, though channel sections and T-sections can also be used. The roof truss is so designed that the member carry only direct stresses (i.e. either tension or compression) and no bending stresses are induced. The members are jointed together using a gusset plate, either through rivets or by welding. When rivets are used, them pitch is limited to 15 cm for compression member and 20 cm for tension members. Generally 15 mm diameter rivets are used for small spans and 20 mm rivets are used for large spans and at least two rivets should be used at each joint. Gusset plate should not be less than 6 mm thick. At the foot of the truss, short angles are fitted on both the sides of the gusset plate, which are connected to the bearing plate. The bearing plate is jointed to concrete bed through rag bolts. At the apex suitable ridge section is fitted.

Steel trusses have the following advantages over timber trusses:

1. The sections comprising the steel truss are readily available in required dimensions, resulting minimum wastage of materials.
2. Steel trusses are light in weight and can be fabricated in any shape depending upon any structural and architectural requirements.
3. Steel trusses are stronger and more rigid in comparison to timber trusses.
4. Steel trusses can be used over any span, while timber trusses are suitable only up to 15.00 m span.
5. Steel trusses are fire proof and termite proof.
6. Steel trusses are most resistance to other environmental agencies and have longer life.
7. The fabrication of steel trusses is easier and quicker than timber trusses since the sections can be machined and shaped in the workshop, and then transported to the construction site for erection.

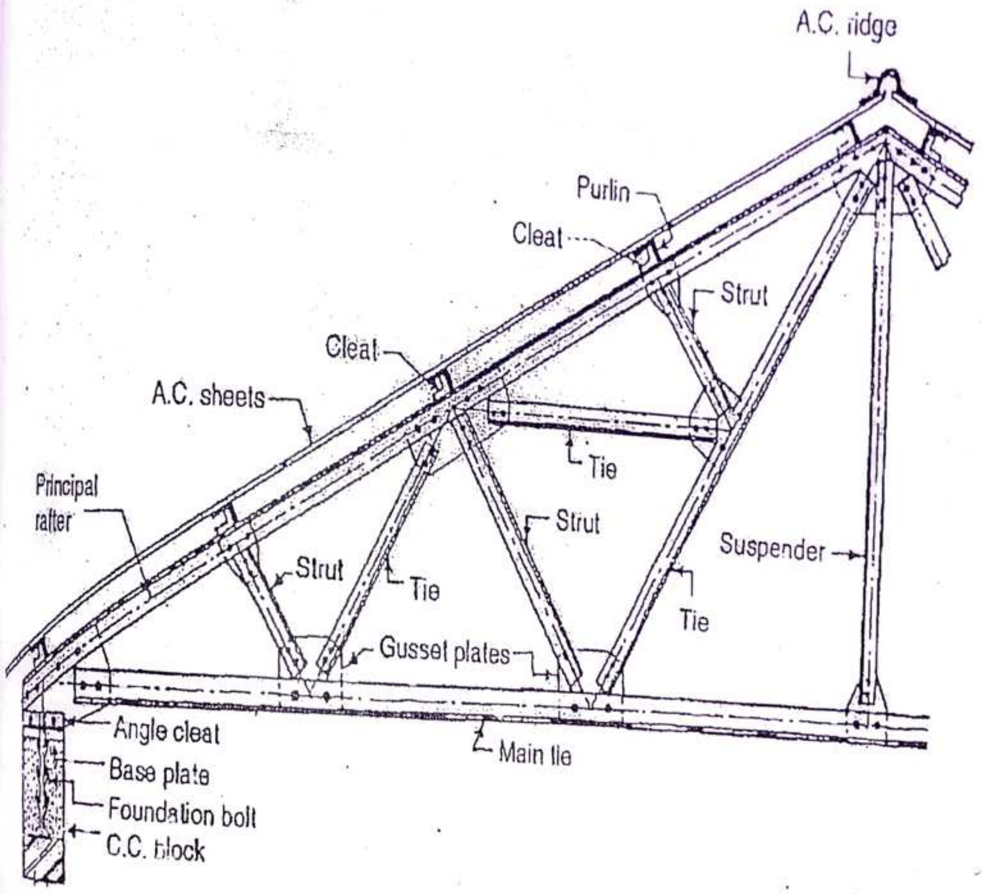


FIG. 15.23. DETAILS OF STEEL ROOF TRUSS

Details of steel roof trusses:

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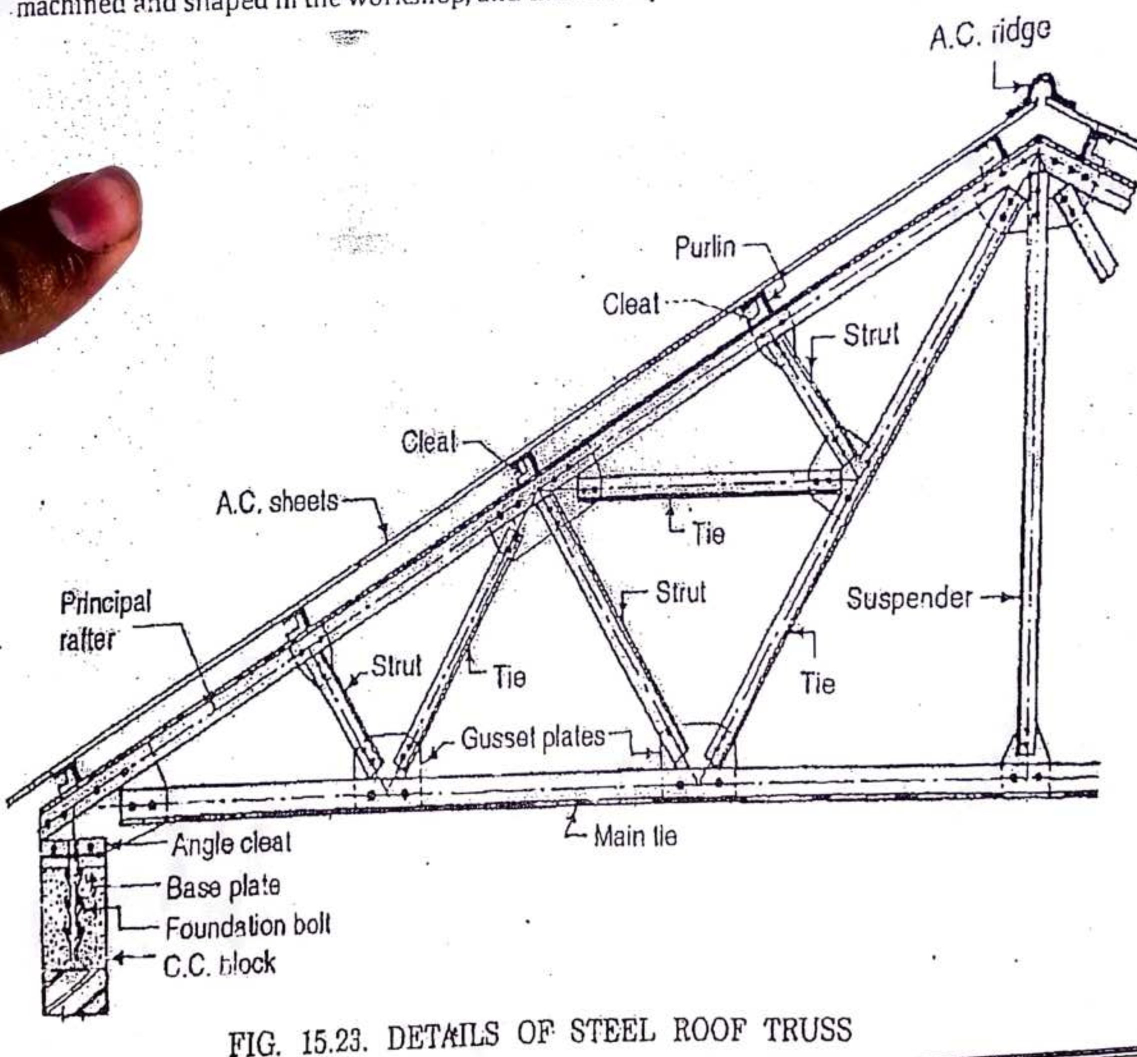
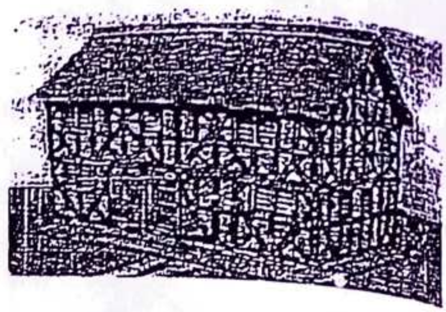


FIG. 15.23. DETAILS OF STEEL ROOF TRUSS

3.9 Roof coverings

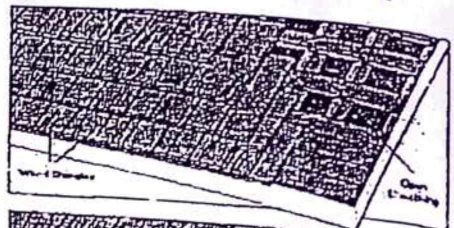
Roof covering is an essential component of pitched roof, to place over the roof framework, to protect it from rain, sun, wind, and other atmospheric agencies. Selection of roofing materials depends upon type of building, type of roof framework, initial cost, maintenance requirements, fabrication facilities, appearance and special features of locality, durability, availability of the material itself and climatic condition. The following are the roof covering materials commonly used for pitched roofs:

1. Thatch covering : slope 40°, thickness 10 – 15 cm, batten distance @ 30 cm c/c
2. Wood shingles
3. Tile roofing
4. CGI-sheet: slope > 25°, lap -15 on edge and 1½ corrugated at side
5. Asbestos Cement sheet (AC – sheet): 2-3 m in length
6. Slates: Overlapped by 50-75 %
7. Light weight roofing



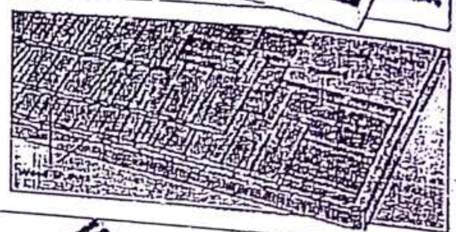
1. Thatch: ⇒

Thatch is the cheapest roof covering of organic material available in nature. This vegetation may be of different type. Sometimes, the rice and wheat straw are also used in thatch roofing, but thatch is a special grass available in wild land. The thatch is simply tied tightly in a bunch in to the battens (in closely distanced about 30 cm) layers. The thickness may be from 10 cm to 15 cm. This type of roof is used largely in rural areas. The slope of this roof is normally more than 40°. The thatch is combustible, absorbs moisture and is liable to rot or decay. It is claimed that the stem thatch can last about 60 years and straw thatch can last for 20 years if properly go to.



2. Wood Singles: ⇒

Singles are thin slabs of wood used to cover roofs. The use of singles is restricted to hilly areas where local timber is easily available at low cost. They are obtained from well-seasoned timber, by either sawing or splitting in sizes varying from in length 30 to 40cm and width from 6 to 25cm with thickness of 10mm approximately. They are laid as in a similar fashion as tiles and slates.



3. Tile roofing:

Tiles are manufactured from clay or concrete to a wide range of design and colours suitable for the pitches from 20° to 45° and work upon the principle of either double or simple lap. The pitch of tile is always less than pith of rafter. Tiles are manufactured somewhat similar manner as bricks. The standard size of plain tile is 265mm x 165 mm and thickness of minimum 10 mm. Tiles are somewhat raised to drain out the rain water. This raised part is called camber. It prevents the rainwater being drawn up between the tiles by capillary action as it would be if the tiles were absolutely flat. The tiles while fixing on the roof have to be overlapped and hung in to battens in a definite interval.

The overlapping is called LAP and the interval is called the GAUGE.

Gauge = (length of tile – Lap)/2

Example: For 265mm length and lap of 65mm,

Gauge, G = (265 - 65)/2 = 100mm

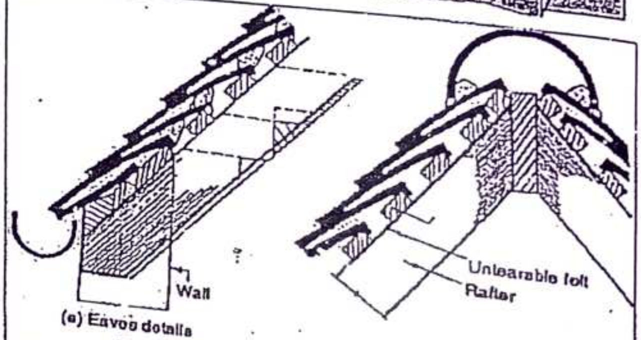
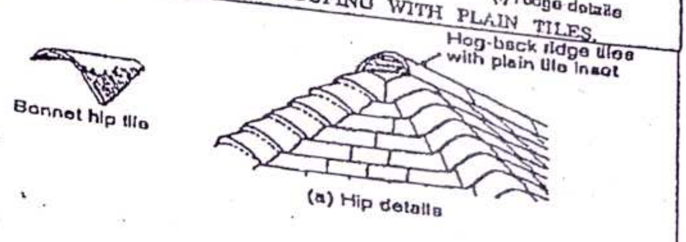
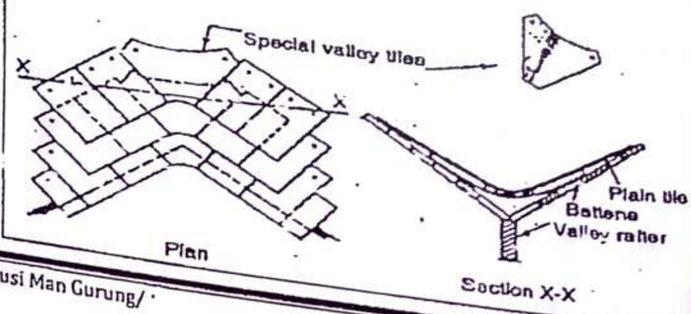
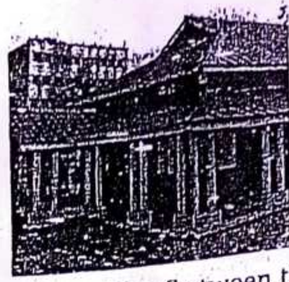


FIG. 15.24. ROOFING WITH PLAIN TILES.



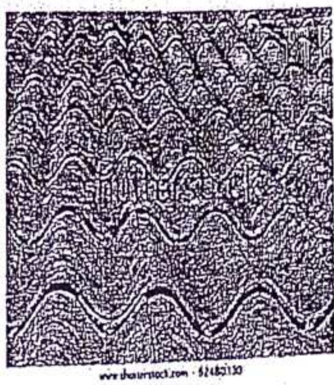


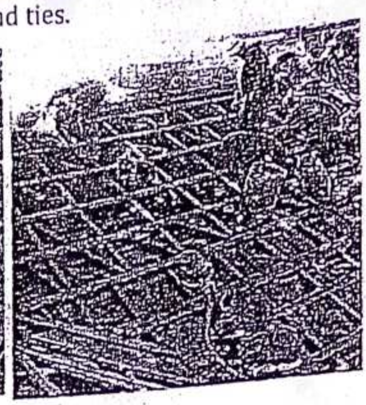
4. Galvanised iron corrugated sheets (CGI Sheets):⇒



CGI sheets are very much popular these days in referent region of Nepal. It is relatively cheap as well. CGI sheet is very easy to fix on the roof. The rafter is fixed to wall plate and to the ridge and purlin is laid on rafter. The holes are either drilled or punched in the sheet crown and the CGI sheets are fixed with curved washers then nailed or bolted by means of GI hook bolts to purlins. Eaves board is nailed to the ends of rafter. The slope of the roof for CGI sheets should be more than 25° and end lapping (on edge) should not be less than 15 cm and 1½ corrugation at side (between the sheets). The sheets should be fixed to eaves by means of flat iron wind ties.

5. Asbestos cement sheets (AC sheets):⇒





AC sheets are produced by the mixture of cement, asbestos fibres and water. This asbestos cement sheet is cheap, light, impervious, durable and fire resistant. These sheets are available in 2 to 3 meters in length. It has the same procedure as CGI sheet to fix on the roof.

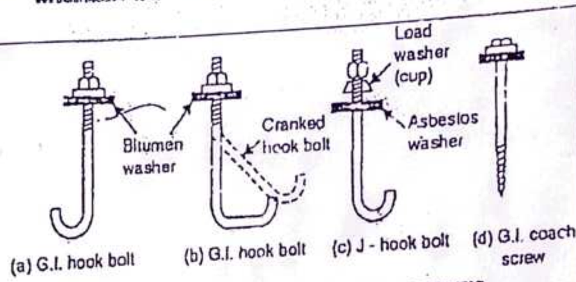


FIG. 15.31. FIXING BOLTS AND SCREWS.

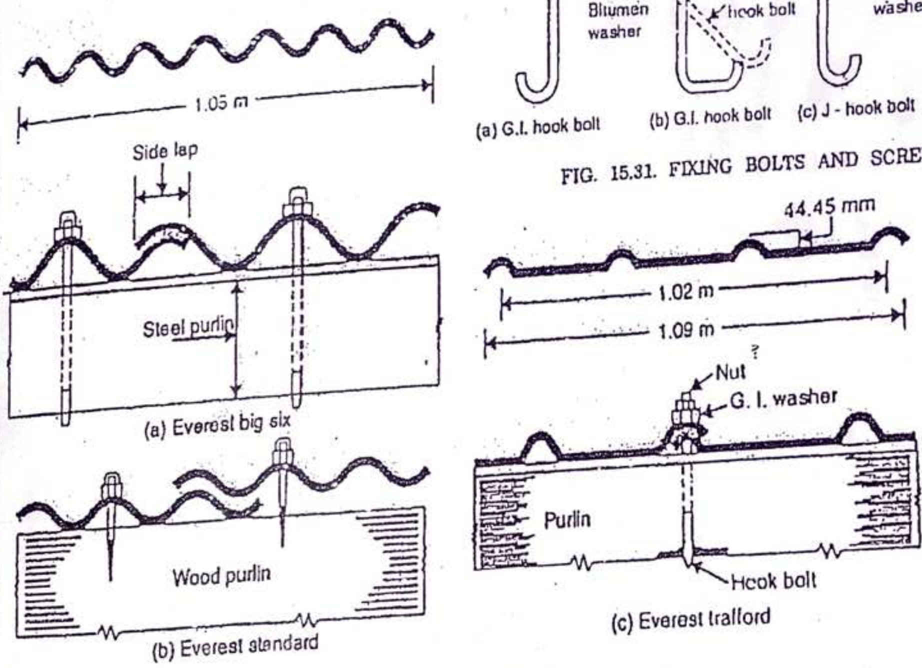


FIG. 15.30. A.C. SHEETS

6. Slate roofing:

Slates are hard fine-grained sedimentary (clayey) stone and are obtained from either open quarries or mines, in the form of blocks. The sizes of slates vary from 600mm X 300 mm to 400mm X 200 mm and thickness vary from 4mm to 8mm. Slates should be hard, tough, durable with rough texture, ring bell when struck, not split when hold or dressed, non-absorbent and satisfactory colour. They may be fixed on the roof in different ways as well. For the methods of fixing slates, copper or zinc nails are nailed making two holes at the head of slate and fixed it to the battens that are fixed on planks or direct on rafters. The slates are overlapped by 50 to 75 %. The spacing of the battens known as gauge is determined from the expression,

Gauge = (length of slate – Lap)/2

Ridge and hips are generally covered with blue or grey ridge tiles-matching the colour of slate. To protect from rain water and moisture, a layer of felt is used below slates.

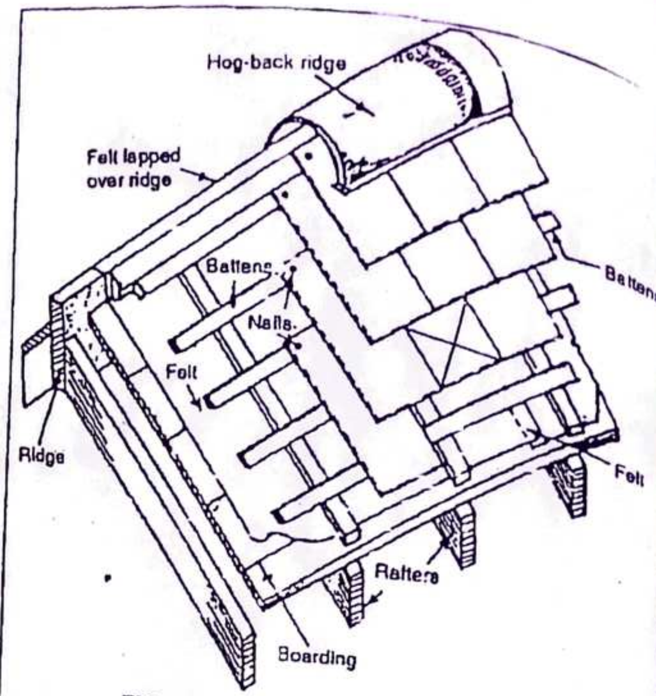


FIG. 15.34. DETAILS OF SLATE ROOFING.

7. Light weight roofing:

For wide span industrial structures, it is desirable to reduce the weight of roof so that structural framing can be economised. Conventional roofing materials (such as tiles, slates etc.) are heavy and require heavy framing to support them.

The light weight roofing materials are of two types:

a) Sheeting

i. Aluminium sheets
ii. Asbestos cement sheets

b) Decking

i. Wood wool
ii. Straw board
iii. Aluminium alloy and steel decking.

All above require a water proof layer of asphalt or roofing felt. Sheeting is used for sloping roofs while decking is used both for sloping as well as flat roofs.

a) Sheeting

i) Aluminium roof sheeting consists of aluminium alloyed with small percentage of manganese for strength. It is lightest of all roofing. The sections are shown below in Fig-15.35

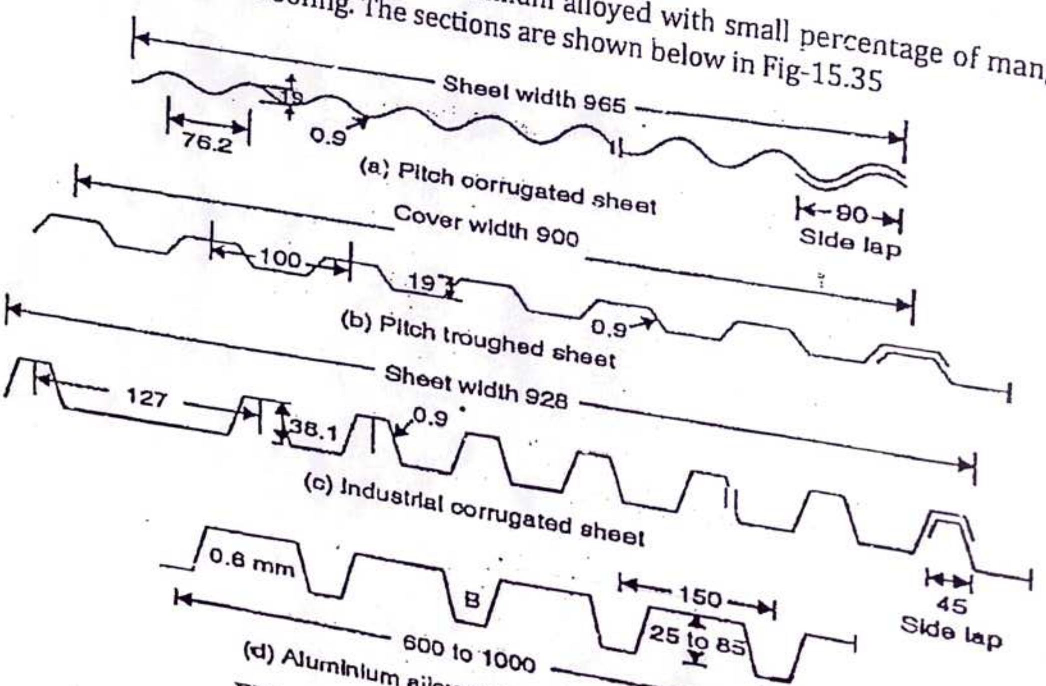


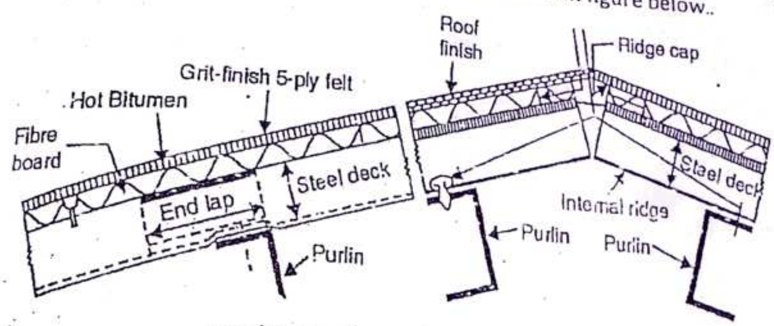
FIG. 15.35. METAL ROOF SHEETING

b) Decking

i) Wood wool is made from wood fibre interwoven together and cement bonded under pressure in a mould. They are available in the form of slabs, varying thickness from 12 mm to 100 mm and size of 0.6 m X 3.90 m and are good sound absorbing as well as thermal insulation properties. They can take load up to 0.75 kN/m². They are nailed to timber joist at 600 to 900 mm centres with help of 102 to 125 mm long clout nails.

ii) Straw board decking is made of compressed straw with thick water proof paper covering. The thickness 50 mm, width 1.20 m and length from 1.80 m to 3.60 m and the board is supported at 600mm centres for roof decking.

iii) Aluminium alloy and steel is pressed to form troughed roof decking with thickness varying from 0.7 mm to 1.2mm, depth of corrugations varying from 25 mm to 85 mm, widths varying from 450 mm to 9000 mm, and length up to 10.00 m. These are suitable up to loads of 0.75 kN/m². The deck is fixed to the roof supports by hook bolts, or bolts and cleat, or by hammer drive screws. A felt vapour is bonded with bitumen to the top of the deck on which an insulating media like fibre board or expanded poly styrene is bonded to be covered with two or three layers of felt roofing. The top surface is finished with a layer of white stone chippings spread on bitumen to provide for solar reflectivity and reduce heat absorption in summer as shown in figure below..



(a) Purlin details (b) Ridge details

FIG. 15.36. ALUMINIUM ALLOY AND STEEL DECKING

RCC flat roof covering (lime concrete terracing with tile paving):

This type of terracing is commonly adopted over R.C.C. roofing. The figure 15.39 below shows a typical section of roofing, which is laid in the following steps:

1. If the span of the roof is small say 3.00m to 3.50 m then no beams may require and R.C.C. slab can be place directly over the wall of the room. In case of large span, intermediate beams which may be of R>C.C. or rolled steel joists are used and then R.C.C. slab is casted over them. The thickness of R.C.C. slab is generally not less than 100 mm and it varies as per load acting on it and also as per span increases.
2. The R.C.C. slab functions as a base for roof covering and the R.C.C. beam functions as structural member. The slab bends downward causing tension at the mid span. Due to this steel bar reinforcement is placed at the bottom at the bottom of the slab, keeping minimum clear cover of 15mm. half of these bars are bent up and formed cracking near ends to take up negative bending moment caused due to partial fixity at the end. The main reinforcement bars are placed in the direction of the span of the slab which is equal to the width of room.
3. The bearing of the slab in the wall should neither be less than the thickness of slab nor less than half the width of the wall.

4. The slab is casted on timber or steel shuttering. Cement concrete of approximate mix (usually M_{20} ($1 : 1^1/_2 : 3$) is then poured and well compacted making the finished surface with a slope of 1 in 30 to 1 in 40 to drain off water. The RCC roof is cured at least 7 to 10 days.
5. After the concrete completely gains it full strength, the slab is cleaned off dust etc., and a layer of hot bitumen is applied at the rate of 1.7 kg/m^2 of roof surface.

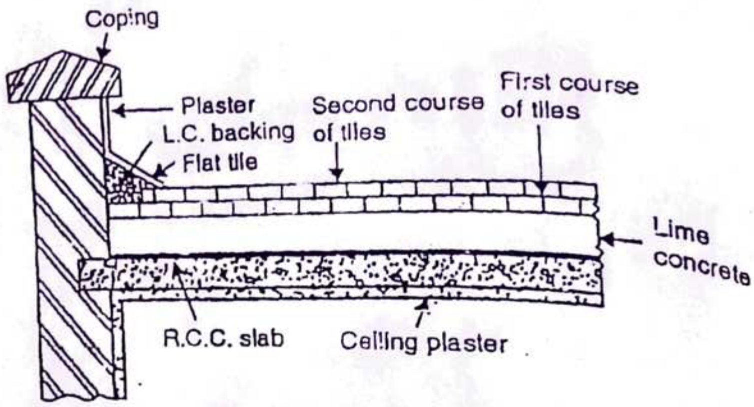


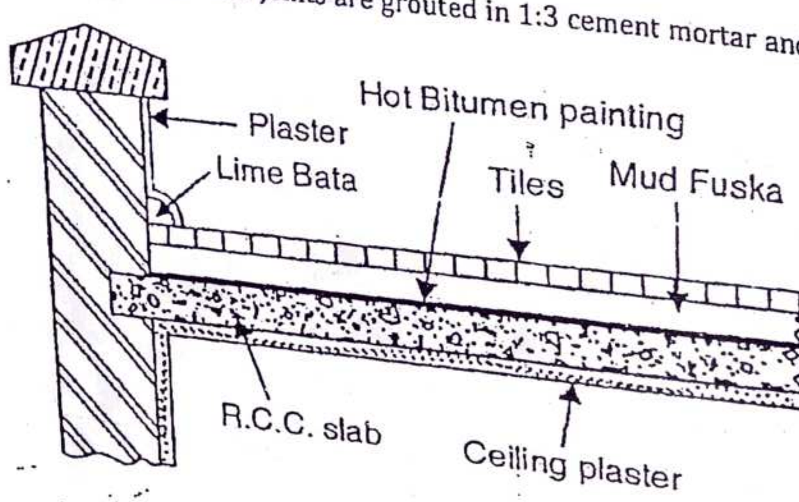
FIG. 15.39. LIME CONCRETE AND TILES ROOFING.

6. A layer of coarse sand is immediately spread over the hot layer of bitumen at the rate of 0.6 m^3 of sand per 100 m^2 of roof surface.
7. A 10 cm thick (average) layer of lime concrete (lime : surkhi : brick ballast of 25 mm gauge in 2:2: 7) is laid; in proper slope. The lime concrete is well beaten and entire slope is given in lime concrete itself.
8. Two courses of flat brick tiles are laid in 1:3 cement mortars. The joints of top courses are pointed with 1:3 cement mortars. The vertical joints in two courses are broken as shown on figure below.

RCC flat roof covering (Mud-phuska terracing with tile paving):

This type of terracing is commonly adopted over R.C.C. roofing which is suitable in hot as well as in arid regions and is commonly used over RCC roofing as shown in the figure 15.38 below:

- Up to step no. 6 are performed in the same manner.
- After these steps mud-phuska is prepared from puddled clay mixed with bhusa @ 8 kg/m^3 of clay.
- 10 cm layer of this mud-phuska is applied over the sand bitumen layer and proper slope (usually 1 in 40) is given in mud-phuska layer. The mud-phuska is consolidated properly and then plastered with 13mm coat of mud-cow-dung mortar (3:1).
- Tile bricks are laid flat on plastered surface. The joints are grouted in 1:3 cement mortar and the work is completed.



15.38 MUD-PHUSKA AND TILE TERRACING

Openings

1.1 Doors: Types and details

A door may be defined as a frame work of wood, steel, aluminium glass or a combination of these materials secured in an opening left in a wall for the purpose of proving access to the users. Generally, a door is provided to give an access to the inside of a room of a building. It serves as a connecting link between various internal parts of the building. Basically a door consists of two main parts: a) Door Frame, and 2) Door shutter

The door shutter is held in position by the door frame which in turn is fixed in the opening of the wall by means of a hold-fast & screws etc. Door frame is made up of two vertical members known as Jambs or posts and a flat member connecting the Jambs at top called head. Rebate cut all around the frame is provided to receive the door shutter.

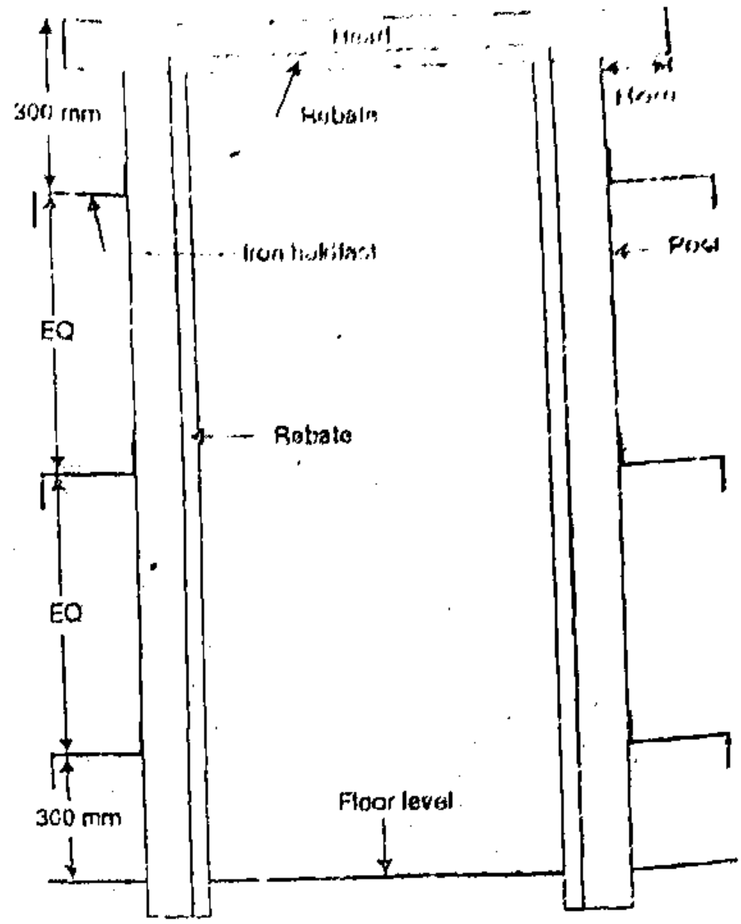


FIG. 17.3. DOOR FRAME.

Materials for doors

The frame is normally made up of timber, but some other materials used for doors frames are:

Timber: Easily available material and it can be worked in to different shapes easily.
Steel: Prevent termite actions, may get corrode.
Pre-cast R.C.C: Low cost and durable, casted in the factory.
Aluminum: Rust proof and gives pleasant appearance

Door shutter are generally made up of timber frame work with panel consist of glass, timber, plywood, block boards or a combination of such materials. Depending upon the sizes of opening two types of door shutters can be used:

Single leaf door: with one leaf or shutter.
Double leaf door: In wider openings, with two leaves.

Sometimes a door is provided with shutter on both sides of the frame such a door in known as double shutter door. Shutter on outer side may be glazed and the inner side is wire gauge mesh for preventing in enter of mosquitoes and other insects but the entrance of fresh air.

Different parts of the typical wooden door:

Frame: It is an assembly of horizontal and vertical members, forming an enclosure, to which the shutters are fixed.

Shutter: These are the openable parts of a door or window. It is an assembly of styles, panels and rails.

Head: This is the top or uppermost horizontal part of a frame.

Sill: This is the lowermost of bottom horizontal part of the window frame. Sills are normally not provided in the door frame.

Horn: These are the horizontal projections of the head and sill of a frame to facilitate the fixing to the frame on the wall opening. The length of the horn is kept about 10 to 15 cm. It is also known as bearing.

Style: It is the vertical outside member of the shutter of a door or window.

Top rail: It is the top most horizontal member of a shutter.

Lock rail: It is the middle horizontal member of a door shutter, to which locking arrangement is fixed.

Bottom rail: It is the lowermost horizontal member of a shutter.

Intermediate or cross rails: These are the additional horizontal rails, fixed between the top and bottom rails of a shutter. A rail fixed between the top rail and lock rail is called frieze rail.

Panel: It is the area of shutter enclosed between the adjacent rails.

Mullion: It is a vertical member of a frame, which is employed to sub-divide a window or a door vertically.

Transom: It is a horizontal member of a frame, which is employed to sub-divide a window opening horizontally.

Hold fasts: These are the mild steel flats (section 200mm x 30 mm x 5mm) generally bent to Z-shape, to fix or hold the frame to the opening. The length of the hold fast is embedded into the concrete block of size 23cmx15cmx15cm.

Jamb: It is the vertical wall face of an opening which supports the frame.

Reveal: It is the external jamb of a door or window opening at right angles to the wall face.

Rebate: It is depression or recess made inside the door frame, to receive the door shutter.

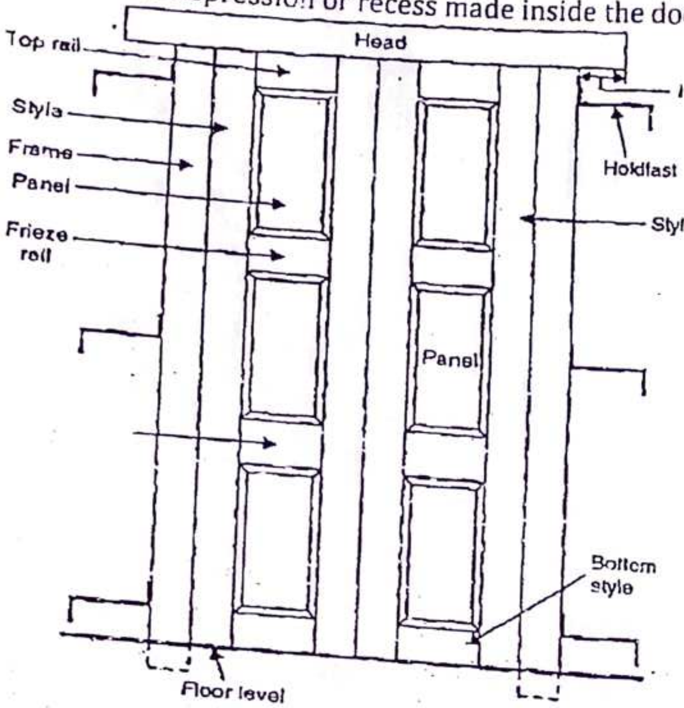


FIG. 17.1. DOOR

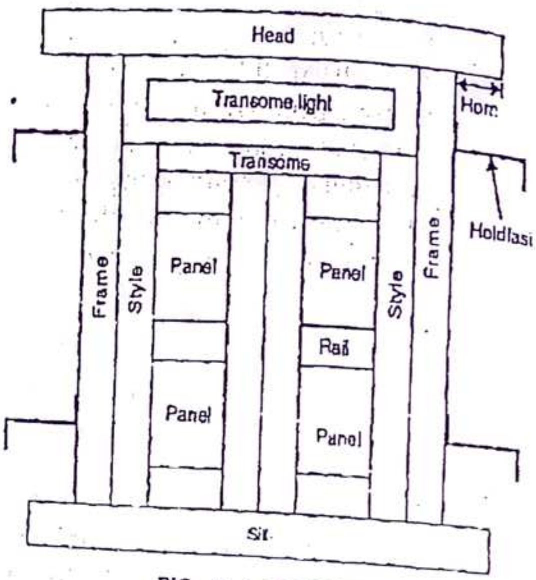


FIG. 17.2. WINDOW.

Location of doors and window:

The number of doors in a room should be kept less since large numbers of doors cause obstruction and consume more circulation space. The following points should be kept in mind, while locating doors and windows:

1. The location of a door should meet the functional requirements of a room. It should not be located at the centre of the length of the wall. A door should preferably be located near the corner of the room nearly 20 cm away from the corner.
2. If there is two doors in a room, they should be placed in opposite walls facing each other in order to provide the cross ventilation.
3. The size and number of windows should be decided on the basis if important factors such as distribution of light, control of ventilations and privacy of the occupants.
4. The location of a window should also meet the functional requirements of the room such as interior decoration, arrangement of furniture etc.
5. A window should be located in opposite wall, facing a door or another window, so that cross ventilation in achieved.
6. A window should be located on the northern side of the room, or in the prevalent direction of wind keeping the view of fresh air blow.
7. The sill of the window should be located about 70 to 80 Cm about floor level of the room.

Size of door and window

The size of a door should be such that it would allow the movement of largest object or tallest person likely to use the door. As a rule, the height of the door should not be less than 1.80m to 2 m. The width of the door should be such two persons can pass through it walking shoulder to shoulder

The common width-height relations used for door are:

(i) Width = (0.4 to 0.6) height   (ii) Height = (Width + 1.20) meters

A. Residential Buildings

Internal doors size: 0.9m x 2.00m to 1.00m x 2.00m

External door size: 1.00m x 2.00m to 1.10m x 2.00m

Bathrooms & Toilets door size: 0.70m x 2.00m to 0.80m x 2.00m

Garages for Cars: 2.50m(W) x 2.25m(H)

B. Public Buildings

Hospitals, Libraries, Cinemas schools etc., size: 1.2x2.00m, 1.2mx2.10m, 1.2mx2.25m etc.

Common criteria for size of doors are

Width = 0.4 to 0.6 x height

Height = width + 1.2m

Types of Doors

A. Classification of door on the basis of arrangement of components.

1. Battened and ledged doors
2. Battened, ledged and braced doors
3. Battened, ledged and framed doors
4. Battened, ledged, braced and framed doors

B. Classification of door on the basis of method of construction.

5. Framed and panelled doors
6. Glazed or sash doors
7. Flush doors (a) Solid core flush door (b) Hollow and cellular core flush door
8. Louvered doors
9. Wire gauged doors

C. Classification on the basis of working operation.

10. Revolving doors
11. Sliding doors
12. Swing doors
13. Collapsible steel doors
14. Rolling steel shutter doors

D. Classification on the basis of material used.

Timber doors: They are already mentioned above

Metal doors: They are as follows:-

15. Mild steel sheet doors
16. Corrugated steel sheet doors
17. Hollow metal doors
18. Metal covered plywood doors

1. Battened and ledged doors

This is the simplest door used for narrow openings, low cost and low strength. This door consists of vertical boards (Battens), which are secured by horizontal pieces (ledges). Batten is 100 to 200mm wide and 20 to 30mm thick. Ledges are 100 to 200mm wide and 25 to 30mm thick. Three numbers of ledges are generally provided, top, middle and bottom.

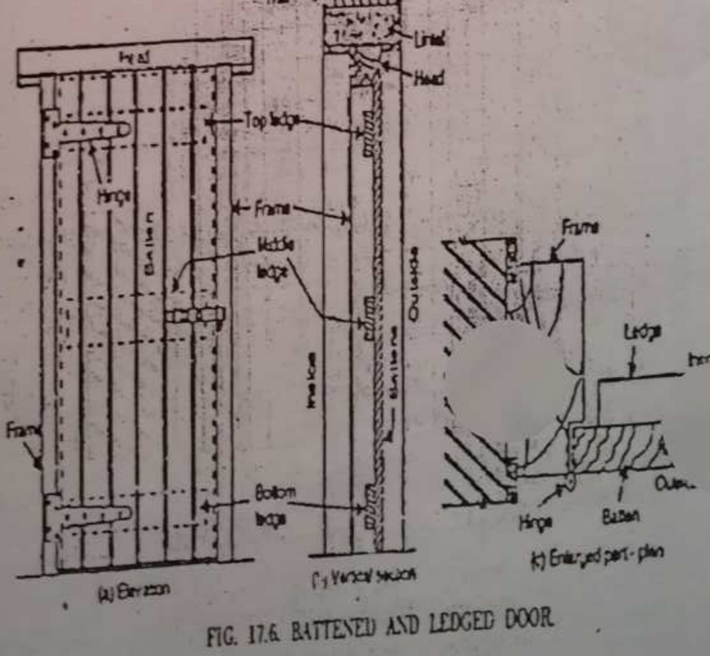


FIG. 17.6. BATTENED AND LEDGED DOOR

2. Battened, ledged and braced doors

This is the modification over batten ledged doors in which additional diagonal members called braces as provided to increase its rigidity and strength. The size of braces is 10 to 15cm in width and 3 to 4cm thick. These braces act as struts.

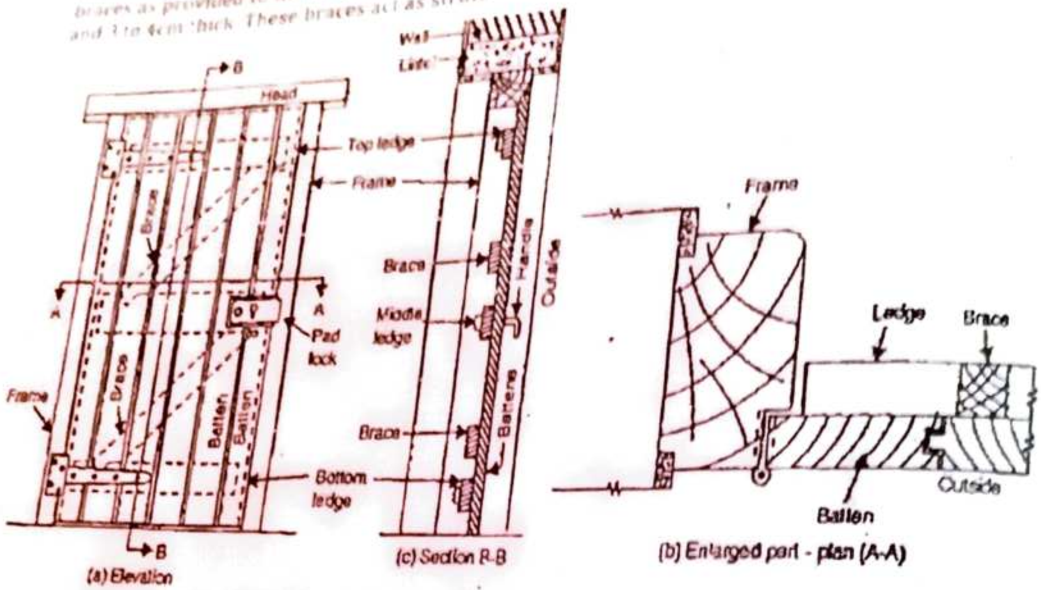


FIG. 17.7. BATTENED, LEDGED AND BRACED DOOR.

3. Battened, ledged and framed doors

This is also the improved form of simple battened and ledged door, in which framework for the shutter is provided in the form of two verticals, known as styles. Styles are generally 100 mm wide and 40 mm thick. Three ledges are provided as usual. The total thickness of the style is maintained equal to the thickness of the ledges plus the thickness of battens.

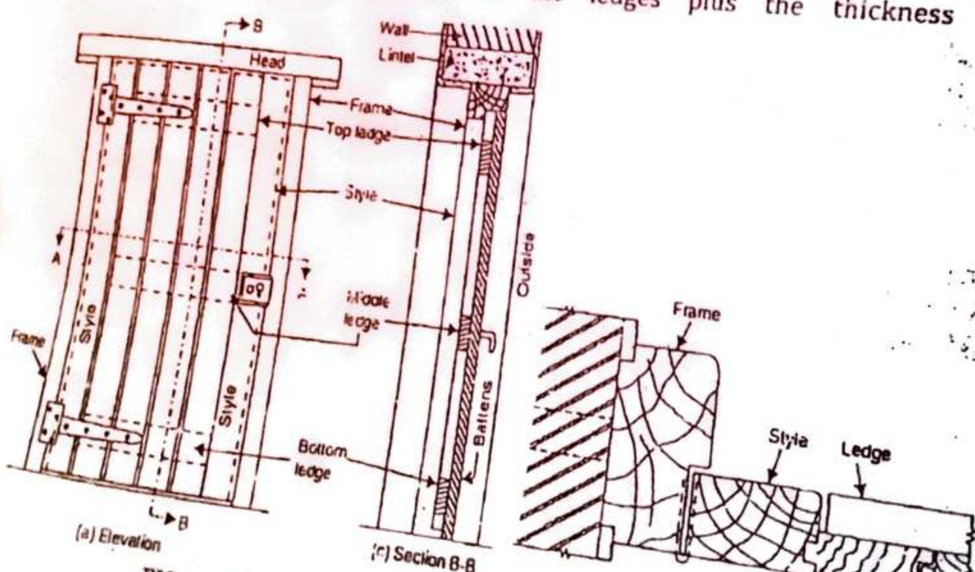


FIG. 17.8. BATTENED, LEDGED AND FRAMED DOOR

4. Battened, ledged, braced and framed doors

This type of door is the modification of battened, ledged and framed door, with the provision of braces, provided diagonally between the ledges to increase its strength, durability and appearance. The braces are housed into the ledges, at about 40 mm from the styles.

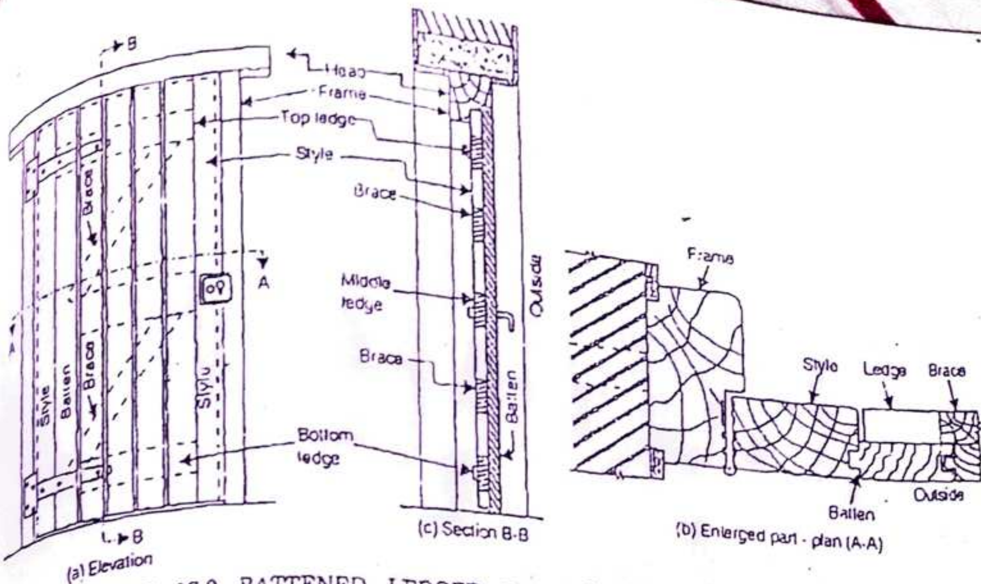
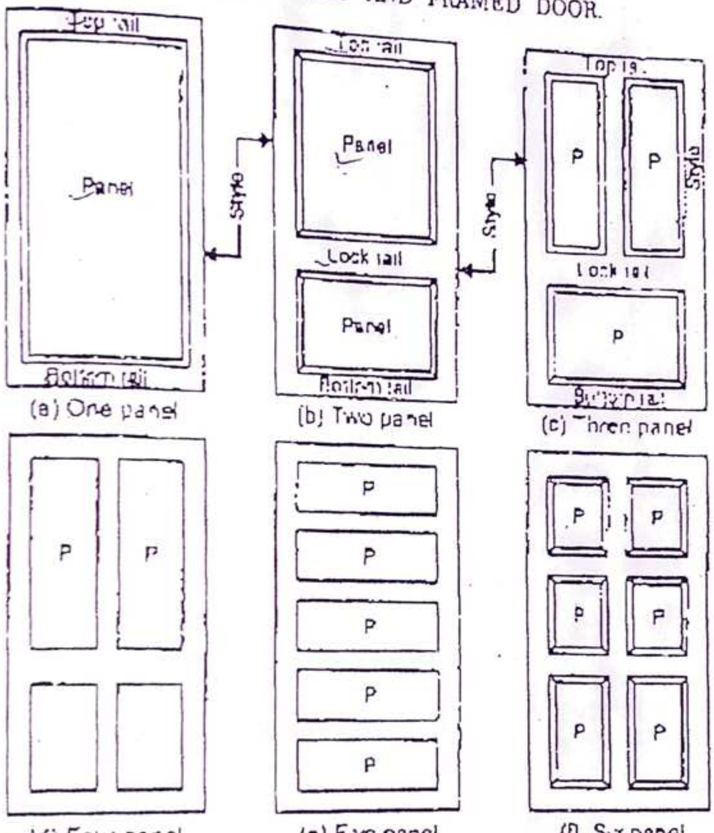


FIG. 17.9. BATTENED, LEDGED, BRACED AND FRAMED DOOR.

5. *Framed and paneled doors*

These types of doors are commonly used in all types of building since they are strong and give better appearance. This door consists of a framework of vertical members (styles) and horizontal members (rails) which are grooved along the inner edges of the frame to receive the panels. The panels are mode from timber, plywood, block board or glasses, further vertical sub-division of panels is done using mullions. Paneled doors may contain single of double leaf. In double leaf each leaf has separate frames, each hinged to the jamb post of the doors



17.10. VARIOUS FORMS OF SINGLE-LEAF PANELLED DOORS.

6. Glazed or sash door

The doors, either fully glazed or party glazed are used to supplement the natural lighting provided by window such doors are commonly used in residential as well as public building like, restaurants, hospitals, colleges etc. The glass is received into the rebates provided in the wooden sash bars and secured by rails putty.

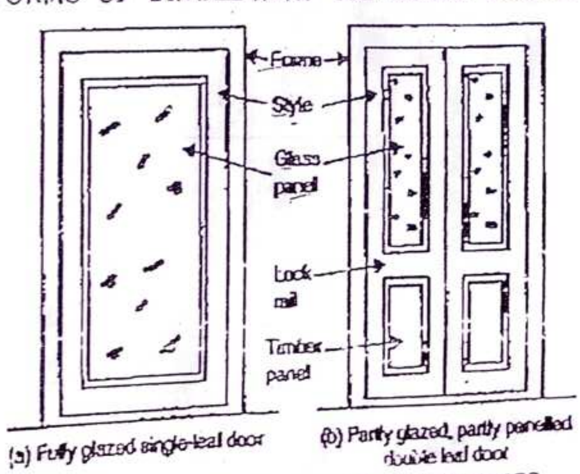


FIG. 17.12. FULLY AND PARTLY GLAZED DOORS.

7. Flush door

With the development of the plywood, the flush doors are being extensively used, especially for interior work. These doors have pleasing appearance, simplicity of construction, economic and high strength and durability. A flush door consists of skeleton or a hollow framework of rails and styles, and it is covered on both the sides with laminated boards or plywood. This door has, therefore, a perfectly flush and joint less. Surfaces on the both sides the flush doors are of the following two types:

a. Solid core flush door

Door or laminated core flush door. This door consists of a core of strips of a wood glued together under a great pressure and faced on each side by plywood sheet. The plywood sheets are also glued under great pressure to the laminated cover. This solid core is housed in the frame consisting of stiles top and bottom rails each not less than 75cm wide.

b. Hollow and cellular core flush door

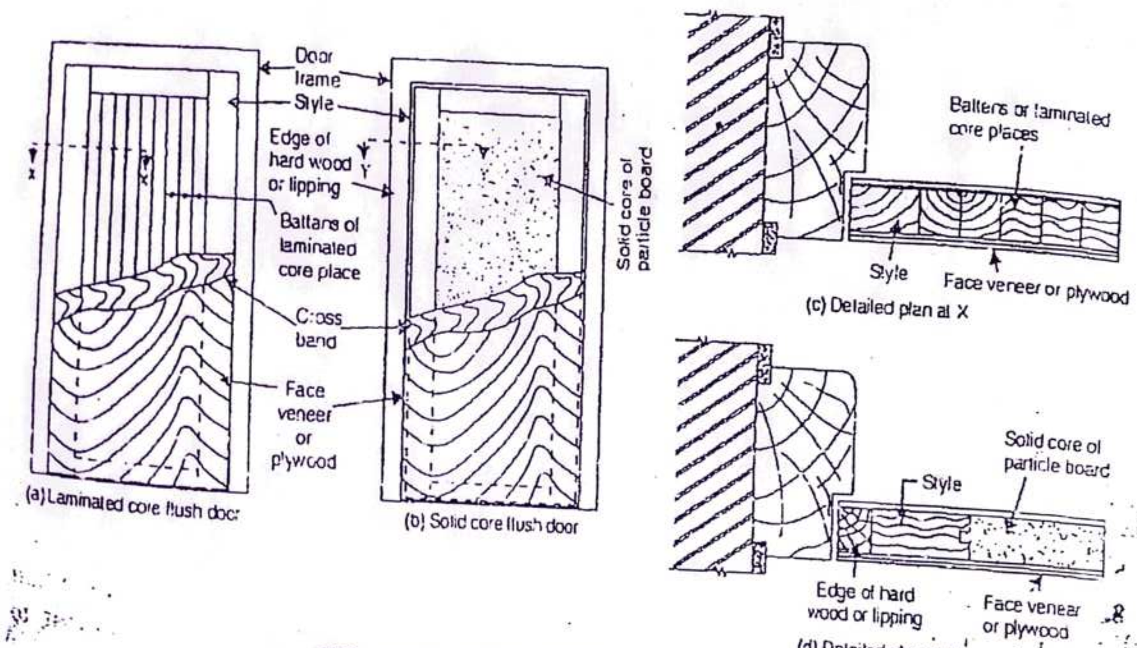


FIG. 17.15. SOLID CORE FLUSH DOORS.

Hollow core flush door: It consists of 6mm thick plywood sheets covered on the frame made up of styles, top rail, bottom rail and minimum two intermediate rails each of at minimum of 75mm width. The inner space of the frame is provided with equally spaced battens each of minimum 25mm width, such that the area of voids is limited to $50cm^2$.

Cellular core type flush door shutters:

It consists of >3mm thick plywood sheets covered on the frame made up of vertical and horizontal batten or ribs not less than 25mm wide and made up of strips of wood or plywood or blocks of compressed wood are so fixed that they provide a grid of void space, each not more than $25cm^2$ in area. Total content of void is < 40 % of the area of the shutter

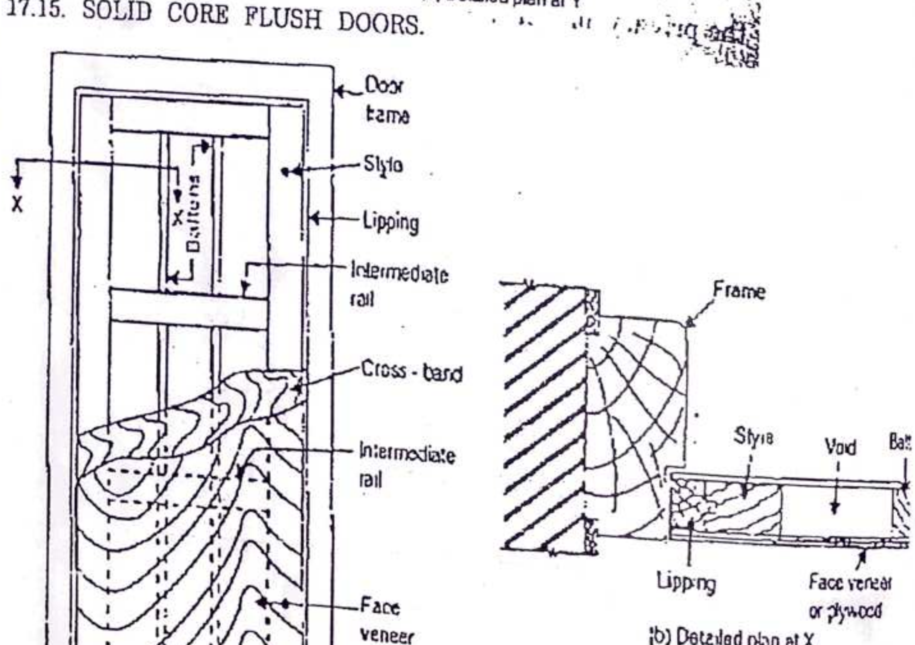


FIG. 17.16. HOLLOW CORE FLUSH DOOR.

8. **Louvered doors (Venetian doors)**

The use of these doors gives privacy combined with natural ventilation because they allow free passage of air even when closed. However these doors harbour dust which is very difficult to be cleaned. They are generally use for latrines and bathrooms. The door may either be louvered to its full height or it may be partly louvered and partly panelled. The inclination is such arranged that vision is obstructed permitting free passage of air. Louvers may be either fixed or moveable.

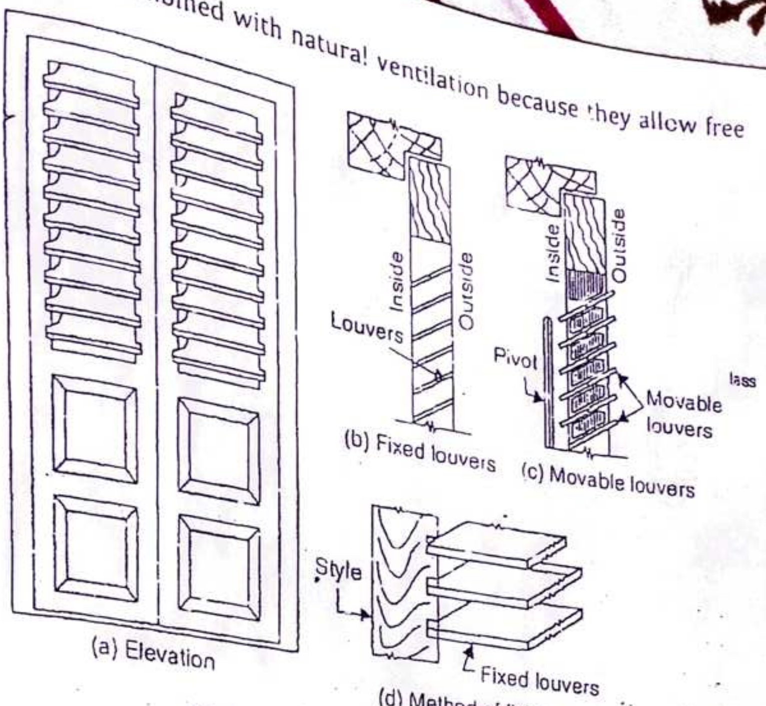


FIG. 17.17. LOUVERED DOORS.

9. **Wire gauged door or fly proof door**

These types of door are provided to check the entry of files, mosquitoes, insects etc. Wire mesh is provided in the panels and therefore they permit free passage of air. The door is framed of a wooden frame work. The panel openings are fitted with fine mesh galvanized wire-gauge. Generally the door has two shutters; the inner shutter is fully panelled while the outer shutter is wire gauged.

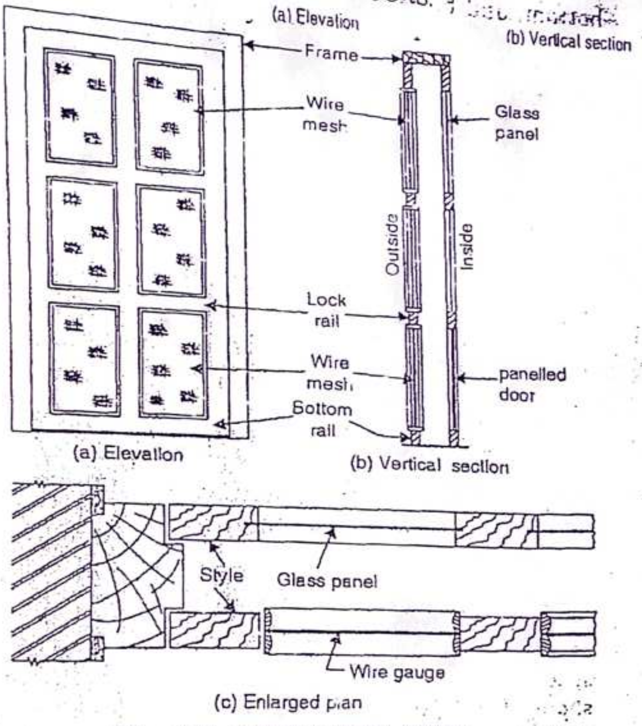


FIG. 17.18. WIRE-GAUGED DOOR

10. **Revolving door**

This type of door provides entrance on one side and exit on the other side simultaneously. These doors keep the opening automatically closed when it is not in use. These doors are used, provided where there is constants foot traffic of people such as, zoo, banks, hotels, hospitals, theatres etc. A revolving door consists of four upright cross wings (shutter) which are arranged diagonally on the sides of a centrally placed pivot. These shutters are fully panelled or glazed or combination.

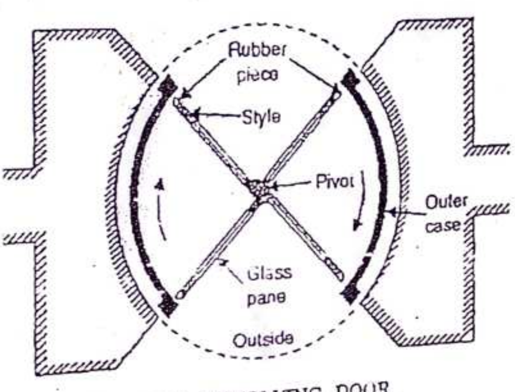


FIG. 17.19. REVOLVING DOOR.

11. **Sliding doors**

In such a door, the shutter slides on the sides with the help of runners and guide rolls. The door may have one sliding shutter, two shutters or even three shutters depending upon the size of the opening and the space available on sides for sliding.

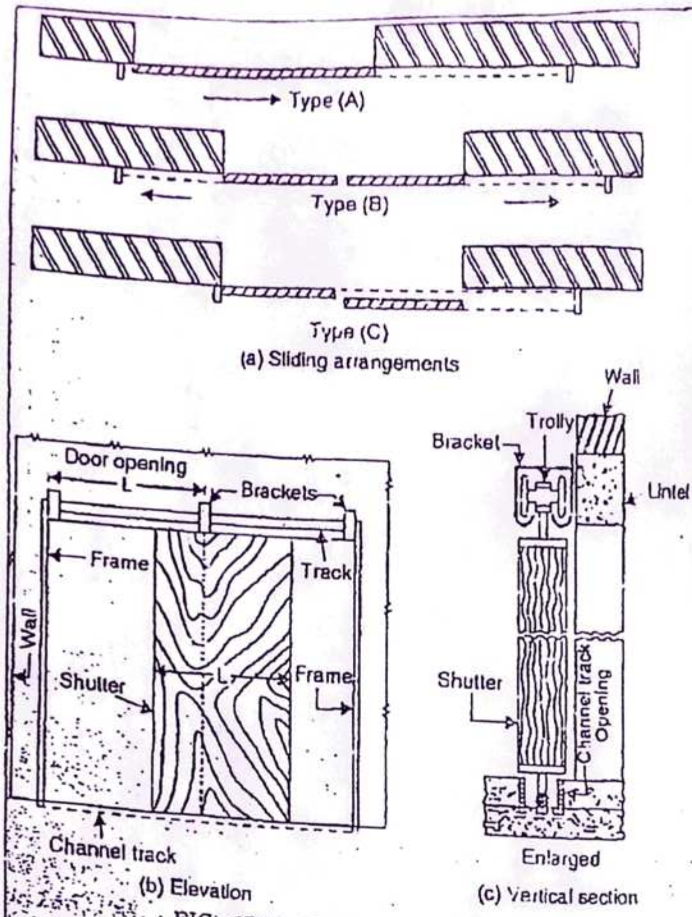


FIG. 17.20. SLIDING DOOR.

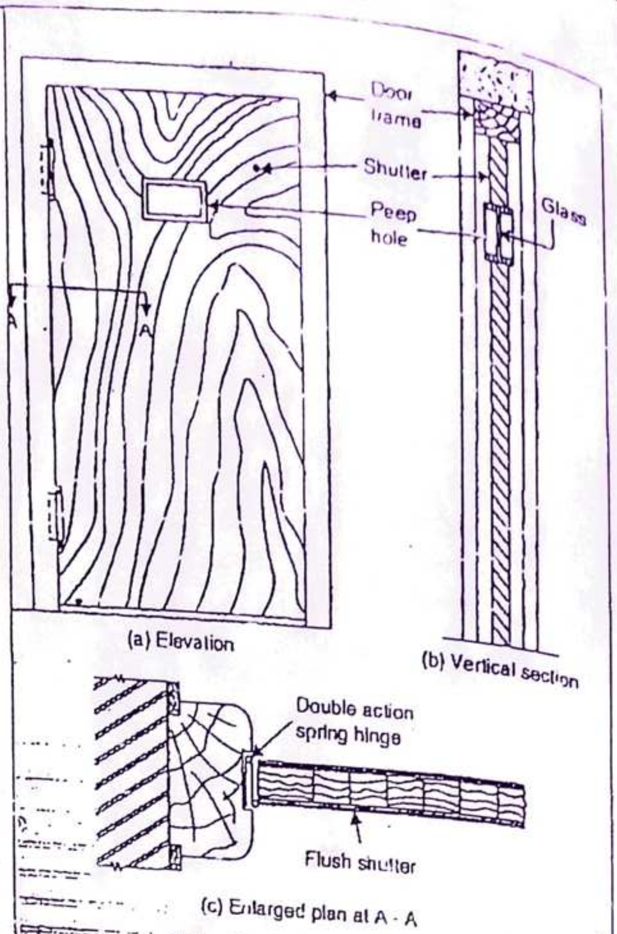


FIG. 17.21. SWING DOOR.

12. Swing doors

A swing door has its leaf attached to the door frame by means of special type of 'Double actions spring Hinge, so that the shutter can move both inward and outward as desired. Since these doors are open in both directions, it is desirable to provide glass panels or peep hole at eye level in order to avoid the accident likely occur due to both side swinging of the door.

13. Collapsible steel doors/Channel gate

These doors are extensively used for main entrance, shops, garages, sheds godowns etc. for providing increased safety and protection to the property. The door neither requires hinges for opening and closing nor any frame for hanging them. It acts like a steel curtain which can be opened or closed by horizontal push. The door is fabricated from vertical double channels (20mmx10mmx2mm) joined together with the hollows on the inside, so that a vertical gap is created. Such channel units are spaced at 10 to 120 mm apart and are braced flat iron diagonals 10 to 20 mm wide and 5 mm thick. These diagonals allow the shutter to open out or get closed. The shutters operate between two iron rails of T- shape, one fixed to the floor and other to the lintel. Rollers mounted on horizontal piece are provided both at the top and at the bottom ends of vertical pieces. The door is also provided with handles, locking arrangements, stoppers etc.

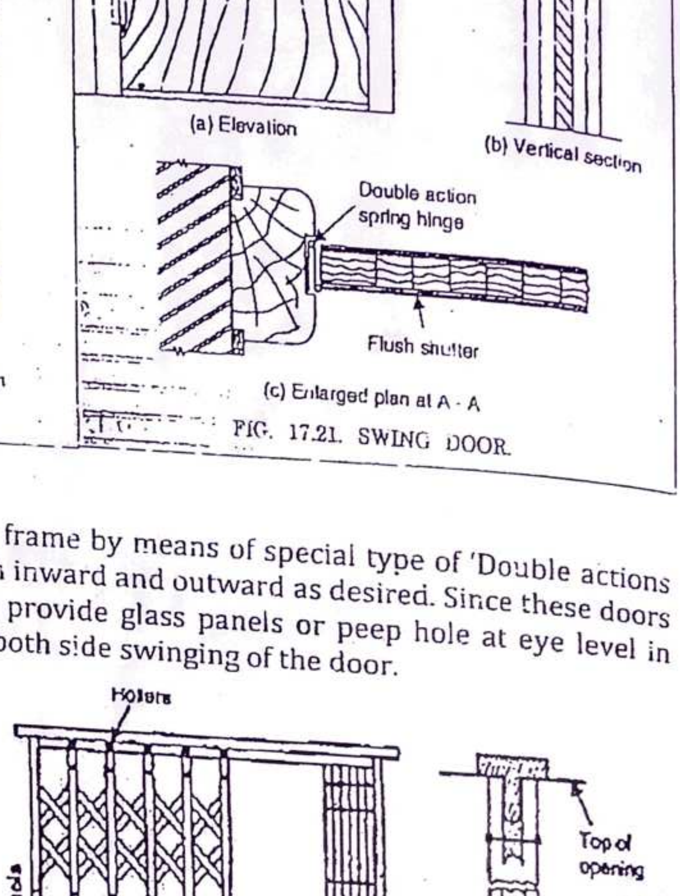


FIG. 17.22 COLLAPSIBLE STEEL DOOR.

14. Rolling steel shutter door (RSS door)

These doors are commonly used for garages, godowns, shops etc. since they are quite strong and offer proper safety to the property. The door consists of frame, drum ad as shutter of thin steel plates, known as laths or slates, which is about 1 to 1.25 mm thick and inter locked together. The frame has steel guides on each sides in which the shutter moves and then coils in the drum. The diameter of the drum varies from 200 to 300 mm. A horizontal shaft and spring are provided in the drum, due to which the shutter is opened oar closed by small push or pull. They are of two types, viz. push or pull type (provided when door area is less than 10 sq. m) and mechanical gear type.

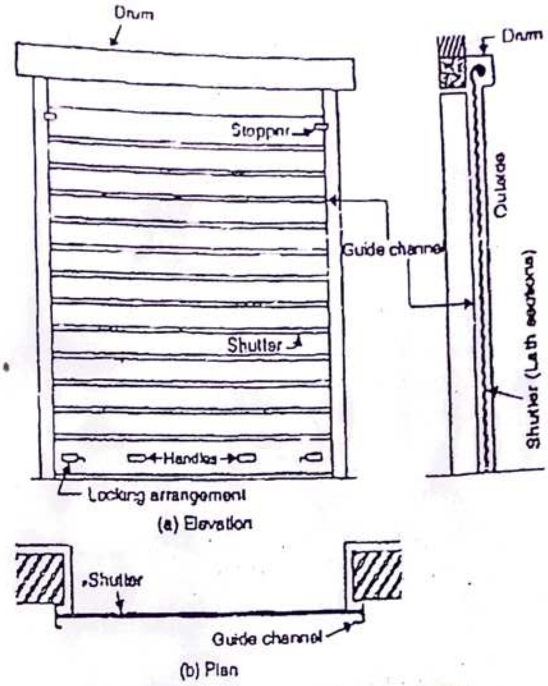


FIG. 17.23. ROLLING STEEL SHUTTERS.

15. Mild steel sheet doors

These doors are provided for garages, godowns, workshops etc. and are quite strong. The door consists of a door frame made of angle or T-sections. The door has generally two shutters. Each shutter is made up of frame of angle of iron, having two verticals and at least three horizontals. Mild steel plates of required thickness are then welded to the shutter frame. The shutters are attached to the door frame by means of steel hinges welded to them.

16. Corrugated steel sheet doors.

The doors are exactly same as the mild steel sheet doors, except the corrugated steel sheets are used instead of mild steel plain sheet. They are stronger than mild steel sheet door.

17. Hollow metal doors

These doors have appearance like wooden doors but are much stronger. These are made of furniture steel sections, which are hollow from inside. The rails, styles etc. are strengthened by welding small T or I sections. In order to avoid the noise while opening and closing, the styles of the doors are filled with any insulating material.

18. Metal covered plywood doors

These doors are composite doors made of plywood and mild steel and are reasonably fir proof. The core of the door consists of two or three layers of planned, tongued and grooved seasoned teak or yellow pine board of total thickness 20 to 25 mm. The core is encased in tight fitting sheet mental such that the core does not ignite.

4.2 Windows

A window may be defined as an opening made in a wall for the purpose of providing daylights, vision and ventilation. The construction of window is identical to door and it also consists of window frame and window shutters. The frame consists of two vertical members called jambs, one horizontal member connecting the jamb at top knows as heads and another at the feet called sill. The shutters can be fully glazed, panelled or combination.

The selection of *size, location and number of windows in a room* depends upon the following factors:

(i) Size of the room
(ii) Location of the room
(iii) Utility of the room
(iv) Direction of the wall
(v) Direction of wind
(vi) Climatic condition such as humidity, temperature etc.
(vii) Requirement of exterior view
(viii) Architectural treatment to the exterior of the building.

Based on the above factors the area of the window opening is determined which are in use as thumb rules.

Thumb rule information regarding the area of the window opening:

1. **Breadth of window** = 1/8 (width of room + height of room)
2. The total area of window openings should normally vary from 10 to 20 % of the floor area of the room, depending upon the climatic area.
3. The area of the widow opening should be at least one square meter for every 30 to 40 cubic meter of inside content of the room.
4. In public building, the minimum area of the windows should be 20 % of floor area.
5. For sufficient natural light, the area of glazed panels should at least be 8 to 10 % of the floor area.

Types of windows

Windows are classified as follows, based on the nature of operational movement of shutters, materials used for construction, manner of fixing and their location.

1. Fixed windows
2. Pivoted windows
3. Double hung windows
4. Sliding windows
5. Casement windows
6. Sash or glazed windows
7. Louvered windows
8. Metal windows
9. Bay windows
10. Clere-storey windows
11. Corner windows
12. Dormer windows
13. Gable windows
14. Lantern lights
15. Skylights
16. Wire gauzed windows
17. Combined windows ventilators
18. Fan lights
19. Circular windows
20. Ventilators

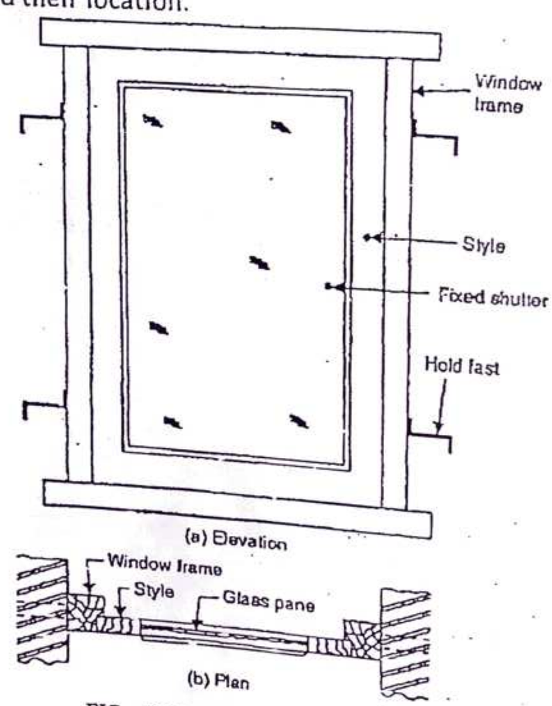


FIG. 17.24. FIXED WINDOWS.

1. Fixed windows

These windows are provided for the role purpose of admitting light or providing vision. The window consists of a window frame to which shutters are fixed which are fully glazed.

2. Pivoted window
In these windows the shutters are allowed to swing rounds pivots fixed to the windows frame horizontally or vertically. The windows frame has no rebates

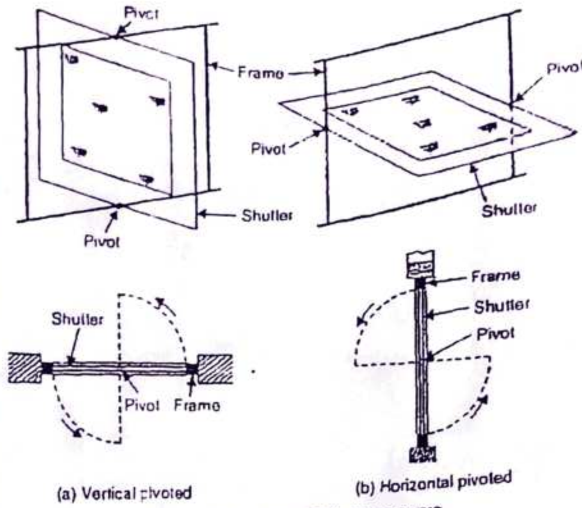


FIG. 17.25. PIVOTED WINDOWS.

3. Double hung window
This type of window consists of a pair of shutters arrange done above another which can slide vertically within the grooves provided in the frame. A pair of metal weights connected by chord passing over pulleys is provided for each shutter. By this arrangement the window can be opened at top or bottom to desired extent by pulling the metal weight suitably. In these types of window it is possible to have controlled ventilation and the shutters can be cleaned easily.

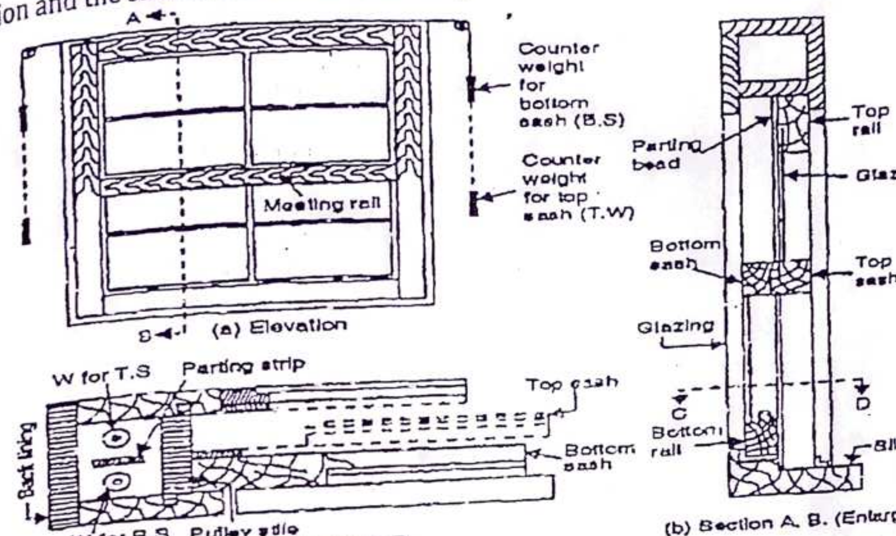


FIG. 17.26. DOUBLE HUNG WINDOWS.

4. Sliding window
This type of the windows is similar to sliding door. The shutters move either horizontally or vertically on small roller bearings. Such windows are provided in train buses and shops.

5. Casement window
These are the main types of windows usually provided in buildings. The shutters of these open like shutters of doors. Similar to doors, this type of window has frame and shutters composed of styles, top rails, bottom rails, vertical and horizontal sash bars with glass panels. Depending upon the design, the frame of a casement window can also have additional vertical and horizontal members known as mullion and transom respectively.

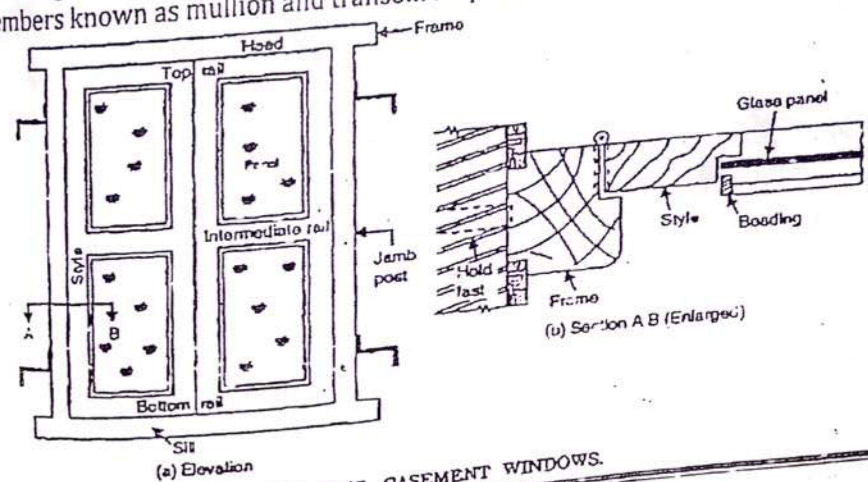


FIG. 17.27. CASEMENT WINDOWS.

6. Sash or glazed window

A sash window is a type of casement window in which the panels are fully glazed. The frame of each shutter consists of two vertical styles, top rail and a bottom rail. The space between the top and bottom rail is divided into small panels by means of small members placed horizontally and vertically, called sash bars or glazing bar

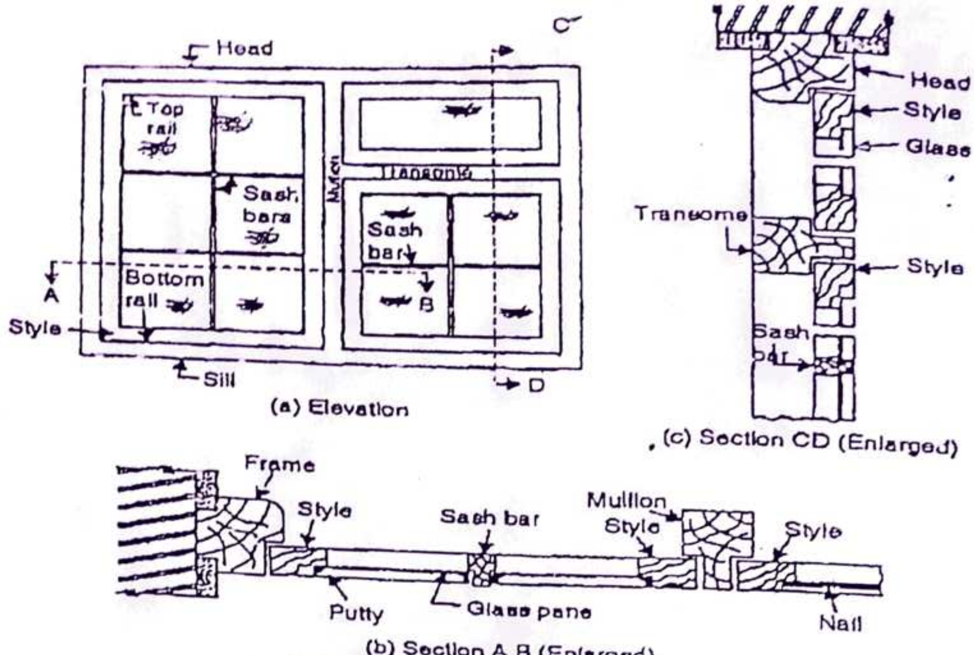


FIG. 17.28. SASH WINDOWS.

7. Louvered window

This type of windows is similar to louvered doors. Such windows provide ventilation and they do not permit outside vision. The shutter consists of top and bottom rails and two styles which are grooved to receive the louvers. The louvers are generally fixed at angle of 45°. The louvers slope down ward to the outside to run off the rain water. This type of window provides ventilation and light even when the openings are closed. Sometimes venetian shutters are provided as shown in fig. 17.30 in which the louvers can be opened at any angle or closed.

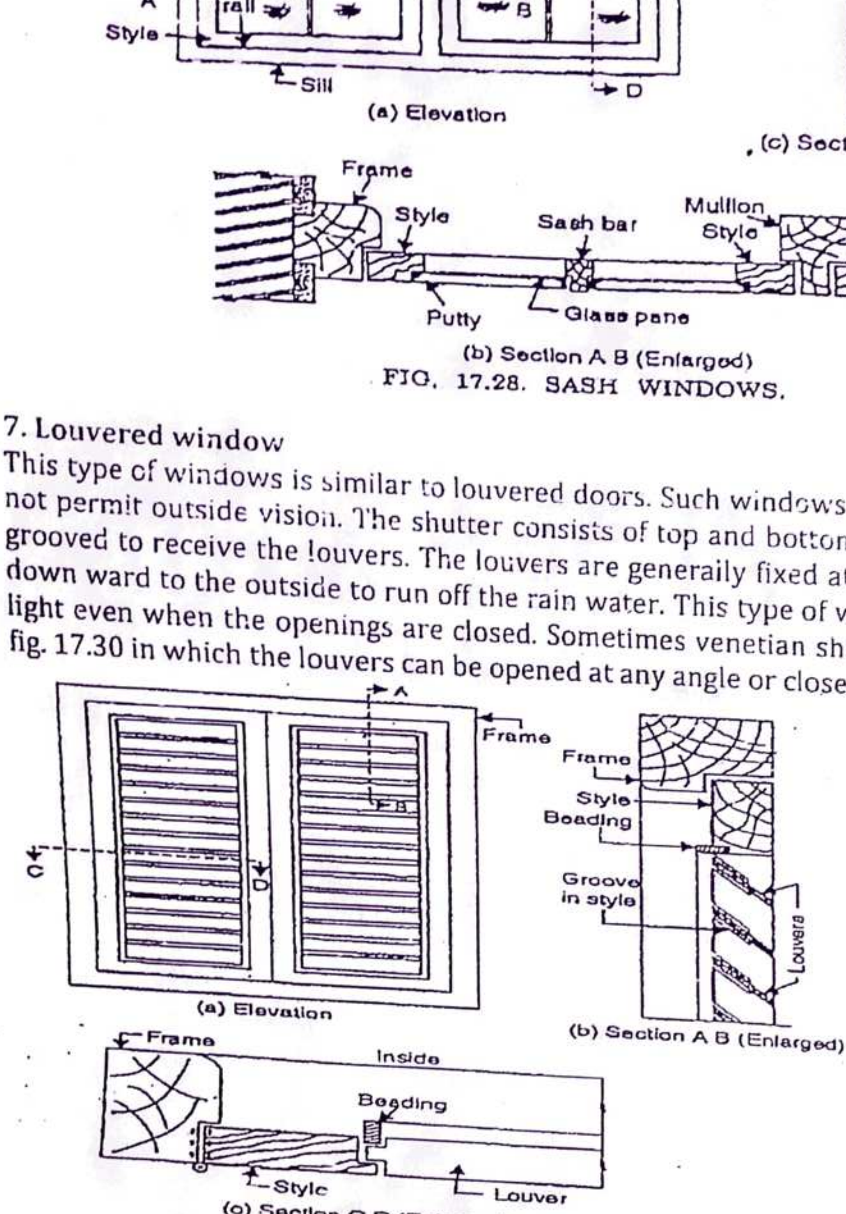
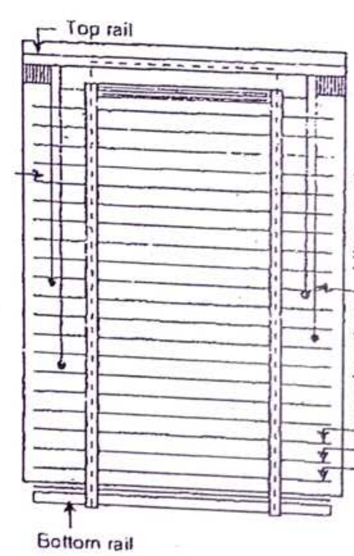


FIG. 17.29. LOUVERED WINDOWS.



17.30. VENETIAN BLIND

8. Metal window

Use of metal windows is getting popular these days. Windows made of metals like mild steel, galvanized steel, aluminium, bronze, stainless steel etc., are used for public buildings like offices, hospitals, schools etc. Bronze and stainless steel being very costly, but aluminium windows are less expensive and hence they are commonly used for buildings. Aluminium windows are rust proof, durable and required no main tenancies and painting. Mild steel being cheapest of the above so steel windows are extensively used in all types of building.

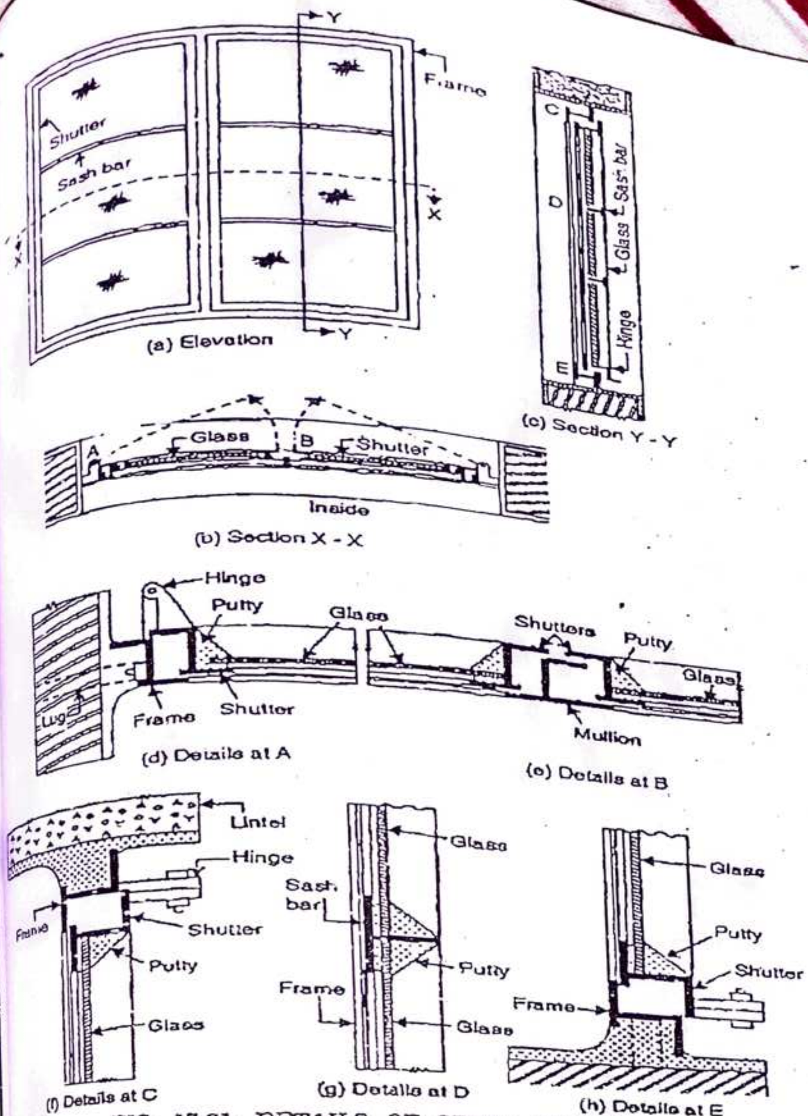


FIG. 17.31. DETAILS OF STEEL WINDOW.

...ay windows

...windows projects outside the external wall of the room. This projection may be triangular, Circular, ...angular or polygonal in plan. Such a window is provided to get an increased area of opening for ...ce in the room and improve the appearance of room as well as the building.

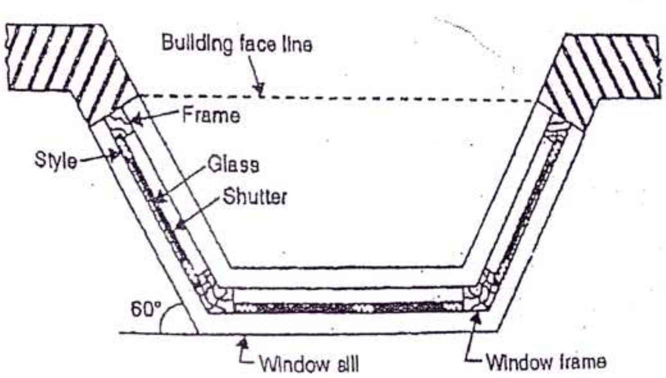


FIG. 17.32. BAY WINDOW.

...Clere-storey window

...e type of window is used to achieve better ventilation and cooling effect in the living room or ...n rooms of a building which have ceiling height greater than the surrounding rooms. Clear ...rey windows are provided near the top of the roof of the main rooms and they open out above ...ean to roof or the roof slab of the adjoining veranda. The window shutter is horizontally pivoted ...d the window can be opened or closed by use of two chords.

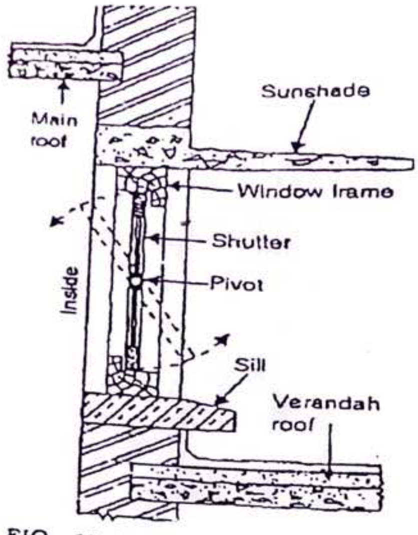


FIG. 17.33. CLERE-STOREY WINDOW.

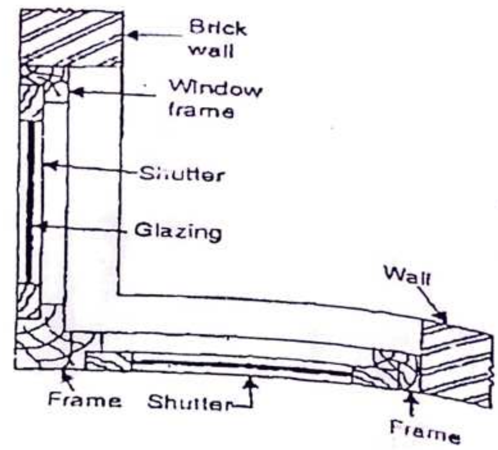


FIG. 17.34. CORNER WINDOW.

11. Corner window

This is special type of window provided in the corner of the walls (rooms). This window has two faces in two perpendicular directions. Due to this, light and air is admitted from the directions. Such a window very much improves the elevation of the building.

12. Dormer window

A vertical window provided in a sloping roof. Such a window provides ventilation and lighting to the enclosed space below the roof, and improves the appearance of the building.

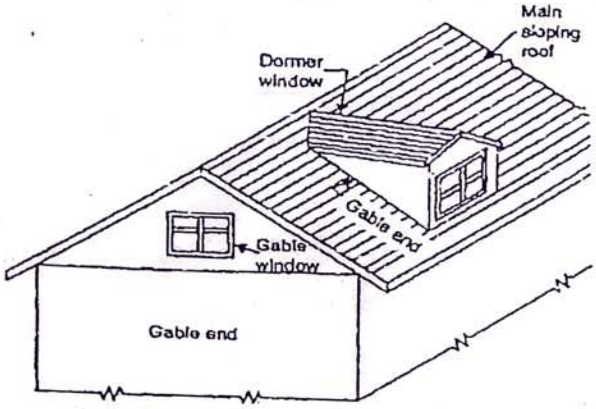


FIG. 17.35. DORMER WINDOW AND GABLE WI

13. Gable window

The window provided in the gable and of the pitched roof is known as gable window.

14. Lantern window

Such windows are provided over the flat roofs, to provide more light and air to the inner rooms of building. The windows project above the roof level. They admit light either through vertical faces or inclined faces.

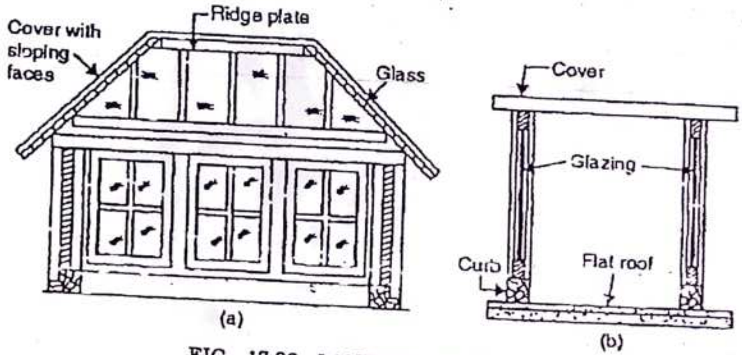


FIG. 17.36. LANTERN WINDOWS.

15. Sky lights

A sky light is provided on a sloping roof, to admit light. The window projects above the sloping surface. The common rafters are suitably trimmed and the sky light is erected on a curb frame

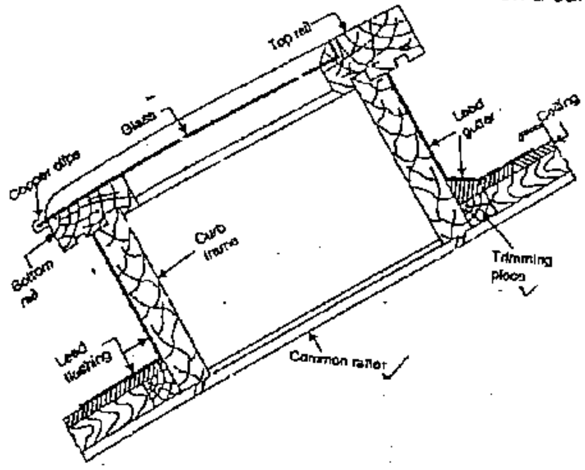


FIG. 17.37. SKY LIGHT.

16. Ventilators

Ventilators are small windows, fixed at the height than windows, the ventilator has a frame and a shutter generally glazed which horizontally pivoted. The shutters can open or closed by means of two chords. The top edge of the shutter should open inside to exclude the rain water. Sometimes ventilators may also be provided in continuation of a window or a door at its top. Such a ventilator is also known as fan light.

Types of ventilators:

1) Side hung ventilator⇒

2) Bottom hung ventilator⇒

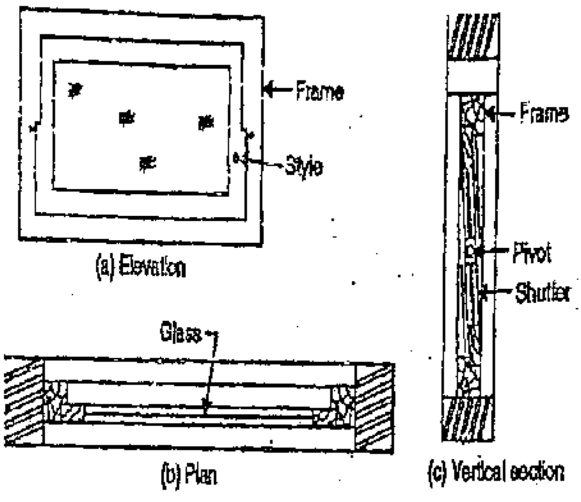


FIG: 17.38. VENTILATOR.

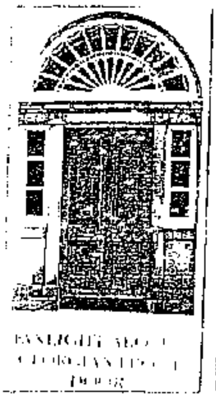
3) Horizontally pivoted ventilator⇒

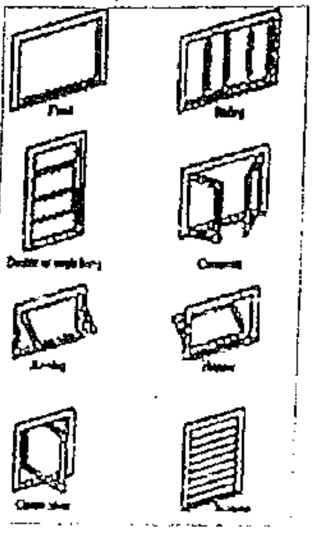
4) Top hung⇒

5) Vertical pivoted⇒

6) Vertical sliding⇒

7) Ventilators combined with doors (Fan light) ⇒





8) Ventilators combined with windows ⇒

Types of windows and ventilators may also be classified in three categories according to use construction materials:

1. Timber
2. Steel
3. Aluminium

Process of fixing of door and windows:

1. Fixing of door and window frames in openings may be done simultaneously at the time of wall construction or later on after completing masonry work in wall.
2. Holdfast of required numbers are nailed before setting frame to position.
3. Frame is carried to position and set with the help of ropes and poles.
4. The frame is then put to plumb (the frame should be perfectly vertical).
5. Once the frame is set and levelled, the hoidfasts are fixed in wall with cement concrete
6. Final checking of plumb is done, if required corrections are done.

Single and double glazed windows:

- The window frame with glass is called glazed section.
- If the layer of glass is single, it is single-glazing and the section with double layer of glass is double-glazing.
- Single glazed is the general practice in our locality.
- Double glazed is done for special purpose, such as insulaton of heat and sound.
- Almost all doors and windows are double glazed in Europe and other cold region. This is not familiar in our Himalayan region.
- Double glazed is worth-some in hot and dry region as well.

4.4 Hardware for doors, windows and ventilators

The following types of fixtures and fastenings are required for doors, windows and ventilators:

1. Hinges
2. Bolts
3. Handles
4. Locks

1. Hinges: Types of hinges are as shown in figure below

(a) Back flap hinge (Fig 17.40 a): These hinges are used where the shutters are thin. These are fixed to the backside of the shutter and the frame, hence the name.

(b) Butt hinge (Fig 17.40 b): These are commonly used for fixing door and window shutters to the frame. The flanges of hinge are made of cast iron, malleable iron or steel, with counter sunk holes. One flange of hinge is screwed to the edge of the shutter while other is screwed to the rebate of the frame.

(c) Counter flap hinge (Fig 17.40 c): This hinge is formed in three parts and has two centres. Hence the two leaves can be folded back to back.

(d) Garnet hinge (Fig 17.40 d): This type of hinge, also known as T-shutter, has a long arm which is screwed to the shutter, and a short arm or plate which is screwed to the door frame. This hinge is used for ledged and battened doors, ledged and braced doors etc.

(e) Nar-madi hinge (Fig 17.40 e): This hinge is used for heavy doors. The flange or strap of the hinge is fixed to the door shutter while the pin on which the strap rotates is fixed to the frame.

(f) Parliamentary hinge (Fig 17.40 f): Theses hinges permit the door shutters, when open, to rest parallel to the wall. Hence, these hinges are used when the opening is narrow and when it is required to keep the opening free from obstruction due to door shutter

(g) Pin hinge (Fig 17.40 g): This hinge is used for heavy door shutters. The centre pin of the hinge can be removed and the two leaves straps of the hinge can be fixed separately to the frame and the shutter.

(h) Rising butt hinge (Fig 17.40 h): This hinge is provided with helical nickel joints, due to which the shutter is raised by 10 mm on being opened. The door is closed automatically. Such hinges are used for doors of rooms having carpets etc. They are used in place of ordinary butt hinge.

(i) **Strap hinge (Fig 17.40 i):** This hinge is a substitute of garnet or T-hinge. It is also used for ledged and braced doors, and for heavy doors such as for garages, stables, gate etc.

(j) **Spring hinges (Fig 17.40 j and k):** Single acting or double acting spring hinges are used for swinging doors. Single acting hinge is used when the door shutter opens only in one direction, while the double acting hinge is used when the shutter swings only in both directions. The door closes automatically due to spring action.

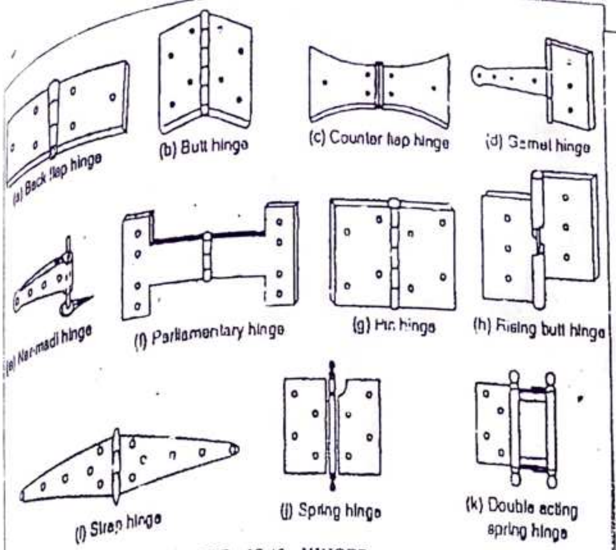


FIG. 17.40. HINGES.

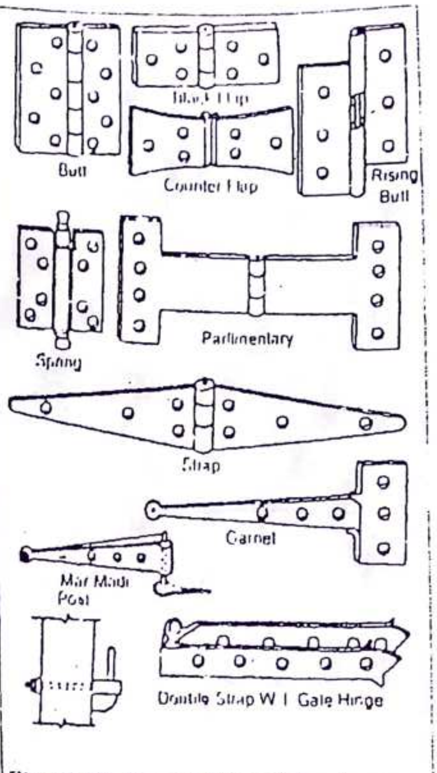


Fig. 18.29. *Various types of door hinges.*

2. Bolts: Different type of bolts commonly used for door and window are as follows:

(a) **Aldrop (Fig. 17.41 a):** It is fixed on external doors where pad locks are to be used.

(b) **Barrel bolt (Fig. 17.41 b):** It is used for fixing back faces of doors. The socket is fixed to the door frame while plate is screwed to the inside of the shutter.

(c) **Espagnolette bolt (Fig. 17.41 c).** This is used for securing high doors and and casement windows, the top of which cannot be easily reached.

(d) **Flush bolt (Fig. 17.41 d):** It is used when it is desired to keep the bolts flush with the face of the door.

(e) **Hasp and staple bolt Fig. 17.41 e):** It is also used for external door where padlock is to be used. The staple is fixed to the door frame, while the hasp is fixed to the shutter.

(f) **Latch (Fig. 17.41 f):** It is made of malleable iron or bronze. It consists of lever pivoted at one end, which can be actuated by a trigger passing through the shutter; the lever is secured in a hasp and staple. It is fixed to the inside face of the door.

(g) **Hook and eye (Fig. 17.41 g):** It is used for keeping the window shutter in position when the window is open. The hook is fixed to the sill of the frame while the eye is filed to the bottom rail of the shutter.

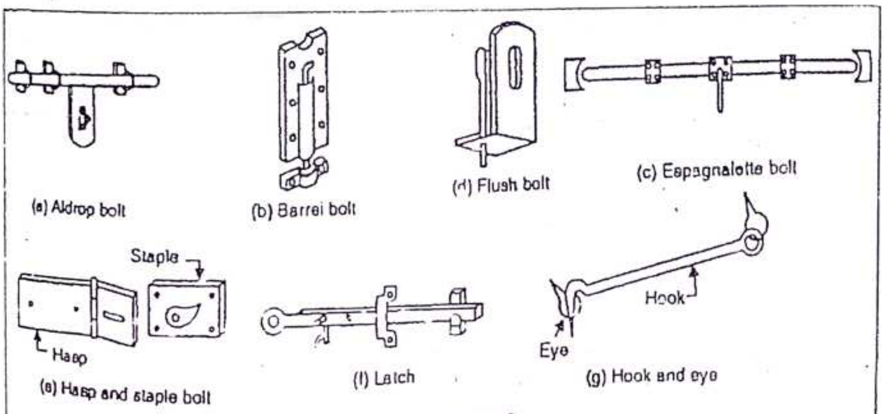


FIG. 17.41. BOLTS.

3. Handles (Fig. 17.42): Handles are manufactured in a variety of designs. Some of the commonly used door handles are shown in Fig. 17.42 (a, b, c, d, e, f, g, h).

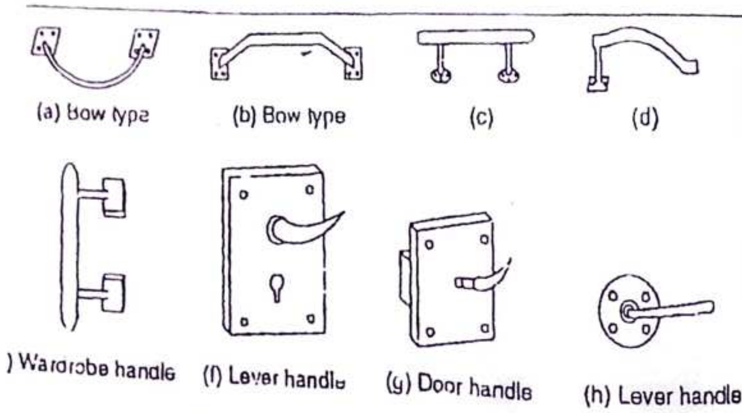


FIG. 17.42. DOOR HANDLES.

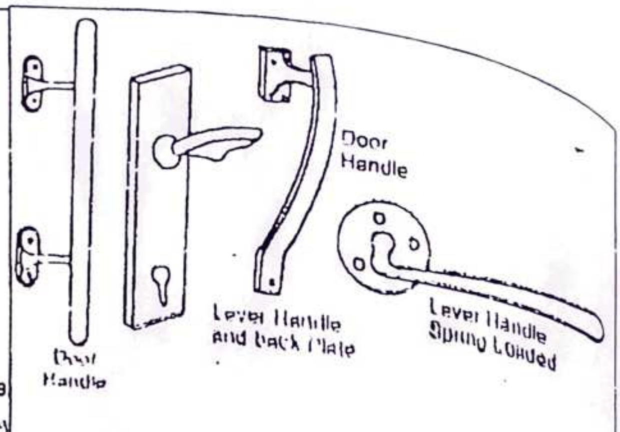
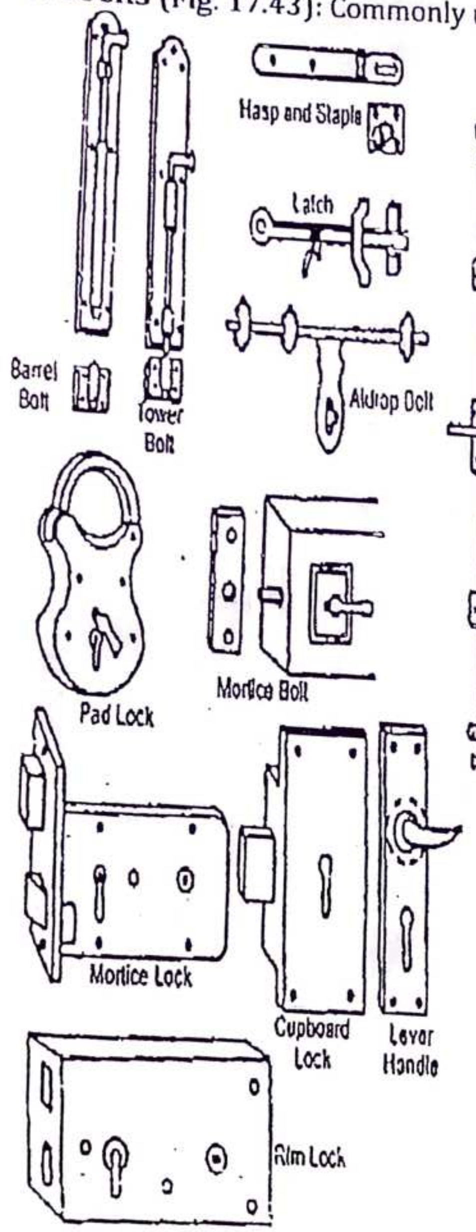
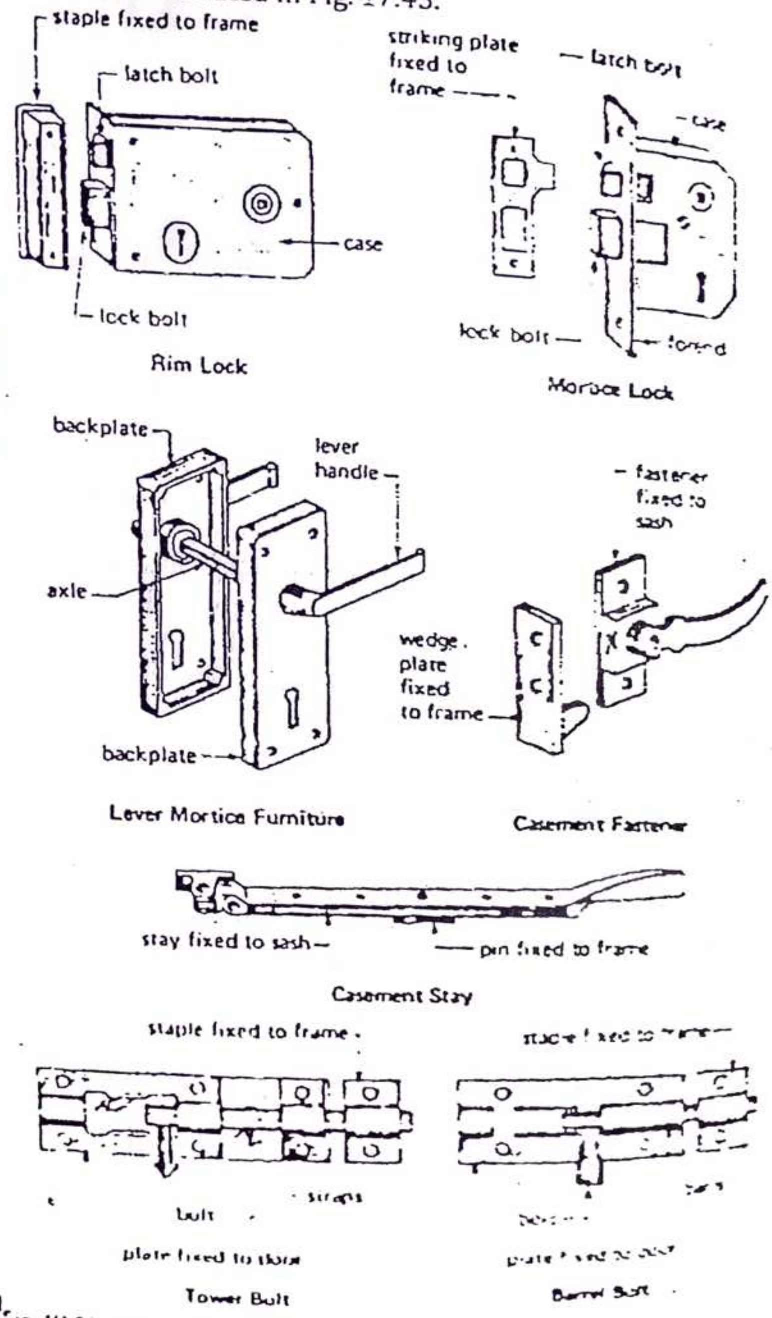


Fig. 18.51. *Various types of handles.*

4. Locks (Fig. 17.43): Commonly used locks are illustrated in Fig. 17.43.





1. *Various types of bolts, staples, latches, aldrops a...*

Fig. 18.29 Door and window ironmongery

4.5 Arch and lintel:

Arch: An arch is a structure constructed of wedge-shaped units (brick or stone) called 'voussoirs' which are designed and jointed together with mortar to support each other and carry the load over the opening, round a curved profile, to abutments on either side. An exception to this form is the flat or 'soldier' arch constructed of brick laid on end or on edge. When constructing an arch it must be given temporary support until the brick joints have set and the arch has gained sufficient strength to support itself and carry the load over the opening. These temporary supports are called centres and are usually made of timber; their design is governed by the span, load and thickness of the arch to be constructed.

Arches are generally provided when:

(a) Loads are heavy
(b) Span is more
(c) Strong abutment are available and
(d) Special architectural appearance is required.

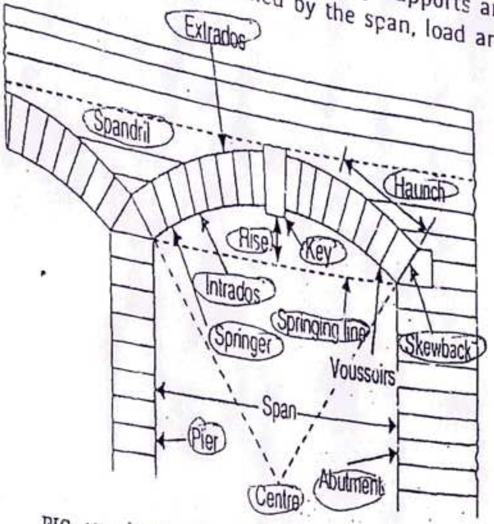


FIG 13.15. ELEMENTS OF A SEGMENTAL ARCH

Technical terms used in arch:

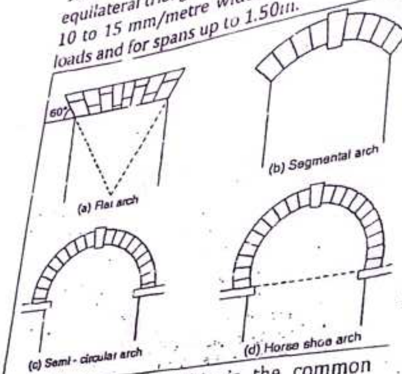
1) **Intrados:** This is the inner curve of an arch.
2) **Soffit:** It is the inner surface of an arch. Sometimes, intrados and soffit are used synonymously.
3) **Extrados:** It is the outer curve of an arch.
4) **Voussoirs:** These are wedge-shaped units of masonry, forming an arch.
5) **Crown:** It is the highest part of extrados.
6) **Key:** It is the wedge-shaped unit fixed at the crown of the arch.
7) **Spandril:** This is a curved-triangular space formed between the extrados and the horizontal line through the crown.
8) **Skew back:** This is the inclined or splayed surface on the abutment, which is so prepared to receive the arch and from which the arch springs.
9) **Springing points:** These are the points from which the curve of the arch springs.
10) **Springing line:** It is an imaginary line joining the springing points of either end.
11) **Springer:** It is the first voussoir at springing level, it is immediately adjacent to the skewback.
12) **Abutment:** This is the end support of an arch.
13) **Pier:** this an intermediate support of an arcade.
14) **Arcade:** It is a row of arches in continuation.
15) **Haunch:** It is the lower half of the arch between the crown and skew back.
16) **Ring:** It is a circular course forming an arch. An arch may be made of one ring or more than one ring.
17) **Impost:** It is the projecting course at the upper part of a pier or abutment to stress the springing line.
18) **Bed joints:** These are the joints between the voussoirs which radiate from the centre.
19) **Centre or striking point:** This is the geometrical centre point from where the arcs forming the extrados, arch rings and intrados are described or struck.
20) **Span:** It is the clear horizontal distance between the supports.
21) **Rise:** It is the clear vertical distance between the highest point on the intrados and springing line.
22) **Depth or height:** It is the perpendicular distance between the intrados and extrados.
23) **Thickness (or breadth of soffit):** This is the horizontal distance, measured perpendicular to the front and back faces of an arch.

Classification of arches: Arches may be may be classified according to:

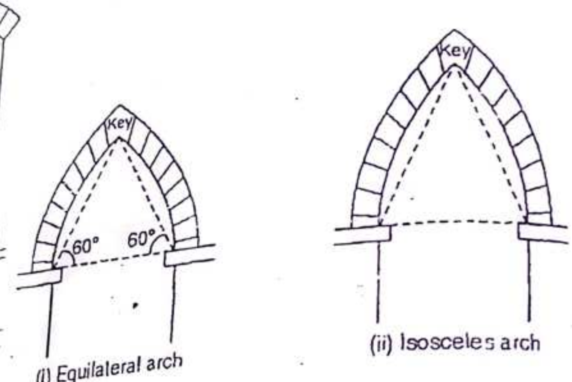
(i) Shape (ii) Numbers of centres,
(iii) Workmanship and (iv) Materials of construction

(i) Classification of arches according to shape:

1. **Flat Arch:** It has usually the angle formed by skewbacks as 60° with horizontal, thus forming an equilateral triangle with intrados as the base. The intrados is given slightly rise of camber of about 10 to 15 mm/metre width of opening allow small settlements. Flat arch are used only for light loads and for spans up to 1.50m.



2. **Segmental Arch:** This is the common type of arch of which the centre of arch lies below the springing line. The thrust transferred to the abutment is an inclined direction.



(e) Pointed arches

3. **Semi-circular Arch:** This is modification of semi-circular arch in which the centres lie on the springing line and the shape is of a semi-circle. The thrust transferred to the abutment is perfectly in vertical direction since the skew back is perfectly horizontal.

4. **Horse Show Arch:** The arch has the shape of horse shoe, incorporating more than a semi-circle. It is provided for from architectural considerations.

5. **Pointed Arches:** This is also known as Gothic arch which consists of two arcs of circles meeting at apex. The triangle formed may be equilateral or isosceles. If the triangle formed is isosceles then the arch is known as *Lancet arch.*

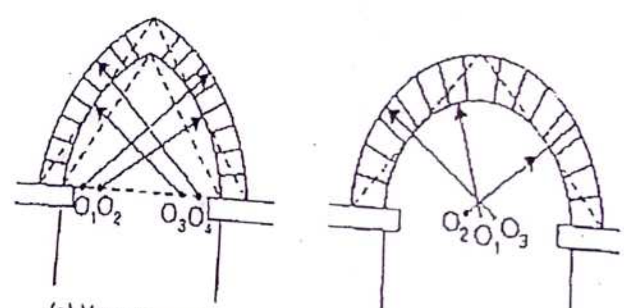
6. **Venetian Arch:** This is another form of pointed arch which has deeper depth at crown than at springings. It has four centres, all located on the springing line.

7. **Florentine Arches:** This is similar to Venetian Arch except that the intrados is semicircle. The arch has thus three centres all located on springing line.

8. **Relieving Arch:** This arch is contructed either on flat arch or on a wooden lintel to provide greater strength. The ends of the relieving arch should be carried sufficiently in to the abutments. The relieving arch makes it possible to replace the decayed lintel later, without disturbing the stability of the structure.

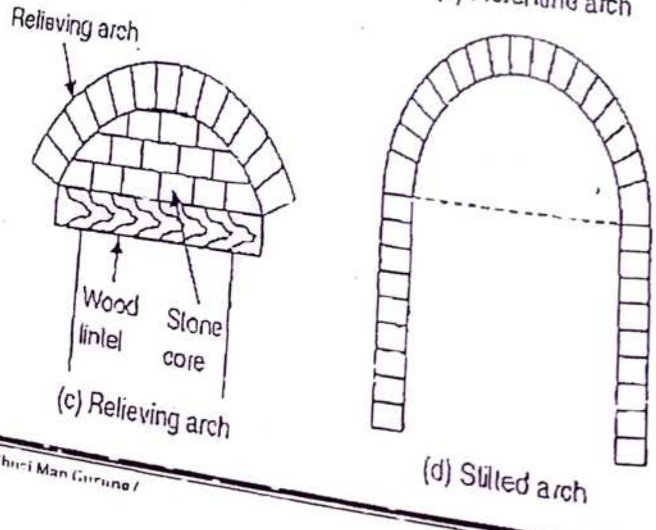
9. **Stilted Arch:** This consists of a semi-circular arch with two vertical portions at the springings. The centre of the arch lies on the horizontal line through the top of the vertical portion.

10. **Semi-Elliptical Arch:** This type of arch has the shape of a semi-ellipse and may have either three or five centres.



(a) Venetion arch

(b) Florentine arch



(c) Relieving arch

(d) Stilted arch

(ii) Classification of arches based on numbers of centres:

1. One-centred Arches: Segmental arches, semi-circular arches, flat arches, horse shoe-arch and stilted arches come under this type of arches. Sometimes a perfectly circular arch, known as Bull's eye arch is also provided for circular windows as shown in figure-13.18 below.

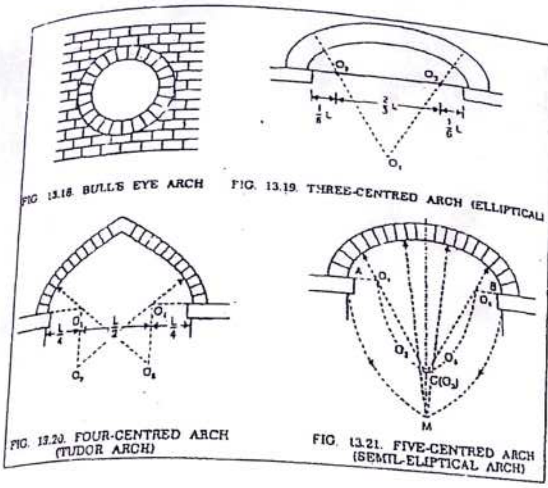


FIG. 13.18. BULL'S EYE ARCH

FIG. 13.19. THREE-CENTRED ARCH (ELLIPTICAL)

FIG. 13.20. FOUR-CENTRED ARCH (TUDOR ARCH)

FIG. 13.21. FIVE-CENTRED ARCH (SEMI-ELLIPTICAL ARCH)

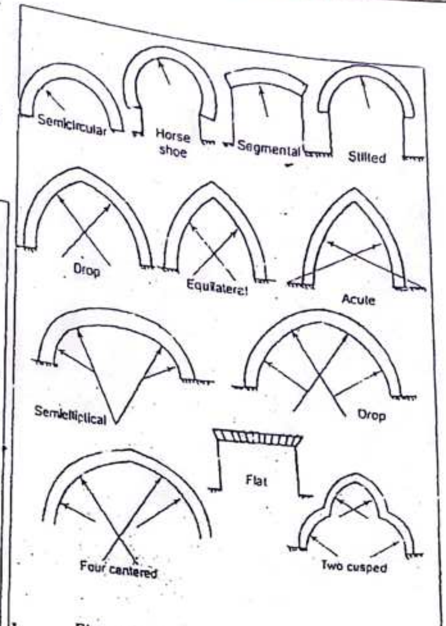


Fig. 13.6. *Various types of arches.*

2. Two-centred Arches: Pointed arches like Semi-elliptical arch and Florentine arch come under this type of arches.

3. Three-centred Arches: Elliptical arch come under this type of arch as shown in Fig 13.19

4. Four-centred Arches: Venetian arch and Tudor arches come under this type of arches. As shown in figure-13.20 above.

5. Five-centred Arches: This type of arch has an attractive semi-elliptical shape with five centres as shown in fig-13.21 above.

(iii) Classification of arches based on material and workmanship:

1. **Stone Arches:** (i) Rubble arch (ii) Ashlar arch
2. **Brick Arches:** (i) Rough brick arch (ii) Axed or rough-cut brick arch (iii) Gauged arch (iv) Purpose made brick arch
3. **Concrete Arches:** (i) Concrete block unit arch (ii) Monolithic arch

1. Stone Arches:

(i) **Rubble arch** is constructed of hammer dressed rubble stones roughly shaped and sized of voussoirs of the arch and fixed in cement mortar. The span of arch used is up to 1.00 m.

(ii) **Ashlar Arches:** The stones are cut to proper shape of voussiors, and are fully dressed which is set in cement mortar. Up to depth of 60 cm, the voussirs are made of full thickness of the arch. The fig-13.22(d) shows the alternative arrangement of voussiors.

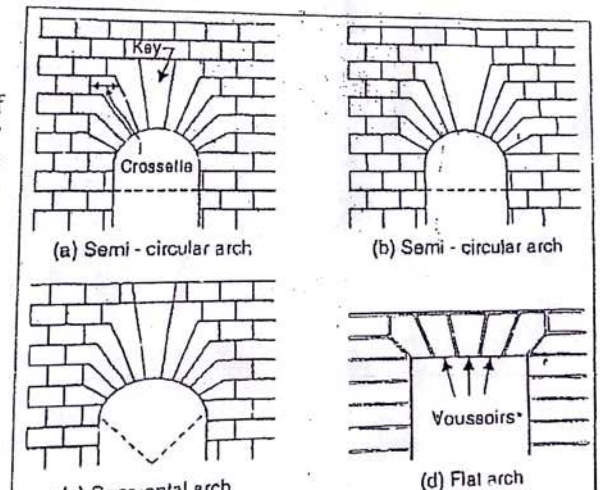


FIG. 13.22. ASHLAR STONE ARCHES.

Ashler stones can also be used to make flat arches, in which the joints are either joggled or rebated as shown in fig-13.23

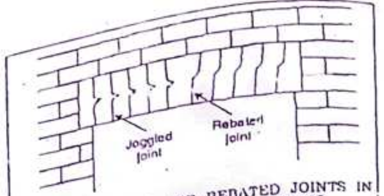


FIG. 13.23. JOGGLED AND REBATED JOINTS IN FLAT ARCH OF ASHLAR STONES

(iv)Depending upon the nature of workmanship and quality of bricks, they are categorised as:

2. Brick Arches

(i) Rough brick Arches: They are constructed with ordinary bricks, without cutting bricks to the shape of voussirs. The joints are made of wedge-shaped, with greater thickness at the extrados and smaller thickness in intrados. Due to this the appearance of arch is spoiled so this type of arch is not used for exposed brick work.

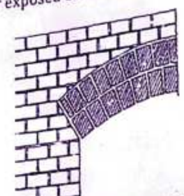


FIG. 13.24. SEGMENTAL ROUGH BRICK ARCH

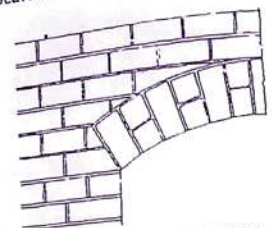
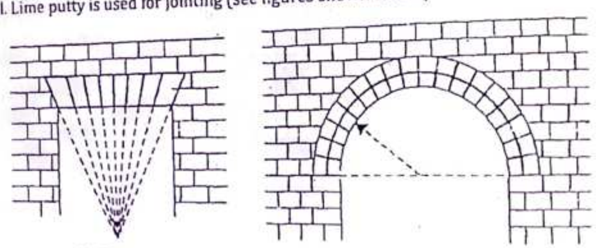


FIG 13.25. AXED BRICK ARCH.

(ii) Axed Brick Arch: This type of brick arch is constructed of bricks which are cut wedge-shaped with help o brick axe. Due to this the joints are uniform thickness along the redial lines. The appurtenance of the arch is not very pleasant because the bricks cut to wedge-shapes are not finely dressed

(iii) Gauged Brick Arch: This type of brick arch is constructed of bricks which are prepared to exact size and shape of voussiors by cutting it by means of wire saw. For this, only soft bricks (called rubber bricks) are used. The joints formed in gauged bricks are fine, thin (1 to 1.5 mm) and truly redial. Lime putty is used for jointing (see figures shown below).



(a) Flat arch (b) Semi-circular arch

FIG. 13.26. GAUGED BRICKS ARCHES.

(iv) Purpose made brick Arch: In this type of brick arch, the bricks are purposefully manufactured matching with the exact shape and size of voussiors, to get a very fine workmanship. Lime putty is used for jointing.

3. ... and (ii) Monolithic concrete arches

(i) Pre-cast Concrete Block arches:

Such arches are constructed from precast concrete blocks which are casted in the mould to the exact shape and size of voussiors. Joints made of cement mortar are quite thin. Cement concrete of 1:2:4 mixes is usually used for casting blocks. It is costly to cast concrete blocks and is economical only when the number of arches to be constructed is very large.

(ii) Monolithic Concrete Arches:

Such types of arches are constructed from cast-in-situ concrete, either plain or reinforced, depending upon the span and magnitude of loading. Such arches are suitable for larger spans. The arch thickness is 15 cm for span up to 3.00 m. Form work is used for casting the arch and is removed after the concrete has sufficiently hardened and gain strength. The curing is done for 2 to 4 weeks.

Construction procedure of arch:

Construction procedure of any type of arches is completed in three steps:

(i) Installation of centering or form work:

- Centering is the form work for construction of arch and the upper surface of the centering should correspond with the intrados of the arch while centering is installed.
- For minor works, centering may be made of mud masonry constructed to match with the inner soffit of the arch and then plastered.
- For wider soffits and large spans, timber or steel centering is used.

(ii) Laying of arch:

- After installation of centering, skewbacks are first prepared and then voussiors are arranged in proper and required forms, starting from skewbacks and proceeding towards the crown.
- Finally key-stone (or key brick) is inserted so that all voussiors are locked in position.
- After placing key stone and all the voussiors are properly bedded, the center or turning piece is eased by slackening the wedges so that it is lowered by a height of 2 to 3 mm.
- This process is essential to permit the voussiors to settle upon their beds properly which is essential requirement in stone arches.

(iii) Removal of centering:

- The centering is removed when the arch gains sufficient strength.
- For small spans removal of centering is done by loosening the folding wedges
- For larger spans (> 7.00 m), sand box method can be used for loosening, so that socks are avoided.
- A sand box, shown in figure-13.30 below is placed below the prop in which sand is filed in box with a plugged hole at its bottom.
- Prop rests on the steel plate placed on the top of sand.

4) Lintels

A lintel is a horizontal structural member designed to support the loads of the portion of the wall situated above the openings, and then transmit the load to the adjacent wall portion over which it is supported. Lintel acts as a beam and its width is made equal to the width of wall and each end is expanded beyond the edge of opening known as bearing. The bearing should be minimum of the following.
(i) 10cm
(ii) Height of lintel
(iii) $1/10^{th}$ to $1/12^{th}$ of the span of the lintel

Purpose of lintel.

The purposes of lintel are

i. To act like a bridge over the openings like door, window, etc.
ii. To transmit load of wall above the openings to the adjacent wall portion over which they are supported.
iii. When it is provided throughout the length of wall, it also acts like a sill band.
iv. To left openings invariably in wall for the provision of door, window, cup boards etc.

Types of lintel: Depending upon the materials of their construction, lintels are of following types

1) Timber lintels
2) Brick lintels
3) Stone lintels
4) Reinforced brick lintels
5) Steel lintels
6) Reinforced cement concrete lintels
7) R.C.C. boot lintels

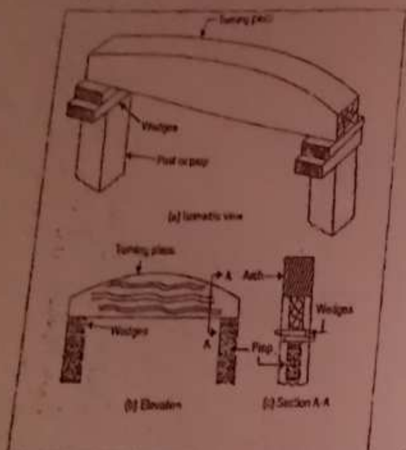


FIG. 13.27. TIMBER CENTERING FOR 10 CM WIDE SOFFITS

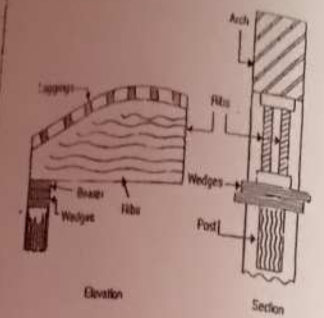


FIG. 13.28. TIMBER CENTERING FOR WIDER SOFFITS

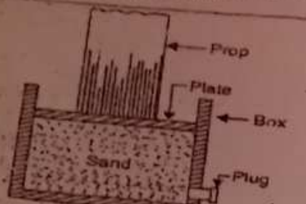


FIG. 13.30 SAND BOX METHOD

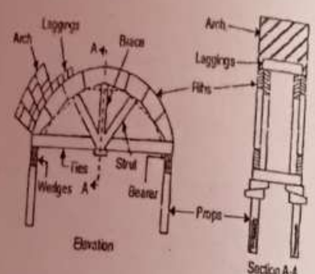


FIG. 13.29. CENTERING FOR WIDE SOFFITS AND BIGGER SPANS

(1) Timber lintels

Timber lintels are oldest types of lintels; through they are not commonly used now-a-days except in villages. Such type of lintels is relatively costlier, structurally weak, and vulnerable to fire. They are also liable to decay if not properly ventilated. Wooden lintels may be either of single pieces of timber or built up of two or more pieces held tighter by bolts at suitable intervals.

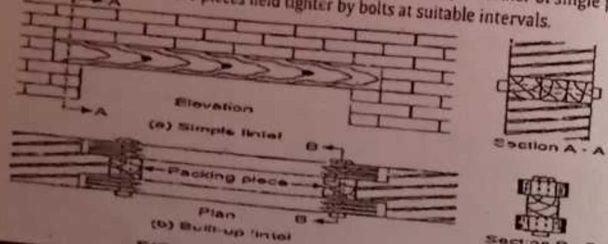


FIG. 13.1. WOODEN LINTEL

(2) Brick lintels

Brick lintels are structurally strong and they are used only when the opening is small (< 1.00 m) and loads are light. A brick lintel consists of bricks placed on end or edge as shown in figure below (i) and (ii). The depth of brick lintel varies from 10 cm to 20 cm, depending upon the span. It is constructed over temporary wooden centering. The bricks with frogs are more suitable for the construction of lintel since frogs when filled with mortar, form joggles which increases the shear resistance of end joints. Such lintels are known as joggled brick lintel

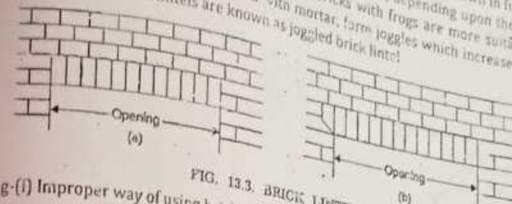


FIG. 13.3. BRICK LINTELS

Fig-(i) Improper way of using brick lintel   Fig-(ii) Proper way of using brick lintel

(3) Stone lintels

Stone lintels are the most common types specially where stone is abundantly available. A stone lintel consists of a simple stone slab of greater thickness. Stone lintels can also be provided over openings in brick wall. Dressed stone lintels give good architectural appearance. Stone lintels may be used in the form of either one piece or more than one piece along the width of the wall. The depth of stone lintel is kept equal to 10 cm /m of span with a minimum of 15 cm. They are used up to spans of 2.00 m, for wider span, stone slabs are kept on edge. Stone is very weak in tension. Also it cracks, if subjected to vibratory loads. Hence, stone lintels should be used with caution where shock waves are quite common.

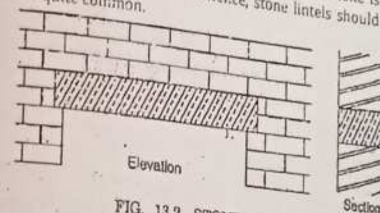


FIG. 13.2. STONE LINTEL

(4) Reinforced brick lintels

When loads are heavy, or span is more, lintels may be made of reinforced brick work. The depth of such lintel is kept equal to 10cm, or in multiple of 10cm i.e. multiple of width of brick. Sometimes, a 15cm thick brick lintel may be obtained by using 5cm thick tiles in conjunction with 10cm thick brick or brick on edge can be used.

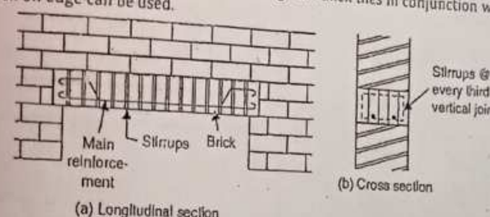


FIG. 13.4. REINFORCED BRICK LINTEL

The bricks are so arranged that 2 to 3cm wide space is left length wise between adjacent bricks or the insertion of reinforcement. The gap is filled with 1:3 cement mortars. Vertical stirrups of 6mm dia. wire are provided in every third vertical joint. Main bar used is 8 to 10mm dia. and is cranked at the ends.

(5) Steel lintels

Steel lintels are provided when the span is large and where the super imposed loads are heavy. It consists of rolled steel joists or channel sections either used singly or in combination of two or three units. When used singly, the steel joists are either embedded in concrete, or cladded with stone facing. So as to increasés its width to match with the width of the wall. When more than one unit is placed side by side, they are kept in position by tube separators.

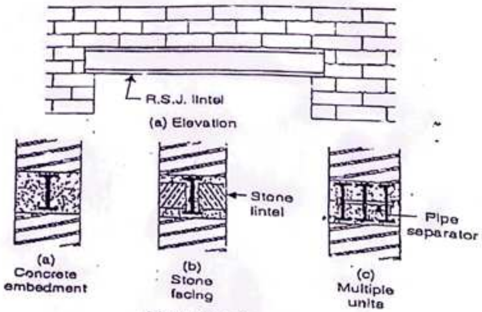


FIG. 13.5. STEEL LINTELS.

(6) Reinforced Cement Concrete lintels (R.C.C lintels)

R.C.C lintel possesses higher strength, rigidity, fire resistance, lesser economy and ease in construction. Thus, they are extensively used now-a-days. These can be used in any span. Its width is kept equal to the width of the wall. The depth depends upon the span and magnitude of loading. Longitudinal bars are kept near the bottom of lintel in order to take the tensile stresses. Shear stirrups are provided to resist transverse shear.

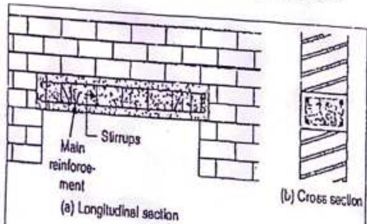


FIG. 13.6. R.C.C. LINTEL.

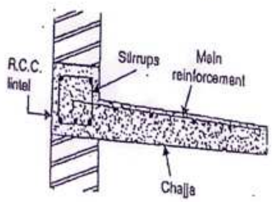


FIG. 13.7. R.C.C. LINTEL WITH CHHAJJA PROJECTION.

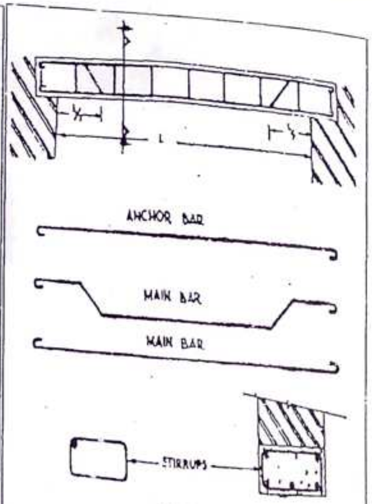
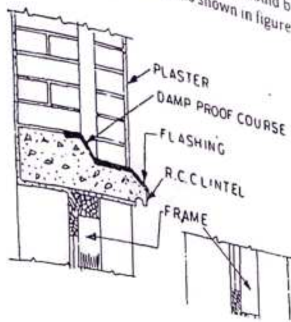


Fig. 15.3. SECTION 'AA'

Details of a Reinforced concrete lintel

(7) R.C.C. boot lintels

R.C.C. boot lintels are provided over cavity walls. Such a lintel gives better appearance and reduces quantity of concrete. However, the toe section of the boot lintel should be strong enough to sustain the loads. A flexible D.P.C. is provided above the lintel as shown in figure below



Chapter – 5: JOINTS

- The word 'joint' is used in building phrasing to cover elements which have to perform quite different functions, e.g. beam-column joints and isolation joints.
- In the former the joint has to provide continuity of structural action between the members meeting at the joint.
- In the latter the joint has to ensure separation between the adjacent members to allow one member to move independently of the other.
- The magnitude of expansion or contraction of all construction materials depend upon the type of material used and the extent of variation in temperature and moisture content.
- Due to this, the special provisions should be made to control or isolate thermal and other movements to avoid danger to the structure.
- The control of expansion is achieved by breaking the continuity of a structure, by introducing joints at regular intervals. Such joints sub-divide the structure in to smaller units and also permit free movement of each unit.

Why joints are needed?

The four basic reasons for requiring joints are because:

- the member or structure cannot be constructed as a monolithic unit in one placement of concrete;
- the member has to be of limited size so it can be handled by cranes, etc.;
- the structure or member on one side of the joint needs to be able to move relative to that on the other;
- the design assumptions for the structure or building need the joint at that point so the analysis is simplified.

Functional requirements of joints:

Joints should be designed so that they fulfil the following requirements

1. Exclude wind, rain and snow.
2. Allow for structural, thermal and moisture movement.
3. Good durability
4. Easily maintained
5. Maintain the thermal and sound insulation properties of the surrounding cladding
6. Easily made or assembled

5.1 Type of joints

There are a number of ways in which joints can be classified apart from the broad division stated above. Joints in structure, according to they perform, can be categorised as follows:

1. Construction joints
2. Expansion joints
3. Isolation joints
4. Contraction joints
5. Sliding joints

1. Construction joints

- A construction joint is defined as 'the surface where two successive placements of concrete meet, across which it may be desirable to achieve bond and through which reinforcement may be continuous. Generally, because continuity of structural action will be required across the joint, bond will be desirable and the reinforcement will be continuous.
- Construction joints are joints formed by the interruption of concrete placements. Construction joints should be placed at locations planned for expansion or contraction joints.
- If it is possible to plan construction in such a way that the day's work end at an expansion or construction joint, the need for contraction joint will not arise.
- For structural stability, it is necessary to ensure that the construction joints are provided at pre-determined locations.

Factors to be kept in view while deciding the ... joints are as follows:

1. The construction joint should be located along or near the plane of minimum shear.
2. The joint may be vertical or horizontal as the case may be except that, in an inclined or curved member, the joint should be at right angle to the axis of the member.
3. As far as possible a key of tongues and groove type joint should be provided at all construction joints. The key is normally formed by fixing bevelled edged strip of wood to a stop-board. In case of large work sheet metal is used to permit repetitive use. The stop board has to be slotted to allow reinforcement to extend from the old concrete to the new one.
4. Prior to laying new concrete the stop board is removed and the face of the concrete that has already hardened is treated and prepared (if new concerting is done within 48 hours then it is cleaned with wire brush but if it is done after 48 hours then the face of old concrete is roughened by chiselling and cleaned with water, then cement slurry is applied before concreting)
5. For structural stability, it is necessary to ensure that the construction joints are provided at pre-determined locations.

Types of construction joints/Location of construction joints for Different Members (Important):

The recommended positions for construction joints in different structural components are as follows:

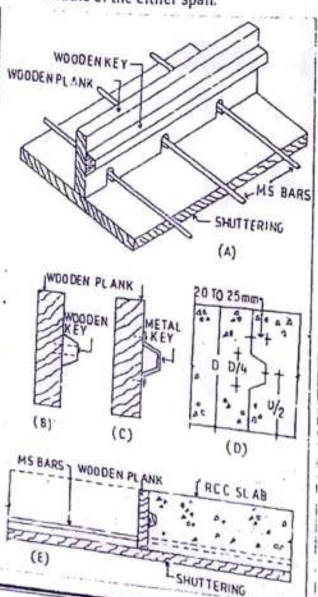
(i) Construction joints for slabs:

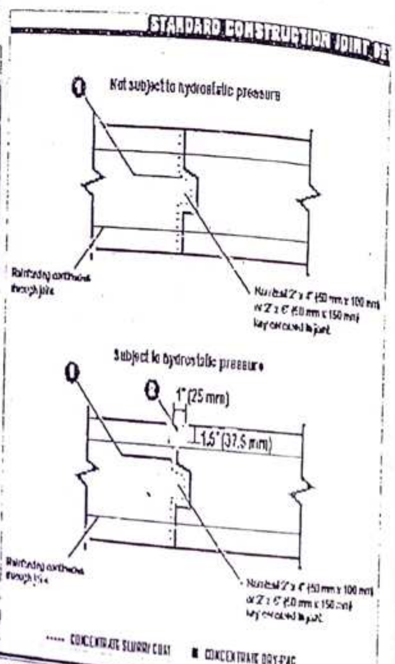
In case of slabs supported on two sides:

- The construction joint should be vertical and parallel to the main reinforcement at the middle of the span at right angles to main reinforcement.
- Alternatively, it can also be provided at the middle of span at right angles to main reinforcement.

In case of two way slabs:

- The joint can be provided near the middle of the either span.





(ii) Construction joints for Beams:

- Construction joints for beams should be located at the middle or within the middle third of span (perpendicularly to the main reinforcement at points of minimum shear) and it should be vertical.
- In case of L or T beams, the rib of the beam should be concreted along with the flange slab.
- In case, of long and deep beams the rib of the beam can be constructed up to 25 mm below the level of soffit of the slab and the construction joint located there.

(iii) Construction joints for columns:

- In case of columns, the construction joint should be formed horizontally by stopping the concrete in column about 75 mm below its junction with lowest soffit of the beam or bottom of hunching (if any).
- The operation of concreting above the construction joint should be taken up after a gap of at least 4 hours.

(iv) Construction joints for wall:

- The horizontal construction joint in wall should be located at the top of plinth, top or bottom of window opening or at any other convenient height.
- In case of concrete or R.C.C. walls, the location of horizontal construction joints is governed by the following factors.
  (a) Convenience in setting the formwork.
  (b) Ease of access for compaction and supervision of concreting.
- The continuity of the joint is achieved by the formation of key. The key is formed by use of bevelled edged planks on the inner face of wall shuttering as shown in Fig. 24.31 below. Prior to pouring concrete above the joints, bevelled edge planks are removed and the surface of old concrete is prepared in manner as described earlier.

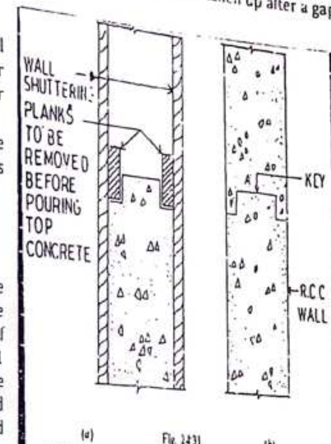


Fig. 24.31
(a) Details of planking for construction joint in wall
(b) Shape of joint after casting

2. Expansion joints

What is an expansion joint?

In building construction, an expansion joint is a mid-structure separation designed to relieve stress on building materials caused by building movement induced by:
- thermal expansion and contraction caused by temperature changes,
- sway caused by wind,
- seismic events, etc.

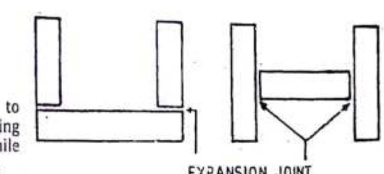


Fig. 24.1
Plans showing location of expansion joint in buildings of different shapes

Expansion joint systems are used to bridge the gap and restore building assembly functions while accommodating expected movements. The term "movement joint" has been widely adopted in preference to "expansion joint" as it more appropriately encompasses the fact that building movement results in both compression and expansion of the material installed.

Expansion joint systems are integral, yet often overlooked, components designed to accommodate cyclic movements. Expansion joints are provided to accommodate the expansoion of adjacent building parts and to relieve compressive stresses that may otherwise develop. Total expansion (I) of a structure can be obtained by the formula:

I = Co-efficient of linear expansion x length of the structure (in cm) x change of temperature in degree F = ...cm.

Based on this formula, it is seen that a structure 30.00 m long expands linearly by about 10mm, through a temperature change of 50°F.

Expansion joints:

- Not necessary for small and regular structures or buildings
- May require provision of one or more expansion joints when length of structure is > 45 m or if the structure changes direction for instance in L, T, H and U shaped structures.
- The recommended maximum centre to centre spacing of expansion joints 30.00m.
- There should be complete discontinuity of masonry, reinforcement or concrete at the joint and the gap should permit unobstructed movement of adjecent parts.
- Joint is formed by providing an initial gap between the adjecent building parts which gets widened or shortend while accomodating the constraction or expansion of the building.
- Materials used for expansion joints should provide neat appereance and serve good architectural fecture in the building.

Material used for Expansion joints

(i) Joint filler:

It is readily compressible material which can accommodate the expansion of adjecent parts of the joint and has ability to regain 75% of its original thickness when pressure is released. In addition it should be durable, resistant to decay (weathering, termites etc.) and regid enough to permit formation of straight joint. *Betumen, betumen containing cellular material, cork strinps, natural or cellular rubber, expanded plastic, mineral fibre, coconut, pith etc. are used as joint fillers.*

(ii) Sealing Compound:

The function of the sealing compound in a joit are to seal the joint against passage of moisture and to prevent the ingress of dust, grit or other fereign matter into the joint. It should be insoluble, non-toxic and tintless and should be reaily workable for placement in position. ***Mastic or hot-applied bitumenous sealing compound is commonly used for this purpose.***

(iii) Water bar:

The function of water bar is to seal the joint against passage of water. The water bar may be of:

(a) Natural and synthetic rubber, polyvinyl chloride (PVC) –

The rubber of PVC water bars are manufactured in a variety of different forms such as ***dumb bell type, centre bulb type etc.***

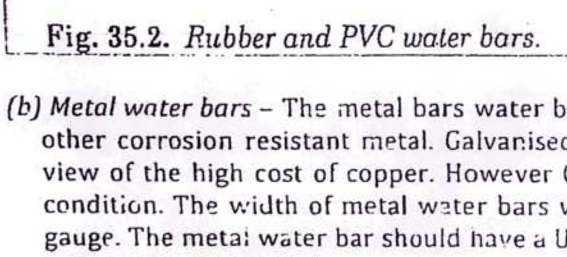


Fig. 35.2. *Rubber and PVC water bars.*

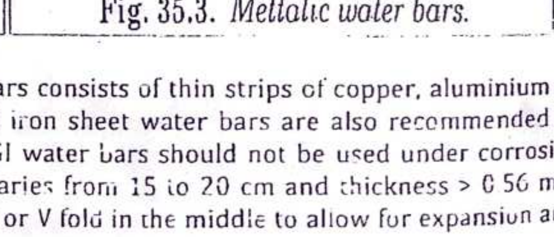


Fig. 35.3. *Mettalic water bars.*

(b) Metal water bars – The metal bars water bars consists of thin strips of copper, aluminium or other corrosion resistant metal. Galvanised iron sheet water bars are also recommended in view of the high cost of copper. However GI water bars should not be used under corrosive condition. The width of metal water bars varies from 15 to 20 cm and thickness > 0.56 mm gauge. The metal water bar should have a U or V fold in the middle to allow for expansion and contraction at the joint.

Types of expansion joints in building:
Expansion joints in roof level
Expansion joits in floor levels
Expansion joints in walls
Expansion joint in foundation

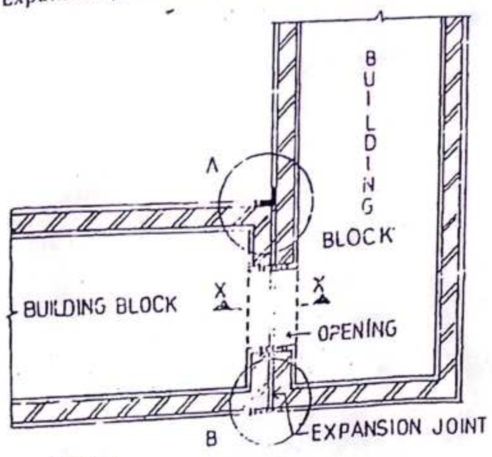


Fig. 24·4
Plan showing location of expansion joint between two building blocks

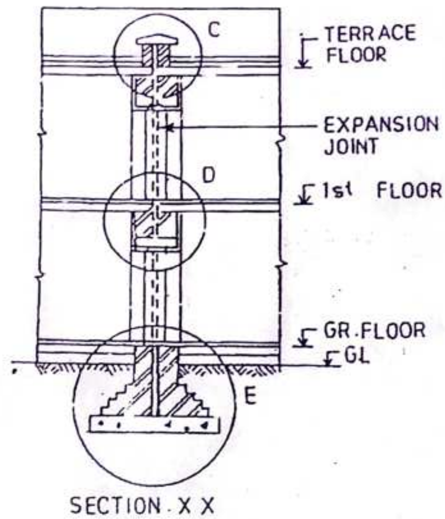


Fig. 24·5

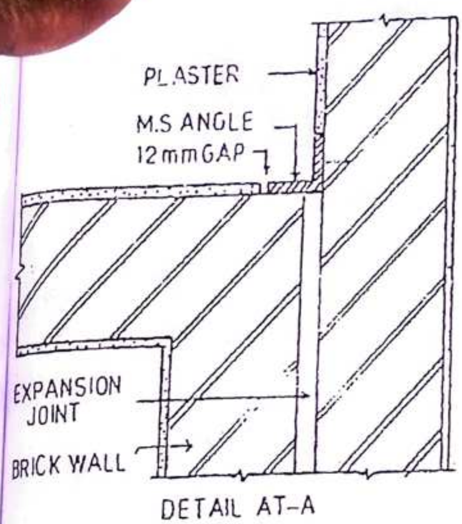


Fig. 24·6
ils of expansion joint between walls (For plan refer Fig. 24·4.

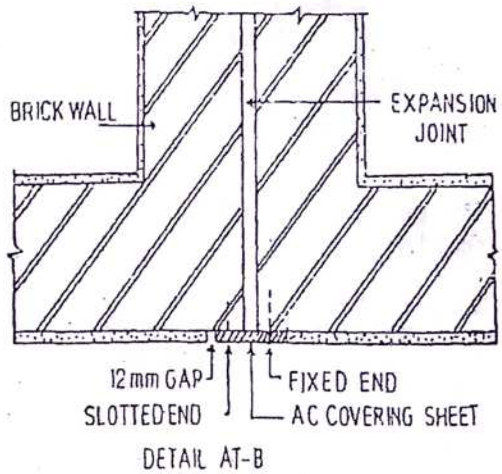


Fig. 24·7
Details of expansion joint between walls (For plan refer Fig. 24·4)

Plan shwoing location of expansion
joint between two building blocks

5.2 Treatment and detailing of joints in the roof level:

Treatment and detailing of joints in the roof level can be done in following steps:

(i) Provision of expansion joints in roof –

Expansion joints in roofs should invariably have a joint fillers and the waterbar to avoid leakage of water through the joint. The joints in floor of roof should be sealed to prevent rubbish accumulating therein (Refer to Fig. 24.8 and 24.9, Sushil Kumar).

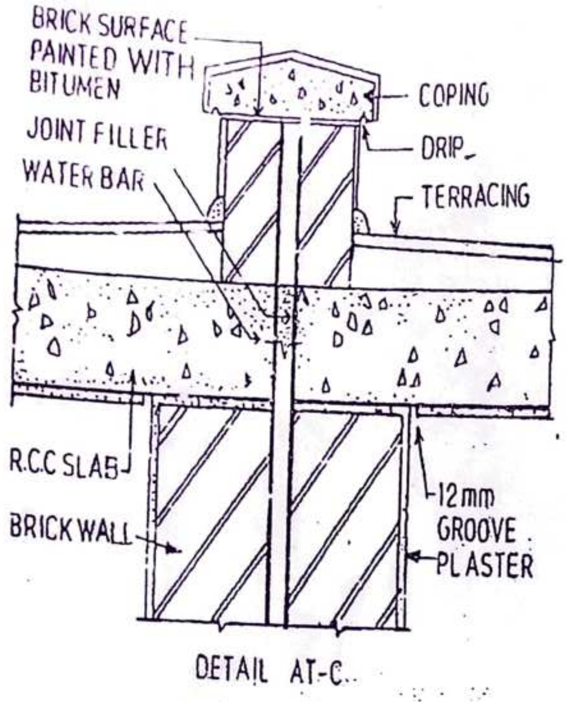


Fig. 24·8 Details of expansion joint at roof level (For section refer Fig. 24·5

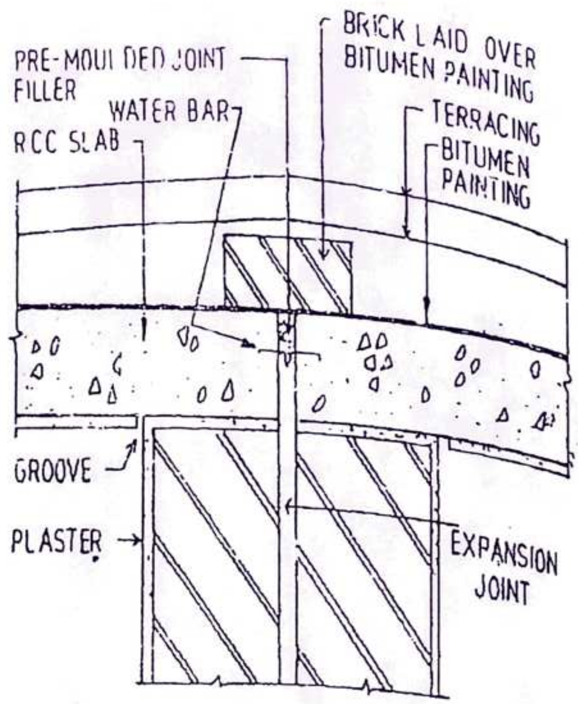


Fig. 24·9 Alternative method of treating expansion joint at roof level (Alternative detail at C)

(ii) Provision of expansion joints in Chajja bolconies etc. - In long chajjas, balconies and parapets etc. the expansion joints may be provided at center to center spacing of 6 to 12 m. The expansion joint in sunshade should be stopped at a distance of 5 cm from face of the wall where the slabe is embedded. The gap of the expasion joint in the chajjaslab should not be field with any material (For details refer to Fig. 24.12 and 24.13, Sushil Kumar).

iii) Provision of expansion joints in Verendah slab In case of covered verendah slab, the expansion joint may be spaced from 12 to 14 m c/c. the joints should not extend beyond the wall (5 cm from wall) and its gap should be sealed with water bar and sealing compound (refer to Fig. 24.14).⟹

To prevent cracks in masonry above or below the expansion joint, it is desirable to provide vertical butt joint inmasonry supporting supporting the verendah siab right from plinth level. In situation where it is not possible, RCC or plain concrete bed block should be provided in the masonery below the expansion joint in slab (for details refer Fig. 24.14 to 24.16 Sushil Kumar).

When verandah slab is to be cast at the same level and in contiuetion with the floor slab of the room, the percentage of distirbution reinforcement in the portion of the slab resting on the masonry should bwe increased to twice its normal amount.

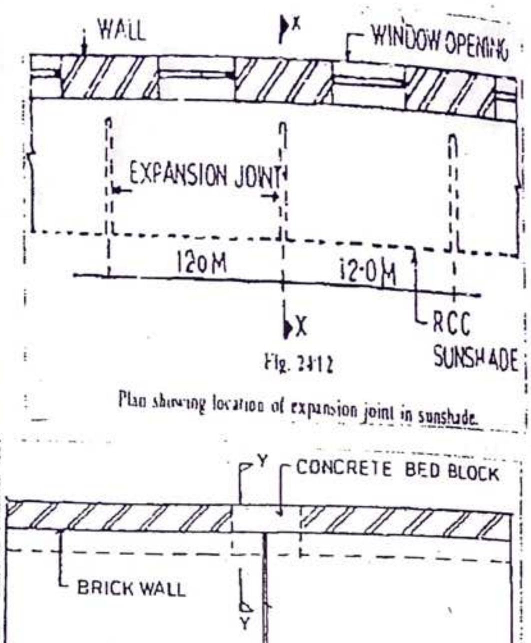


Fig. 24·12

Plan showing location of expansion joint in sunshade.

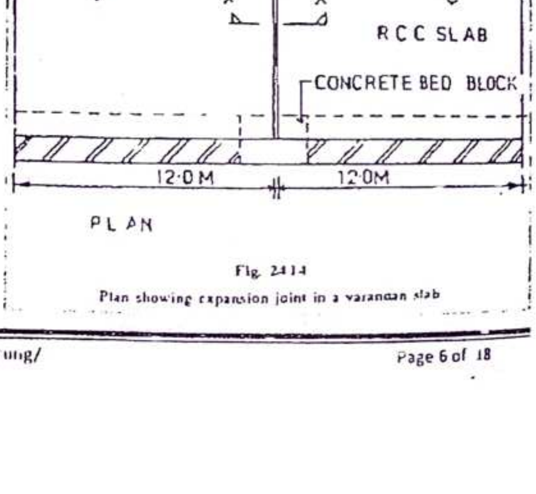
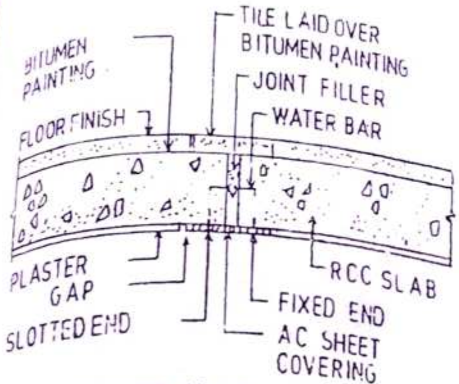
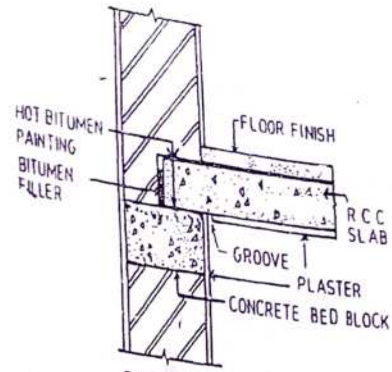


Fig. 24·14

Plan showing expansion joint in a varandah slab



SECTION AT X.X



SECTION AT-Y.Y

For verendah slab, the expansion joints may be provided as shown in figures above (For details of sections X-X & Y-Y refer to Fig 24.15 in plan)

Fig. 24.16
(For plan refer Fig. 24.14)

Provision of expansion joints in frame structures:

The treatment to be given to the joint is same as applicable to masonry construction as shown in Fig. 24.17 & Fig. 24.18, Fig. 24.19 below.

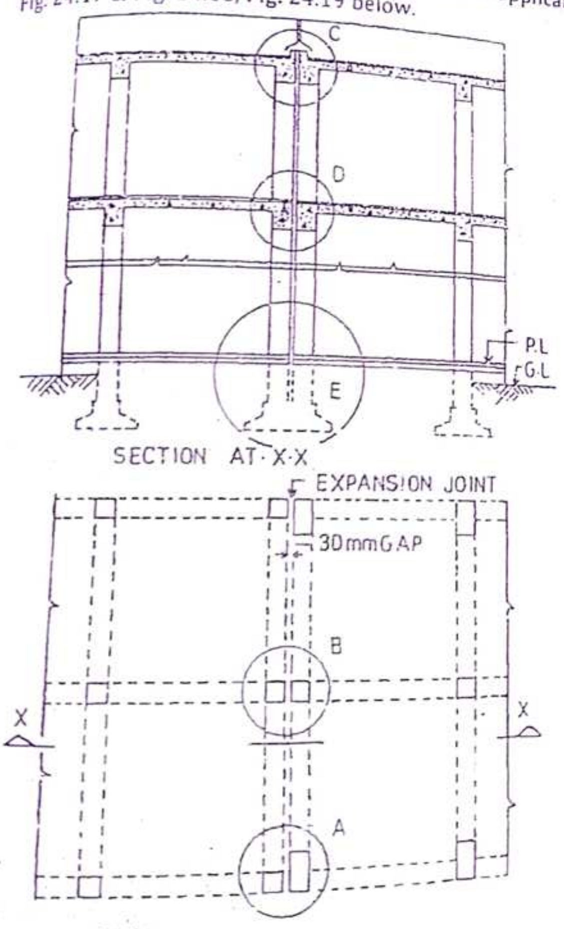
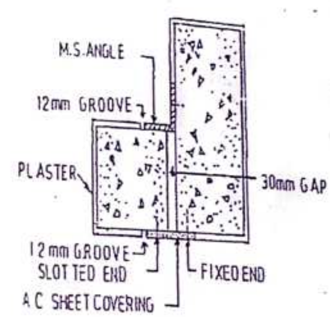
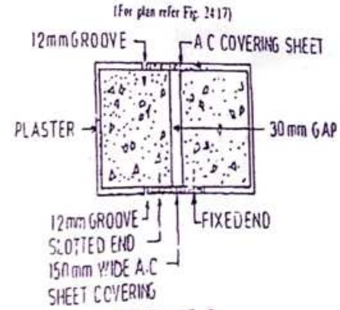


Fig. 24.17
Plan and section of a R.C.C. framed structure showing location at expansion joint



DETAIL AT-A

Fig. 24.18
Details of expansion joint between two columns
(For plan refer Fig. 24.17)



DETAIL AT- B

Fig. 24.19
...tails of expansion joint between two columns (For plan refer Fig. 24.17)

5.3 Treatment and detailing of joints in the floor level:

For provision of expansion joints in floor levels the expansion joints should have a joint fillers and the waterbars to avoid leakage of water through the joint. Joint in floor shall be invarably sealed to prevent accumulation of dirt, dust, therein. The joints in all floors (except ground flors) shouid be sealed with water bars as shown in Fig below (Refer to Fig. 24.10 and 24.11, Sushil Kumar).

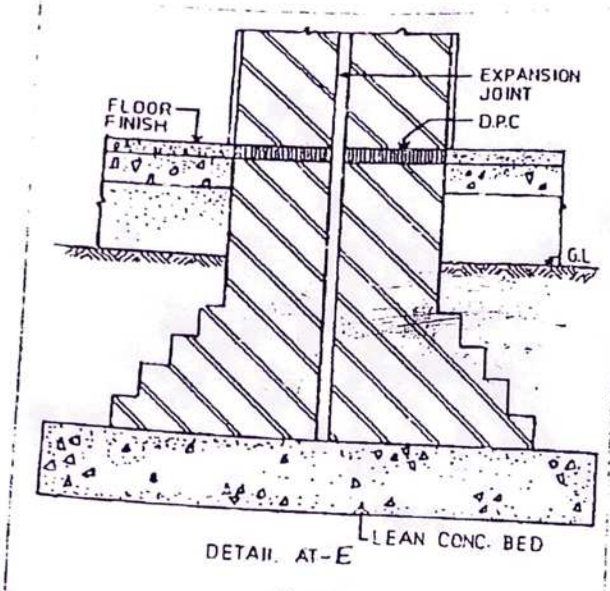


Fig. 24.11
Details of expansion joint at foundation level (For main section refer Fig. 24.5)

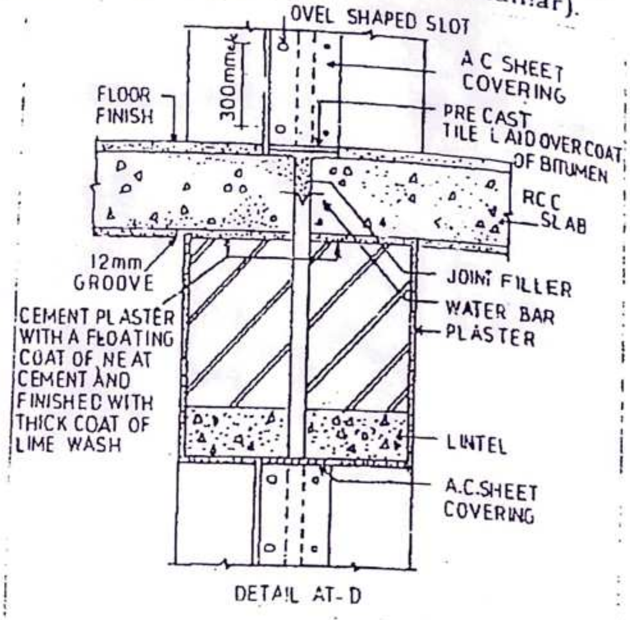


Fig. 24.10
Details of expansion joint at first floor level (For section refer Fig. 24.5)

5.4 Treatment and joints in external walls:

The centre to centre spacing of joints in all continous external and internal masonry walls should not exceed 30.00m and width or gap of joint should preferably be not less than 15 mm. The joint should start from top of foundation concrete and should extend up to top of the wall i.e. up to bottom side of cooping. In case the wall rests on grade beam of the pile foundation then joint should start from top of grade beam. The positions of these joints in a building are shown in Figs. 24.4 and 24.5 below:

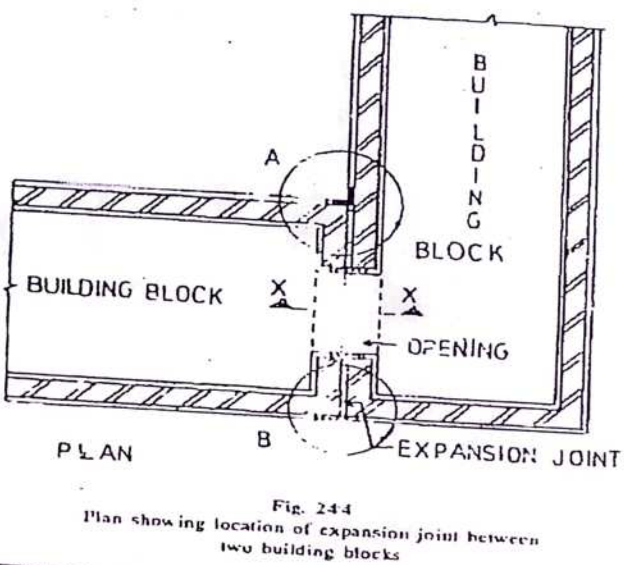


Fig. 24.4
Plan showing location of expansion joint between two building blocks

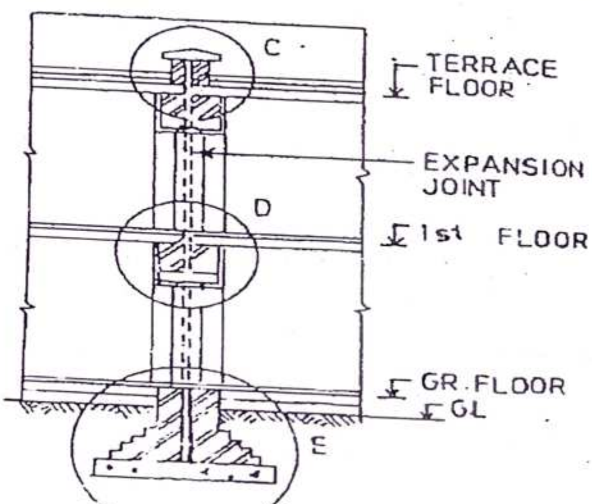
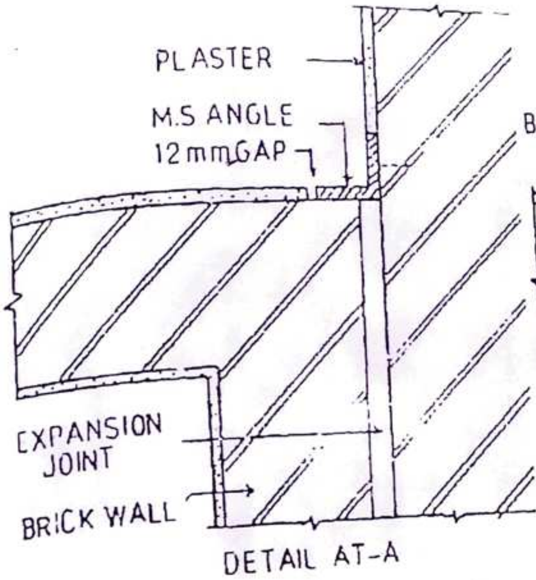


Fig. 24.5



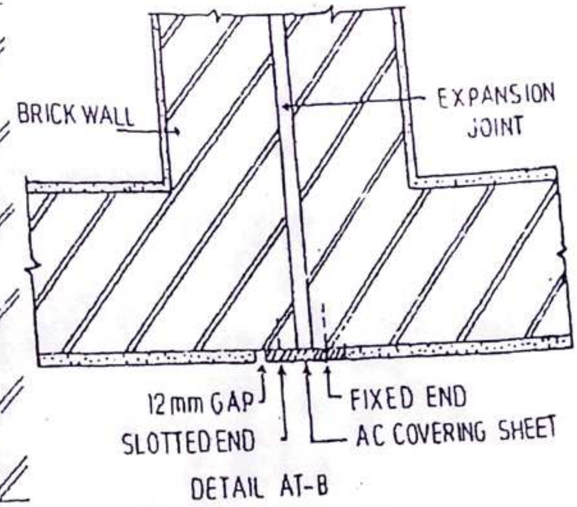


Fig. 24·7

Details of expansion joint between walls (For plan refer Fig. 24·4)

Fig. 24·6

ils of expansion joint between walls (For plan refer Fig. 24·4)

Plan shwoing location of expansion joint between two building blocks

Alternative methods of treating an expansion joint in walls are shown in Fig 24.6 & 24.7 above. The joints in wall are covered with covering sheets which may be of aluminimum, hard board, AC sheet or timber plank. The sheet covering is firmly fixed to the wall on one side of joint with the help of trawl plugs and screws provided at 30 cm c/c and fixing through oval-shaped slots to the wall on other side of joint. The oval shaped holes permits the movements at the joint without damaging the covering sheet.

B. Isolation joints

- When one portion of a building is higher than the other, the soil below the higher portion will be subjected to greeater pressure than the soil below the lower portion of the building. In such cases it is desirable to have complete saparation of two paerts by providing an isolation joint. *The detailing of an isolation joint is similar to that of an expansion joint.* The arrangement permits vertical movement of the building rts due to difference in the unit soil pressure without causing any damage to the structure.

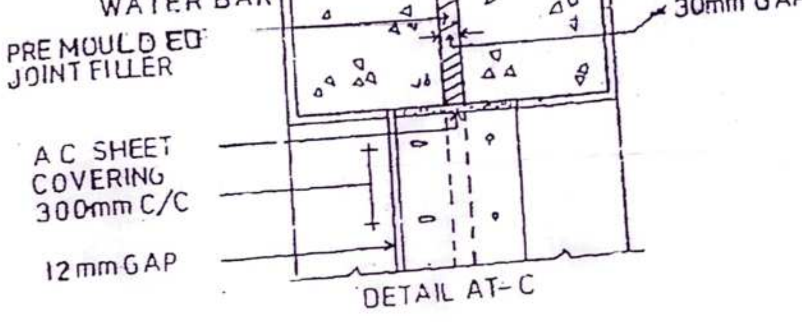


Fig. 24·20

Details of expansion joint at roof level (For section refer Fig. 24·17)

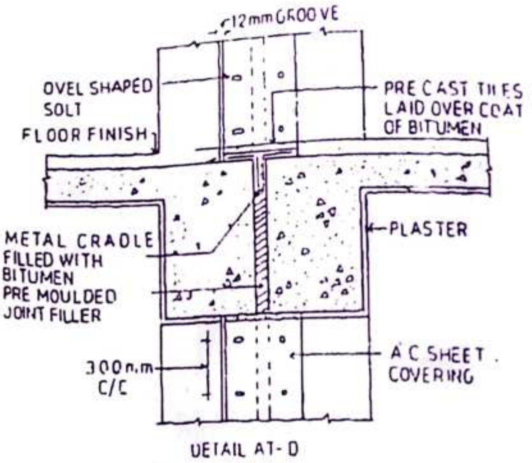


Fig. 24.21

Details of expansion joint at first floor level (For section refer Fig. 24.17)

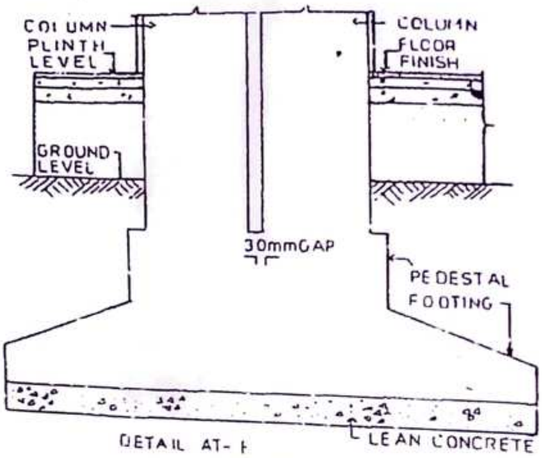


Fig. 24.22

Details of expansion joint at foundation level (For section refer fig. 24.17)

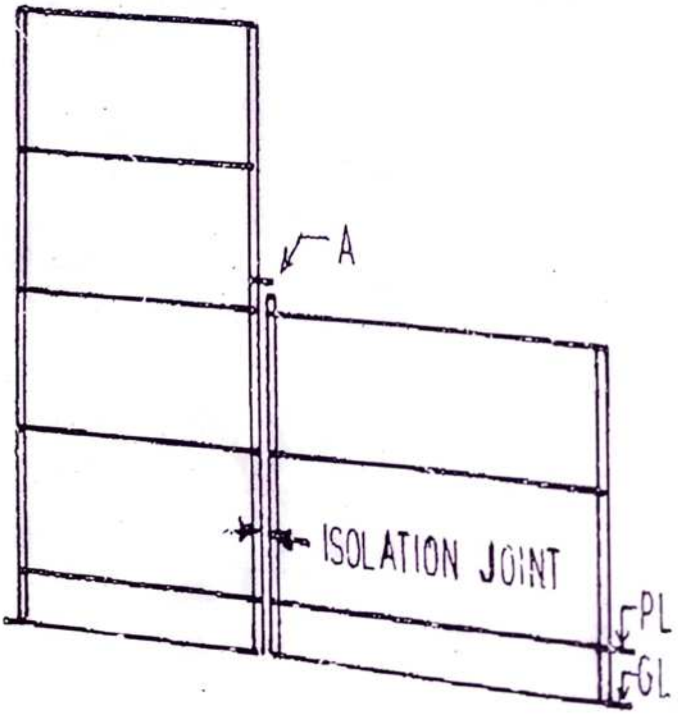


Fig. 24.23

Location of isolation joint between two building blocks

- If one portion of building rests on rock and the adjecent part on compressible clayey soil, the two parts should be separated by providing isolation joint.
- Provision of isolation joint becomes necessary to separate out the foundation of machines from rest of the structure to avoid trancferance of dynamic or other types of stresses from the machine to the structure. In general, an isolation joint is provided to take care of horizontal or vertical movements of the adjacent building parts wihtout damaging to the building. For dtails refer Fig. 24.23 and 24.24

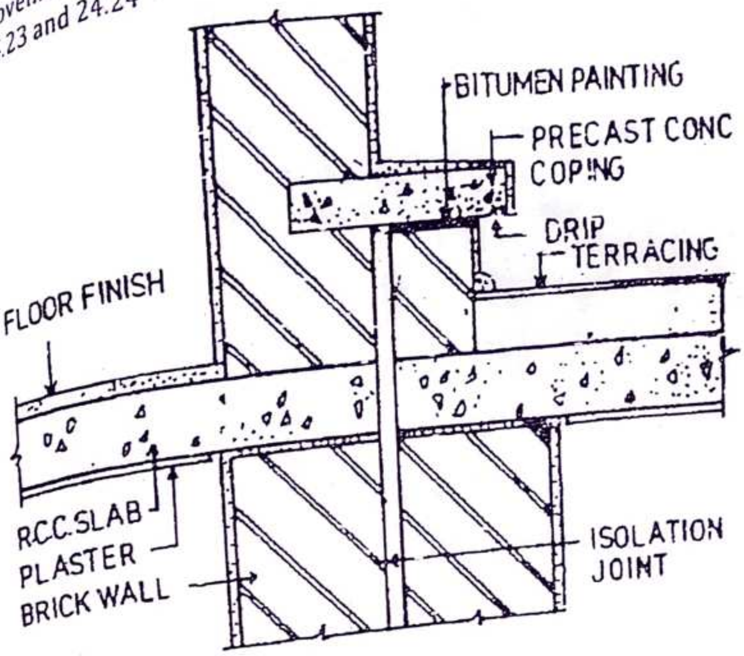


Fig. 24·24

Details of isolation joint (For elevation refer Fig. 24·23)

4. Contraction joints

- When concrete sets and hardens in air it shrinks in its volum. He magnitude of shrinkage or contraction is almost directly proportional to rhe quantity of of water in the mix. Hence the contrete mix having more water shrinks more than a concrete mix having low slump value. When the concrete dries and the tensile stresses exceeds than the tensile strength of concrete., the cracks are formed in concrete. This pheenomena in building continues during Its life time so such dimensional changes should be taken care of in its planning and detailing.
- This contraction joints may be either a *complete contarction joint* in which there is complte discontinuity of both concrete and steel as shown in Fig 24.25 or it may be *partial contraction joint* in which there is discontinuity of of concrete but reinforcements contonue acrosss the joint as shown in Fig. 24.26. It may be noted that in both cases no gap is provided for the joint but only complete or partial separation of the adjecent sections is created.
- The third form of contraction joint is *dummy joint* in which a groove is created in the concrete member to act as a joint as shown in Fig. 24.27. The depth of the groove is 1/3 to 1/5 of the total thickness of the member.

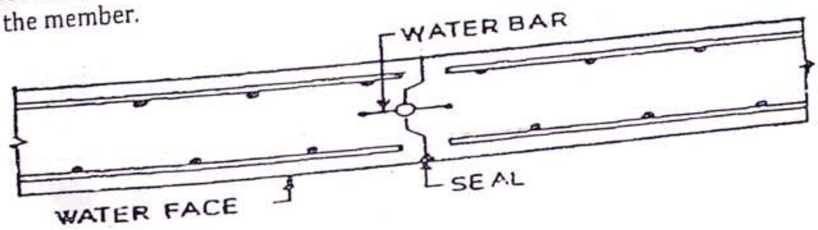


Fig. 24·25

Sectional plan showing details of complete contraction joint in the wall of a reservoir

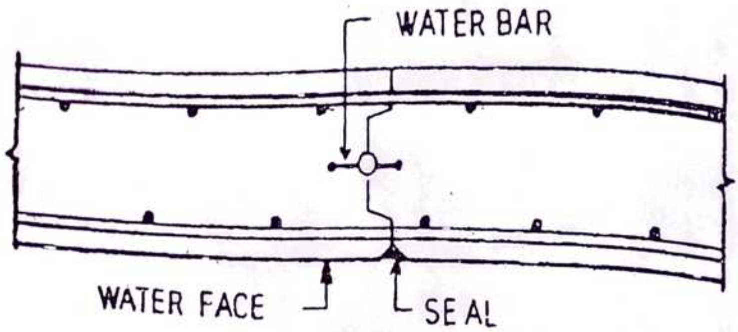


Fig. 24·26
Sectional plan showing *details of partial contraction joint* in the wall of a reservoir.

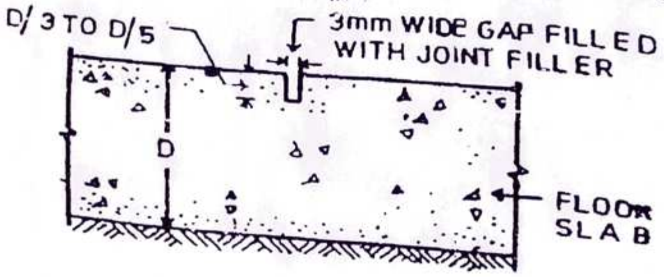


Fig. 24·27
Dummy joint (contraction joint) in a factory floor slab

5. Sliding joints

This type of joint is provided between two parts of a structure when one part has a tendency to slide over the other due to variations in temperature and moisture content. A typical example of this joint is the treatment given to the R.C.C. slabs and beams on the masonry walls. In order to facilitate free movement of the components of the joint, pr ur to the casting of slab, a 6 mm thick layer of rich cement plaster (1:3) finished is provided oever the area of bearing on the masonry walls. The bearing plaster is is then finished with athick coat of lime wash or covered with kraft paper. After casting, the sides and top of the slab and beams to come in contact with masonry are painted with a thick coat of hot bitumen. This treatment prevents physical contact between the surface of concrete and masonry and also permits movements of the building parts by sliding action as shown in Fig. 24.29 below.

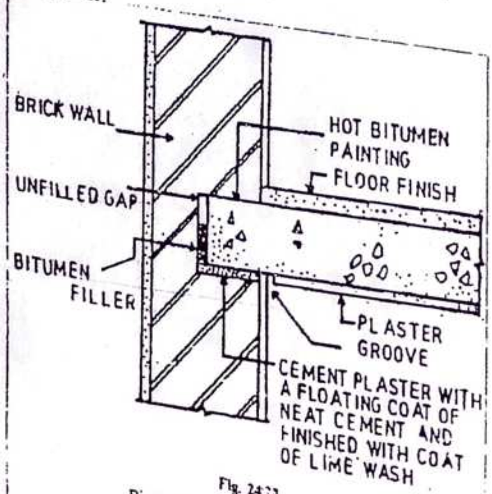


Fig. 24·28
Details of sliding joint at first floor level

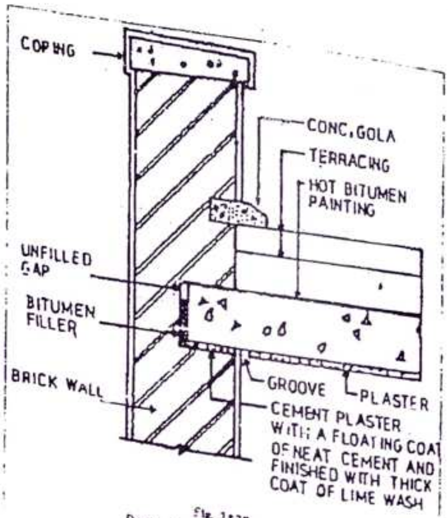


Fig. 24·29
Details of sliding joint at roof level

Provision of floor construction joints in large structures

The factors to be kept in view while deciding upon the type and location of points in floor (at or below ground level) of large structure are:

1) ***The contraction joints*** should be provided at centre to centre spacing varying between 4.5 to 7.5 min two directions at right angles The maximum size of floor panels should normally be not more than 7.5m x 7.5 m.

2) In case the floor slab is reinforced, it is desirable to discontinue the reinforcement at the contraction joint.

3) The floor panel should be cast alternatively in chess board fashion. The adjacent slab panels should preferably be laid after a gape of seven days. The joints should thereafter be sawn to a depth of about 20 mm and filled with molten lead or joint sealing compound.

4) ***Isolation joints*** should be provided at junction of the floor with column, walls etc. This takes care of the horizontal movements due to contraction as well as vertical movements due to difference in unit soil pressure under floor and columns, walls etc.

5) Expansion joints should be provided at intervals of about 30m to accommodate thermal movements as shown in Fig. 24.38 to Fig. 24.41

In case of floor slab of factories where there is possibilities of wheeled trolleys moving across the joints, the edge of concrete face should be protected by steel angles as shown in Fig. 24.40

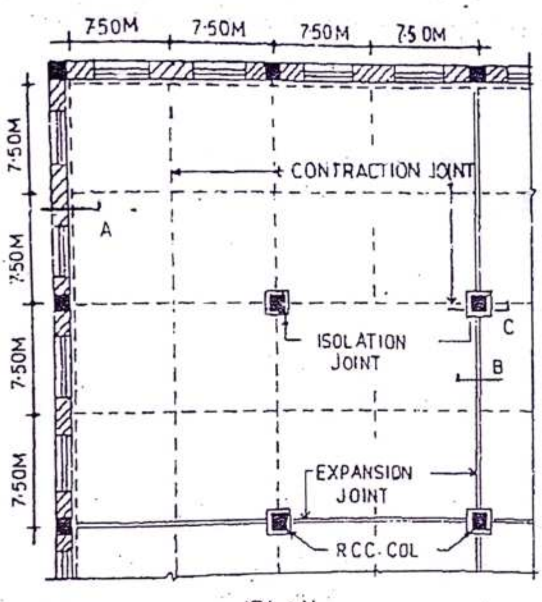


Fig. 24.38 Plan showing location of contraction, expansion and isolation joint

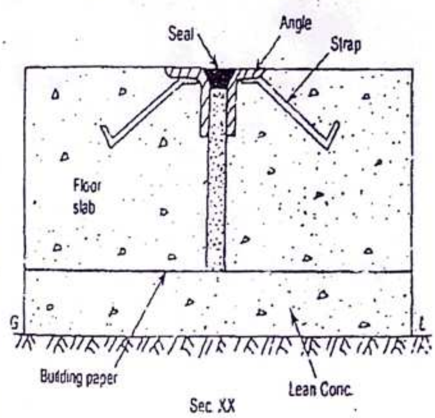


Fig. 35.28. *Expansion joint protected by M.S. angles.*

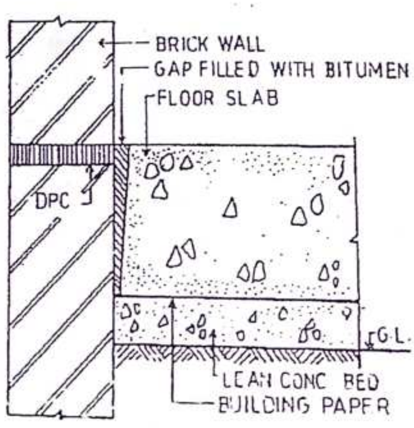


Fig. 24·39 Details of isolation joint between floor slab and wall

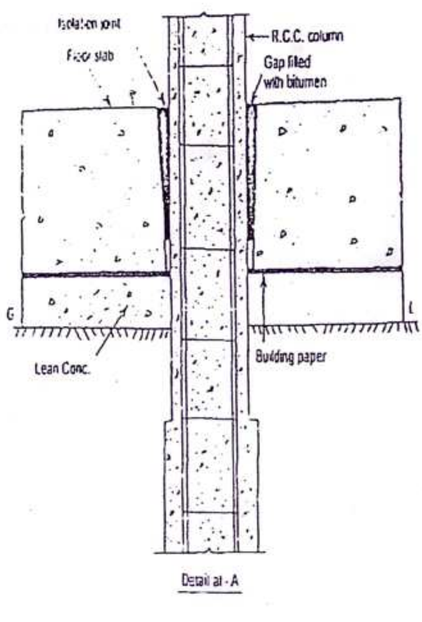


Fig. 35.30. *Isolation joint between R.C.C. column and floor slab.*

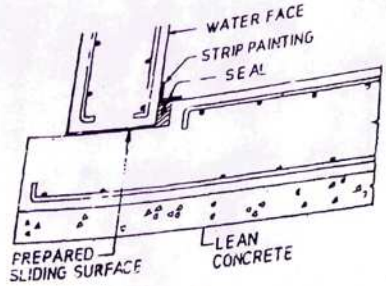


Fig. 24.36

Details of sliding joint between the wall and floor of reservoir

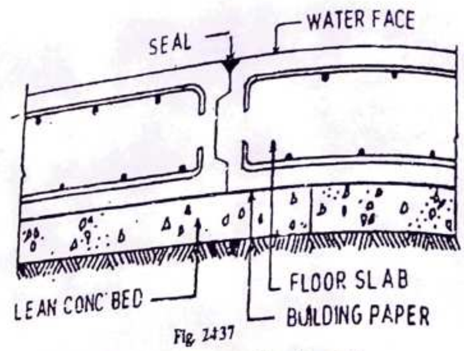


Fig. 24.37

Details of construction joint in the floor of reservoir

Provision of construction joints in water or liquid retaining structures

Concrete mix for water retaining structures should not be weaker than M20 (1:1.5:3), preferably M25 (1:1:2) and it is necessary to make adequate provision of contraction and expansion joints to control shrinkage and thermal movement. The provision of joints in the different components should be as under:

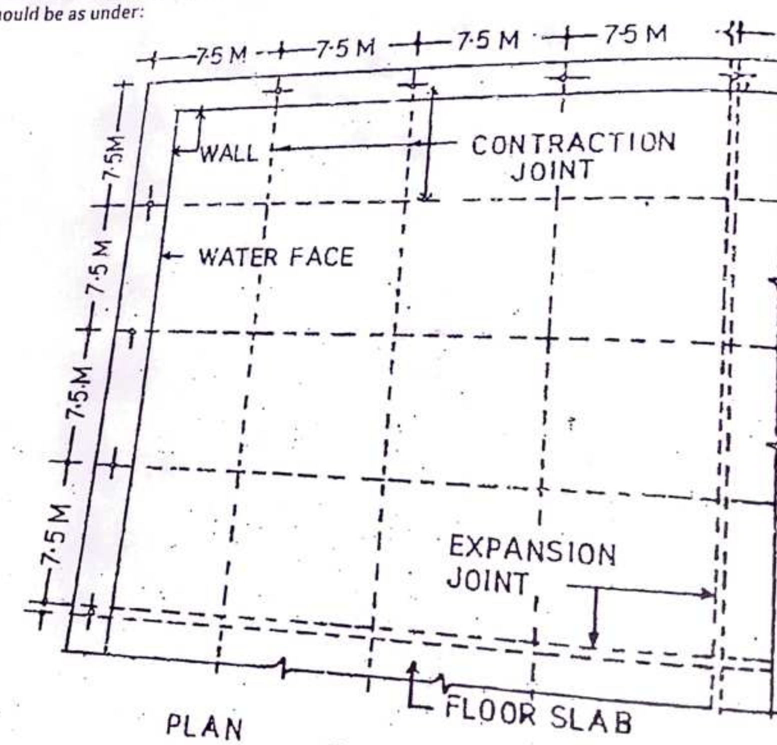


Fig. 24.32

Plan showing location of expansion and contraction joints in a reservoir

(a) Construction Joints in wall of water retaining structure:

(i) It is necessary to provide vertical contraction joints at a maximum centre to centre spacing of 7.5 m. The joint may be in the form of partial connection as shown in Fig 24.33 or Fig. 24.26.

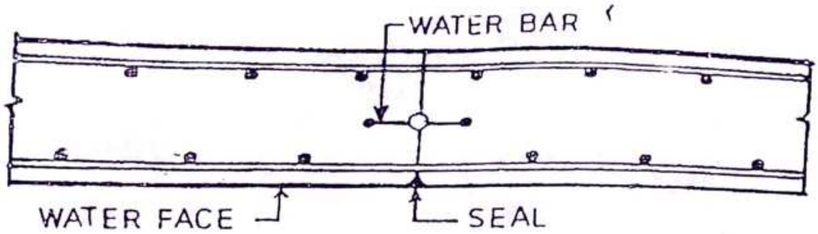
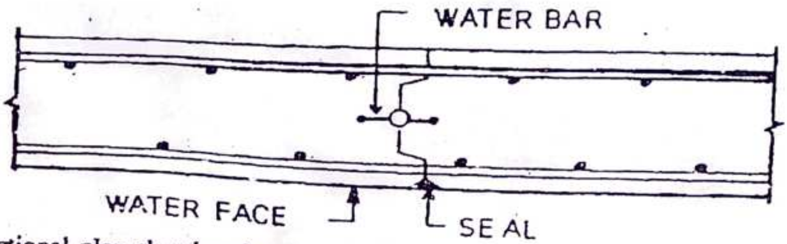


Fig. 24·33

Sectional plan showing details of contraction joint in the wall of reservoir



Sectional plan showing *details of partial contraction joint* in the wall of a reservoir.

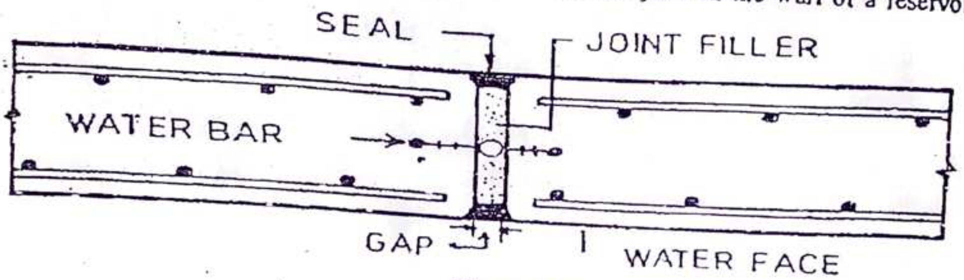


Fig. 24·34

Sectional plan showing details of vertical expansion joint in the wall of reservoir

(ii) Provision of vertical expansion joints in walls should be at a spacing of not more than 30 m. Since expansion joints also function as contraction joint, there should be 3 contraction joints (at c/c spacing 7.50 m) between any two expansion joints to meet the requirements of (i) above.

(iii) The height of lift while concreting the wall should normally not exceed 2m and hence a horizontal joint is the form of construction joint has to be introduced between any two lifts. This has been explained in article 24.7 (Fig. 24.31)

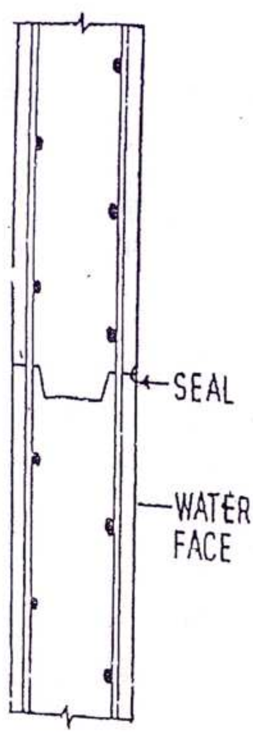


Fig. 24·35

Horizontal construction joint in the wall of reservoir

(b) Construction Joints in floors of water retaining structure:

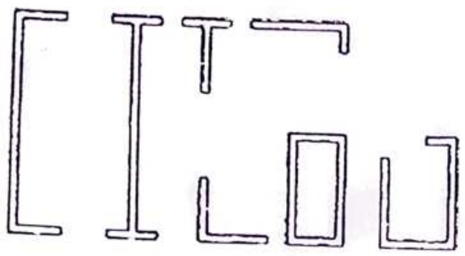
- To permit free movement, the floor slab of reservoir resting at or below ground level is cast over a bottom layer of concrete normally M10 mix. The thickness of the layer of lean concrete should not be less than 75 mm. A layer of building paper or other suitable material is provided over the lean concrete to facilitate free movement of the floor slab above.

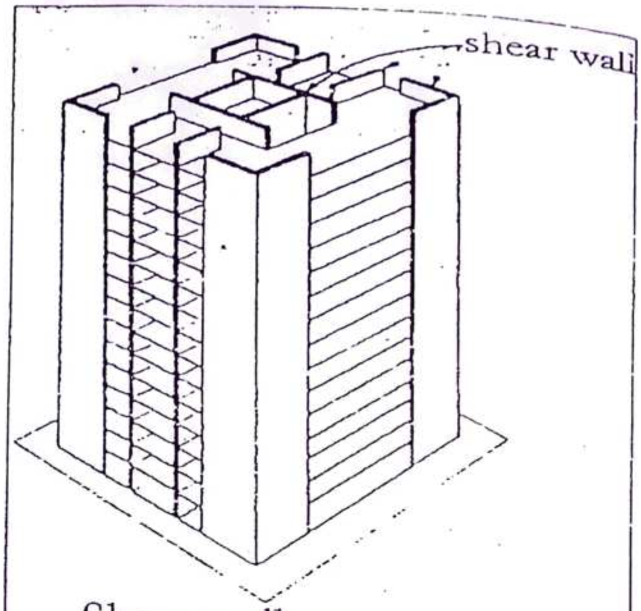
- The wall and floor joints should be in line except where sliding joint is provided between wall and floor. Hence the centre to centre spacing of contraction and expansion joints in floor should be 7.5 m and 30 m respectively. The joints should be provided in two directions at right angles to each other. The contraction joint in floor should normally be of complete contraction type (reinforcement discontinued) and as far as possible, the floor should be cast alternatively in chess board fashion.

5.5 Treatment and joints in shear walls:

Shear walls are specially designed structural walls included in the buildings to resist horizontal forces that are induced in the plane of the wall due to wind, earthquake and other forces.

- They are mainly flexural members and usually provided in high-rise buildings to avoid the total collapse of the high-rise buildings under seismic forces.
- Shear wall has high in-plane stiffness and strength which can be used to simultaneously resist large horizontal loads and support gravity loads.
- However, when the buildings are tall, say more than twelve story or so, beam and column sizes workout large and reinforcement at the beam and column junction works out quite heavy, so that, there is a lot of congestion at these joints and it is difficult to place and vibrate concrete at these places, which does not contribute to the safety of buildings.
- These practical difficulties call for introduction of shear walls in high-rise buildings.
- Deep straight walls or angular, U shaped and box shaped shear walls were used based on functional and architectural requirement of the high-rise building.


Shear wall types and efficiency



Shear wall structure

Shear walls may be constructed of:

1) Cast-in-place, reinforced concrete
2) Precast concrete
3) Reinforced masonry
4) Light-frame stud construction sheathed with structural wood panels, such as plywood, oriented-stand board (OSB) or diagonal board sheathing.

- Reinforced concrete or masonry walls are effective in absorbing energy if firmly tied to floor and roof diaphragms.
- Shear wall must be well proportioned to avoid excessive lateral deflection and high shear stresses.
- Shear wall should occupy a minimum of 20% to 25% of the total number of bays.
- There are generally very few openings or penetrations in shear walls. If a shear wall dose have regular penetrations, its structural action is intermediate between that of a shear wall and a moment resisting frame.

Treatments to be done for joints in shear wall

1) Special tension anchors (as shown on next pages in Figures) should be arranged between shear wall and diaphragm to resist the uplifting and overturning tendency of the wall due to the shear at the top of the wall.
2) Reinforced concrete or reinforced masonry walls are effective in absorbing energy so the shear walls constructed in such way must be tied to floor and roof diaphragms.
3) As far as possible the joints should be minimised between shear walls and diaphragms and gaps should be sealed with suitable sealants.

Fig: Provision of Tension Anchorage for shear wall and diaphragm

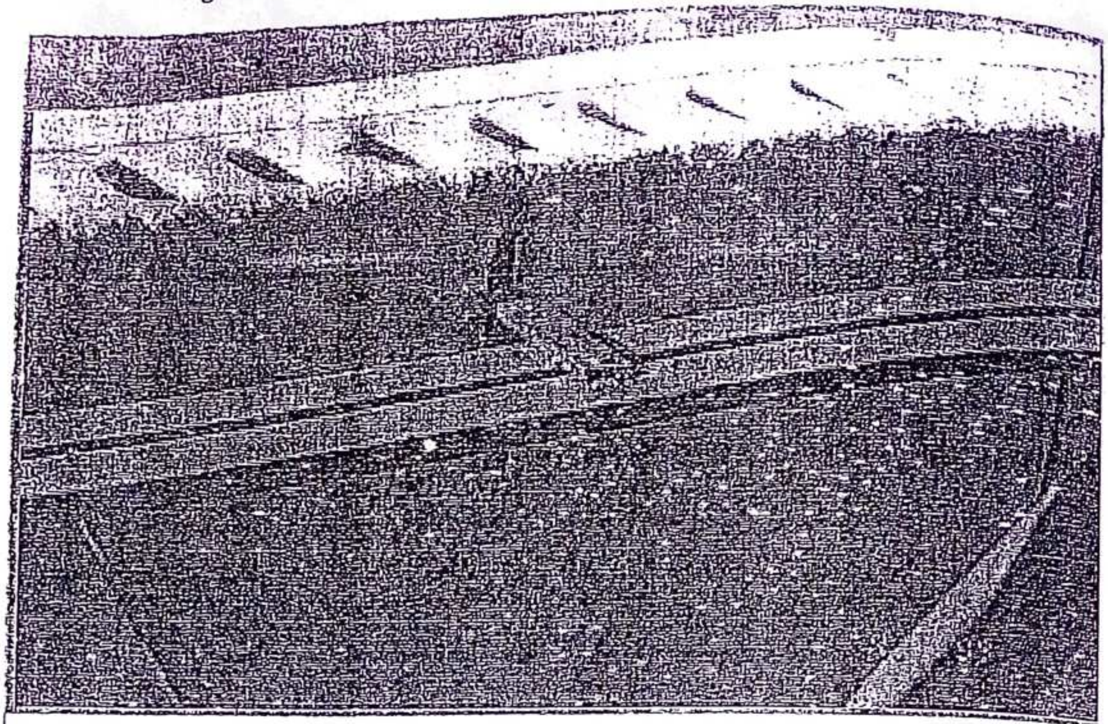


Figure 6. Corewall attachment to roof

Fig: Provision of Tension Anchorage for shear wall and diaphragm

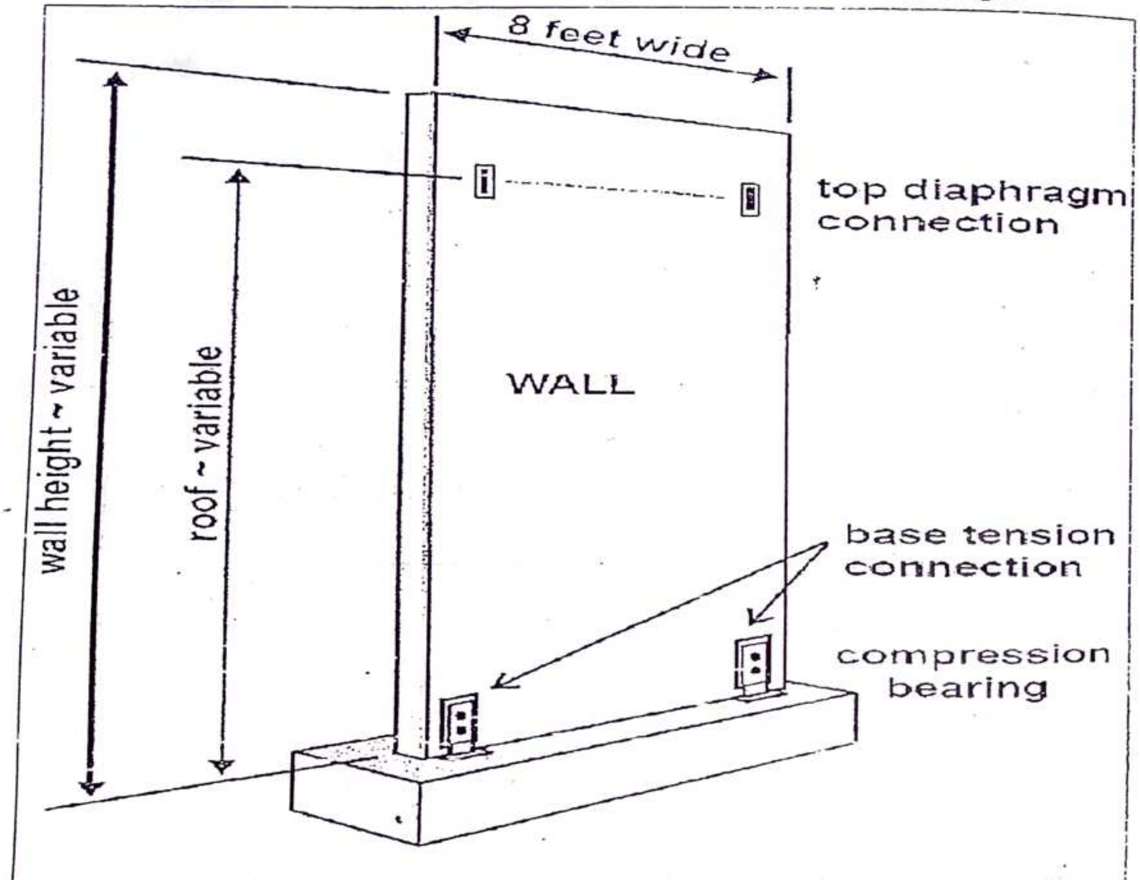


Figure 5. Components of the proposed system

Chapter – 6: Temporary Construction

6.1 Scaffolding: Single and double scaffolds

When the height of wall or column or other structural members of a building exceeds about 1.50m, the temporary construction is needed to support the platform over which the workman can sit and carry on the construction works. These, temporary structures, constructed very close to the wall is known as scaffolding. They can be made either by timber especially bamboo or steel framework.

Common parts

I. Standards
These are the vertical members of the frame-work, supported on ground or drums or embedded into the ground.

II. Ledgers
These are horizontal members, running parallel to the wall.

III. Braces
These are diagonal members fixed on standards.

IV. Putlogs
These are transverse members, placed at right angle to the wall with one end supported on ledgers and other end on the wall.

V. Transoms
These are the putlogs whose both ends are supported on ledgers.

VI. Bridle
This is a member used to bridge a wall opening: supports one end of putlog at the opening.

VII. Boarding
These are the platform to support workmen and materials; these are supported on the putlogs.

VIII. Guard rail
This is a rail, provided like a ledger, at the working level.

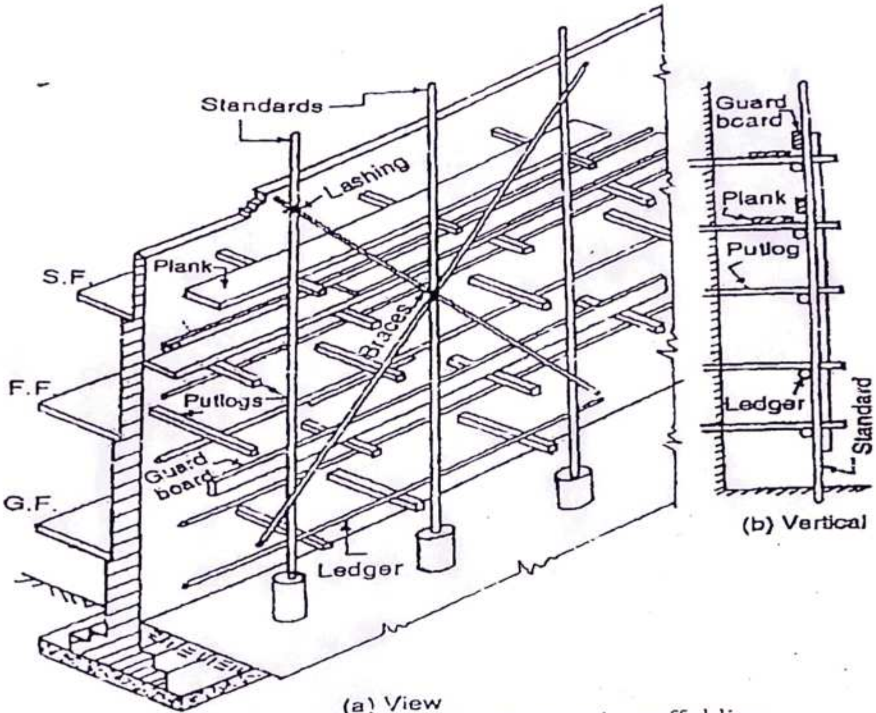
IX. Toe board
These are boards, placed parallel to ledgers & supported on putlogs, to give protection at the level of working platform.

Types of scaffolding

1) Single scaffolding or brick-layers scaffolding
2) Double scaffolding or masons scaffolding
3) Cantilever or needle scaffolding
4) Suspended scaffolding
5) Trestle scaffolding
6) Steel scaffolding
7) Patented scaffolding

1) Single scaffolding

Standards are parallel to wall about 1.2m apart and 2 to 2.5m interval. Ledgers connect the standards and are provided at a vertical interval of 1.2 to 1.5m. Putlogs are placed with one end on the ledgers and other end in the hole left in the wall at an interval of 1.2 to 1.5m. Then, wooden planks are laid over putlogs at the toe of the platform toe board is fixed in order to prevent the full of materials & equipment. At convenient height guard rail is tied parallel to ledger. The standards are tied diagonally by braces and each junction is tied with GI string. Such kind of scaffolding is generally used for brick-laying and hence called as brick-layers scaffolding. This is also known as putlogs scaffolding.



(a) View

Fig - Single scaffolding or brick- layer's scaffolding

2) Double scaffolding or masons scaffolding

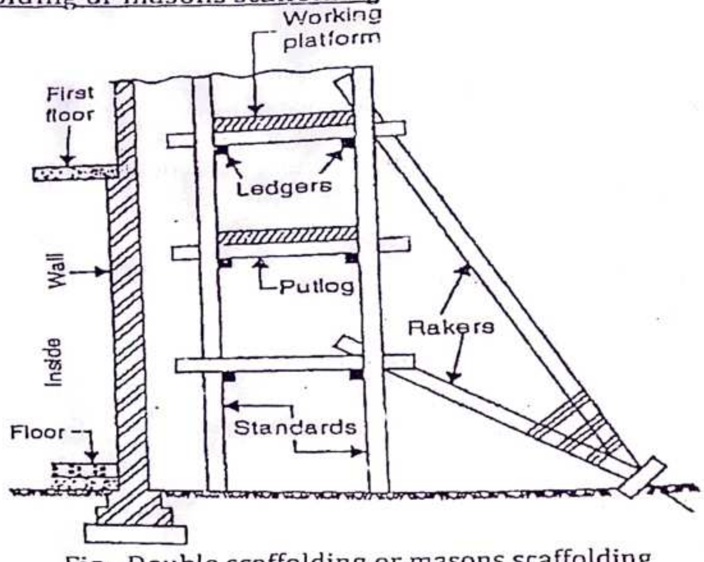


Fig - Double scaffolding or masons scaffolding

When it is very difficult to provide holes in the wall to support putlogs then scaffolding is constructed by using two rows of standards called Double scaffolding. Each row thus forms a separate vertical frame work. The first raw is placed 20 to 30cm away from the wall while the other row is placed at 1m a part. Putlogs are then supported on both the frames. Rackers and cross braces are provided to make the scaffolding more strong and stable. This type of scaffolding is also known as independent scaffolding.

3) Cantilever or Needle scaffolding

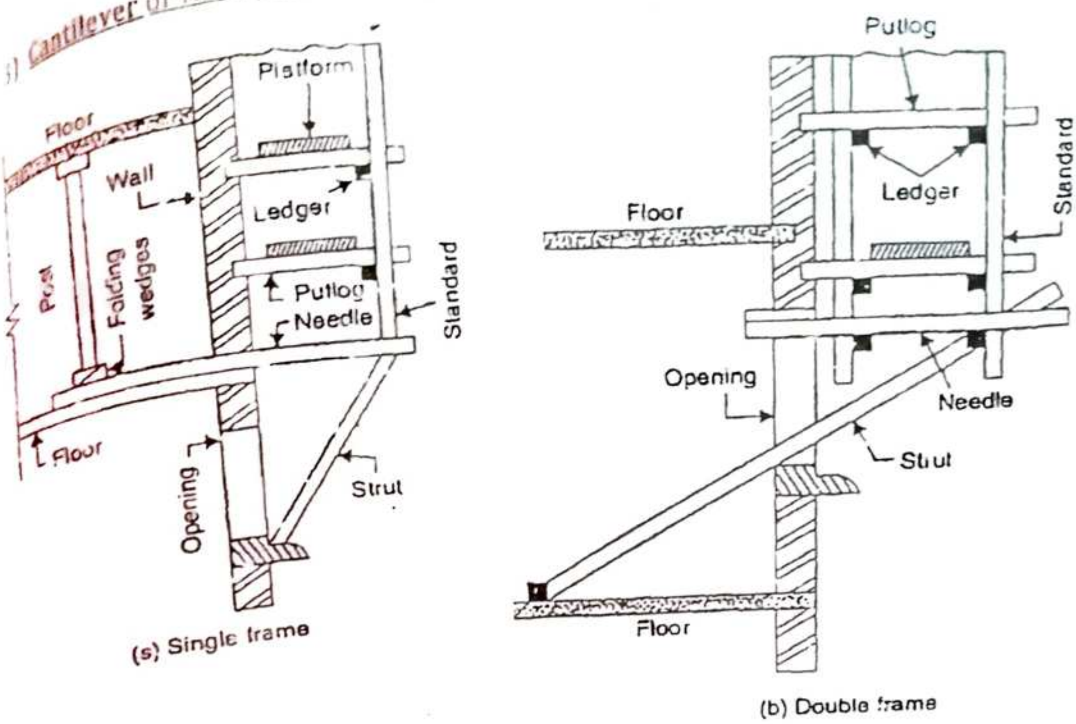


Fig - Cantilever or Needle scaffolding

Needle scaffolding may be single frame or double frame type. In single needle type, the standards are supported on series of needles taken out through opening or through holes in the wall. But in case of double frame type, needles are strutted inside the floors, through the openings.

Such types of scaffolding are used under the following circumstances.

a) When ground is week to support standards.
b) When construction of upper-part of the wall is to be carried out.
c) When it is required to keep the ground near wall, free for traffic etc.

4) **Suspended scaffolding**

This is a light weight scaffolding used for repair works such as pointing, painting etc. The working platform is suspended from roofs by means of wire ropes or chains etc. The platform can be raised or lowered at any desired level.

5) **Trestle scaffolding**

This type of scaffolding is used for painting and repair works inside the room, up to height of 5m. The working platform is supported on the top of more able contrivances such as tripods, ladders etc. mounted on wheels.

6) **Steel scaffolding**

Steel scaffolding is practically similar to timber scaffolding except that wooden members are replaced by steel tubes and rope lashings are replaced by steel couplets or fittings. Such scaffolding can be erected and dismantled rapidly. It has greater strength, greater durability and higher fire resistance. Though its initial cost is more but its value is higher. The use of steel scaffolding is growing day by day.

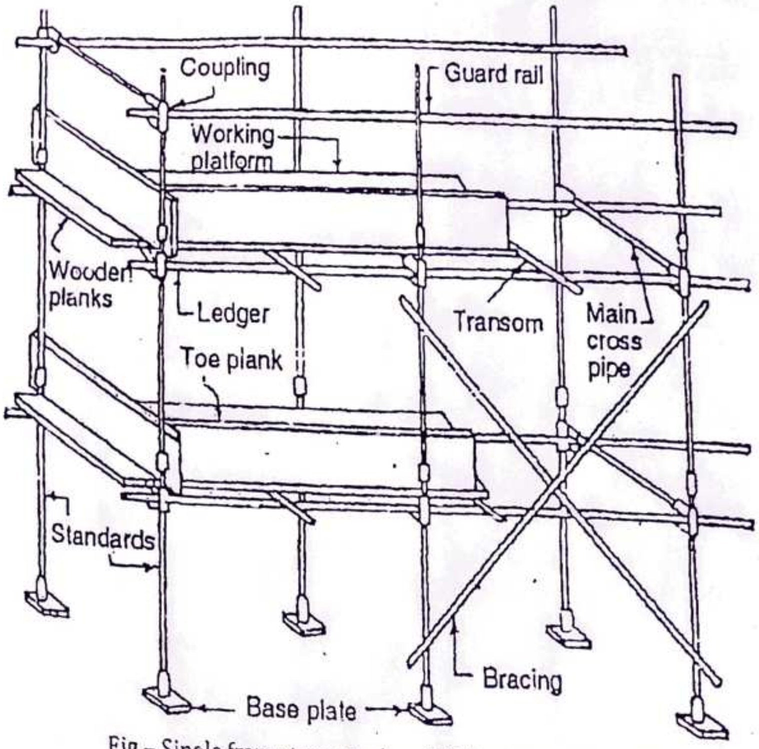


Fig – Single frame type steel scaffolding for brick wall

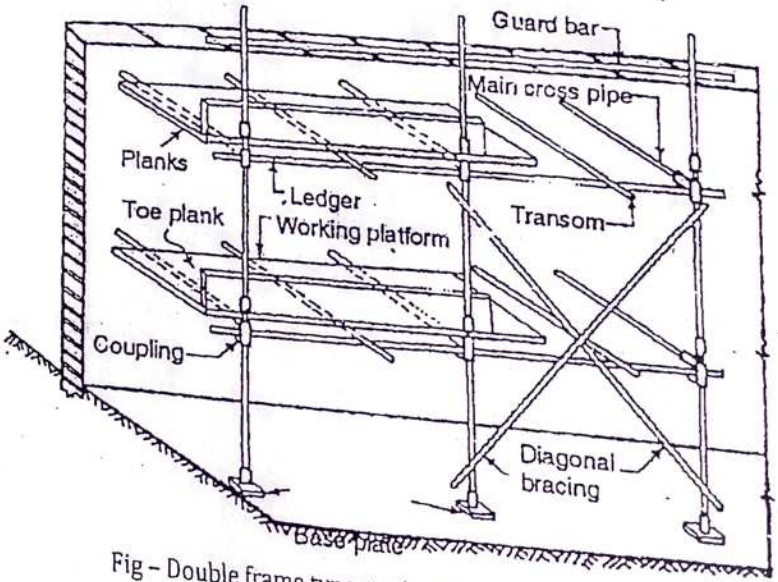


Fig – Double frame type steel scaffolding for stone wall

7) Patented scaffolding

These scaffolding are equipped with special couplings frames etc. The working plate form is supported on brackets which can be adjusted at any suitable height.

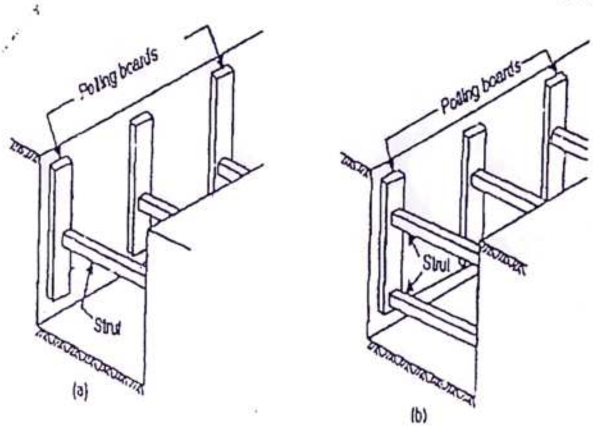
6.2 Formwork for excavation and trenches

Formwork for trenches consists of a temporary arrangement of boarding's or poling boards, wailings and struts provided to give support to the sides of trench during the construction stage. It is necessary in order to:

1) Protect the operatives while working in the excavation.
2) Keep the excavation open by acting as a retaining wall to the sides of the trench.

The types and amount of timbering required will depend upon the depth and nature of soil. Over a short period many soils may not require timbering of trenches. For hard and firm nature of soil & if the depth of excavation is moderate, there is no need of shoring in almost all soil except rock & hard compacted soil. However, we can do timbering of deep trenches with the help of following methods;

a) Stay Bracing
b) Box sheeting
c) Vertical sheeting
d) Runner system
e) Sheet piling



a) Stay Bracing

- Used for supporting the sides or a bench excavated in fairly firm soil, when the depth of excavation does not exceed about 2 m.
- Consist of placing vertical (200mmx50mm) opposite to each other against the two walls of the trench and holding them in position by one or two rows of struts (100mmx100mm).
- The poling boards are placed at an interval of 2 to 4 m and generally extend to full height of the trench
- Poling boards generally have 40 to 50 mm thickness and 200 mm width.
- The struts may be of size 100x100mm for trench up to 2m and 200x200 mm for trench up to 4m.

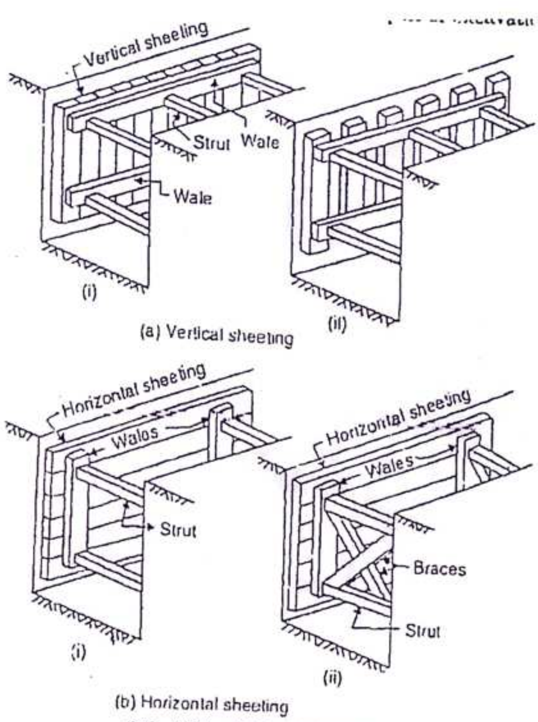


FIG. 2.32. BOX SHEETING

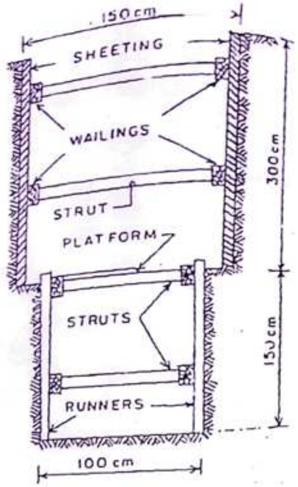
b) Box sheeting

- Adopted in loose soils, when the depth of excavation does not exceed 4m.
- Consists of vertical sheets placed very close to each other supported longitudinally by horizontal members called Wales and finally the Wales supported by strut as shown in Fig. 2.32

c) Vertical sheeting

- Adopted for deep trenches up to 10 m depth in soft soils.
- Similar to box sheeting except the excavation is carried out in stages and at the end of each stage, an offset is provided, so that the trench goes on decreasing as the depth increases.
- Each stage is limited to 3m in height and offset may vary from 25 to 50 cm.
- For each stage, separate vertical sheeting supported by horizontal wailings and strut are provided.

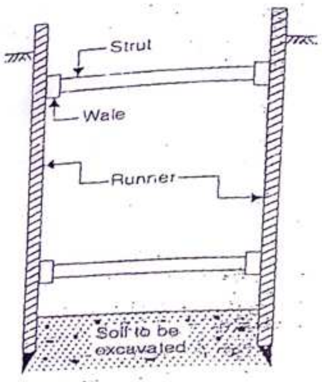
Fig: Vertical sheeting→



d) Runner system

- Extremely used in loose and soft ground, which needs immediate support as excavation progress.
- The system is similar to vertical sheeting of box system, except that in the place of sheeting runners, made of long thick wooden sheets or planks with iron shoe at the ends are provided.
- Runners are provided about 30 cm in advance of the progress of the work by hammering.

Fig: Runner system→



e) Sheet piling

- Sheet piles are driven in the ground by mechanical means.
- They can be used for excavating very large depth.
- This method is adopted when
    - Soil is to be excavated is soft or loose.
    - Depth of excavation is large.
    - Width of trench is also large.
    - There is sub-soil water.

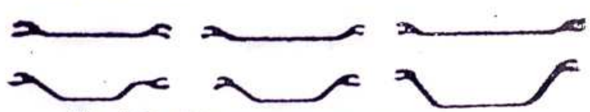


Fig. 3.25. *Different forms of steel sheet piles.*

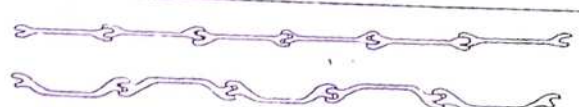


Fig. 3.26. *Steel sheet piles connected with clutches.*

6.3 Formwork for reinforced concrete construction

Form work or shuttering is a temporary ancillary construction used as a mould for the structure in which concrete is placed, hardens and matures. When the formwork is used only once or whose elements cannot be re-used is called stationary formwork and the formworks, whose components can be reused several times are called panel forms. The lost of formwork may be up to 20 to 25 % of the lost of the structure in building work & even higher in bridges.

Principal requirement of formwork

A good formwork should have the following requirements:

a. Strength
It should be strong enough to withstand all type of dead load and live loads such as self-weight of reinforcement, fresh concrete, equipment, workman and forces caused by placement & consolidation of concrete.

b. Rigidity
It should be rigid enough to retain the shape without undue deformations. That's why; it should be efficiently propped and braced both horizontally & vertically.

c. Leakage proof
The joints in the formwork should be leakage proof.

d. Economy
The materials of the formwork should be cheap, easily available and should be suitable for re-use several times.

e. Smoothness
The inside surface of the formwork should be smooth so as to give good appearance. To achieve this, the inside surface of the formwork is usually applied crude oil of soft soap solution. This also facilitates the removal work.

f. Weight
The formwork should be as light as possible.

g. Water proof
The material of formwork should be practicably water proof so that it does not absorb water from concrete. Also its shrinkage and swelling should be minimum.

h. Economy
The material of formwork should be cheap and it should be suitable for re-use several times.

Characteristics of good formwork

A good formwork always possesses the principals or ideal requirements of it listed above. After fulfilling the principal requirement, a formwork becomes a good formwork.

Materials for formwork

The type of materials to be used for form work depends upon the nature of construction or the availability and cost of it. Timber formwork is being used from early time, with the introduction of steel, steel formworks are being used. Fibre glass is used mainly for making pre-cast concrete. Aluminium formwork are used when curves surfaces has to be constructed.

Types of formwork:

1. *Depending upon the materials used.*
    i. Wooden formworks (timber & plywood or wooden plan)
    ii. Metal formworks
        a) Steel (plain or sheets, props)
        b) Aluminium
    iii. Fibre glass

2. *Depending upon the use*
    I. Formwork for column
    II. Formwork for beam and slab floor
    III. Formwork for stairs
    IV. Formwork for walls

Double

6.3 Formwork for reinforced concrete construction

Form work or shuttering is a temporary ancillary construction used as a mould for the structure in which concrete is placed, hardens and matures. When the formwork is used only once or whose elements cannot be re-used is called stationary formwork and the formworks, whose components can be reused several times are called panel forms. The lost of formwork may be up to 20 to 25 % of the structure in building work & even higher in bridges.

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   ii. Metal formworks
      a) Steel (plain or sheets, props)
      b) Aluminium
   iii. Fibre glass

2. *Depending upon the use*
   I. Formwork for column
   II. Formwork for beam and slab floor
   III. Formwork for stairs
   IV. Formwork for walls

(i) Formwork/shuttering for column

It consists of the following components.

i. Sheathings all-round the column periphery
ii. Side yokes and end yokes
iii. Wedges, and
iv. Bolt with washers

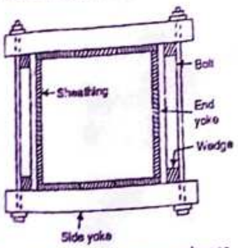


Fig – Shuttering for square columns

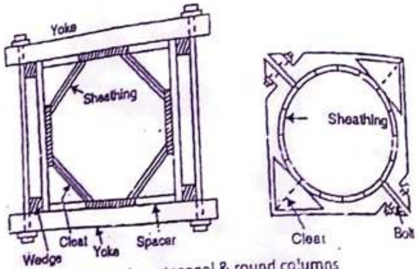


Fig – Shuttering for octagonal & round columns

The side yoke and end yokes consist of two nos. each and are suitably spaced along the height of the column. The two-side yokes are comparatively of heavier section and are connected together by two long bolts of 16mm dia. Four wedges one at each corner, are inserted between the bolts and the end yokes. These are nailed to the yokes.

(II) Formwork/shuttering for beam and slab floor

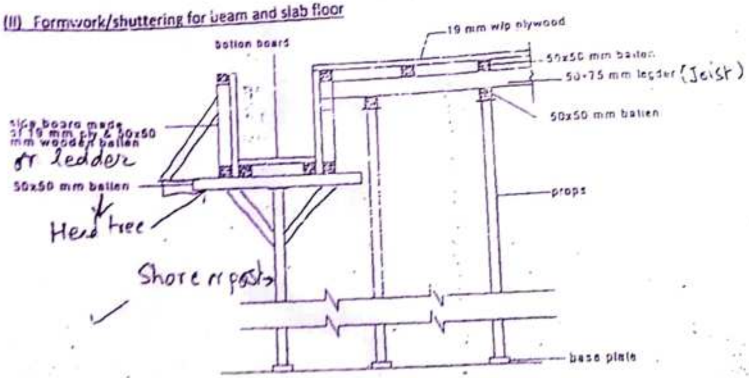


Fig - Shuttering for beam & slab

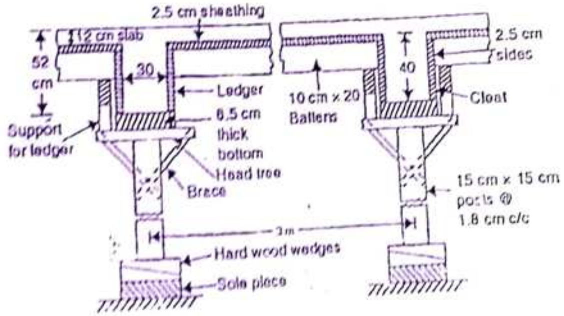


Fig - Shuttering for beam & slab

(i) Formwork/shuttering for column
It consists of the following components
i. Sheathings all round the column periphery
ii. Side yokes and end yokes
iii. Wedges and
iv. Bolt with washers

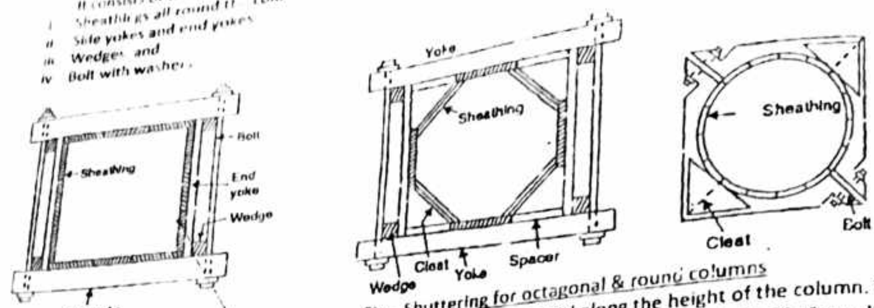


Fig - Shuttering for square columns

Fig - Shuttering for octagonal & round columns

The side yoke and end yokes consist of two nos each and are suitably spaced along the height of the column. The two side yokes are comparatively of heavier section and are connected together by two long bolts of 16mm dia. Four wedges one at each corner, are inserted between the bolts and the end yokes. These are nailed to the yokes.

(II) Formwork/shuttering for beam and slab floor

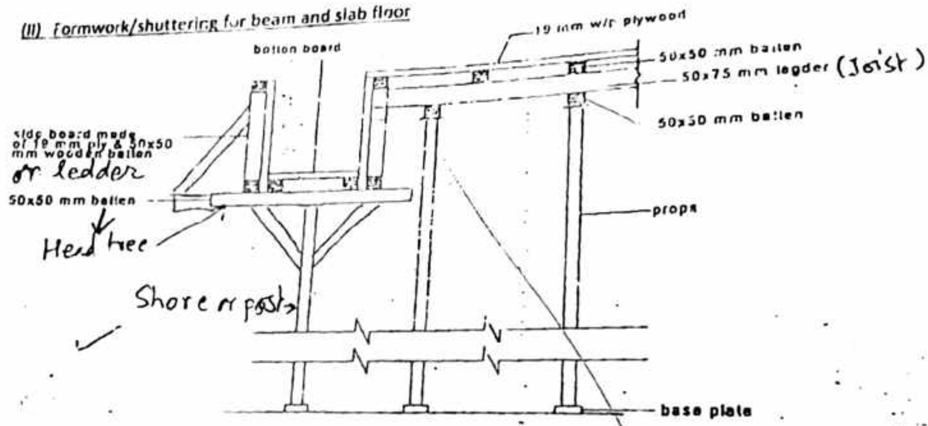


Fig - Shuttering for beam & slab

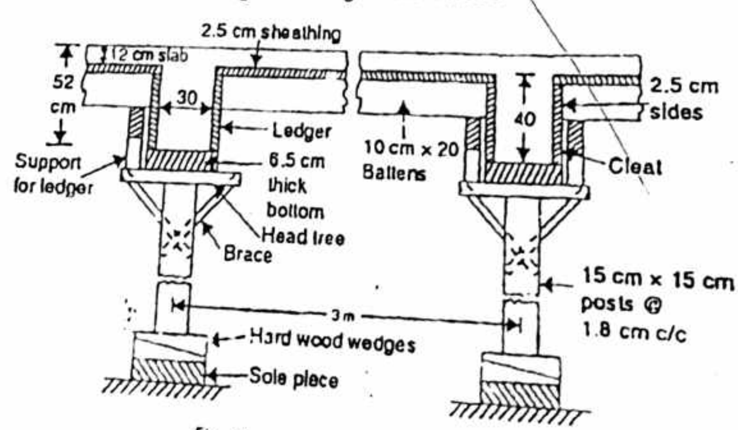


Fig - Shuttering for beam & slab

6.4. Shoring: Horizontal, Slant and Vertical shores

Shoring

Shoring is the construction of temporary structure to support temporarily an unsafe structure. Shoring renders lateral support s to the wall and they are used under the following circumstances:

1) when a wall cracks due to unequal settlement of foundation and the cracked wall needs repairs.
2) when a wall shows signs of bulging out due to bad workmanship.
3) when an adjacent structure is to be dismantled.
4) when openings are to be made or enlarged in the wall of a safe structure

Shoring may be of timber, steel or combination of both. Duration of shoring may be for a week or even up to years depending upon the nature of unstable conditions. It can be removed as soon as unstable structure is made safe by carrying out necessary repairs and modifications.

Types of shoring

Depending upon their supporting characteristics, the shores may be classified in to following three types:

1. Horizontal shores
2. Slant shores
3. Vertical shores

1. Horizontal shores

- Horizontal shores also known as Flying shores are used to give horizontal support to two adjacent, parallel party walls which have become unsafe due to removal or collapse of the intermediate building.
- All type of arrangements of supporting the unsafe structure in which the shores do not reach to the ground fall under this category.
- If the walls are quite near to each other (distance up to 9.00m), single flying shore can be constructed.
- It consists of wall plates, needles, cleats, struts, horizontal shore, straining pieces and folding wedges.
- When the distance between the walls is > 9.00 m, a compound or double flying shore may be provided.
- Flying shores are arranged when old building is being removed and should be kept in position till the new unit is constructed.
- Flying shores have the advantage that building operations of the ground are not obstructed.

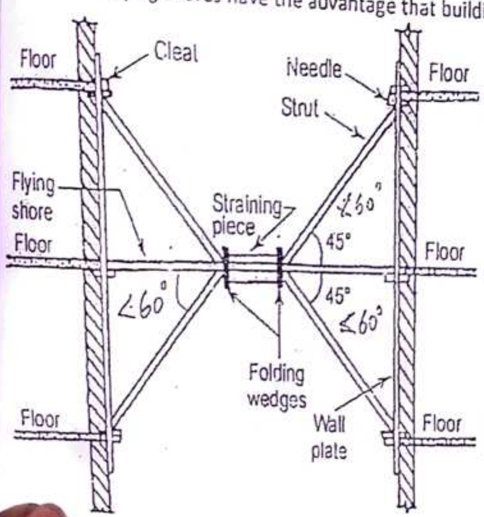


Fig. 11.9. *Single flying shore.*

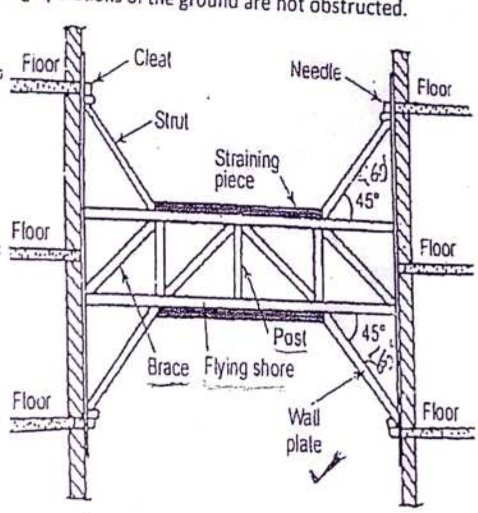


Fig. 11.10. *Double flying shore.*

2. Slant shores:

Slant shores are also known as Raking shores. It is an arrangement of providing temporary support to an unsafe wall. In this method, inclined members, called "rackers" are used to give lateral support to the wall as shown in Figure 18.1

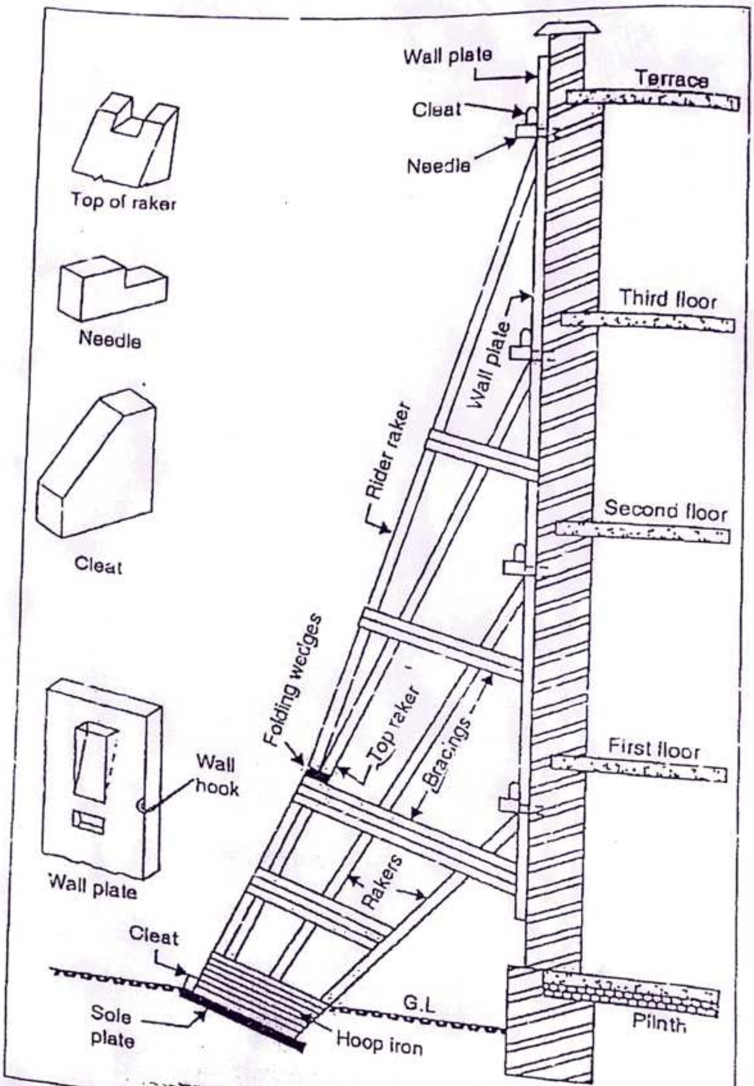


FIG. 18.1. RAKING SHORE.

- The construction of racking shore also known as inclined shore varies with the conditions of site.
- In all cases wall plat (20 cm x 5 cm to 25 cm x 7.5 cm in size) is fixed against the unsafe walls with hooks.
- The wall plate is further secured to the walls by means of needles. The needles which are 10 cm x 7.5 cm in section penetrate inside the wall for a depth of about 15 cm; in turn the needles are strengthened by providing wooden cleats.
- The top ends of the inclined rakers rest against the needles at their base while the bottom ends are secured to the sole piece by cleats and dogs at ground.
- In soft ground the area of the sole plate is increased so as to distribute the pressure over large area.
- In places, where more rakers are provided, they are bound together by means of hoop iron or braces of 25 mm thick and 150 mm wide.
- The inclination of raker to the ground is should be vary between 45° to 75°.
- The sets of shores should be usually placed at 3.00 m to 4.50 m centre to centre along the wall length.
- This type of shoring system is recommended to prevent the wall from collapsing outward, they are not used to give direct support to any part of the structure as lean shore.

3. Vertical shore

Vertical shores consist of horizontal members known as "needles" and vertical bullies or posts known as "dead shores." The needle beams are driven through the wall and supported at their ends by dead shore, vertical post or bullies. Dead shores are provided to serve the following purposes:

i) To rebuild the detective part of the wall

ii) To rebuild or deepen the existing foundation

iii) To make large openings in the existing safe wall

Holes are cut at a distance of about 1.00 m to 1.50 m. depending upon the type of masonry, needle are inserted in the holes.

Each needle is supported at its two ends by vertical posts or dead shores. The dead shores stand away from the wall so that repair work is not obstructed. The shores are supported on sole plates and folding wedges.

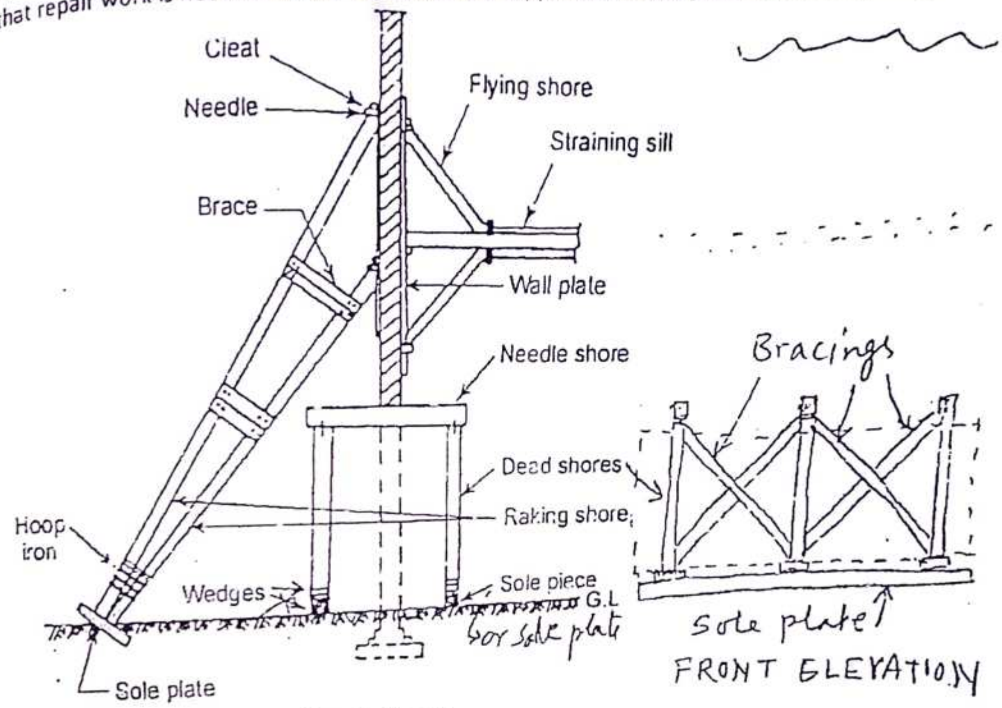


Fig. 11.11. *Dead shores.*

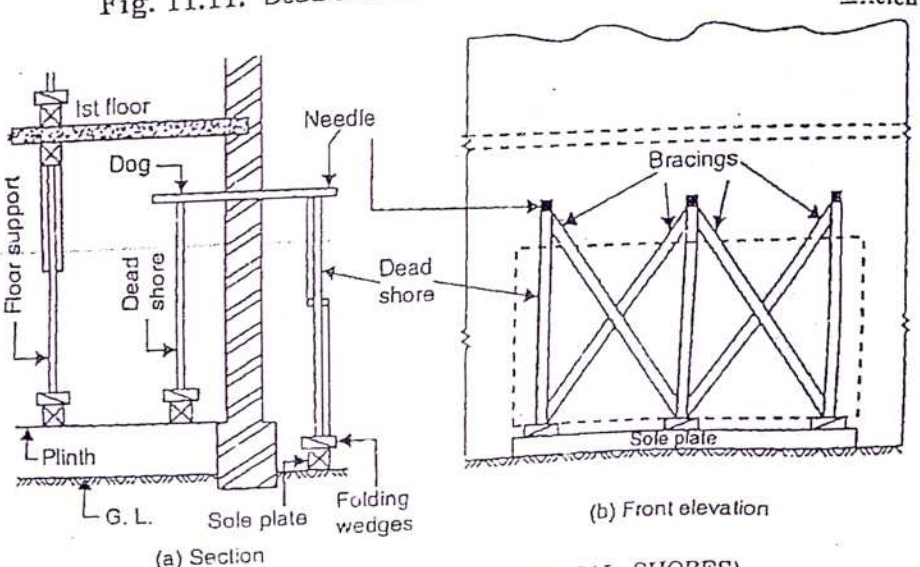
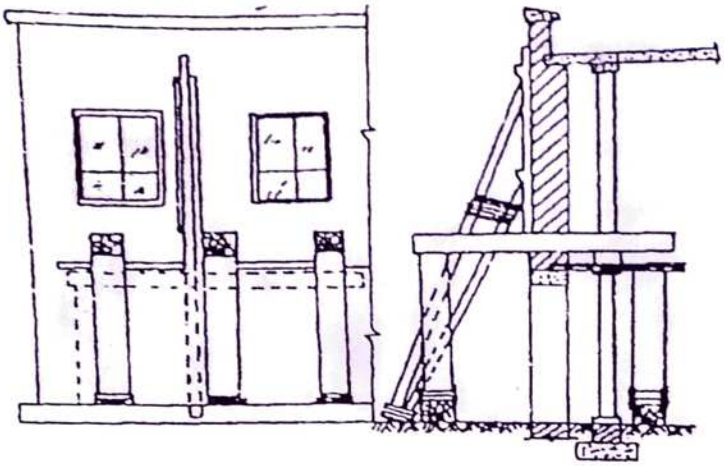


FIG. 18.4. DEAD SHORES (VERTICAL SHORES).



11.12. *Elevation and section of a dead shore for making opening in wall.*

6.5 UNDERPINNING

The process of constructing a new foundation below an existing foundation or strengthening the existing foundation without disturbing the stability of the structure is known as *underpinning*. Underpinning work indicates the strengthening of elements lying below the structure which is always a foundation. It is, therefore, also known as *underpinning of foundations*. Following situations demand process of underpinning :

(i) A basement is to be provided below an existing building.

(ii) Deepening or strengthening of existing foundation to make it capable of bearing increased loads due to proposed new construction over the existing one.

(iii) Foundation has settled and serious cracks have developed in the walls.

(iv) A new building with deep foundation has to be constructed adjacent to the existing building.

Underpinning process is a very expensive process and should be avoided as far as possible. In old constructions this process may have to be adopted, but in new constructions use of this process is completely eliminated as foundations of new structures are nowadays laid after thorough investigations of soils. However, if underpinning has to be done, following points should be carefully attended to, before work of underpinning is taken in hand:

(i) The structure should be completely strutted and shored to withstand all the expected movements likely to occur during underpinning.

(ii) All the cracks in the structure should be adequately repaired and grouted. Tie rods etc. should be inserted.

METHODS OF UNDERPINNING

Underpinning may be done by the following methods :

1. Pit method.
2. Pile method.
3. Miscellaneous method.

1. Pit Method. In this method wall to be underpinned is divided into 1.2 to 1.5 m long sections. Every alternate section is underpinned first and remaining alternate sections are underpinned later. Holes are cut in the wall slightly above ground level at an interval of about 1.2 m to 1.5 m. The needle beams, strong enough to carry the load of the structure, are then inserted through the holes. Bearing plates are used between needle beams and wall, to have a uniform

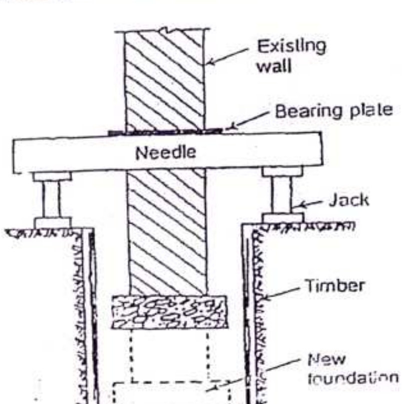


Fig 11.13. *Pit Method of under pinned.*

Now foundation trench is excavated to the required depth and new foundation laid as per designs. Following precautions should be observed :

(i) Only one section of 1.2 to 1.5 m should be underpinned at a time.
(ii) First of all alternate sections should be underpinned.
(iii) Excavated trenches should be properly timbered.
(iv) Jacks should be founded on sole plates placed over firm hard surface.
(v) Jacks should be placed sufficiently away from the edge of the trench.
(vi) Needle beams should be strong enough to bear the expected load on them.

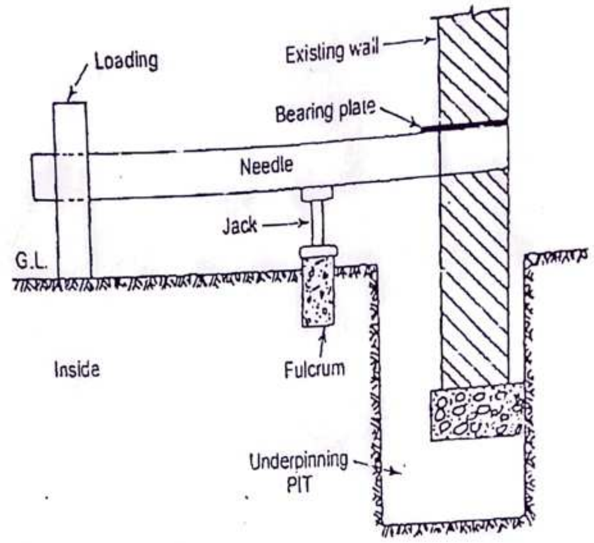


Fig. 11.14. *Support given to the super-structure through cantilever needles.*

If open space on one side of the wall is not available for jacking cantilever needles, needles projecting inside only may be provided as Fig. 11.14.

2. Pile Method. In this method concrete piles are driven along both the sides of the existing wall. The needle beams designed as pile caps are then provided

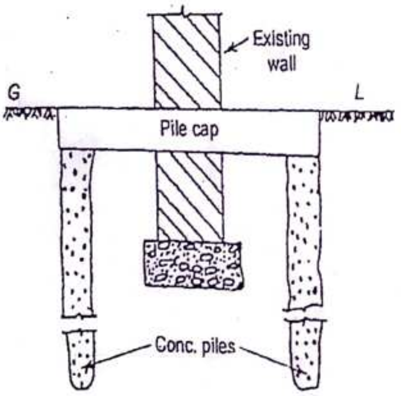


Fig. 11.15. *Pile method of underpinning.*

over these piles through the wall. Needle beams relieve existing wall from load. This method is useful in water-logged areas where walls carry quite heavy loads. In this case piles and needle beams, become a permanent part of the foundation and existing foundation of wall is not touched.

3. **Miscellaneous Methods.** Foundations of buildings carrying not very heavy loads can be strengthened by *cement grouting. Chemical consolidation, freezing* and vibro-floatation methods. But these methods are specialised methods and prove very costly, and are not recommended for normal conditions. In chemical consolidation method, inclined perforated pipes are driven

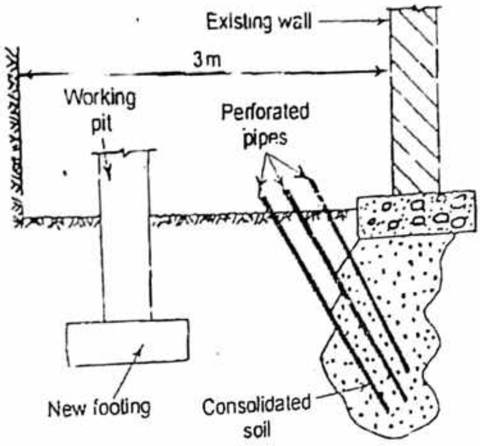


Fig. 11.16. *Method of chemical consolidation.*

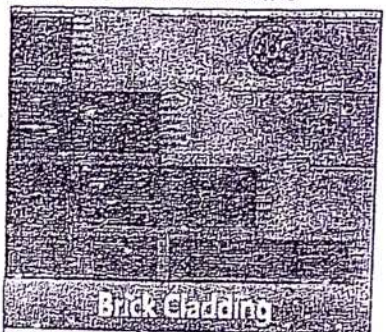
below the foundation. Solution of sodium silicate is continuously injected through the pipes when they are being driven and solution of calcium or magnesium chlorite is injected when pipes are being withdrawn. The chemical reaction between chemicals injected during driving and withdrawal of pipes cause consolidation of the soil. This method is suitable in sandy or granular soils only. In freezing method, soil around existing foundations is frozen and thus its bearing capacity is increased. Vibro-floatation method involves consolidation of soils by vibration effect.

Chapter – 7: Cladding and External Finishing

Cladding

Claddings are a form of masking or infilling a structural frame and can be considered under the following headings:

1. Panel walls with or without attached facings:
   (a) Panel walls with attached facing (Claddings fixed to a structural backing) - e.g. brick facing, stone facing, tiles, slates, shingles, timber boarding, plastic boards facing etc.
   (b) Panel walls without attached facings - e.g. cavity walls with Chines brick facing, stone facing cavity walls etc.
2. Concrete and similar cladding panels
3. Light infill panels
4. Curtain walling which can be defined as a sheath cladding which encloses the entire structure



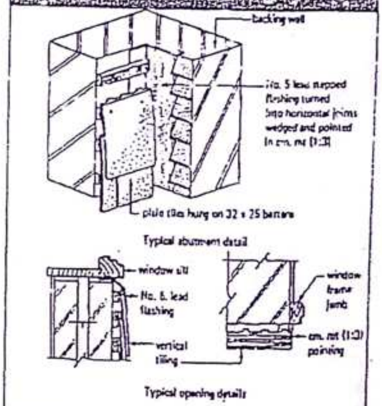


Fig. III.27 Vertical tile hanging – typical details 2

Generally in building construction, cladding is known as the materials applied on the surface of wall. Cladding does not necessarily have to provide a water-proof condition but it is instead a control element only serving safely to direct water or wind in order to control run-off and prevent infiltration into the building structure. Cladding applied to window is often referred to as window capping.

All forms of cladding must fulfil following functions:

1. Be self-supporting between framing members.
2. Provide necessary resistance to rain penetration
3. Be capable of resisting both positive and negative wind pressure.
4. Provide the necessary resistance to wind penetration.
5. Give the required degree of thermal insulation.
6. Provide the required degree of sound insulation to suit the building type.
7. Provide sufficient openings for the admittance of natural daylight and ventilation
8. Give the required degree of fire resistance.
9. Be constructed to a suitable size.

7.1 Cladding for load bearing and framed structures

Generally cladding is non-load bearing and it does not take up or transfer load of the structure. However, at times the main structural material like stone or brick are laid and dressed to provide a desired external surface, hence are load-bearing cladding. Therefore in case of brick and stone cladding, they may be load bearing type. In framed structures cladding may be non-load bearing.

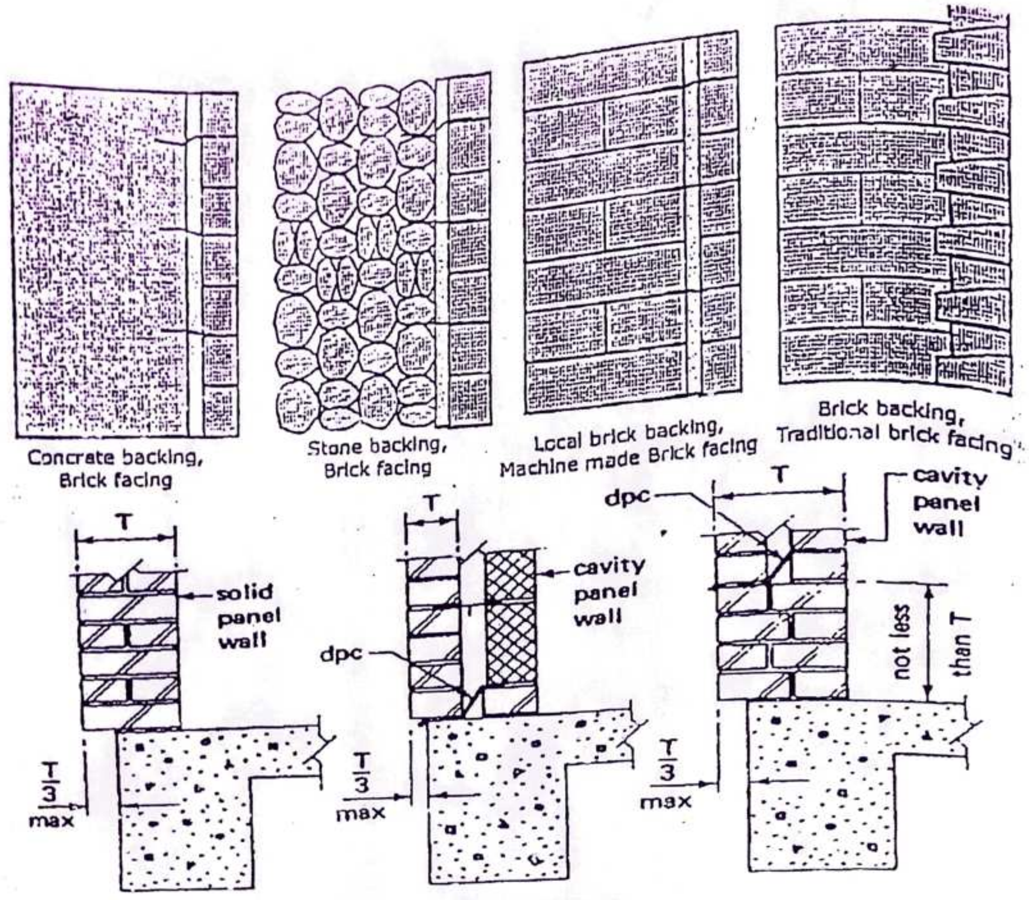
7.2 Brick and stone facing

Brick facing (Brick cladding):

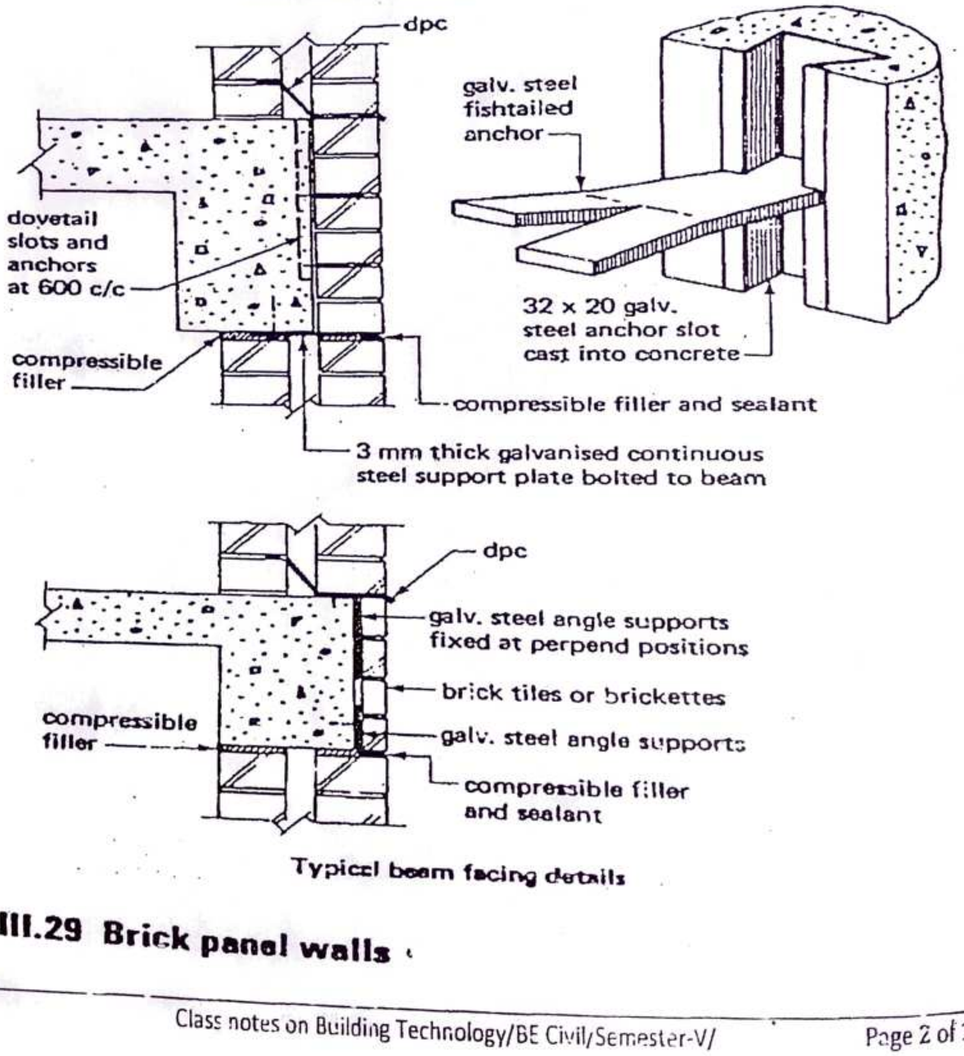
Machine cut bricks (Chinese bricks) are more common for exposed brick facades and works as load bearing cladding.
The framed structured buildings mostly have bricks for partitions as well as the cladding materials.
Brick tiles in different shape, size and color are available in the market, which are used for brick facing.

They are held in place with plaster and mortars or sometimes clamps

- Requirements
  - It should fulfill the functional requirements of the claddings. The construction is such that the panels are supported at each structural floor and tied at vertical edges.
- Method of tying to the vertical structural members:
  - Butterfly wall ties are cast in to the column and built in to the brick joints at every fourth course intervals.
  - Galvanized pressed steel dovetail slots are cast in to the column and dovetail anchors are used to form the tie as shown in Fig. III, 29.



Maximum overhang for panel walls



Typical beam facing details

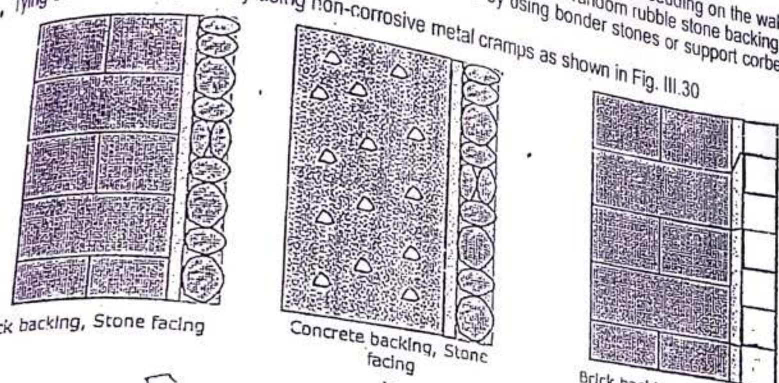
Fig. III.29 Brick panel walls

Stone facing (Stone cladding):

Stone are also popular cladding material. Artificial or reconstructed stones are also produced. Stone claddings are either pasted or held in place with the help of dowels and clamp.

a. Requirements

- Stone claddings are the thin layers of stone. Its thickness vary from 40mm (hard stones like slates, marbles etc.) to 75mm (soft stones like sandstone, limestone etc.)
- They may be slate stone or any other sedimentary rocks.
- Normally stone clads are small in size (up to $1.00m^2$) and have cement mortar bedding on the wall.
- This kind of cladding may be applied on the normal brick backing or random rubble stone backing.
- Care must be taken to transfer the load to the structure by using bonder stones or support corbels at each floor level as shown in Fig. III.3
- Tying back the facing unit by using non-corrosive metal cramps as shown in Fig. III.30



Brick backing, Stone facing — Concrete backing, Stone facing — Brick backing, Stone facing

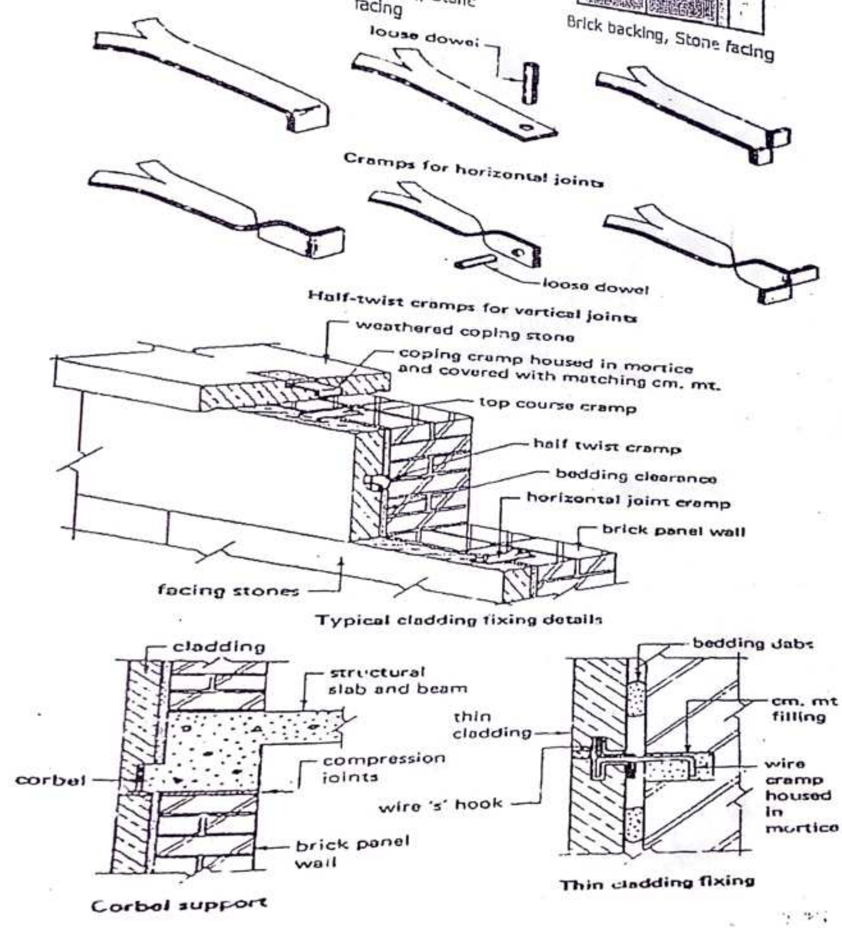


Fig. III.30 Cladding fixings

7.3 Cladding in concrete panels and their construction details:

Concrete panel claddings are common in large construction mass housing, industries, and high- rise buildings, retaining structures. They are generally used in high risk reasons from weather or miscreant (wrong doer or criminal). Concrete cladding panels are usually made of precast concrete with desired textured face in a storey height or undersill panel format.

The storey height panel is designed to span vertically from beam to beam and if constructed to a narrow module will give illusion of a tall building.

Undersill panels span horizontally from column to column and are used where a high wall/window ratio is required. Combinations of both formats are also possible.

Concrete cladding panels are made of dense concrete mix and suitably reinforced of galvanized or stainless steel reinforcing bars. The panels are incorporated with lifting lugs, positions or holes for hoisting in the correct manner. The usual specification for cover of concrete over reinforcement is 25mm minimum.

- The following points should be taken in to account while designing or selecting concrete panel:
  1. Column or beam spacing
  2. Lifting capacity of the plant
  3. Jointing method
  4. Exposure condition
  5. Any special planning requirements as to finish or texture

Typical examples of storey height and undersill panels are shown in Fig. V.1 and V.2 below

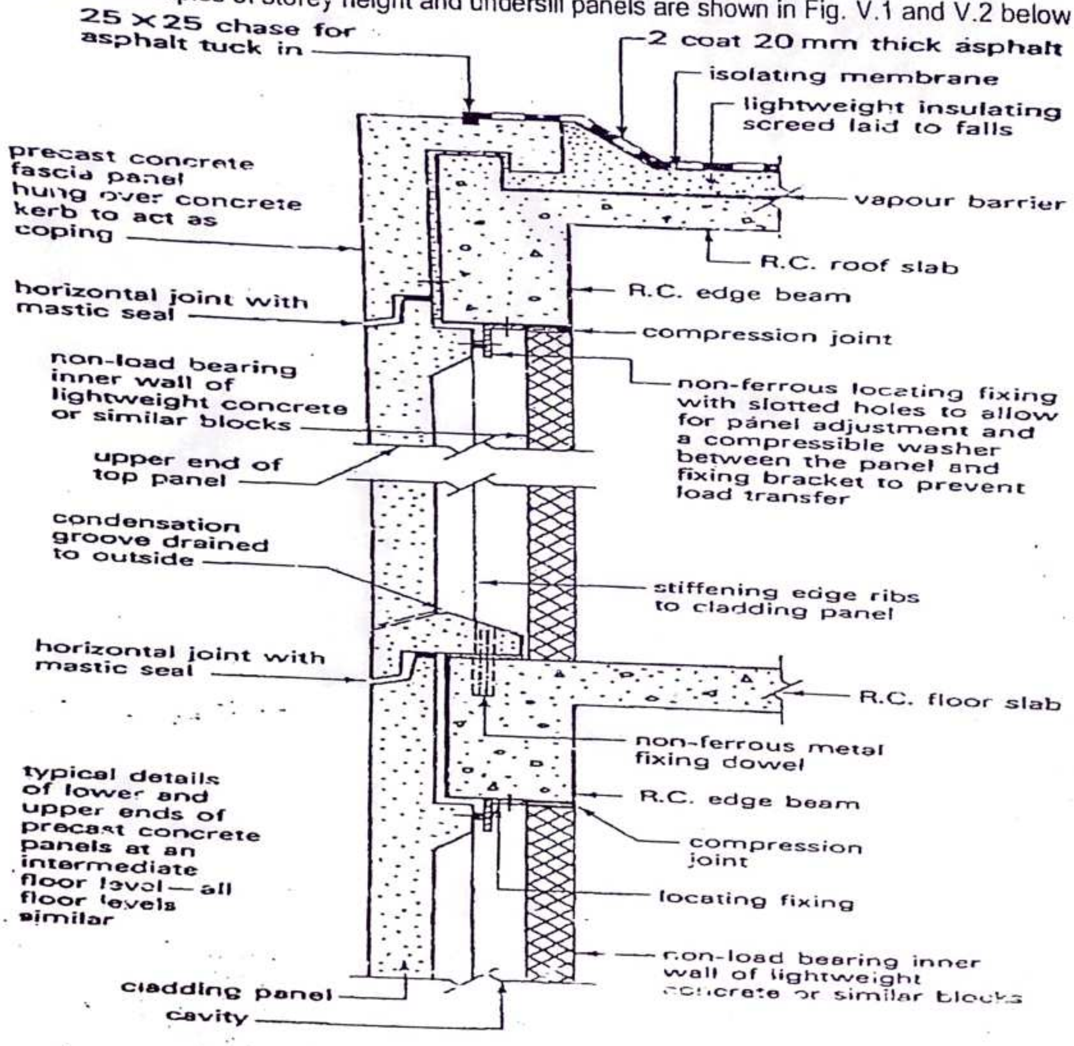
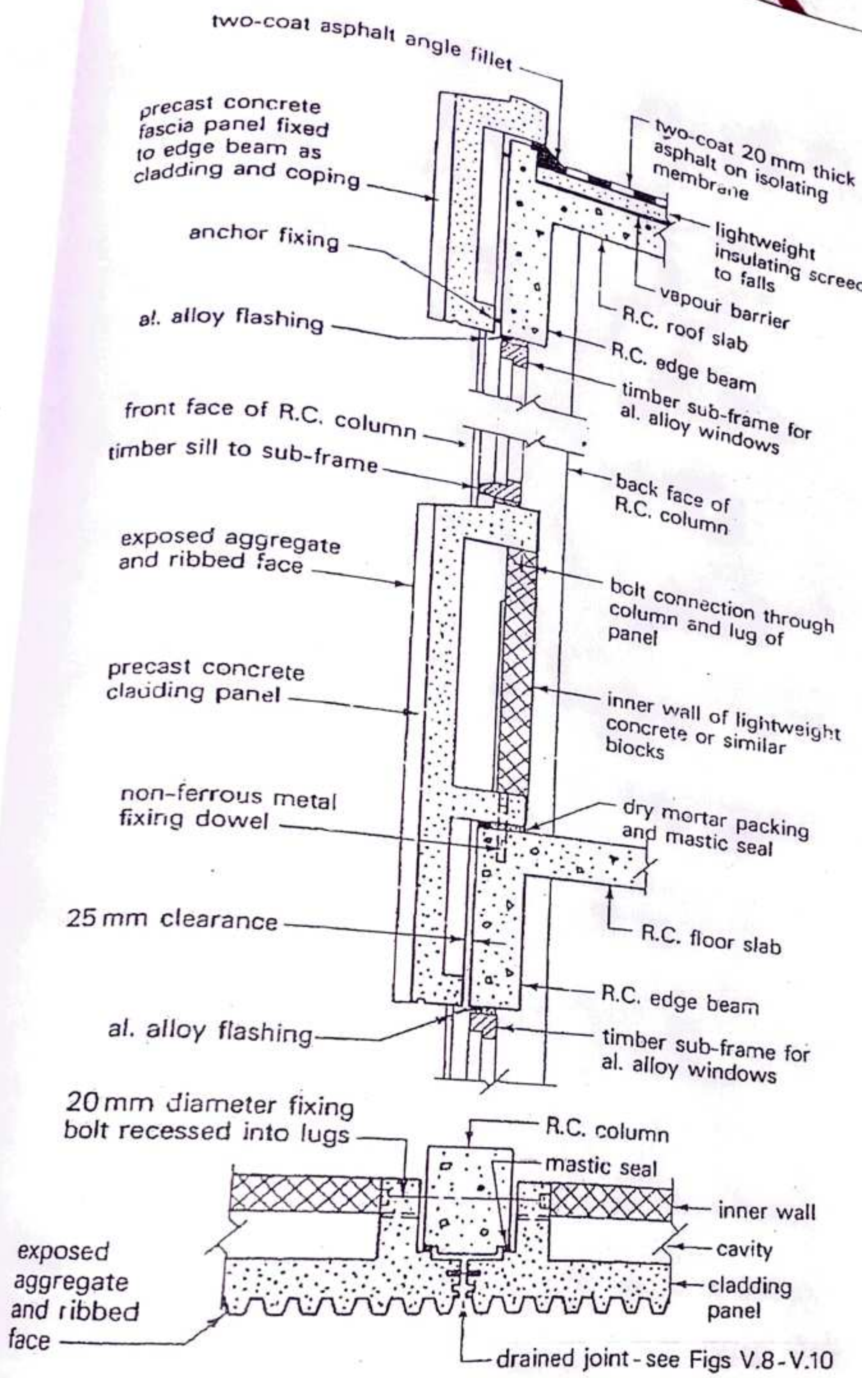


Fig V.1 Typical storey height concrete cladding panel



Plan showing column connection

Fig V.2 Typical undersill concrete cladding panel

Concrete cladding panels can be large and consequently heavy. To reduce the weight they are often designed to be relatively thin (50 mm to 75 mm) across the center portion and stiffened around the edges with suitably reinforced ribs which usually occur on the back face but can be positioned on front face as a feature.

7.4 Plastering, punning and pointing

Plastering

It is the process of covering rough surfaces of walls, columns, ceilings, and other building components with thin coat of plastic mortars to form a smooth durable surface.

Objective

Plastering is done in order to achieve the following objectives.

1. To protect the external surfaces against penetration of rain water and other atmospheric agencies.
2. To give smooth surface in which dust and dirt cannot lodge.
3. To give decorative effect.
4. To conceal (keep something hide or secrete) inferior materials or defective workmanship.

Requirement of good plaster.

1. It should adhere (stick firmly to) to the background and should remain adhered during all variations in seasons and other atmospheric conditions.
2. It should be hard and durable.
3. It should possess good workability.
4. It should be possible to apply in all weather condition.
5. It should be cheap.
6. It should effectively check penetration of moisture.

Terminologies

1. **Background**
   It is the surface to which the first coat of plaster is applied.
2. **Blistering**
   This is the development of local swelling of one or more fissures in the plaster due to residual unslaked lime nodules.
3. **Cracking**
   This is the development of one or more fissures in the plaster due to movements in the background or surrounding structures.
   This may be due to following reasons singly or in combinations.
   a. Imperfect preparation of background.
   b. Structural defects in building
   c. Discontinuity of surfaces.
   d. Movements in background due to its thermal expansion or rapid drying.
   e. Movement is plaster surface itself due to shrinkage and swelling.
   f. Excessive shrinkage caused due to application of thick coat.
   g. Faulty workmanship. etc.
4. **Crazing**
   This is the development of hair cracks, usually in irregular pattern over the finished surface.
5. **Dado**
   This is the lower part of plastered wall, where special treatment is given to make it better resistance.
6. **Dots**
   These are small projections of plaster laid on background for fixing of screeds (piece of writing) etc. The size of dots may be 15cm x 15cm.
7. **Dubbing coat**
   This is the process of filling up hollow spaces in the solid background before applying the main body of the plaster.
8. **Finishing coat**
   It is the final coat of plaster. This coat is also known as setting coat or skimming coat.
9. **Flaking**
   It is the process of scaling away patches of plaster of pervious coat due to lack of adhesion (sticking with something) with the under coat.
10. **Gauging**
    It is the process of mixing various constituents of plaster.
11. **Grinning**
    It is the reflection or appearance on the surface of plaster of the pattern of joints or similar pattern in the background.
12. **Grounds**
    These are the wooden strips fixed to the background to which primary finishing may be secured.
13. **Hacking**
    This is the process of roughening the background to provide suitable bond or key for plastering.

Mortar ratios for cement mortar
1:4 in normal use and 1:3 in high rainfall localities.

Procedure for cement plastering
1. For single coat plaster; used for inferior works
2. For double coat plaster
3. Three-coat plaster.

Lime cement plaster

When some amount of cement is added to the lime (1:1:6, 1:2:9,1:3:12) to use as a binding material for plastering then such type of plastering is called lime cement plaster. It is done so for improvement of binding property of the lime plastering. This type of plastering is economical as compared to the cement plaster.

Heritage plaster

It is the traditional method of plastering done for old temples, church etc. which uses an especially prepared bajra mortar and has been using from ancient time. Bajra mortar is the mixture of lime, surkhi (dust prepared by pulverization of well burnt brick) and other specially prepared plastering materials. When the mixture is properly mixed in dry condition then required amount of water is added and mixed thoroughly. Thus formed paste is used as mortar for plastering. In the olden building, temples, these types of plastering were done. Now-a-days, when renovation works of old temples is to be done to match with the architecture of the olden times, this old technology may be used as a heritage plaster.

Method of cement plastering (procedure for cement plastering):

Cement plastering can be done either in single coat or double coat or sometimes in three coats depending upon the types of finishing required. Anyway we have to prepare the surface on which we are going to plaster, called the preparation of background. Preparation of background is same for all.

Preparation of background

Before plastering on new surfaces, all the masonry joints should be raked to a depth of 10mm in brick masonry and 15mm in stone masonry for providing key to the plaster. All the mortar droppings and dust, and laitance (in case of freshly laid concrete) should be removed with the help of stiff wire brush. Any unevenness is leveled before rendering is applied. For three coats plaster, the local projections should not be more than 10mm and local depression should not exceed 20mm. For two coats plaster, these limitations should be 5mm and 10mm respectively. The surface should be washed with clean water and kept damp uniformly to produce better suction. In no case, surface should be left soaked with water so as to cause to sliding of mortar before it sets or kept less wet to cause strong suction which withdraws moisture from mortar and makes it weak, porous and friable.

If plaster is done in old surfaces, all dirt's, oil, paint etc. should be cleaned off. Loose and crumbling plaster layer should be removed to its full thickness and the surface of the background should be exposed and joints properly raked. The surface should be washed and kept damp to obtain optimum suction.

Processes for single coat cement plaster:

Single coat plaster is used in inferior quality or temporary natures of works. In order to maintain the uniform thickness of plaster, screeds are formed of plaster on wall surface by fixing dots of 15cm*15cm size and depth equal to the thickness of proposed plaster. Two dots are formed in vertical line, at a distance about 2 m and are plumbed by means of plumb. A vertical strip of mortar, known as screed, is then formed. A number of such screeds are formed at certain spacing or at any convenient distance say 1m etc. Cement mortar is then applied on the surface between the successive screeds and the surface is properly finished off immediately after it has sufficiently hardened.

Process for double coat plaster:

Steps

1. **Background is prepared.**
2. If the surface to be plastered is very uneven, a preliminary coat is applied to fill up the hollows, before the first coat. This is known as rendering coat. This is achieved by mason's trowel and pressed well into the joints and over the surface. The normal thickness is 12mm. the rendering coat is allowed to harden and scratched cross cross with the edge of trowel. This surface is left to set for at least 7 days. During this period the surface is completely cured and then allowed to dry completely.
3. Then, first coat is applied. It consists of the following.
In order to maintain the uniform thickness of plaster, screeds are formed of plaster on wall surface by fixing dots of 15cm*15cm size and depth equal to the thickness of proposed plaster. Two dots are formed in vertical line, at a distance about 2 m and are plumbed by means of plumb. A vertical strip of mortar, known as screed, is then formed. A number of such screeds are formed at certain spacing or at any convenient distance say 1m etc. Cement mortar is then applied on the surface between the successive screeds and the surface is properly finished

off immediately after it has sufficiently hardened and scratched criss-cross with the edge of trowel. This surface is left to set for at least 2 days. During this period the surface is completely cured and then allowed to dry completely. The thickness of the first coat is made generally made 2 to 3mm less than the overall thickness of plaster.
4. Then, second coat is applied. This coat is called as floating coat or finishing coat. It consists of the following.
The thickness of the finishing coat varies from 2 to 3 mm. Before applying the floating coat, the previous layer is wetted thoroughly. Then, final coat is applied with wooden floats to a true even surface and finished with steel trowels. As far as possible, the floating coat should be applied starting form top towards bottom and completed in one operation to eliminate joining marks.

Process for three coat plaster.

The procedure for applying three-coat plaster is similar to the two-coat plaster except that an intermediate coat, known as floating coat is applied before applying the finishing coat. The purpose of applying this coat is to bring the plaster to an even surface. The thickness of rendering coat, floating coat and the finishing coat are kept 9 to 10mm, 6 to 9 mm and 2 to 3mm respectively. The rendering coat is made rough. The floating coat is applied after 4 to 7 days after the rendering coat. The finishing coat may be applied about 6 hrs. after the application of floating coat.

Defects in plastering

The following defects may be seen is plastering, viz.

1. *Blistering of plastered surface*
This is the formation of small patches of plaster swelling out beyond the plastered surface due to lake slaking of lime particles in the plaster.
2. *Cracking*
This is the formation of fissures in the plaster work because of the following reasons.
   - imperfect preparation of background
   - Structural defects in building
   - Discontinuity of the surface
   - Movements in the background due to its thermal expansion or rapid drying
   - Movements in the plaster surface itself, either due to expansion (in case of gypsum plaster), or shrinkage (in case of lime sand plaster).
   - Excessive shrinkage due to application of thick coat
   - Faulty workmanship.
3. *Crazing*
When there is formation of series of hair cracks on plastered surface, then it is called crazing. Crazing occurs due to the same reasons that cause cracking.
4. *Efflorescence*
It is the whitish crystalline substance which appears on the surface due to presence of salts in plaster making materials as well as building materials kike bricks, stone, sands, cement etc. and even water. It affects the adhesion of paint with wall surface and also looks very bad appearance.
5. *Flaking*
It is the formation of very loose mass of plastered surface due to poor bond between the successive coats.
6. *Peeling*
It is the complete dislocation of some portion of the plastered surface, resulting in the formation of a patch. This also results from imperfect bond.
7. *Popping*
It is the formation of conical hole in the plastered surface due to presence of particles which expand on setting.
8. *Rust stains.*
This is the rusting of the plastered surface adjoining to the metal parts having rust.
9. *Uneven surface*
This is the result of poor workmanship.

Pointing works in brick and stone masonry

Pointing: It is the process of treatment of joints in the masonry works and this term is used to define the finishing of mortar joints in masonry. In exposed masonry, joints are considered to be the weakest and more vulnerable spots from which rain water or dampness can enter. It consists of racking the joints to a depth of 10 to 20 mm and filling it with better quality mortar in desired shape.

Mortar for pointing
1. Lime mortar: 1:2
2. Cement mortar 1:3

Preparation of surface:

New surface: All the joints are raked down to a depth of 20 mm while mortar is still soft. The surface and joints are then cleaned and thoroughly wetted.

Old surface: All loose pointing (if any) and superfluous mortar on the surface and in the joints are removed. The surface and joints are then cleaned and thoroughly wetted.

Methods of pointing
After preparing the surface and cleaning and wetting the joints as desired, mortar is carefully placed in desired shape in these joints. A small trowel is used for placing the mortar in the joint: the mortar is pressed to bring perfect contact between the old inferior mortar of the joint and new mortar.

Types of pointing: The following types are common in use for pointing work in masonry walls.

a) **Flush pointing**
This type of pointing is formed by pressing mortar in the raked joint and by finishing off flush with the edge of masonry units. The edges are neatly trimmed with trowel and straight edge. It does not give good appearance but considered the most durable type. Hence, such pointing is more in common use.

b) **Recessed pointing**
This pointing is done by pressing the mortar back from the edge by 5 mm or more. The face of the pointing is kept vertical, by a suitable tool. Such kinds of pointing give good appearance.

c) **Rubbed, keyed or grooved pointing.**
This type of pointing is the modification of flush pointing by forming a groove at its mid height by a pointing tool. It gives better appearance.

d) **Beaded pointing**
This is the special type of pointing formed by steel or ironed with a concave edge. It gives better appearance but is liable to damage easily.

e) **Struck pointing**
This is the modification of flush pointing in which the face of the pointing is kept inclined with its upper edge pressed inside the face by 10 mm. This pointing drains water easily.

f) **Tuck pointing**
This type of pointing is formed by first pressing the mortar in the racked joint and finishing flush with the face. While the mortar is green, a groove having 5 mm with and 3 mm depth is cut in the center of the groove. This groove is then filled in or tucked in with white cement putty, kept projecting beyond the face of the joint by 3 mm. If projection is done in mortar, then such kind of pointing is called Bastard pointing or half tuck pointing.

g) **V-pointing**
This pointing is formed by forming V-groove in the flush finishing face.

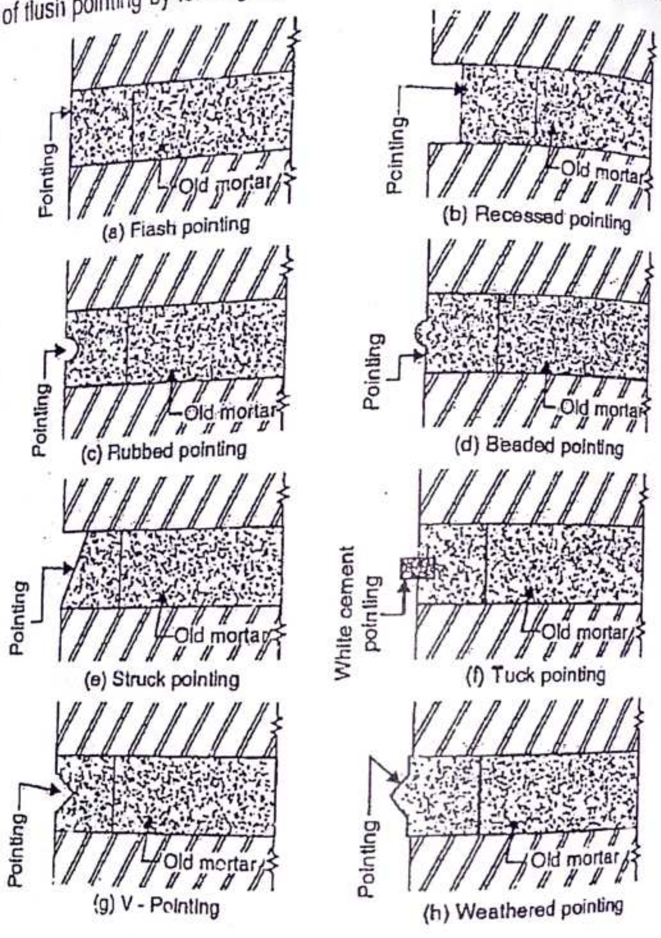
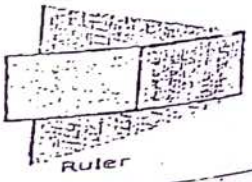


FIG. 19.3. TYPE OF POINTINGS.

h) **Weathered pointing**
This pointing is made by making a projection in the form of V-shape

i) **Ruler pointing**
This pointing is made by raising mortar in the joint.



7.5 Properties and application of paints

Paints are liquid compositions of pigments and binders which when applied to the surface in thin coats dry to form a solid film to impart the surface a decorative finish, apart from giving protection to the base material (background surface) from weathering, corrosion and other chemical and biological attack. It preserves timber structures from warping and decay.

Properties (Characteristics) of ideal paint

An ideal paint should possess the following characteristics.

1. It should well stick to the surface and seal the pores thereby.
2. It should have consistency to easy workability.
3. It should have adequate thickness for good protection and decoration of surface..
4. It should give attractive appearance.
5. It should be cheap and easily available.
6. It should be workable (should have good spreading ability).
7. It should dry in reasonable time.
8. It should have hard and durable surface after drying
9. It should not show hair cracks on drying.
10. It should form a film of uniform color on drying.
11. It should be stable for longer period.
12. It should not be affected by the atmospheric agencies.

Types of paints:

1. Aluminum paints – used for wood work and metal surface
2. Anticorrosive paints – metal protective paint
3. Asbestos paints – for patch work in metal roof, it controls leakage.
4. Bituminous paints – for water proofing on roof and DPC.
5. Bronze paints – used for metallic surfaces.
6. Cellulose paints – prepared from celluloid sheets and amyl-acetate substitutes, superior type of paints
7. Casein paints - contains substance milk, curd etc.
8. Cement paints - available in powder form, water is vehicle, used on masonry surfaces.
9. Enamel paints - base material - lead, white zinc etc., vehicle – varnish
10. Rubber base paints - rubber with chlorine gas, applied on cement surface
11. Emulsion paints - contains synthetic resins and polyvinyl acetate
12. Graphite paints - of black color and used in mines.
13. Plastic paints - plastic in suspension and gives pleasing shades.
14. Silicate paints - mixer of calcium and silicate with resinous materials
15. Luminous paints - mixer of calcium sulfide with varnish, it is very shiny.

Constituents of paint

Paint generally is made up of the following constituents;

1. A base: It is a solid substance in the form of fine powder, forming the bulk of paint.
2. A vehicle or carrier: It is a liquid substance which holds the different ingredients of paint in liquid suspension. It consists of water, polyvinyl lacetate, styrene, alkyds, synthetic resin etc.
3. A drier
4. A colouring pigment
5. A solvent or thinner

Cement paint

This paint is a type of water paint in which white or coloure4d cement forms the base. No oil is used. It is available in powdered form, consisting of cement, pigment, accelerator and other additives. The paint is readily made by mixing water to the powder to obtain thick smooth paste and then diluting it to the required consistency. This type of paint is very useful in painting the external surfaces due to its water proofing ability. Generally, it requires three coats in new surface and two in old surfaces.

Enamel

The enamel paint consists of four basic constituents; viz, metallic oxide (white lead or zinc oxide), oil, petroleum spirit, and resinous matter. The paint dries slowly, but on drying it produces a hard, impervious, glossy, elastic smooth and durable film. Different types of enamel are available in readymade forms, in a variety of colour. They can tolerate the effect of alkalis, acids, fumes of gas, hot and cold water etc. They are commonly used in wooden surfaces, metallic surfaces like door, window, CGI roof coverings etc. and the concrete surface as well.

White Washing

White wash is prepared from fat lime. The lime is slaked at the site and mixed and stirred with 5 litres of water for 1 kg of unslaked lime to make a thin cream. The mixture should be allowed to stand for a period of 24 hrs. and should be screened through a clean coarse cloth. 1 kg of gum is dissolved in hot water to each cubic metre of lime cream. Then, the solution is ready for application. The operation in each coat should consist of a stroke of the brush given from top towards bottom and in reverse direction in its second coat. Similarly, right to left and vice versa in the succeeding course. Each coat should be allowed to dry before the next coat is applied.

Washable distemper

Distemper may be water bound or oil bound. Both of them consist of the following constituents; viz. Base, carrier (water), binder (glue or casein) and colouring pigments. They are available in powder form. And, the oil bound distemper is washable. They are cheaper than oil paints. They are generally light in colour and they provide good reflective coating. They are less durable than the oil paints. They should be applied in 2 to 3 coats. The succeeding coat should be applied only after the undercoat has dried up and became hard. The surface to be distempered should be thoroughly rubbed and cleaned. The efflorescence patches should be carefully wiped out by clean cloth. The irregularities should be filled with putty. Before distempering the new surface, it is desirable to expose the surface 3 to 6 month. Then, the surface should be washed with solution containing 1 kg of zinc sulphate on 10 litres of water and then allowed to dry. Then only the surface is ready for distempering. For old surfaces, loose surface should be removed by scraping and profuse (plentiful) watering and repaired by putting.

Emulsion paints

This paint contains binding materials (vehicles) such as polyvinyl lacetate, styrene, alkyd resin and other synthetic resins. The vehicle imparts alkali-resistance to the paint. The paint dries quickly, within 1.5 to 2 hrs. It has good workability and high durability. The principle film forming constituent of this paint is emulsified in water, so that it may be thinned with water instead of solvent. The paint surface can be washed with water.

Procedure to apply paints on wooden, steel and wall surfaces:

Painting on new wood work (timber) surfaces (important for exam)

Steps 1: Preparation of surface

For good result, the wood should be well seasoned (moisture content should be less than 15%). The surface is dusted off thoroughly to remove dust, shavings, foreign matter etc. Head of nails are punched to a depth 3 mm below the surface to be painted.

Step 2: Knotting

This is the process of filling any holes present on wood surface like knots, minor cracks etc. It is done in two coats. The first coat consists of grounding 15 gm of red lead in 2 litres of water, adding 225 gm of glue (fevicol etc.). When this coat is dried completely then second coat is applied, which consists of red lead ground in boiled linseed (the seeds of the flax plant) oil and thinned with turpentine oil (a liquid substance produced by certain trees).

Step 3: Priming

After knotting, the surface is rubbed with an abrasive paper. The priming consists of applying first coat of paint to fill all the pores. Priming coat creates a layer or film which provides adhesion of the paint with the surface. The composition of primer coat may be the mixture of 1 Kg red lead, 1 Kg white lead in 1 litres of linseed oil or turpentine. Generally, the priming coat is applied before fixing wood work in position. Wood primers are available in market for priming.

Step4: Stopping

It is the process of rubbing down the wood surface by means of pumice stone or glass paper after prime coat is applied and then filling up all cracks, nails holes, dents, open joints etc. with putty.

Step 5: Under coatings

The first coat applied after stopping is called under coating. The undercoating should be of the same shade as that of the finishing coat. This coat helps in imparting opaque (invisible) surface for the finishing coat. Under coating may be single, double or more in coats depending upon the requirement.

Step 6: Finishing coat

This is the final coat and is applied only when the under coating is perfectly dried. The coat should be applied by skill manpower in order to give a smooth, uniform and patches free surface along with brush mark.

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Painting on old wood work sufaces

- Old painting if blistered & flaked should be completely removed.
- Removing of old surfaces by blow lamp
  - The old paint is soften by heat (from blow of lamp)
  - Thus softened paint is removed by string knife.
- Removing of old paint by paint remover.
  - Paint removers are available in market and are applied on the old painted surfaces
  - The old paint lifts up, wrinkles, and can be easily removed by sharp knife etc.
  - Caustic soda solution is also useful for removing old paint. The solution of caustic soda and water is applied on the surface and it is made wet for 48 hours
  - The old paint is soften and easily scraped off.
- First coat of desired paint is applied on the clean and surface of woodwork. If necessary second coat is also applied.
- Finishing coat: Final coating is applied to give smooth uniform, and pleasing surface. Knotting and priming do not require in the painting of old woodwork. However, the stopping may be required if holes, cracks and opens are seen on the surface.

Painting on new iron and steel work (important for exam)

Step 1: Surface preparation
The surface is cleaned off properly in order to remove all rusts, scale etc. by scrapping or brushing with steel wire brush. Oil, grease etc. are removed by washing the surface with petrol, benzene (a liquid hydrocarbon present in coal tar and petroleum referring to a resin obtained from tree) or lime water.

Step 2: Treatment to the surface
The cleaned surface is treated with a film of phosphoric acid. This film protects the surface from rusting and provides better adhesive surface for the paint.

Step 3: Priming
This is the first coat and is consists of dissolving 3 Kg of red lead in 1-litre of boiled linseed oil or turpentine. Usually, this coat is applied by hand brush.

Step 4: Under coating
Under coating may be in two or more layers according to the requirement. This should be applied when the priming coat is perfectly dried. This consists of 3 Kg of red oxide dissolved in 5 litres of boiled linseed oil or turpentine oil.

Step 5: Finishing coat
When the under coat is completely dried, then the desired colour is applied over it. The finishing coat should give smooth and uniform colour.

Repainting on old iron and steel work

- Before repainting, the old surface is thoroughly cleaned by application of shop water. The grease, if any may be removed by washing the surface with lime and water.
- However if the old surface has cracked, it should be removed by flame-cleaning.
- The surface is then scrapped with wire brush and wash with solution of caustic soda and fresh slaked lime.
- After the surface is thus prepared, painting is carried out as for the new surface.

Painting work on masonry wall surfaces (important for exam)

Step 1: Preparation of surface (Clean the surface)
Use the power washer with some bleach if a lot of mold or algae are present in the wall surface. In a place where the mesh of power wash is not appropriate, tackle that old loose paint with a scraper and wire brush. After all the loose paint has been removed, make sure that subtract is clean. Any oil or grease on the masonry surface will bleed through the paint, causing discoloration, and possibly interfering with the longevity of the paint job. Use tri-sodium phosphate, also simply known as TSP, to clean the concrete surface before applying any product. Mix it up in a bucket and scrub it into the surface with a scrub brush to remove any grease or oil, ensuring that the paint will stick well.

Step 2: Treatment to the surface (make any repair);
For any major defects in the surface to repair, ready mix concrete patch is used to make those repairs after cleaning

Step 3. Sealing and Priming
Almost any masonry surface needs to be both sealed and primed before the paint is applied. The sealer keeps moisture from coming through the concrete. This is especially true in basement, which tend to hold the moisture. The two step process sealing and priming is used to build a strong, water resistant foundation (surface).

Step 4: Undercoating
After sealer and primer coats are completely dry, paint actually forms a harder surface when thin coat are laid on top of each other. Under coating may be in two or more layers according to the requirement. It shall be applied only when the priming is completely dried. It generally consists of the same colour which is going to be used in the finishing coat

Step 5: Finishing coat
When the under coating is completely dried. Then, the finishing coat is applied with more care in order to give the smooth and uniform colour.

Painting work on plastered wall surfaces (important for exam)

Step 1: Preparation of surface (Clean the surface)
The newly plastered surface contains considerable moisture. Hence, it is desirable to leave the plastered surface 3 to 6 month prior to painting. The surface is cleaned by pumice stone, checked whether there are any defects in the plastered surface or not. If yes, this shall be repaired to its original finish. The whole surface should be treated with white putty/paris in order to give smooth touch.

Step 2: Treatment to the surface (make any repair):
The plastered surface are highly alkaline (produced during hydration of cement). Thus, the surface shall be treated with alkali resistant primer. Surface is washed with dilute solution of zinc sulphate to neutralize free lime on wall surface. If the surface is porous, it can absorb the liquid from the paints and uneven sucking may cause lack of uniformity. Hence care should be taken while selecting the primer.

Step 3: Priming coat:
Mixture of equal parts of white and red lead in boiled linseed oil is applied on the surface

Step 4: First coat and final coat application
- First coat of desired paint is applied on the surface.
- Final coat of the desired paint is applied on the dried first coating.

Varnish

It is a clear and pale solution of resinous substance dissolved in either turpentine oil or alchohol, The solution on drying forms a hard, transparent glossy film on the varnish surface.

Importance of varnish

- The varnish applied on the decorative surfaces enhances the appearance of the paint.
- Safeguards the wood work from atmospheric agents.
- Increases the durability of the paint.

Types of varnish

1. Oil varnish

   Oil and resin dissolved in volatile liquid (takes 24 hours to dry)
2. Spar varnish

   Used in spar and other parts of ship, weather resistance.
3. Flat varnish

   Dull appeared varnish, addition of more wax, metallic soap etc.
4. Asphalt varnish

   Dissolving asphalt in linseed oil and gives black colour, used for metal.
5. Spirit varnish

   Resin dissolved in volatile liquid (spirit) and fast to dry.

Chapter – 8: Internal Finishing

8.1 Partitions: types, functions and methods of construction

A partition wall may be defined as a thin internal wall or division made up of brick, studs, glass or other such materials and provided for the purpose of dividing one room or portion of a room from another. Generally partition walls are designed as non-load bearing walls. It may be of folding, collapsible or fixed type. The lighter the partitions, the lighter and smaller will become the structural elements and the building as a whole will become more economical.

Advantages:

1. Divides the whole area into number of rooms.
2. Thin in section and therefore occupy less floor area
3. Offers privacy for both sight and sound
4. Are light in weight and cheaper in cost of construction.
5. Easy in construction in any position

Requirements of good partition

1. Thin in cross-section so that maximum floor area can be utilized.
2. Provide adequate privacy in rooms both in respect of sight and sound.
3. Constructed from light, sound, uniform, homogeneous, durable and sound insulated materials.
4. Simple in nature, easy and economical in construction having proper coherence with the type of building structure.
5. Offer sufficient resistance against fire, heat, dampness, white ant or fungus, etc.
6. Rigid enough to take the vibrations caused due to loads.
7. Strong enough to support sanitary fittings and heavy fixtures.

Types of partition according to their function

1. Load bearing partition
2. Non-load bearing partition

Load bearing partition

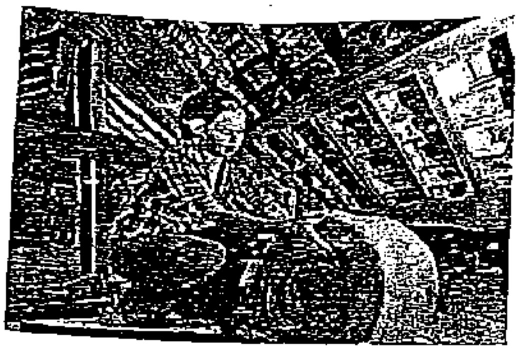
Load bearing partition is designed and constructed to receive super imposed loads and transfer the load to the foundation. It supports the joist of floor, purlins and ceiling's joist of the roof.

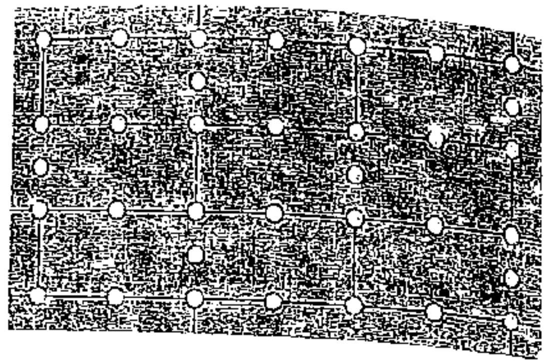
Non-load bearing partitions

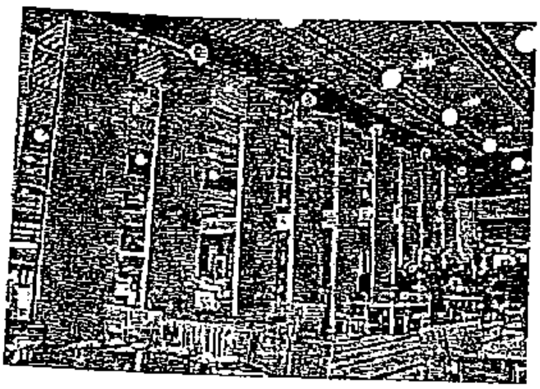
Non-load bearing partitions neither receive superimposed loads nor transmit any structural loads to the structural member below. Such partitions have only their own weight to hold in position. They also carry fixers and fittings necessary in the room. Non-load bearing wall must be able to resist impact loading on its face and also vibration caused from any reason.

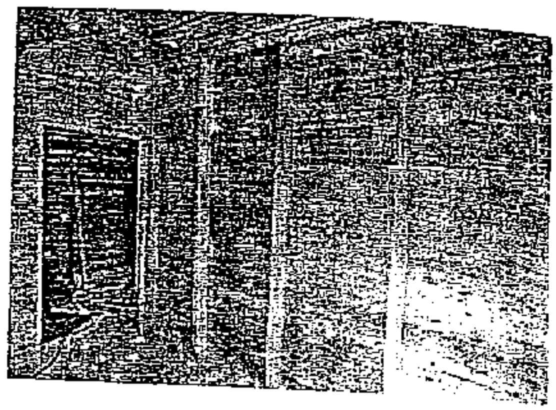
Types of partition according to the materials used are as follows:

1. Brick partitions
   a) Plain brick partition
   b) Reinforced-brick partition
   c) Brick-nogging partition
2. Hollow block partition
3. Clay-block partitions
4. Concrete partitions
5. Glass partition
6. Timber (wooden) partitions
7. Straw-board partitions
8. Plaster slab partition
9. Metal partition or metal lath partitions
10. Asbestos cement sheet and CCI sheet partitions
11. Wood-wool slab partitions
12. Plastic board partition

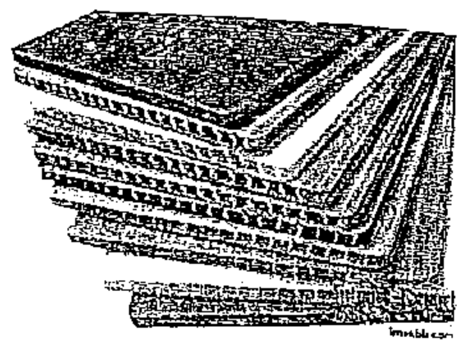








12. Plastic board partitions



Plastic sections have unlimited possibilities for uses:

1. Partitions and cabins for interior with timber and aluminium framing
2. Suspended type false ceiling
3. False ceiling with timber grid support
4. Wall panelling etc.

Plastic board partitions are

- Light in weight, impervious, durable, water proof and can be used all ordinary carpentry tools.
- Plastic sections and boards are made of PVC and are manufactured in foamed and unfoamed categories.
- Foamed sections have a solid outer skin and a foamed core.
- Unfoamed sections have solid outer skin and hollow cavities inside.

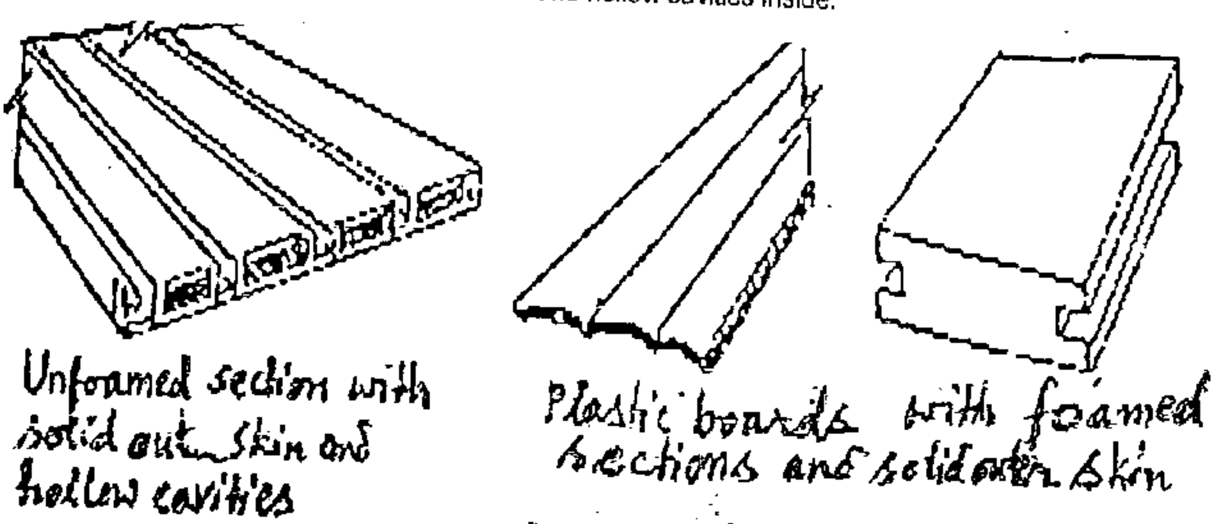


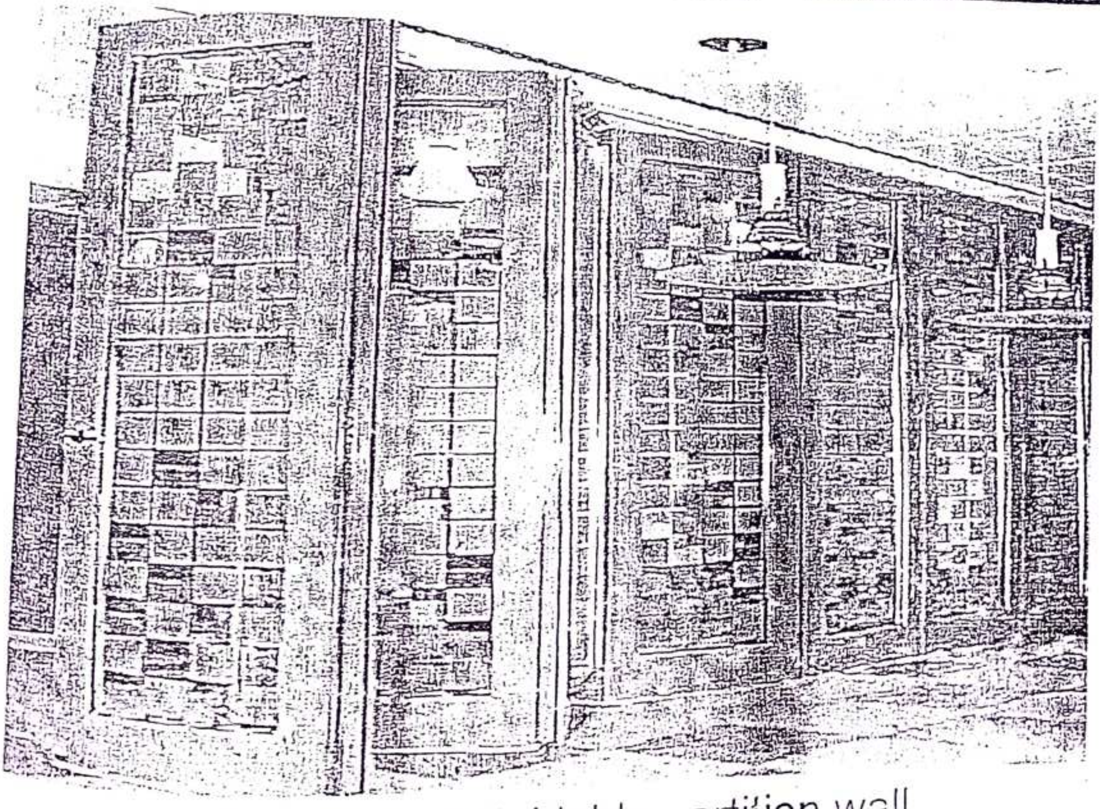
Fig. Plastic boards

8.2 Mobile partitions

Mobile or moveable partitions are used where the walls of a room are frequently opened to form one large floor area.

There are three types of mobile partitions:

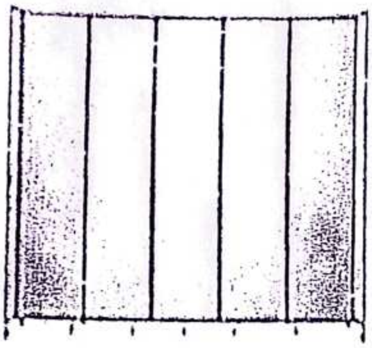
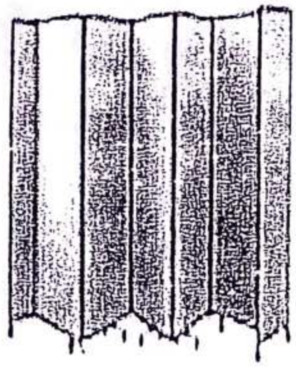
- **Sliding:** Sliding partitions consists of series of panels that slide in tracks fixed to the floor and ceiling. The partition may be operated by the machine if the partition is similar to those of sliding doors.
- **Sliding & folding:** Sliding and folding partitions operate in a similar manner to sliding folding doors. They are normally used for smaller spans.
- **Screens:** Screens are usually constructed of a metal or timber frame. It is fixed with plywood and chipboard inside. The screen supported with legs for free standing and easy movement.



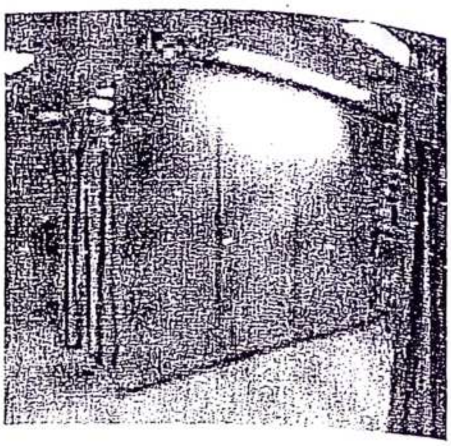
Sliding and Foldable partition wall

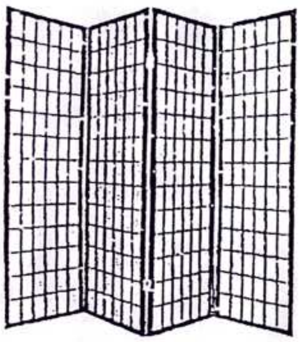
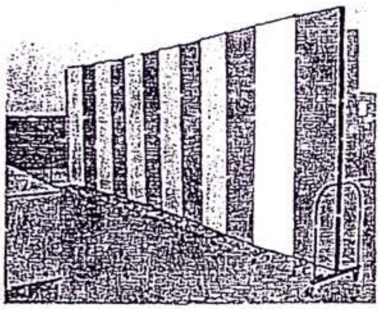
Mobile partitions

- Rolling mobile folding partitions which provide temporary walls
- The portable wall partition has two full panel end members which provide support, rigidity, privacy, and noise reduction.
- They fold and are on wheels enabling mobility and ease of storage.

The Room Divider 360



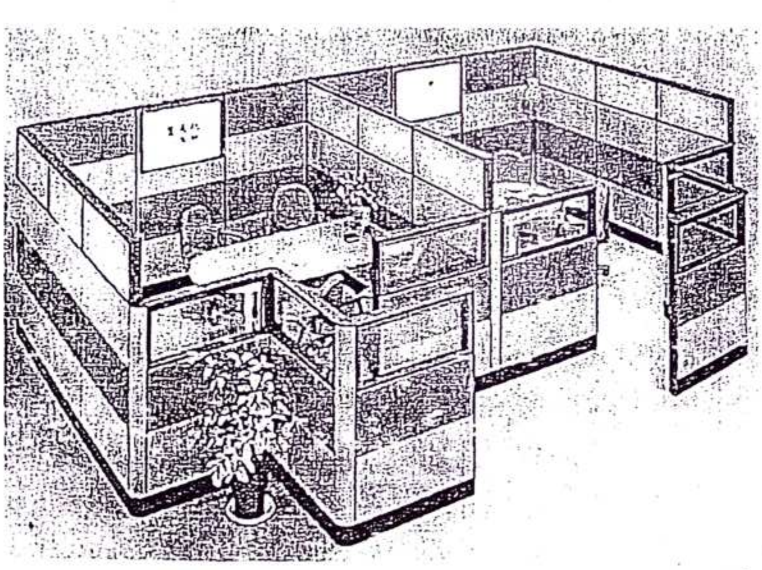




Three common uses (functions) of mobile partitions are:

- To divide space quickly where non-mobile permanent room dividers may be unavailable or unpractical.
- As a cost effective way to create a classroom or meeting room in existing space.
- Convenient sight divider to conceal door openings to restrooms, commercial kitchens, and other backroom areas.

Mobile partitions are used in

- Arena's
- Churches/Houses of Worship/Funeral Homes
- Conference/Convention Centres
- Government/Corporate offices
- Hotels/Restaurants
- Residences
- Salons and Spas
- Schools of all levels



8.3 Suspended and false ceilings: types, functions and methods of construction

Suspended ceiling:

- A suspended (false) ceiling is the construction below the roof slab.
- It is the false structure means not load bearing in overhead of the room below the roof or slab.
- It has the framework suspended or supported from the main structure, usually in the roof slab and covering material is then fixed on the frame.
- It forms void between the ceiling and roof /slab
- Light fixers, air diffusers and other equipment are usually integrates into the linear pattern.
- Acoustic material may be supported above the ceiling material
- Depending upon the purpose. plaster boards, straw-boards etc. are secured to ceiling.

Uses (advantages) of suspended ceiling

- It is used for attractive appearance
- It is used to conceal (hide) the housing utilities, pipes, electrical wires. Telephone wires, channel wires etc.
- It is used for sound and heat insulation purposes

Requirements of suspended ceiling

It should be easy to construct.
It should be easy to clean, repair and maintenance

Types of suspended ceiling according to use of materials:

1. Timber
2. R.C.C.
3. Metal
4. Composite
5. Gypsum board
6. Straw board
7. Glass
8. Paper

Types of suspended ceiling according to construction:

1. Joint less
2. Jointed
3. Open

1. Joint less suspended ceiling:

- The joint less ceiling is monolithic in appearance and no joints can be seen on the surface is termed as joint lees ceiling.
- This can be done by applying plaster on the ceiling board or expanded metal lathing etc.

Jointed suspended ceiling:

- These are very commonly used in practice.
- The joints on ceiling may be made in decorative appearance.
- The frame is made according to desired shape and size of ceiling boards.
- Ceiling materials may be fixed with spring clips, nails or screws.

Open suspended ceiling:

- In the open ceiling, the frame is fixed in such way that voids are formed to give virtual (essential) effect.
- Voids are largely provided.
- It is used for decorative purpose

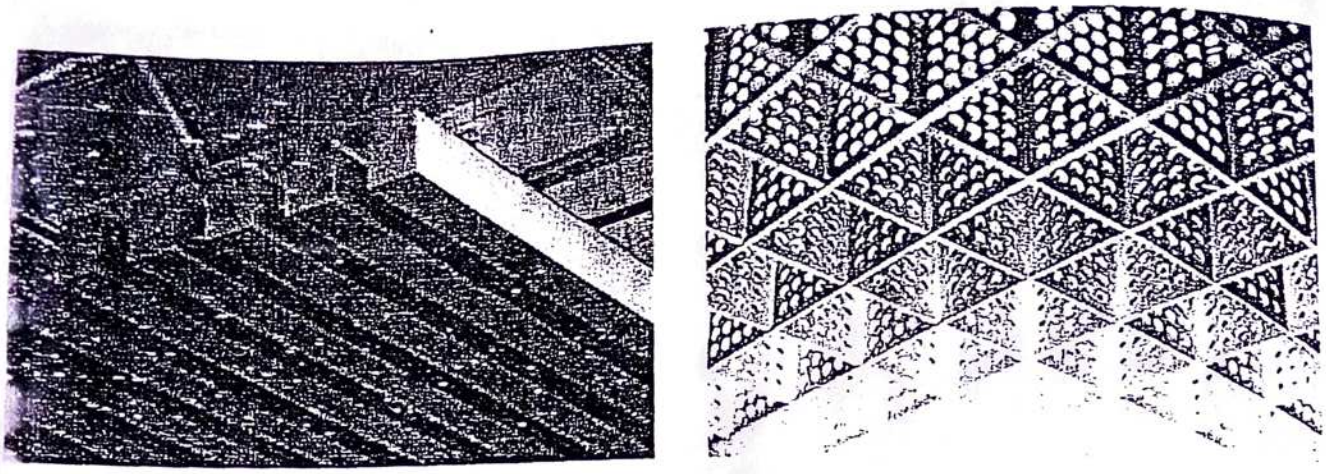
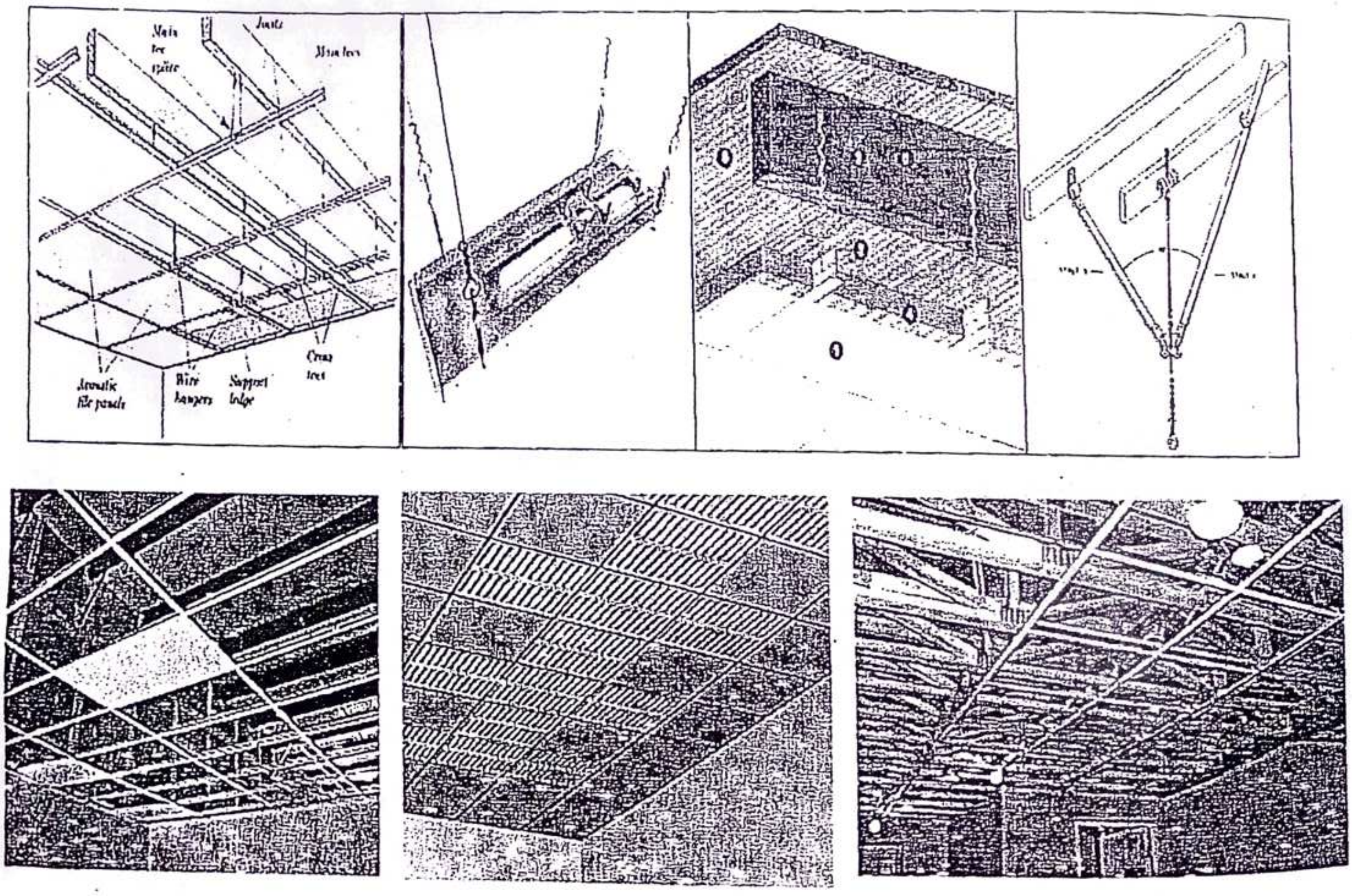


Fig. Open suspended ceiling

Procedure for ceiling fixing

- Ceiling joist are fixed on desired height from the floor.
- If necessary vertical struts are fixed to set joists.
- Battens are then fixed on the joist.
- Ceiling materials like planks, plywood, metal sheets etc. is fixed on the battens.
- Finally, painting and finishing is done.



Different types of suspended ceilings

Chapter – 9: Water Supply and Drainage

Introduction

- An adequate supply of water is a basic requirement for most buildings for reasons of cooking, cleaning, personal hygiene and sanitation as well as for manufacturing processes in industries etc.
- In most areas of a country, including Nepal, the consumers or water users get water by a piped supply of water mains available from a Public Water Board or Public Utility Company mains supply system.
- In some of the cities of Nepal, at current situation, some private companies have also been supplying additional water to the consumers by conveying it in water tankers.
- Anyway, the water supplied to the consumers should be free of micro-organisms, pathogens and other harmful impurities.
- Public water supply system follow the sequence of water collection from source of supply, conveyance to treatment plants (treatments including disinfection) and finally its distribution.
- Ultimately, water is distributed for various consumption purposes in a building through internal water distribution system.
- The water so supplied ultimately gets converted in to waste water, which has to be properly drained.
- Hence, Water Supply and Drainage system is to be carried out simultaneously in proper manner.

9.1 Mains of water supply:

Storage and Distribution system

According to the function of pipes, the pipes used in distribution system of a Public Water Board may be classified into following categories:

(1) Mains or trunk or primary pipeline (2) Communication pipes or secondary pipeline (3) Consumer pipes or service mains

1. Mains or trunk or primary pipeline:

The mains of water supply are also known as municipal water mains.

i. They consist of large-sized pipe carrying wholesome water for drinking and other uses, for a various localities of the city.

ii. These mains are laid underground along the roads leading to locality to be served by them and at a depth where they will be unaffected by traffic movement or extremes of weather (excessive heat, frost etc.)

iii. The layout of the mains of a water supply system is generally a circuit with trunk mains feeding a grid of subsidiary mains for distribution to specific areas or districts.

iv. The materials used for main pipes are cast iron and asbestos cement which can be tapped whilst under pressure; a plug cock is inserted into the crown of the mains pipe to provide the means of connecting the communication pipe to supply an individual building.

v. However, the system of lay-out of mains and other pipelines depends upon the topography, location and water source-elevation etc. according to which laying of pipelines may be: (a) Dead end, (b) Grid iron, (c) Ring system (d) Radial systems

<u>Layout of pipelines in distribution system may be as follows:</u>

<u>(a) Branch/Dead End Pattern:</u> - The branch pattern evolves when distribution mains are extended along streets as the service area expands. Avoid dead ends and stagnant areas in the distribution system to the greatest extent if possible.

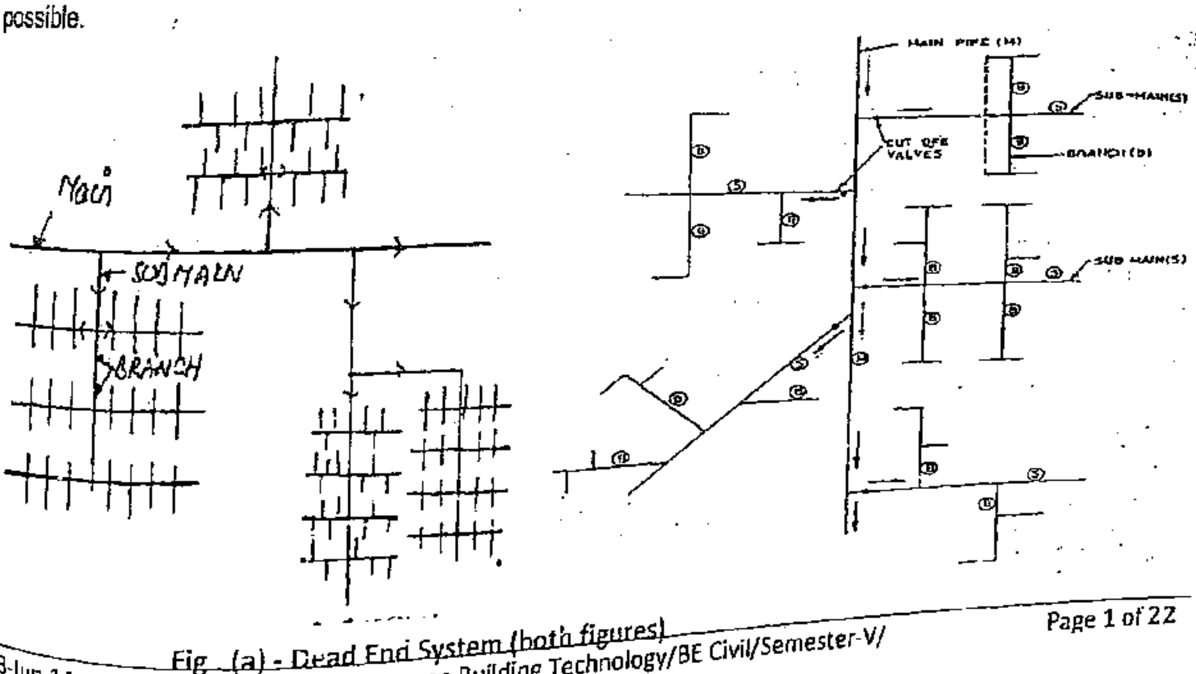
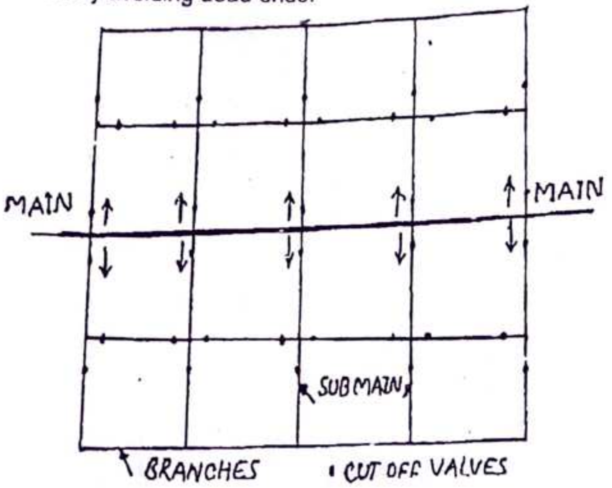


Fig. (a) - Dead End System (both figures)

(b) Grid/Loop Pattern.

The grid/loop pattern has the hydraulic advantage of delivering water to any location from more than one direction, thereby avoiding dead ends.



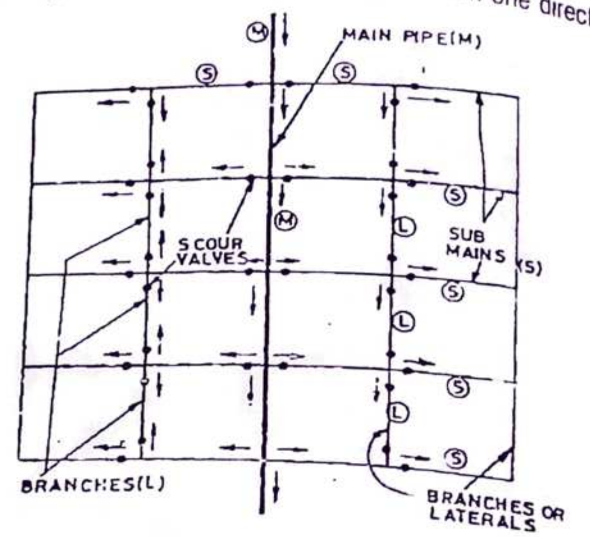
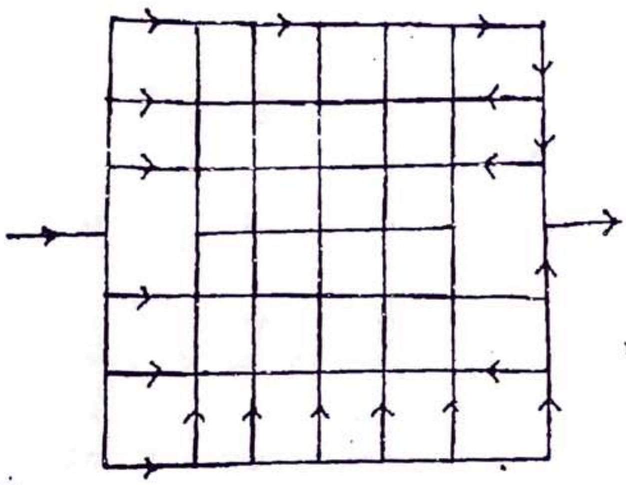


Fig. (b) – Grid Iron or Loop pattern System (both figures)

(c) – Circular or Ring System



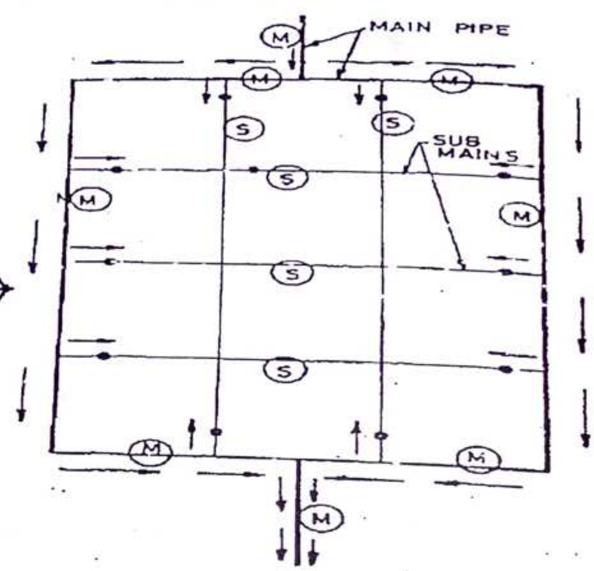
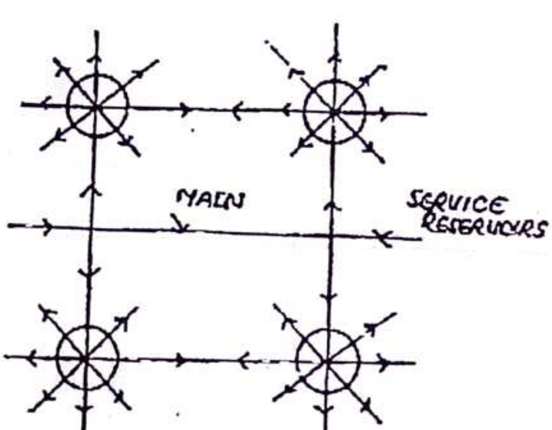


Fig. (c) – Circular or Ring System (both)

(d) – Water distribution in Radial System:



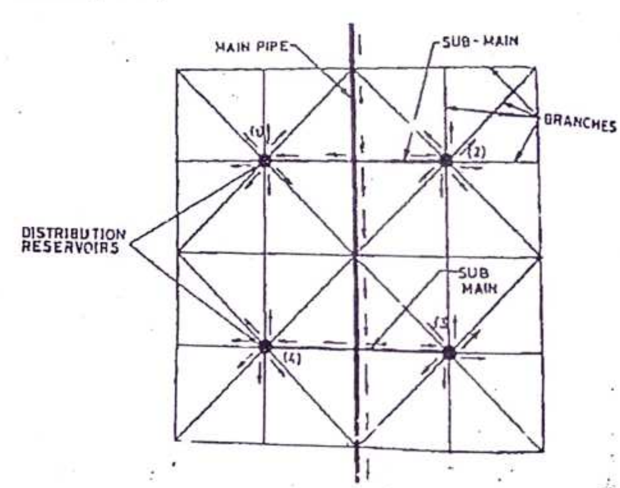


Fig . (d) – Water distribution in Radial System (both)

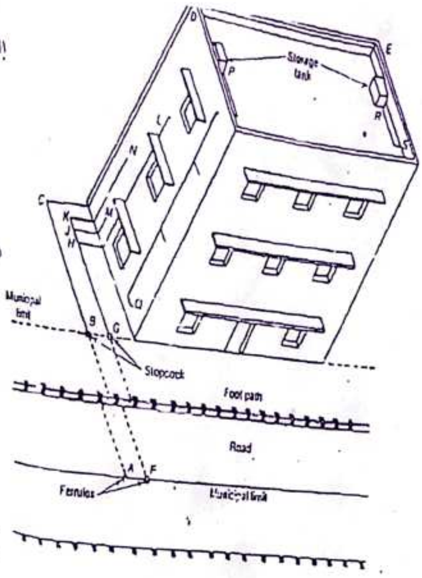
9.1 Mains of water supply: storage and distribution system

The pipelines used in distribution system of a Public Water Board ma[y]
categories:

1. Mains
2. Communication pipes
3. Consumers pipes

1. Mains of water supply (continuous...):

Fig. Water supply of a multi-storeyed building⇒



Principals to be followed for the Mains of water supply:-

I. Adequate size to give the required rate of flow or amount of water.
II. Water mains should be divided into sections by the provision of sluice valves and other valves so that water may be shut-off while repair is to be done.
III. There should be no dead ends in the network of mains. If dead end is unavoidable a hydrant must be provided to act as washout but the washout point should be located in a safe place to avoid water contamination from sewer water etc
IV. Air valves should be provided at all summits and wash-out valves at low points
V. Mains should be laid according to the general contour of the ground to provide a positive pressure at all the points of the mains.
VI. Mains of water supply should be laid at a minimum depth of 90 cm at road and 75 cm at foot-paths and this depth is measured from the top of the pipe to the ground surface.
VII. The mains should be located sufficiently away from other service lines like electric and telegraphic cables to assure safety and where the mains cannot be located away from such lines, suitable protective measure should be accorded to the mains.

2. Communication pipes or secondary pipeline:

A communication pipe is the part of the service pipe extending from the water main up to stop-cock and including the stop-cock, which is under the control of the municipal authority and not consumer.

Principals to be followed for Communication pipes or secondary pipeline:

- All the premises (buildings) supplied with water by the municipal authority have their own separate communication pipes. In case of group or block of premises belonging to the same owner, the same communication pipe shall supply water to more than one premises with the prior permission of the authority.
- The communication pipe between the water main and the stop cock at the boundary of premises shall be laid by municipal authorities.

Principals to be followed for Communication pipes or secondary pipeline: (continuous....)

(i) All the premises (buildings) supplied with water by the municipal authority have their own separate communication pipes. In case of group or block of premises belonging to the same owner, the same communication pipe shall supply water to more than one premise with the prior permission of the authority.
(ii) The communication pipe between the water main and the stop cock at the boundary of premises shall be laid by municipal authorities.
(iii) Connection up to 50 mm diameter pipe may be made on the water pipe by mains of screwed ferrules, provided the size of the connection does not exceed one-third the size of the water main. In all cases the connection shall be made by T-branch.

Ferrule Screwed Male Ends

Gun Metal Ferrule Cock

3. Consumer pipeline or service mains:

The portion of service pipe used for supply of water and the internal pipes inside the house which are the properties of the owner of house is known as consumer pipe. Consumer pipeline is connected to the communication pipe with stop-cock. Consumer pipes should be covered with suitable cover. Each and every service main should have separate stop cock and gate valve. There should be a proper provision of cleaning and repair in consumer pipeline.

Principals to be followed for Consumer pipeline or service main:

(i) No consumer pipe should be laid in the premises to connect the communication pipe without the approval of the municipal authority.

(ii) The consumer pipe should be within the underground with suitable cover to safeguard against damage from traffic and extremities of weather.

Principals to be followed for Consumer pipeline or service mains :(continuous...)

(i) No consumer pipe should be laid in the premises to connect the communication pipe without the approval of the municipal authority.

(ii) The consumer pipe should be underground with suitable cover to safeguard against damage from traffic and extremities of weather.

(iii) To control the branch pipe to each separately occupied part of a building supplied by a common service pipe, a stop tap should be fixed to minimise the interruption of the supply during repairs

(iv) Consumer pipes should be so located that they are not unduly exposed by accidental damage and should be fixed in such positions as to facilitate cleaning and avoiding accumulation of dirt.

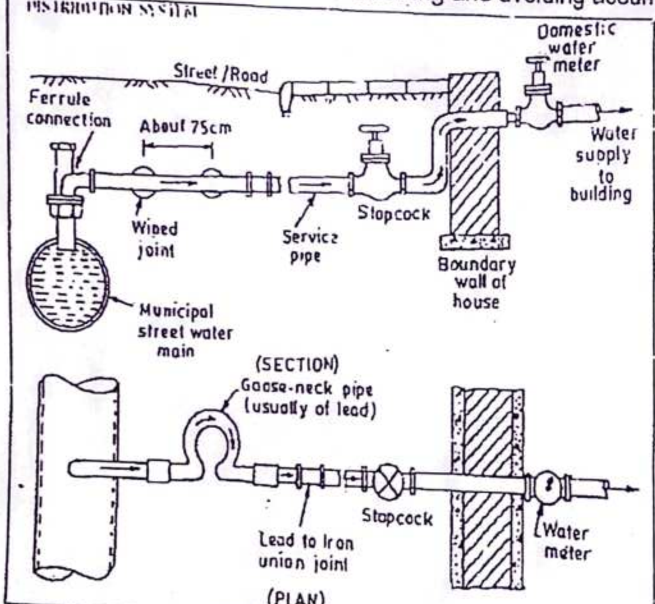


Fig. - Consumer's pipe connection with water mains of the street

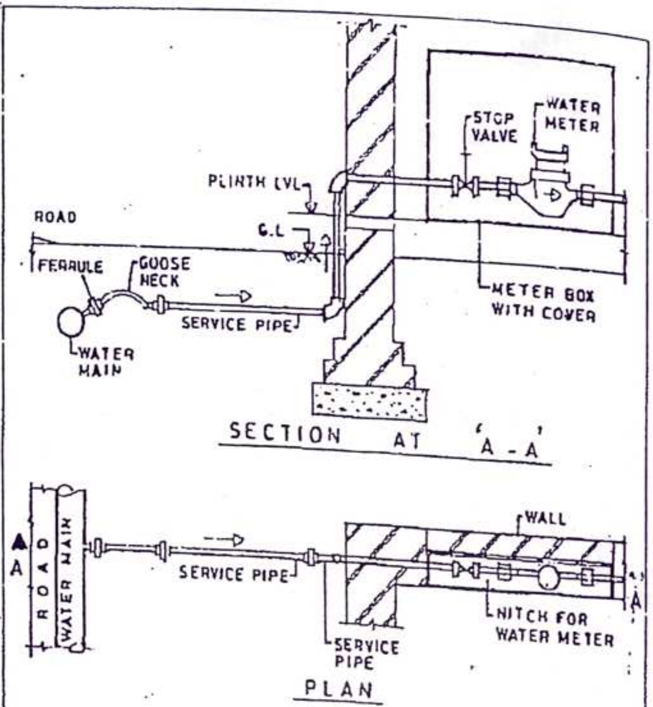


Fig. 296

Storage and distribution system:

- The water supply to a building may be either continuous or intermittent. Even in the case of continuous supply in the mains, the pressure of water may not be sufficient to rise to all the floors of the building. In either case, the storage tanks are required.
- The storage tank may be situated either at the ground level or at the top roof level or at both the levels.
- If pressure of water is sufficient to raise the roof level, storage tank is provided only at roof level, so as to store water because of intermittent supplies.
- If the pressure of water is not sufficient, water is first stored at the ground tank from where it is pumped to the top storage tank.

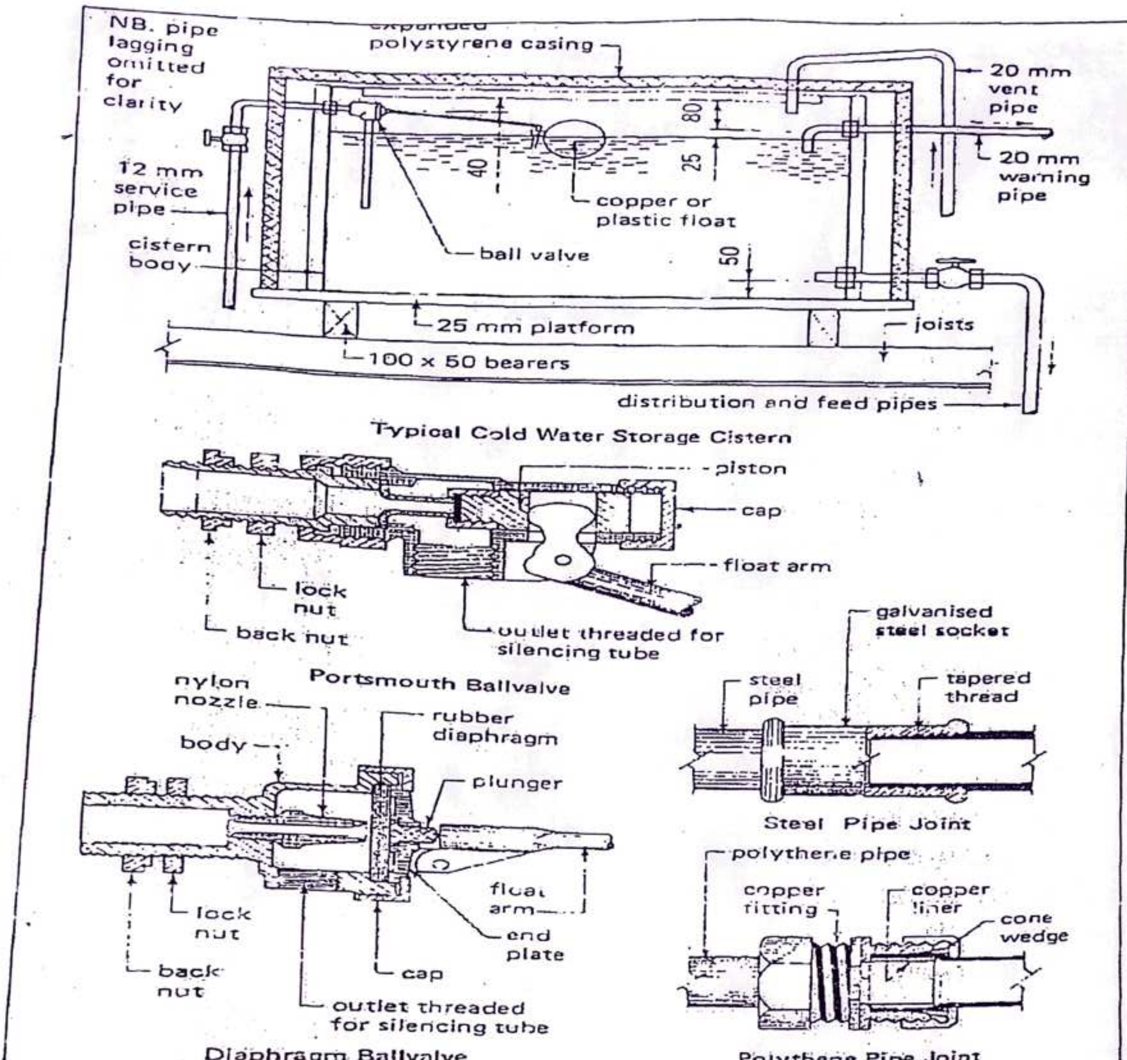


Fig. IV.3 Cisterns, ball-valves and joints

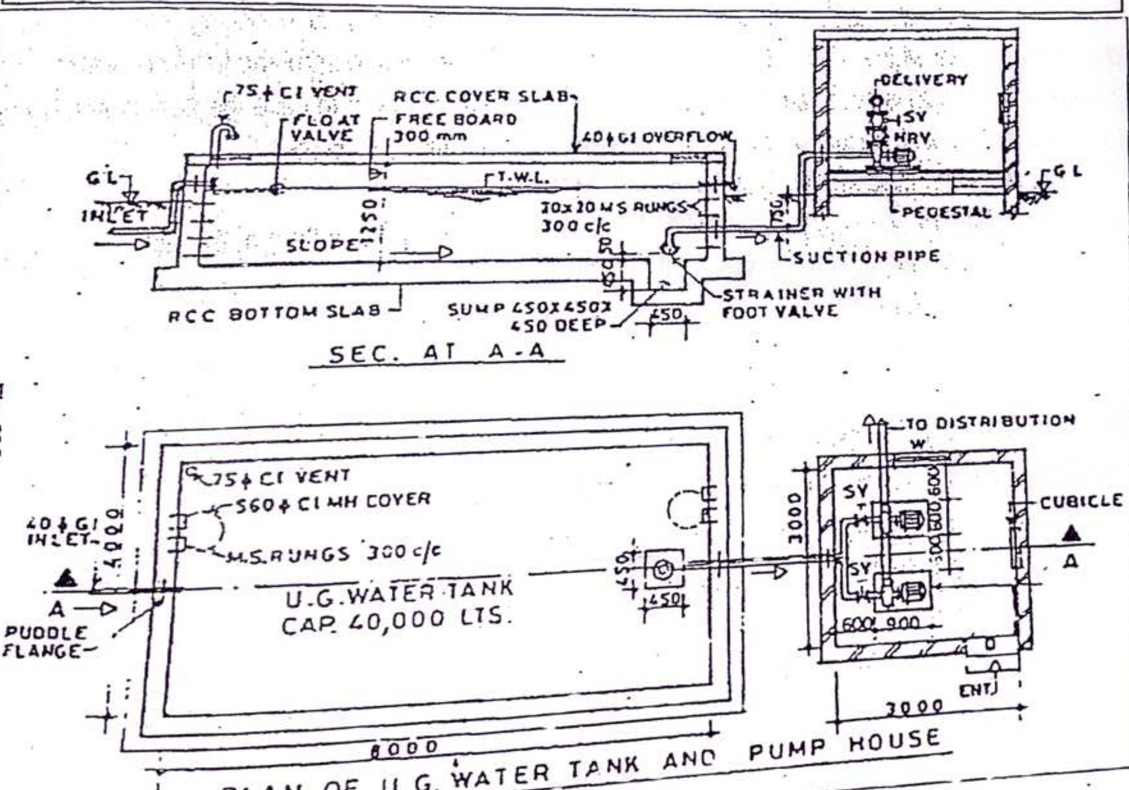


Fig. 299

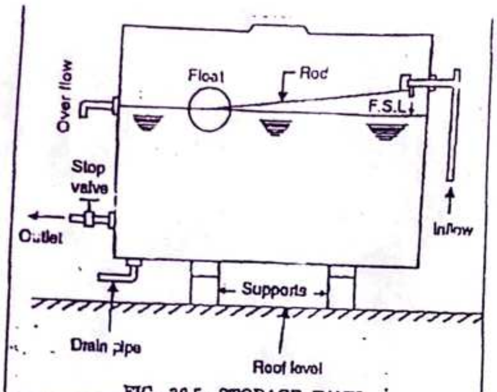


FIG. 30.5. STORAGE TANK.

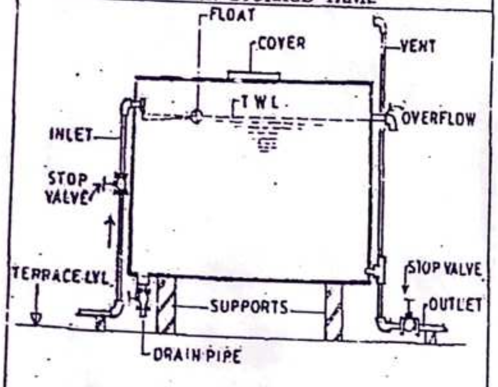


Fig. 29.7

Details of various pipe connections to an R.C.C. overhead (O.H.) water storage tank are shown in Fig. 29.8.

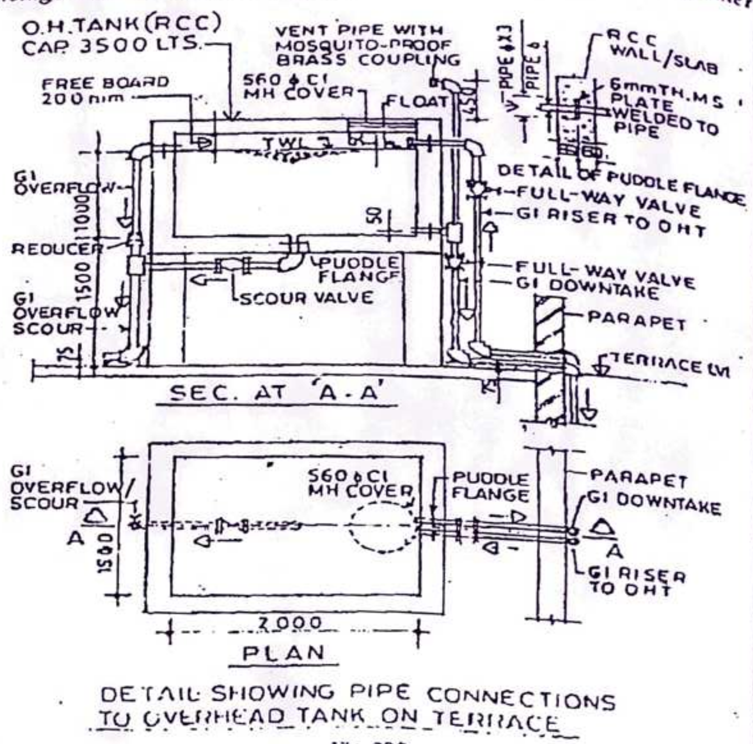


Fig. 29.8

Storage and distribution system:

A storage tank for a building is made of the following materials.

1) Mild steel pressed plates
2) Reinforced concrete
3) Stone or brick masonry
4) Plastic and polyethylene storage tanks etc.

A storage tank consists of the following accessories:

1. **Top cover** made of mild steel, aluminium or other light material and it may have locking arrangement.
2. **Ball valve** with float which is provided near the inlet to the tank, so as to control the inflow of water.
3. **Over flow pipe** which is set about 2.5 cm above full supply level (F.S.L.). In case the float assembly fails, the inflow is not cut-off and the water entering the tank overflows through this pipe.
4. ***Supply pipe or inlet pipe*** admitting water in to the tank.
5. ***Outlet pipe with stop valve*** is provided about 2.5 cm to 5 cm above the bottom of the tank, for cutting of the supply to down tank pipes
6. ***Drain pipe or scour pipe*** is provided for cleaning the tank periodically.

Capacity of Storage Tank:

The capacity of a storage tank depends upon the following factors:

(i) Supply hours from main, with sufficient pressure
(ii) Frequency with which the tank can be refilled during 24 hours
(iii) Rate and regularity of supply from the mains
(iv) Fire fighting requirement

- The underground storage tank is designed to have a minimum storage capacity equivalent to 50 % of daily demand if the water supply is intermittent.
- In such cases the capacity of overhead tank should be 100 % or a maximum of one day requirement.

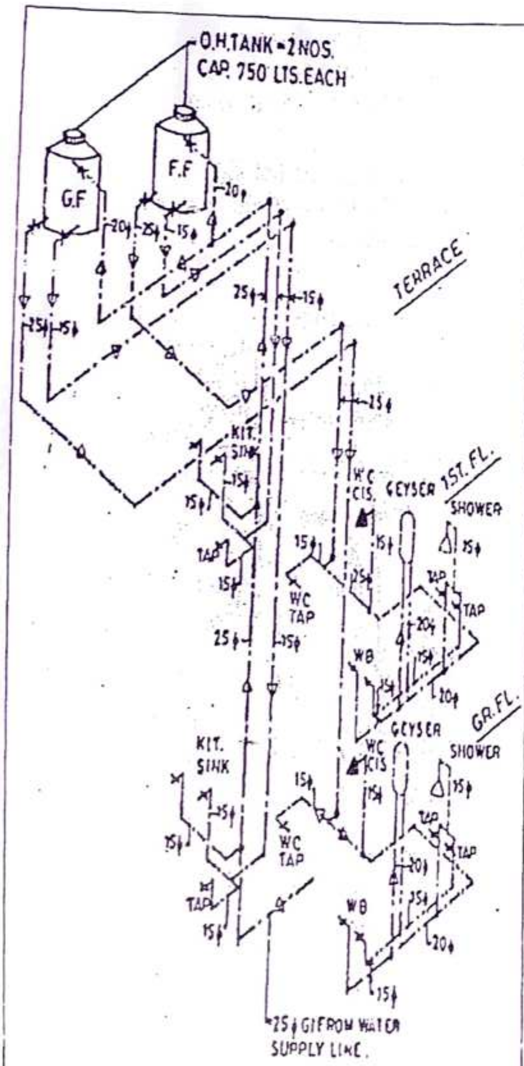
Distribution system for domestic supply:

There are two distinct systems of supply of water in a building from the mains:

(1) Direct system and

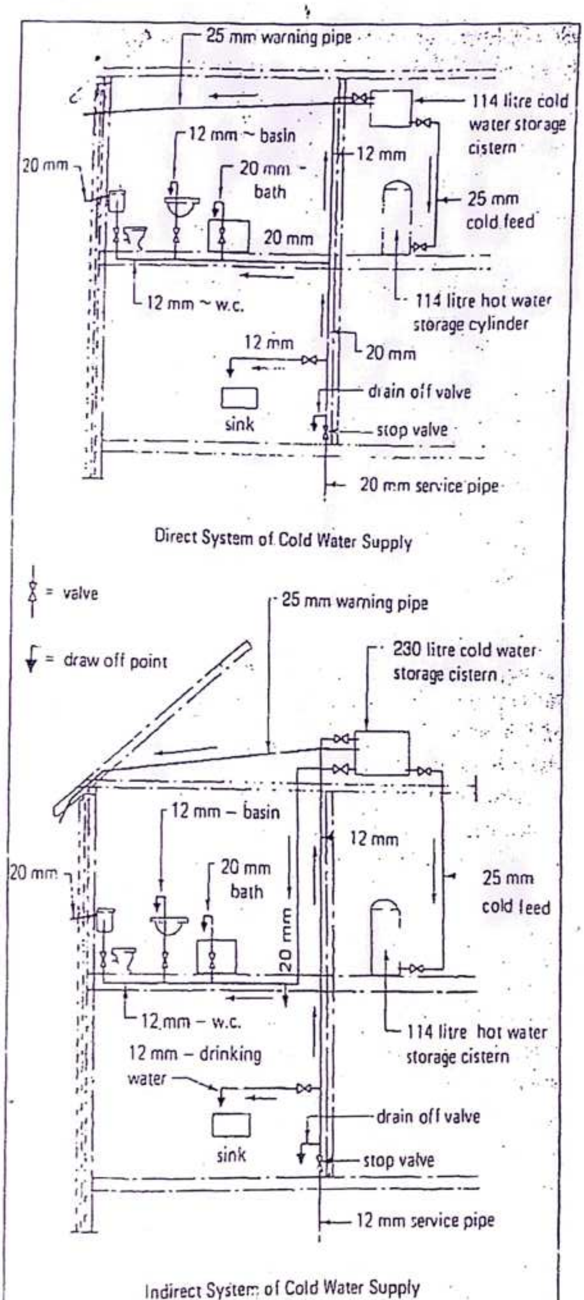
(2) Indirect system

1. ***Direct system:*** In direct system, also known as upward distribution system, the supply of water is given to various floors in a building directly from the mains which have sufficient pressure to feed all the floors and water fittings at the highest part of the building.
2. ***(2) Indirect system:*** In indirect system also known as down take supply or downfall distribution system, the water supply from the mains may be drawn either by
   a) Feeding water directly in to the overhead tank provided at roof of the building from where the water is supplied to different floors by gravity or
   b) Feeding the water into a underground water storage tank The water from the underground tank is pumped to overhead storage tank from where the water is supplied by gravity.



WATER SUPPLY RISER DIAGRAM AT 'X'

Fig. 2912



Direct System of Cold Water Supply

Indirect System of Cold Water Supply

2 Cold water supply systems

9.2 Hot water supply

Introduction

The supplies of hot water to domestic sanitary fittings are usually taken in the form of a glass fired, oil fired or solid fuel boiler. Other alternatives of domestic hot water supply are the back boilers to an open fire or an electric immersion heater fixed into the hot water storage tank. When quantity of hot water is drawn from the storage tank, it is immediately replaced by cold water from the cold water storage cistern. Generally copper or steel pipes are used for any hot water system and care must be taken when connecting copper to steel because of the electrolytic corrosion between dissimilar materials.

The supply of hot water from hot water cylinder or tanks to domestic purpose may be in two forms:

(1) Direct hot water system
(2) Indirect hot water system

1. Direct hot water system

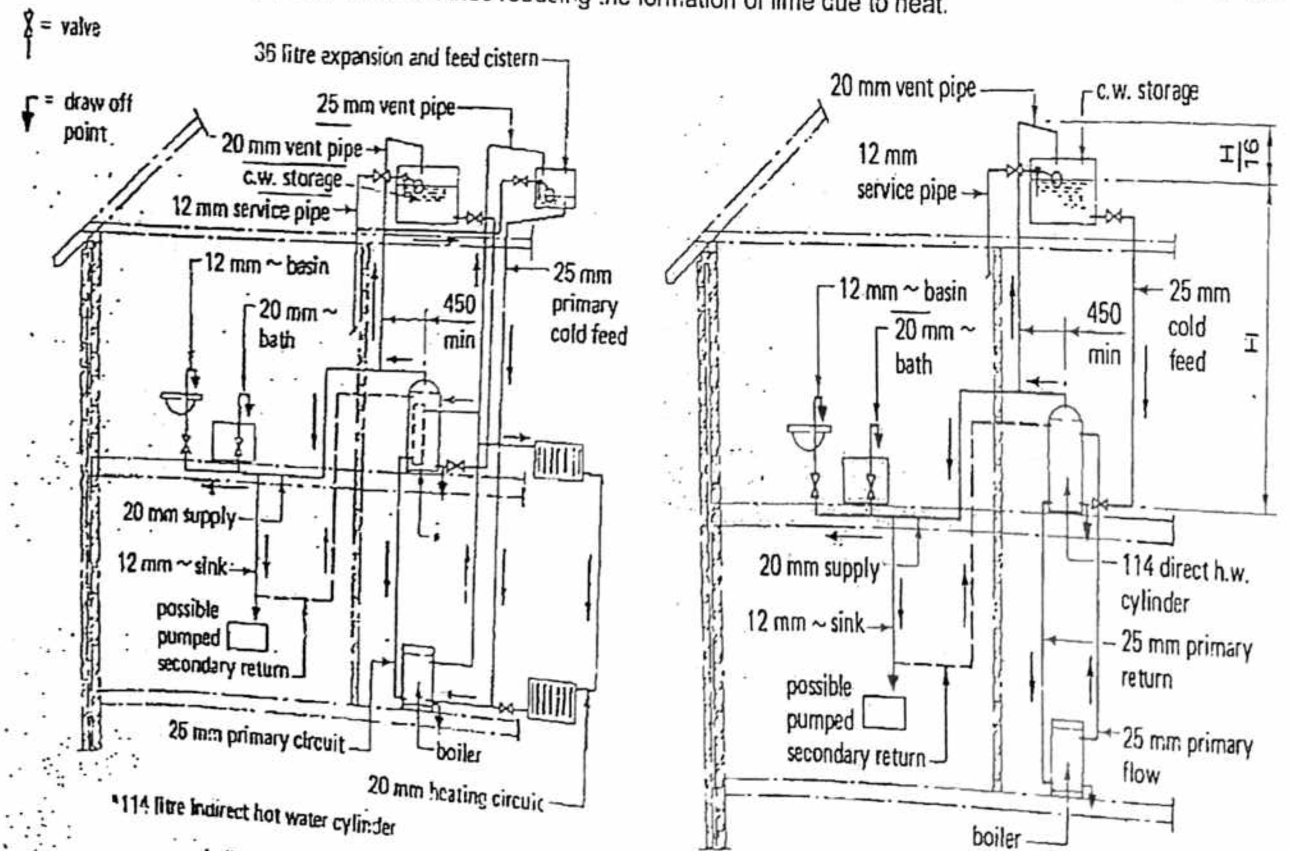
It is the simplest and cheap system. Cold water flows through the water jacket in the boiler where its temperature is raised and convection currents are induced which causes the water to rise and circulate. The hot water living the boiler is replaced by colder water descending from the hot water cylinder or tank by gravity thus setting up the circulation. The hot water supply is drawn off from the top of cylinder by a horizontal pipe at least 450 mm long to prevent 'one pipe' circulation being set up in the vein or expansion pipe.

1. Direct hot water system (continuous....)

This system is not suitable in for supplying a central heating circuit or hard water areas because the pipes and cylinders will become furred with lime deposits. This precipitation of lime occurs when hard water is heated to temperatures of between 50° and 70° C, which is the ideal temperature range for domestic hot water supply.

(2) Indirect hot water system

This system is designed to overcome the problems of furring which occurs with the direct hot water system. The basic difference is in the cylinder design which now becomes a heat exchanger. The tank is made in such way that cold water is not constantly permitted into it thus reducing the formation of lime due to heat.



Indirect Hot Water System

in hard water areas primary circuit to be 32 mm

IV.4 Hot water systems

Direct Hot Water System

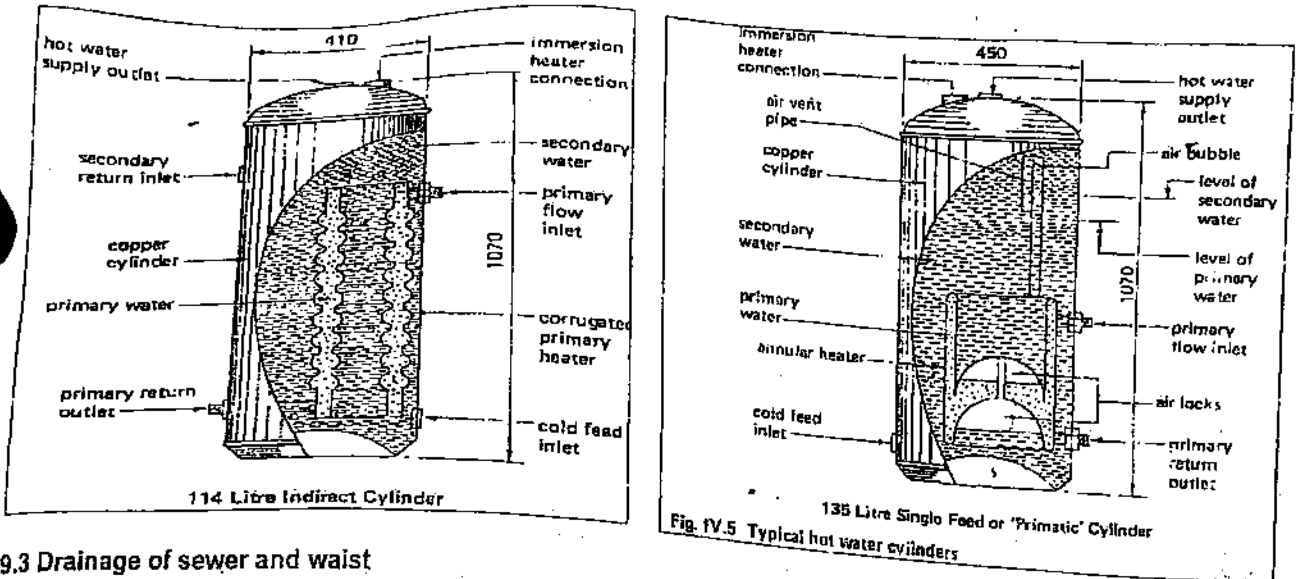


Fig. IV.5 Typical hot water cylinders

9.3 Drainage of sewer and waist

Methods of carrying refuse from a house may be in three forms:

1. Conservancy system (It include construction of septic tanks, soak pit, sludge pits and soakways)
2. Water carriage system
   (a) Combined
   (b) Separate (for sewer and storm)
   (c) Partially combined

COMBINED SYSTEM

All the drains discharge into a common or combined sewer. It is a simple and economic method since there is no duplication of drains. This method has the advantages of easy maintenance, all drains are flushed when it rains and it is impossible to connect to the wrong sewer. The main disadvantage is that all the discharges must pass through the sewage treatment installation, which could be costly and prove to be difficult with periods of heavy rain.

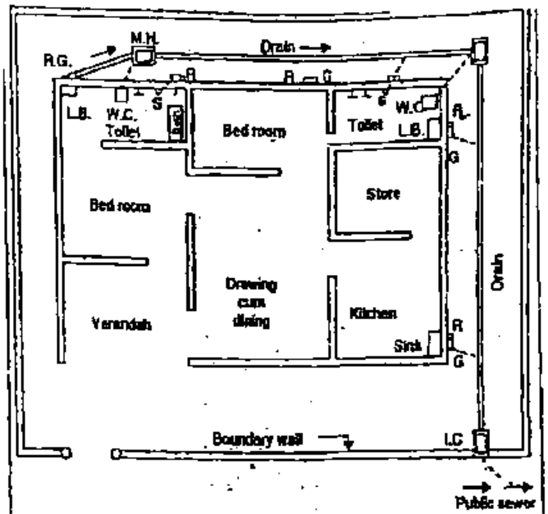
TOTALLY SEPARATE SYSTEM

The most common method employed by Local Authorities; two sewers are used in this method. One sewer receives the surface water discharge and conveys this direct to a suitable outfall such as a river where it is discharged without treatment. The second sewer receives all the soil or foul discharge from baths, basins, sinks, showers and toilets; this is then conveyed to the sewage treatment installation. More drains are required and it is often necessary to cross drains one over the other. There is a risk of connecting to the wrong sewer and the soil drains are not flushed during heavy rain, but the savings on the treatment of a smaller volume of discharge leads to an overall economy.

PARTIALLY SEPARATE SYSTEM

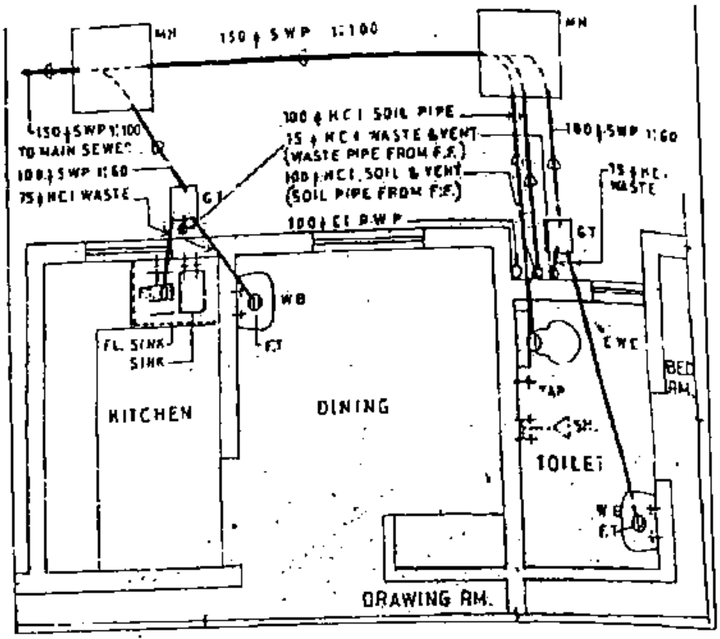
This is a compromise of the other two systems and is favoured by some Local Authorities because of its flexibility. Two sewers are used, one to carry surface water only and the other to act as a combined sewer. The amount of surface water to be discharged into the combined sewer can be adjusted according to the capacity of the sewage treatment installation.

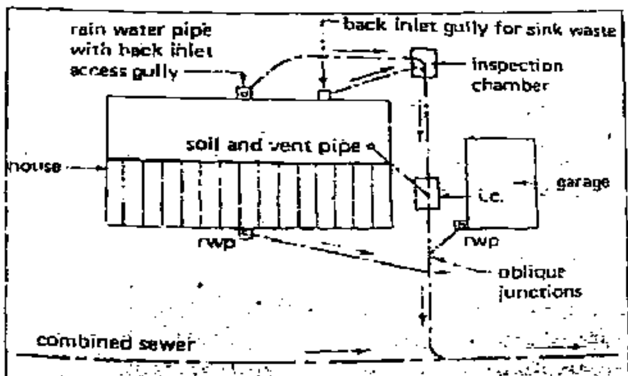
Soakaways, which are pits below ground level designed to receive surface water and allow it to percolate into the soil, are sometimes used to lessen the load on the surface water sewers. Typical examples of the three drainage systems are shown in Fig. IV.6.



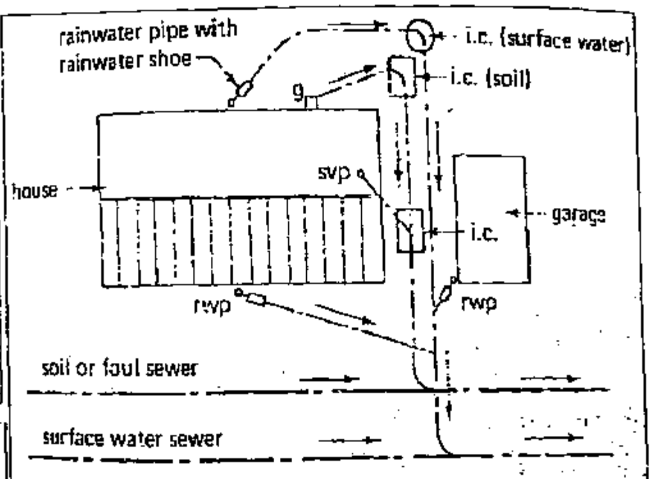
R- RAINWATER PIPE ; G- GULLEY TRAP ; L.B.- LAVATORY BASIN ; W.C.- WATER CLOSET ; S- SINK M.H.- MANHOLE ; I.C.- INTERCEPTING CHAMBER

FIG. 30.19. DRAINAGE PLAN OF A BUILDING.

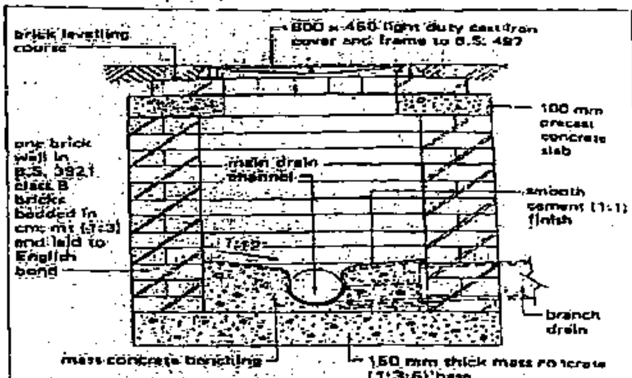




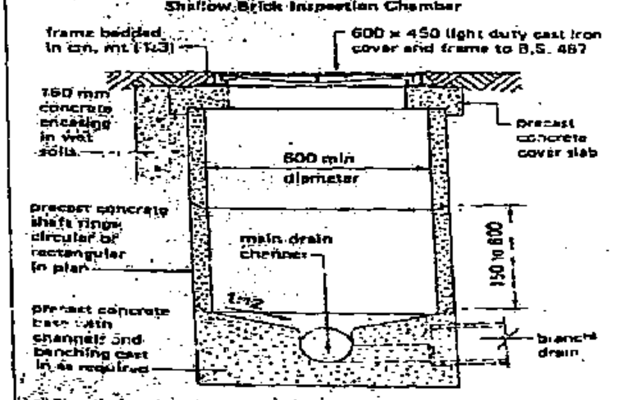
Combined System



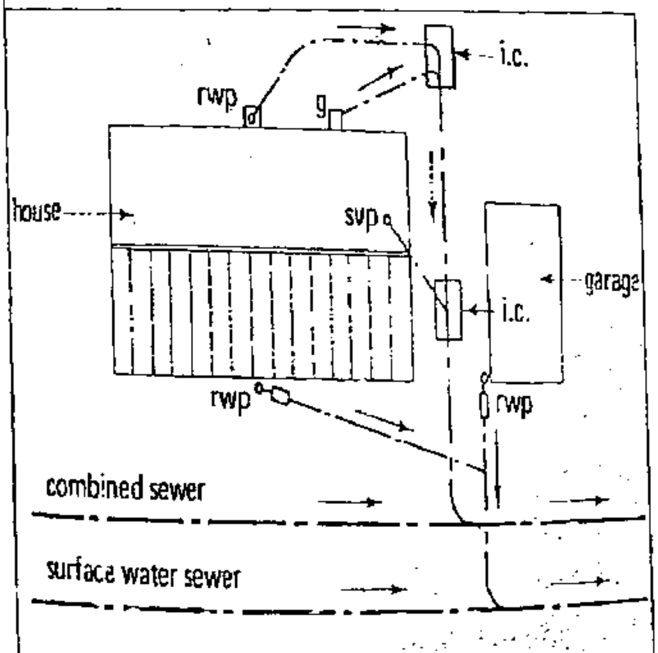
Separate System



Shallow Brick Inspection Chamber



Precast Concrete Inspection Chamber (B.S. 5911)



Partially Separate System

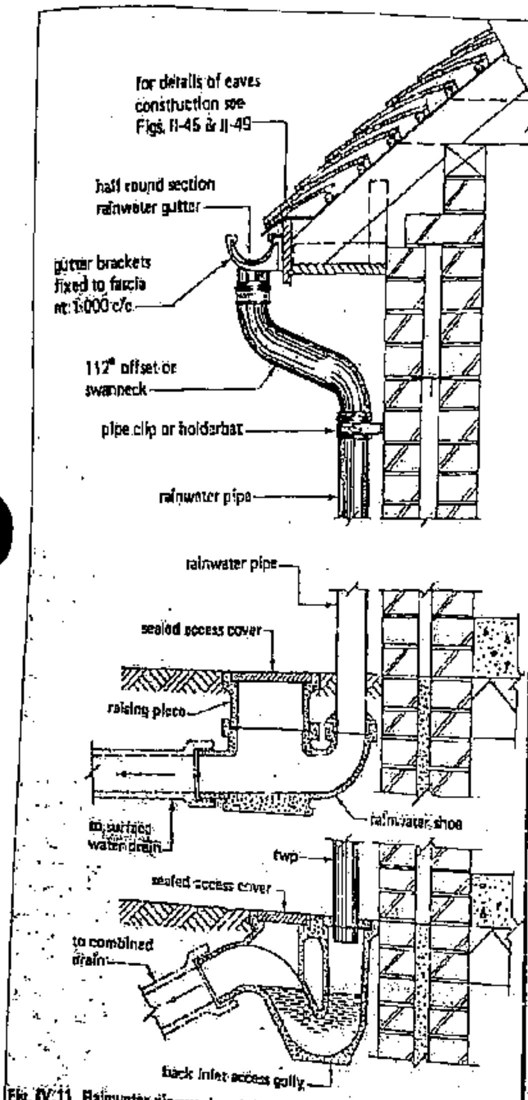


Fig. IV.11 Rainwater pipework and drainage

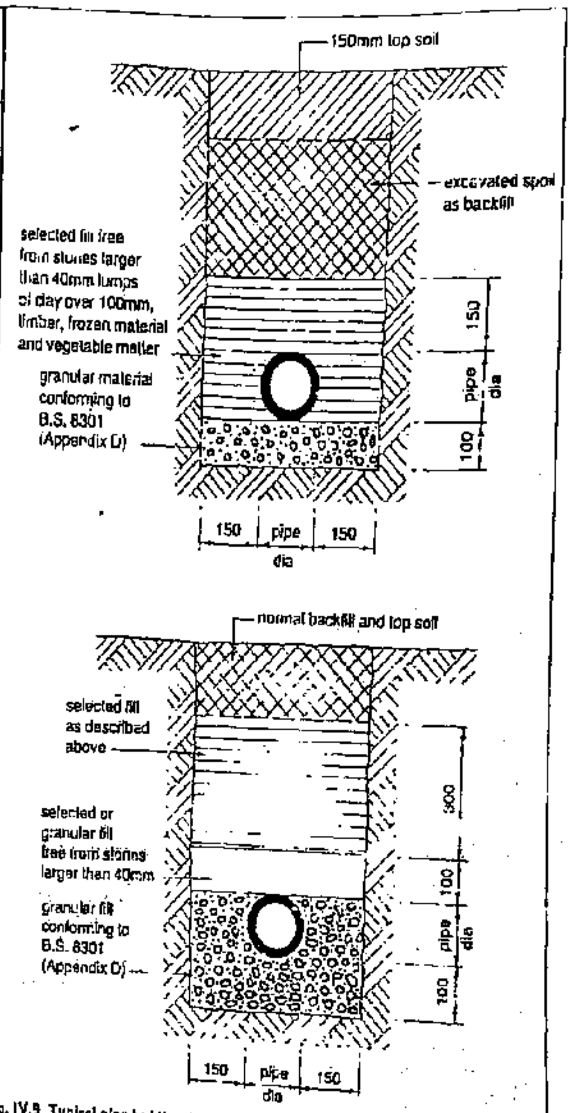


Fig. IV.9 Typical pipe bedding details

General principles of good house drainage:

1. Provide by the side of building
2. Provide adequate size
3. Ensure appropriate level to drain out from lowest level
4. Provide proper gradient for self-cleaning velocity
5. Provide non-absorbent type foundation
6. Provide straight lines with successive inspection chambers
7. Provide properly ventilated system
8. Provide house drain intercepting trap to connect to public sewer (this prevents entry of unwanted gases).

Types of drainage for sewer and waist:

A sewer can be defined as a means of conveying waste, soil or rainwater below the ground that has been collected from the drain and conveying it to the final disposal point.

1) **Public drainage for sewer and waist:** If the sewer is owned and maintained by the local authority it is generally called a public sewer.
2) **Private drainage for sewer and waist:** A sewer owned by a single person or a group of people and maintained by them is called a private sewer.

When planning the connections of houses to the main or public sewer one method is to consider each dwelling in isolation but important economics in design can be achieved by the use of a private sewer. A number of houses are connected to the single sewer which in turn is connected to the public sewer and the distance from the public sewer the following savings are possible:

1. Total length of drain pipe
2. Number of connections to public sewer
3. Amount of opening in the road
4. Number of inspection chambers

A comparative example is shown in Fig, VII.1

Types of drainage for sewer and waist pipes to connect with main sewer and drainage may be:

1. Public drainage
2. Private drainage

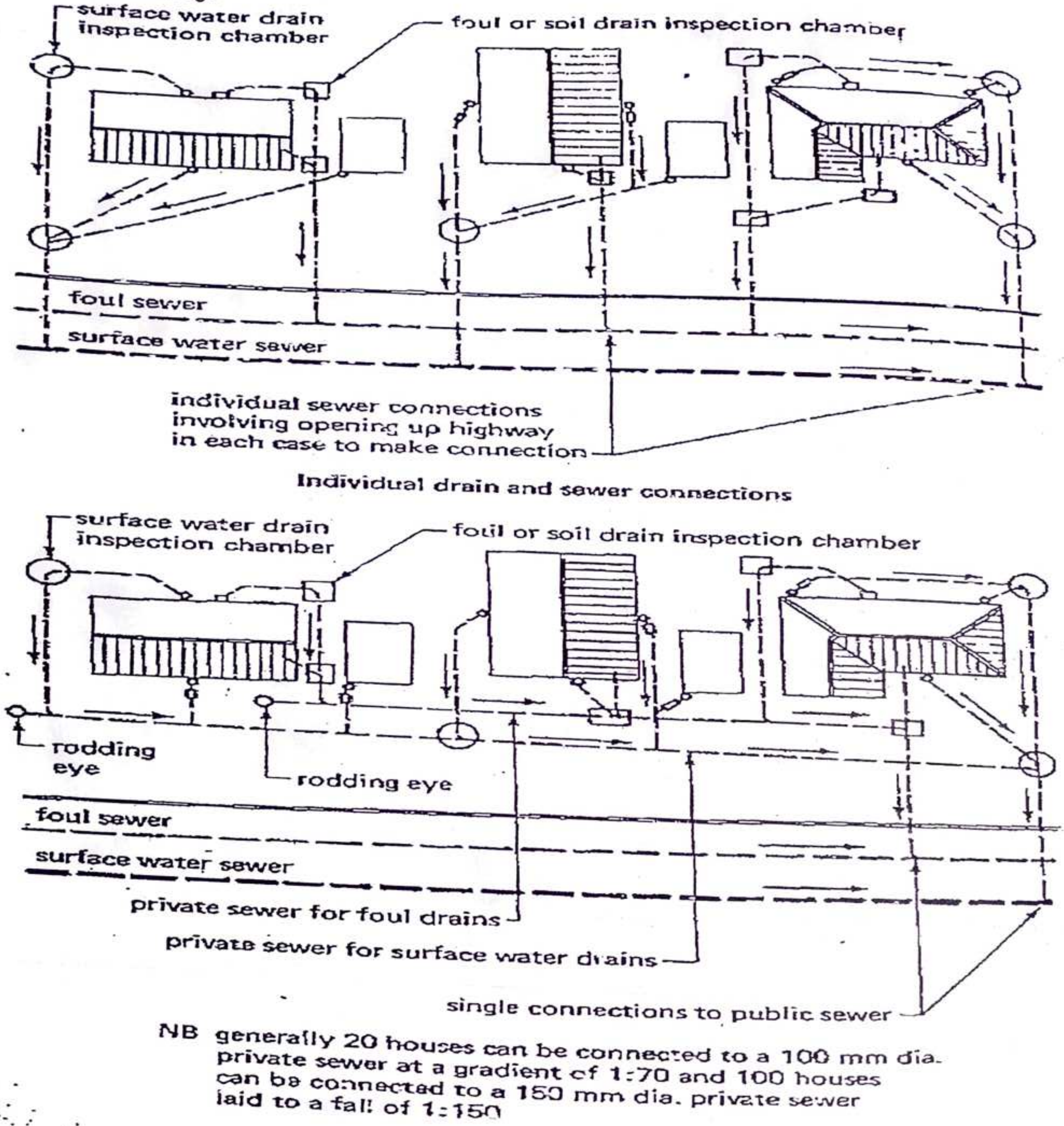


Fig. VII.1 Example of a private sewer arrangement

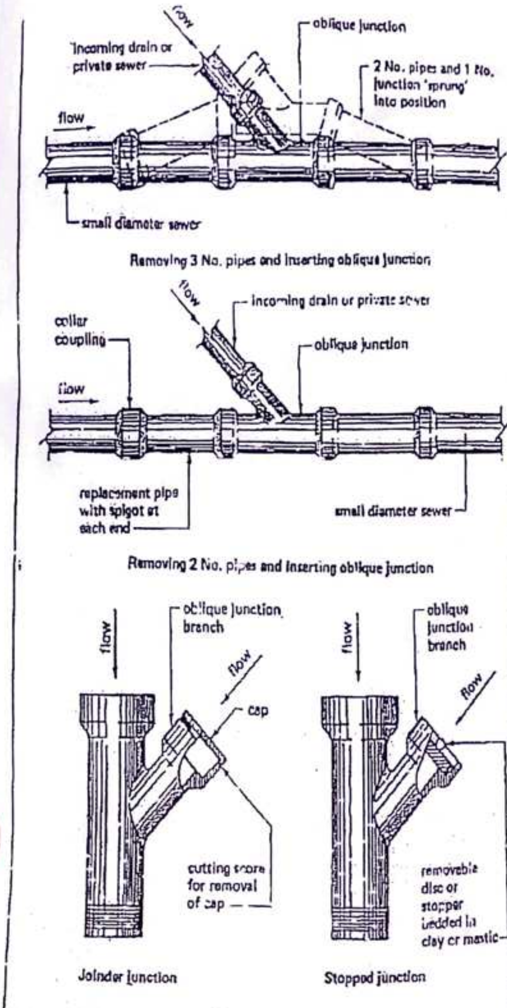


Fig. VII.2 Connections to small diameter sewers

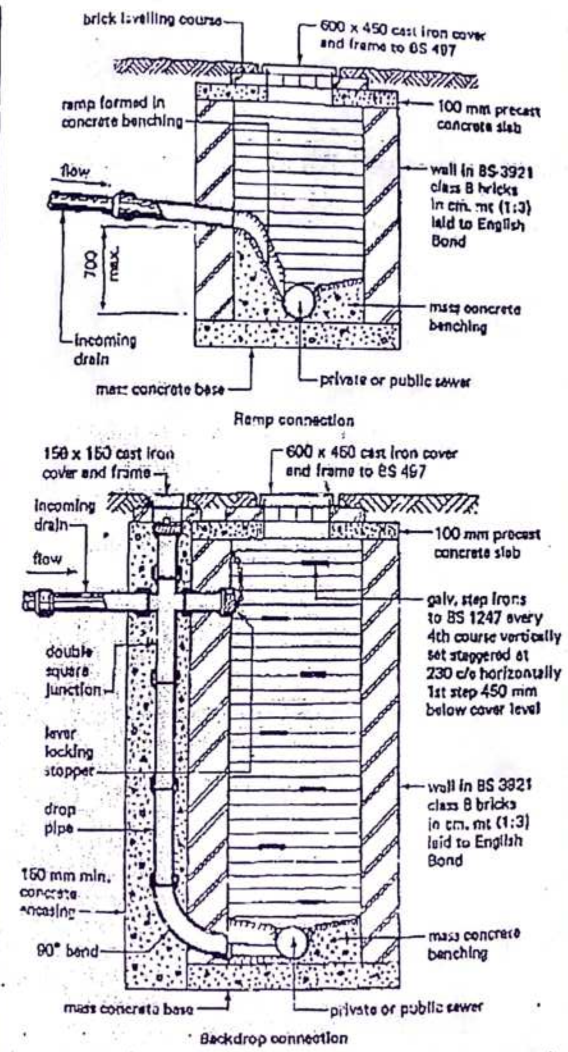


Fig. VII.3 Manhole and inspection chamber sewer connections

9.4 Rain water pipes and gutter

- A rainwater drainage installation is required to collect the discharge from roofs and paved areas, convey it to a suitable drainage system.
- Paved areas such as garage forecourts or hardstands are laid to fall so as to direct the rainwater into yard gully which is connected to the surface water drainage system.
- A rainwater installation for roof consists of a collection of channels called 'gutter' which is connected to vertical rainwater pipes.
- If a separate system of drainage or soakways are used it may be possible to connect the rainwater pipe direct to the drains, providing there is an alternative means of access for cleaning
- The rainwater pipe is terminated as its lowest point by means of a rainwater shoe for discharge to a surface water drain or a trapped gully of the discharge is to combined drain as shown in Fig IV.11.

A rainwater pipes and gutter installation consists of following works:

- Drainage of rain water from roof and premises
- Water drain from the roof through pipes and gutters
- Water drain from the ground to sewer line by the road-sides
- Pipe and gutter size depend upon:
    I. the roof area
    II. the intensity of rain
    III. material of gutter and downpipe

Soakways

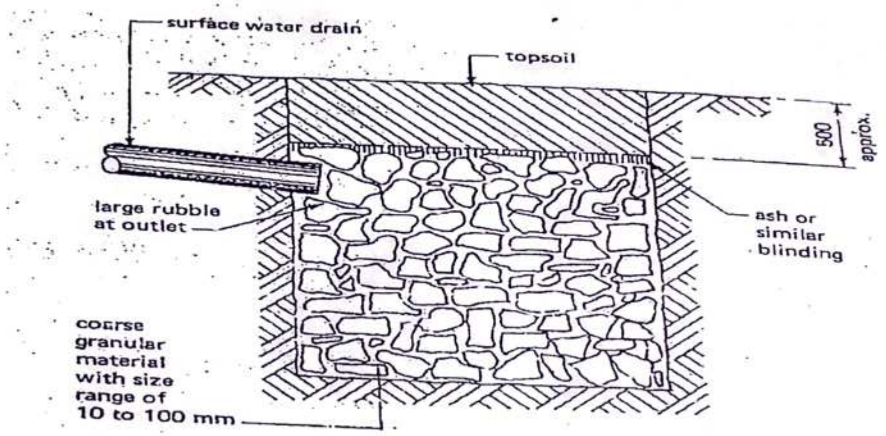
A soakway is a pit dug in permeable ground which receives the rainwater discharge from the roof and paved areas of a small building and is so constructed that the water collected can percolate into the surrounding subsoil.
The volume of the soakways is calculated by allowing for a storage capacity equal to one-third of the hourly rain falling on the area to be drained. The rate of rainfall corresponding to a two-hour storm occurring on average not more than once in ten years is 0.015 m; therefore if the area to be drained is 150 m² the required capacity of the soakway is: $150\ m^2 \times 0.015\ m = 2.25\ m^3$

Types of soakways:

1) Filled soakways
2) Lined soakways

1. Filled soakways

Filled soakways are usually employed only for small capacities and the life of such soakways may be limited due to silting up of the voids *between the filling materials.*



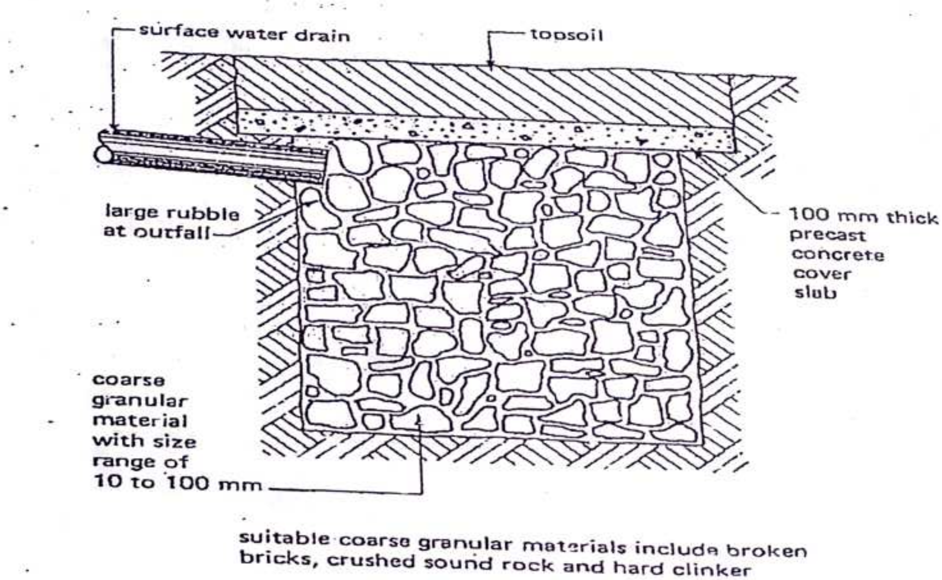


Fig. VII.8 Filled soakaways

2. *Lined soakways*

Lined soakways are generally more efficient, have a longer life and if access is provided can be inspected and maintained at regular intervals.

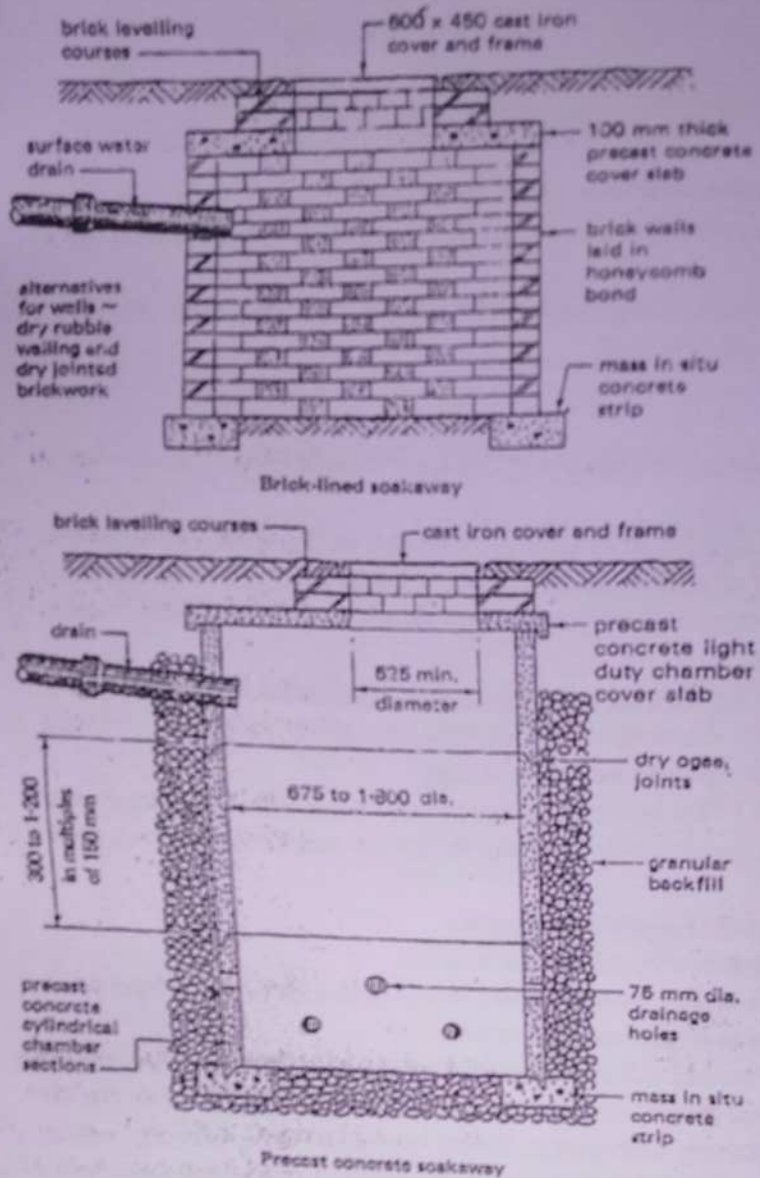


Fig. VII.9 Lined soakways

9.4 Rain water pipes and gutter

Pipes and gutters used in rainwater are as shown in figures

The materials available for domestic rainwater installation are asbestos, galvanised pressed steel, cast iron and UPVC (Unplasticised Polyvinyl Chloride plus additives), the latter being the usual specification for new work.

Cast iron rainwater goods

- Cast iron rainwater pipe, gutters and fittings are generally produced in half round section gutter with a socket joint in diameter from 75mm to 150mm and effective length of 1800mm.
- The gutter is supported at 1000 to 18000mmc/c by means of mild steel gutter brackets screwed ton the feet of rafters for an open to eaves or to facia board with a closed eaves.
- For cast iron half round gutters, a full range of fittings such as outlets, stopped ends, internal and external angles are available
- For down pipes, fittings such as bends, offsets and rainwater heads are available.

Unplasticised PVC rainwater goods (continuous...)

The advantages of UPVC rainwater pipes over cast iron are:

1. Easier joining, gutter bolts are not required and the joints are self-sealing, generally by means of a butyl or similar strip.
2. Corrosion is eliminated
3. Decoration is not required; the two standard colours available are black and grey.
4. Breakages are reduced.
5. Better flow properties usually enable smaller sections and lower falls.

- Half round gutters are supplied in standard effective length of 1800mm and 3600mm and with diameter rage of 100mm to 110mm.
- The pipes are supplied in two standard effective lengths of 2000mm and 4000mm with diameters of 63mm, 68mm and 75mm. (For details refer to Fig. IV.II)

9.5 Septic tank

- Septic tank is a chamber constructed in masonry or RCC to house the refuse of human beings which is usually built underground.
- The function of septic tank is to produce certain biological and chemical changes by partial liquefaction and gasification (or decomposition) of human excreta discharged into it, through the action of anaerobic bacteria, which flourish in the absence of free oxygen, humidity, darkness and warmth. This is the condition created in the tank.
- During the course action in a septic tank, the lighter matter (grease, fat etc.) rise to the surface and form a thick floating layer called "scum" while heavier materials sink to the bottom to form "sludge". The tank is made air tight, water tight and dark to help decomposition of the sewage).
- A septic tank is used to treat sewage from isolated group of country houses, where a piped sewage (i.e., public sewer) is not available. It is a horizontal sedimentation tank in which sewage moves very slowly. Septic tanks serve two purposes:
    I. Deposition of settling solids in sewage by sedimentation
    II. Partial or complete digestion of the sludge prior to its disposal
- A septic tank produces septic action by anaerobic bacteria, wherein proteins, carbohydrates, cellulose and fatty matter present in sewage are broken to simpler compounds.
- The nitrogen is converted to ammonia, while the colloidal matter is flocculated, is discharged either into soak pit of below ground level through open jointed agricultural drains, so that the effluent gets absorbed in the soil.
- The aerobic bacteria in the soil bring about necessary changes in the organic matter and make it suitable. The effluent from the septic tank should be discharged in open drains (soak pit). The following figure shows a simple septic tank.
- The septic tank is so constructed that direct current between inlet and outlet is prevented. This is achieved by using pipe at inlet and outlet. A baffle wall with openings is constructed at some distance away from the outlet. The outlet pipe is kept about 15 cm lower than the inlet pipe. The sludge, which is deposited in the bottom is cleaned periodically, say once in 6 to 12 months. A vent pipe is provided for the escape of gases.

Design of septic tank

- The size of the tank is based on the number of users and the amount of dilution water in the sewage.
- Average retention period (for the septic action to take place) of sewage in the tank is 12 to 24 hours. This period may be more for residential installation and less if sewage is coming from a long distance.
- According to IS code 2470, septic tank shall have minimum width of 75 cm and minimum depth below water level of 100 cm. The minimum liquid capacity shall be one cubic meter.
- The length of the tank should be 2 to 4 times the width

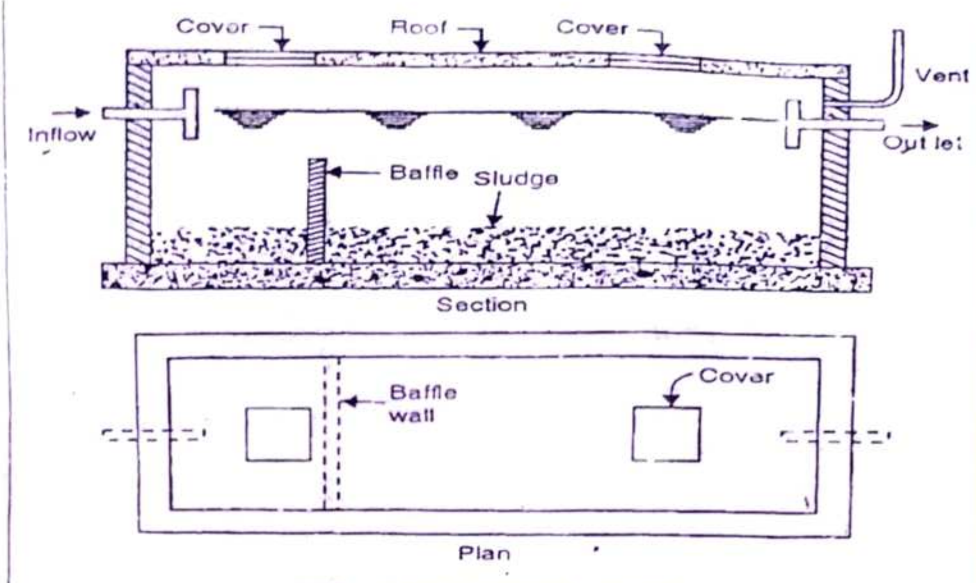


FIG. 30.20. SEPTIC TANK

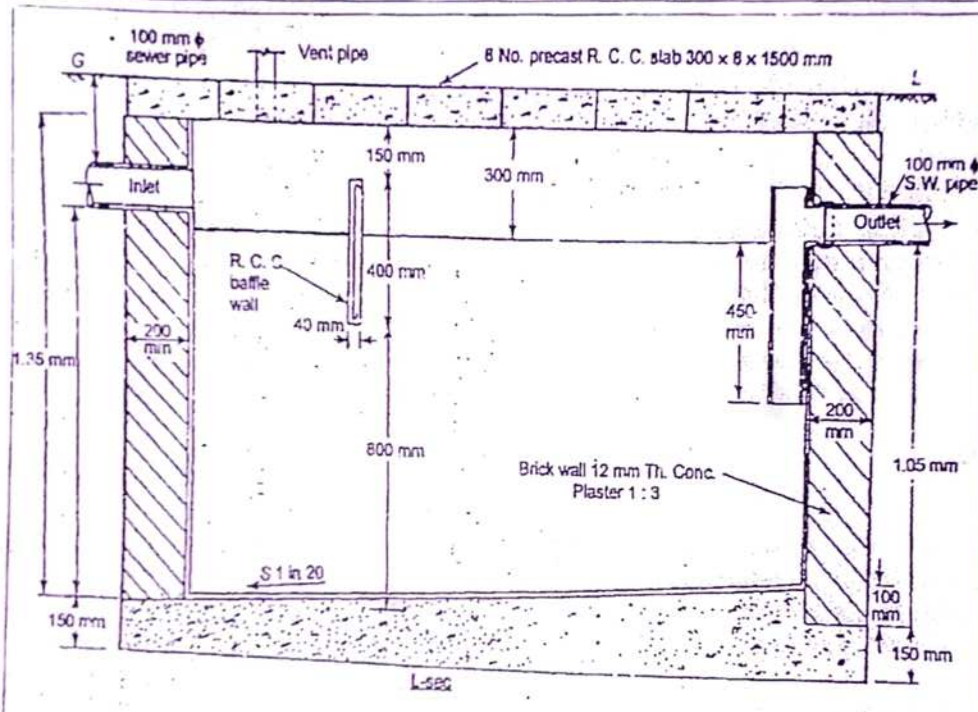


Fig. 34.31. *Section of all septic tank.*

Soak pit (seepage pit):

A soak pit is a covered pit dug in permeable ground, in which effluent (waste) from septic tank is discharged. It is generally constructed in the pervious soil which can absorb the effluent.
Soak pit may be of two types: (a) lined, and (b) unlined

Lined soak pits are used when the inner volume is kept empty. The lining may be of bricks, stone or concrete blocks, with dry open joints and with at least 7.5 cm backing of coarse aggregate.

Unlined soak pit: The inner volume of unlined soak pit is filled with stone, brick and aggregates, so no lining is required, except for the masonry ring provided at the top.

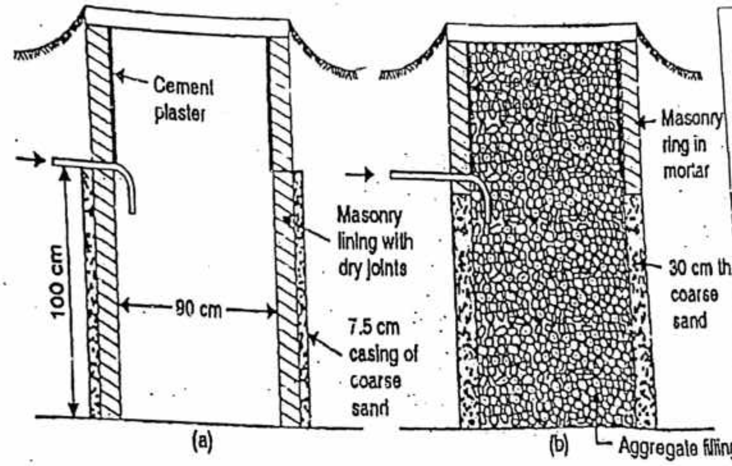


FIG. 30.21. SOAK-PITS.

Fig. (a) Lined soak pit

Fig. (b) Unlined soak pit

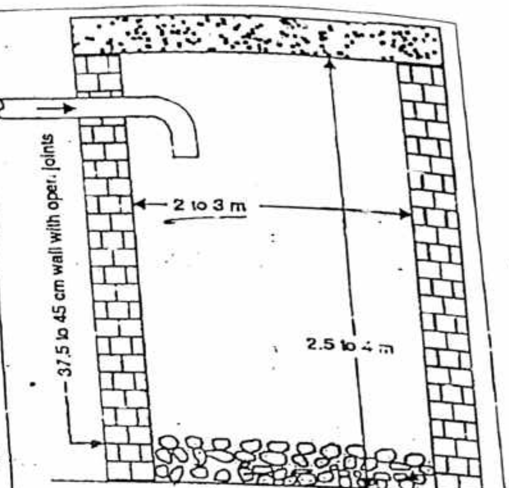


FIG. 30.22. SLUDGE SOAK PIT.

Sludge soak pit:

A sludge soak pit is the one in which the sewage effluent from the house drain is *directly discharged*. The water in the accumulated sewage is soaked by adjoining pervious soil while the sludge is digested in the pit. Such soak pits are quite common in areas where subsoil is highly pervious. Fig. 30.22 shows a typical section of such soak pit. It is lined with masonry with open joints. The top is covered with a rigid slab. The diameter of such a tank varies from 2.00 m to 3.00 m while the depth varies from 2.50 m to 4.00 m. Each individual house having one such soak pit has a life of about 20 years for a family of 6 persons. When the soak pit gets filled up, the lope cover is removed and the tank is emptied.

9.6 Rainwater harvesting

Basic principles of rainwater harvesting:

Rain water harvesting can be defined as the collection of run-off rainwater, its treatments and use for the domestic water supply to individual household or community level for domestic purpose, such as drinking, cooking, washing., agriculture and environmental managements etc.

All rainwater harvesting system consists of three basic components:

1. Catchment or roof surface to collect water.
2. Delivery system to transport the water from roof to the storage tank (gutter and drain pipes)
3. Storage reservoir or tank to store water until it is used. The storage reservoir has an extraction device depending on the location of the tank-may be a tap, rope and bucket, or a pump.

Technical aspects

The construction of a RWH system is determined by several critical technical factors:

1. Use of impermeable roofing materials such as CGI sheets, tiles, slates, asbestos-cement sheet etc.
2. Availability of an area of at least 1.00 m² near each house for constructing a storage tank.
3. Water consumption rate (number of users and types of users) and storage capacity required.
4. Availability of other water sources, either ground water or surface water that can be used when stored rainwater runs out.
5. Availability of labours with technical building skills in or nearby the community.
6. Availability of required, suitable local construction material and labour.

Designing a rainwater harvesting system

The main consideration in designing a rainwater harvesting system is to size the volume of the storage tank correctly. The tank should give adequate storage capacity at minimum construction costs.

Five steps to be followed in designing a RWH system:

Step 1 Determine the total amount of required and available rainwater

Step 2 Design your catchment area

Step 3 Design your delivery system

Step 4 Determine the necessary size of your storage reservoir

Step 5 Select suitable design of storage reservoir

These steps are described below.

Step 1: Total amount of required and

Available rainwater

Estimating domestic water demand

The first step in designing a rainwater harvesting system is to consider the annual household water demand. To estimate water demand the following equation can be used:

Demand = Water Use × Household Members × 365 days

Rainfall data

The next step is to consider the total amount of available water, which is a product of the total annual rainfall and the roof or collection surface area. These determine the potential value for rainwater harvesting. Usually there is a loss caused mostly by evaporation (sunshine), leakage (roof surface), overflow (rainwater that splashes over the gutters) and transportation (guttering and pipes). The local climatic conditions are the starting point for any design.

Calculating potential rainwater supply by estimating run-off:

The amount of available rainwater depends on the amount of rainfall, the area of the catchment, and its run-off coefficient. For a roof or sloping catchment it is the horizontal plan area which should be measured.

The run-off coefficient (RC) takes into account any losses due to evaporation, leakage, overflow and transportation. An estimate of the approximate, mean annual run-off from a given catchment can be obtained using the following equation:

$S = R \times A \times Cr$

Supply = Rainfall × Area × Run-off coefficient (RC)

Where:

S = Mean annual rainwater supply (m^3)

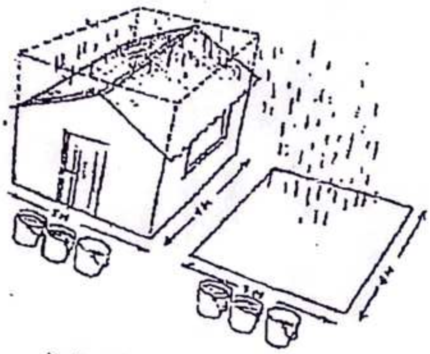
R = Mean annual rainfall (m)

A = Catchment area (m^2)

Cr = Run-off coefficient

Designing your catchment area

Roofs provide an ideal catchment surface for harvesting rainwater, provided they are clean. The roof surface may consist of many different materials. Galvanized corrugated iron sheets, corrugated plastic and tiles all make good roof catchment surfaces. Flat cement roofs can also be used. Traditional roofing materials such as grass or palm thatch may also be used.



Horizontal plan area of the roof for calculating the catchment surface

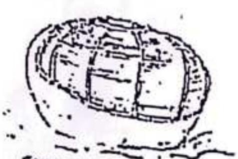
Designing your delivery system

The collected water from a roof needs to be transported to the storage reservoir or tank through a system of gutters and pipes, the so-called delivery system or guttering. Several other types of delivery systems exist but gutters are by far the most common. Commonly used materials for gutters and downpipes are galvanized metal and plastic (PVC) Pipes.

Determine the necessary size of your storage reservoir

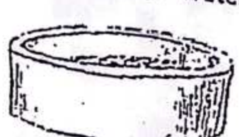
i) Surface tanks - Water jar or jumbo jar built of ferro cement (3-6.5 m^3)

- Consists basically of concrete with chicken wire to provide the strength and shape of the structure.



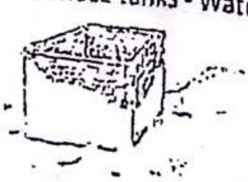
Construction of a water jar

ii) Surface tanks - Water tank built of concrete in situ /formwork (5000 litres / 5 m^3)



Water tank built of concrete

Surface tanks - Water tank built of bricks or blocks 10 m^3



iv) Plastic-lined tanks (5,000 litres/ 5 m^3)

v) Sub-surface tanks or cisterns

Water quality aspects

Protecting water quality in rural areas rainwater is generally unpolluted and pure before reaching the ground. It is also in these areas that rainwater from roof catchments is most commonly used for drinking. Rainwater from well-maintained roof catchments is generally safe to drink without treatment. Except in heavily urbanized and industrialized areas or regions adjacent to active volcanoes, atmospheric rainwater is very pure and any contamination of the water usually occurs after contact with the catchment system. Regular cleaning and inspection of the catchment area and gutter are important to ensure good water quality.

Filters

The quality of water can be much improved if debris is kept out of the system. To accomplish this filters and separators can be added to a rainwater harvesting system at the inlet, outlet or both. Filters simply catch the debris and allow all water to flow through.

Treatment of stored water

Treatment of stored rainwater makes sense only if it is done properly. There are several possible treatment methods, the most common being sand filters, chlorination, boiling and exposure to sunlight.

Sand filters

Sand filters provide a cheap and simple method to purify water. In a sand filter, additional layers of gravel and charcoal are also commonly used to further improve the filtering capacity and thus the water quality. Sand filters do require careful operation and maintenance to ensure they continue to work effectively.

Chlorination

Chlorination can be an effective way to purify the water. The chlorine will, however, affect the taste of the water and over-application can cause health problems.

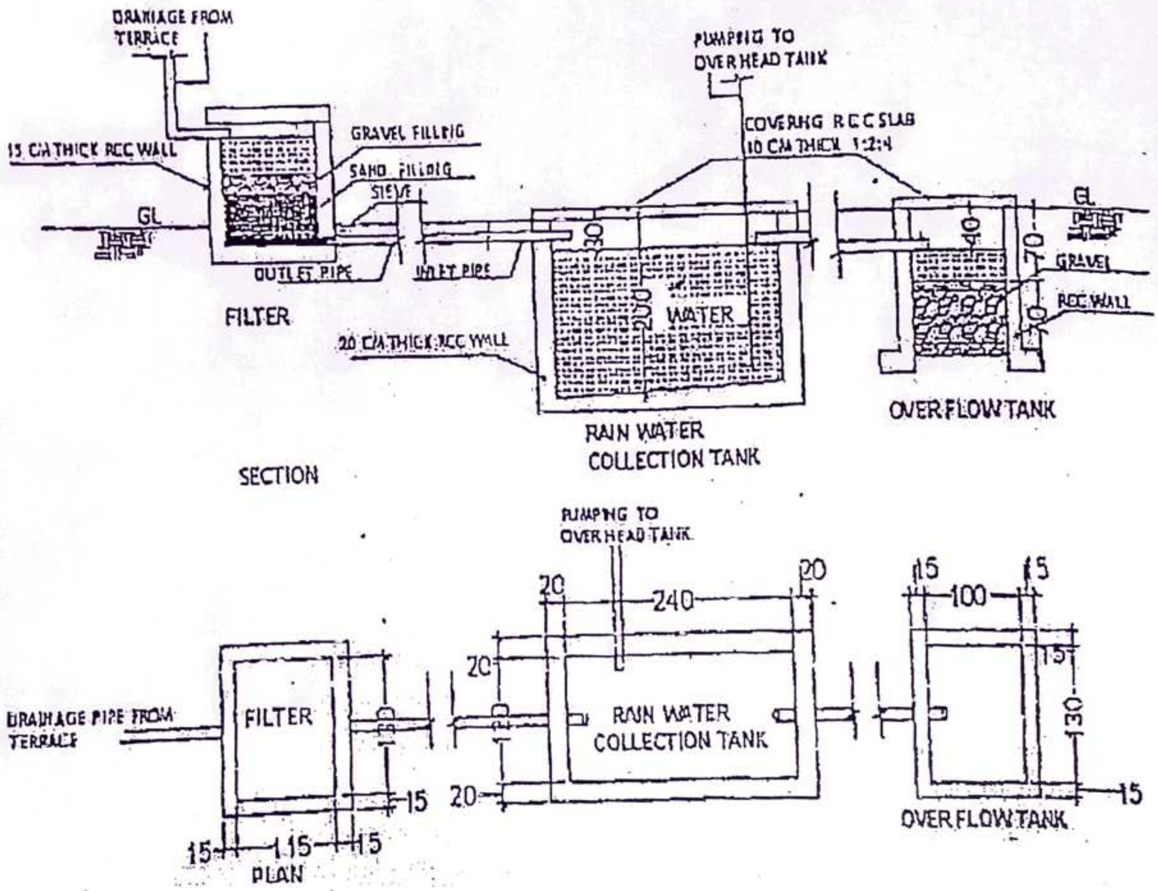
Boiling

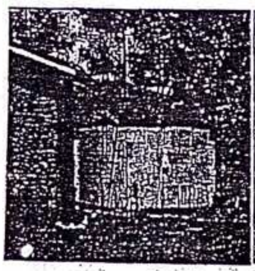
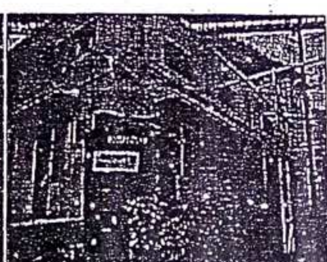
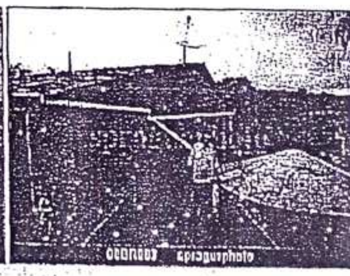
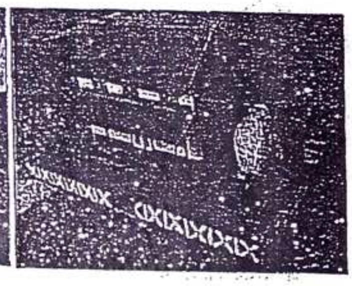
Boiling water for two or three minutes normally ensures that it is free from harmful bacteria or pathogens.

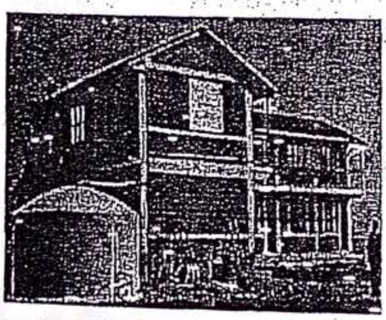
Sunlight

Another way to kill many harmful bacteria in water is to put it in into clear glass or plastic bottles and place them in direct sunlight for several hours. This method is known as Solar Water Disinfecting (SODIS).

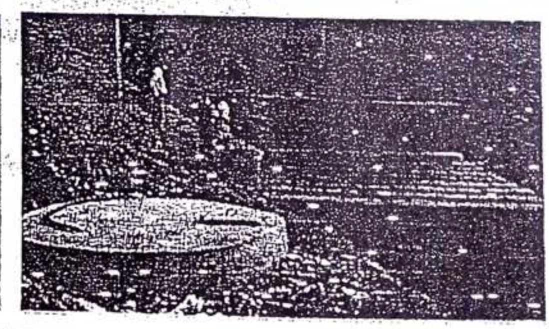
Rainwaterharvesting is the accumulating and storing of rainwater for reuse before it reaches the aquifer. It has been used to provide drinking water, water for livestock, water forirrigation, as well as other typical uses. Rainwater collected from the roofs of houses and local institutions can make an important contribution to the availability of drinking water.



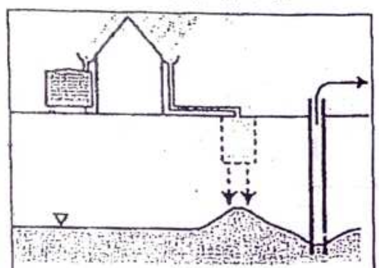







Rainwater harvesting done for school in Kaski District: Shivalaya Higher Secondary School, block Thumki-7;.



Rainwater Harvesting Capacity Centre (RHCC) for Nepal. Through this centre, BSP-Nepal together with other organizations is actively operating on areas ...



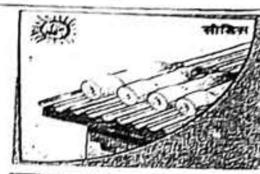
Rainwater Harvesting

In a bid to put an end to water shortage, rainwater harvesting and refilling underground water resources has started in Patan area.

Domestic methods of purification and disinfection of water

1) **Solar Disinfection (SODIS)⟹**

- Simple technique for disinfection of water
- Sun rays (Ultra violet) kills bacteria
- At least 6 hours exposure to direct sun
- Use mineral water bottle. Thick bottle is not recommended

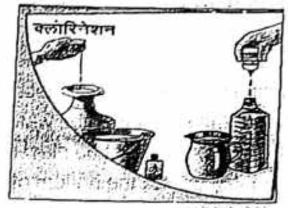


2) **Boiling⟹**

- Boil water at least 5 minutes
- Consumes firewood (kerosene/gas/electricity etc.)
- Taste not good (khallo), some do not like

3) **Use of 0.5% chlorine solution (Piyus)**

- Simple, Reliable and cheap
- 0.5% chlorine solution
- 3 drops per litre, water can be used after 30 minutes⟹
- 1-2 months for 4-5 member family
- NCR 17 per bottle (60ml)
- Available in medicine shops
- Expiry date – 1 year



4) **Candle filter⟹**

- Not cheap at community level
- Frequent cleaning of candle
- Do not use brush to clean candle

Disinfection of water by SODIS

SODIS Principle

- Sunlight generates Ultra Violet (UV-A) radiation and heat which inactivates or kills micro-organism or bacteria.

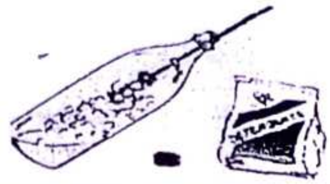
Effect of SODIS⇓

Research & Results

Microorganisms:

Pathogen	Illness	Reduction trough SODIS (6h, 40°C
Bacteria		
E. coli	Indicator for Water Quality & Entetritis	[1] [2]
Y. enterocolitica	Diarrhoea	
C. jejuni	Diarrhoea	
S. typhi	Typhoid	> 99.999%
S. entetritis	Typhoid	
S. typimurium	Typhoid	
Sh. flexneri	Dysentery	
V. cholerae	Cholera	
Viruses		
Rotavirus	Diarrhoea, Dysentry	99.9 - 99.99% [4]
Polio Virus	Polio	99.9 - 99.99%

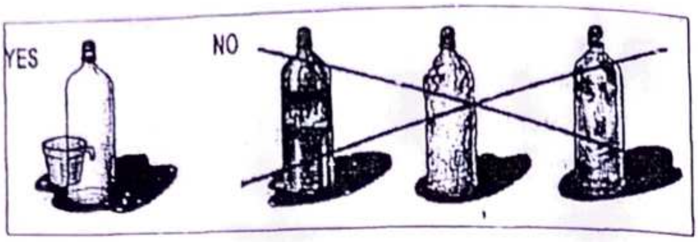
Wash the bottle well the first time you use it



How to use (make) SODIS?

- Recommend using PET bottles because
- Light and do not break easily
- Easily available. We are used to mineral water bottle.
- However, glass bottles can also be used but it is breakable, heavy and costly.

Use PET Bottle (Polyethylene Terephthalate) ⟹

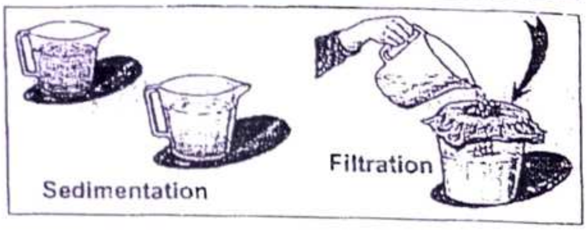


- Not more than 4 inches dia.
- Max 3 litres cap.
- No scratches
- Not twisted/smashed
- Not coloured
- Because they reduces UV-A transmittance

If Turbidity less than 30 NTU then use the following methods: ⟹

- If the water is very turbid, the effectiveness of the method is reduced.
- How to determine whether the water is sufficiently clear:
- The filied PET bottle must be placed on top of a newspaper headline. Now one must look at the bottom of the bottle from the neck at the top and through the water. If the letters of the headline are readable, the water can be used.

If Turbidity less than 30 NTU,
then use sedimentation and filtration methods⟹



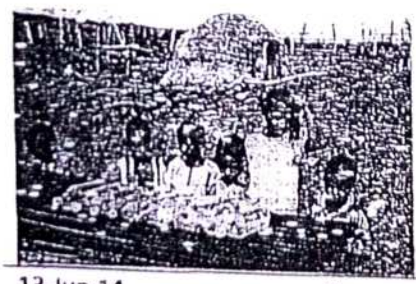
Cloudiness (Cloudy day)

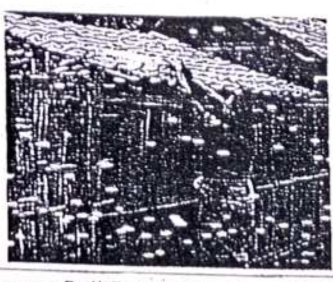
- Cloudiness affects the strength of solar radiation and thus also the effectiveness of the method.
- Rule of thumb: If less than half of the sky is clouded over, 6 hours will be enough to completely disinfect the water.
- If more than half of the sky is covered with clouds, the bottle must be placed in the sun for 2 consecutive days.

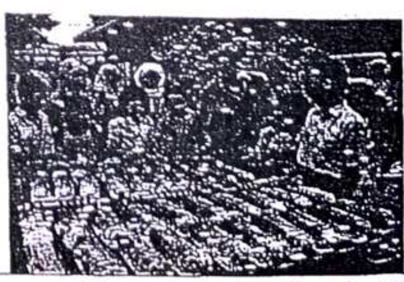
Preventing recontamination

- The treated water should be kept in the bottle and drunk directly from the bottle, or poured into a cup or glass immediately before it is drunk. In this way, it is possible to prevent the treated water from becoming contaminated again.

Exposure to sun – some practices: ⇓⟹







Earthing:-

Earthing means connections of the neutral point of a supply system or the non- current carrying parts of electrical apparatus such as metallic frame, earth terminal of socket etc. to the earth in such a manner that immediate discharge of electrical energy takes place without danger.

Earthing is provided:

↳ to avoid electric shock.

↳ to avoid risk of fire

↳ to ensure that no current carrying conductor rises to a potential w.r.t. general mass of earth.

Important specifications about earthing recommended by Indian standards,

↳ An earthing electrode shall not be situated within a distance of 1.5m from the building.

↳ Earth conductor should not be less than 2.9 mm² (14SWG)

↳ Earth resistance should be low.

Max^m values of earth resistance:

Lower power station ⇒ 0.5 Ω

Major " " ⇒ 1.0 Ω

Small substation ⇒ 2.0 Ω

In other cases ⇒ 5 Ω max^m.

Earth wire and earth electrode will be of same material.

Earthing electrode should be placed in vertical position.

Types of Earthing:

1. Strip or wire Earthing:-

- In this system of earthing strip electrodes of x-section not less than 25mm x 1.6 mm if of copper and 25mm x 4mm if of galvanised iron or steel are buried in minimum depth of 0.5m.
- If round conductors are used, x-sectional area shall not be smaller than 3.0 mm² if of copper and 6mm² if of galvanised iron or steel. The length of buried conductor must not less than 1.5 m.
- Used at places which have rocky soil earth bed because at such places excavation work of plate earthing is difficult.

2. Rod Earthing:

- In this system of earthing 12.5mm diameter solid rods of copper or 16mm diameter solids rods of galvanised iron or steel or hollow section 25mm GI pipes of length not less than 2.5 meters are driven vertically into the earth either manually or by pneumatic hammer.
- This system of earthing is suitable for areas which are sandy in character. This system of earthing is very cheap as no excavation work is involved.

3. Pipe Earthing:

- Most common and best system of earthing.
- Pipe used is of 40mm dia and 2.5m length.
- The pipe is placed at a depth of 3.75 m (min^m)
- Alternate layers of coke and salt are used to increase the effective area of the earth and to decrease the earth resistance respectively.
- A galvanised steel and perforated (cated) pipe is used.
- In order to maintain moisture content it is provided with funnel to put the water.

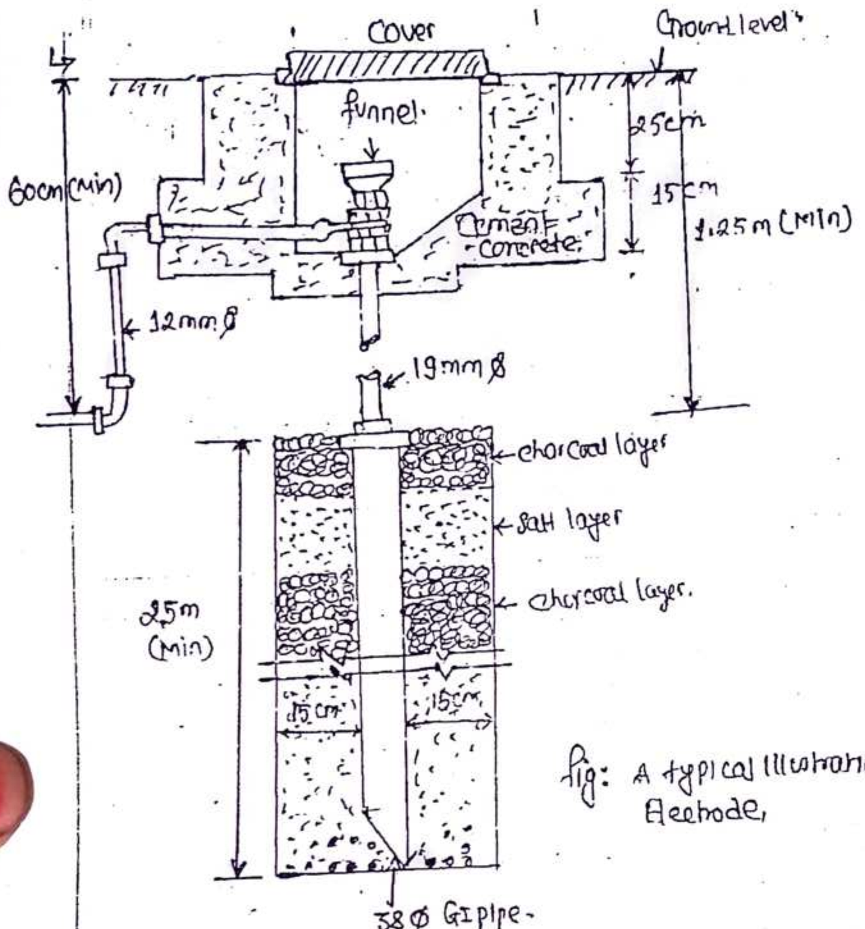


fig: A typical illustration of pipe Earth Electrode,

↳ The earth wire is carried in a GI pipe of diameter 12mm at a depth of about 60 cm from the ground.

Note:- Three or four buckets of water to be pured into sump every few days to keep the soil surrounding the earth pipe permanently moist.

Safety Techniques in Electrical Engineering:-

↳ The different techniques for handling electrical equipment or appliances are:

(a) The electric shocks are easily received and easily avoided being careful. The risk is not always apparent (स्पष्ट) so be careful.

(b) Be aware of line conductor whether bared or insulated.

(c) Before switching on, be sure that insulation of the Cable is healthy and safe.

(d) Before switching on, make sure that portable equipment is properly earthed.

(e) Never energise any line conductor unless you are sure that all is clear and there is no one working on the line.

(f) Maintain good earthing connection with appliances.

(g) Electric wiring should be safe and good and protecting device should be connected properly.

Wiring system:-

A network of wires connecting various accessories for distribution of electrical energy from the supplier meter board to the numerous electrical energy consuming devices such as lamps, fans, and other domestic appliances through controlling and safety devices is known as a wiring system.

Systems of wiring:-

The types of internal wiring usually employed in our country are:

1. Cleat wiring.
2. Casing and capping wiring.
3. C.T.S or TRS or PVC sheathed wiring.
4. Lead sheathed or metal sheathed wiring.
5. Conduit wiring.
   - (a) Surface conduit wiring.
   - (b) Concealed conduit wiring.

1. cleat wiring :-

This system comprised ordinary pvc insulated wires braided and compounded, held on walls and ceilings by means of porcelain cleats. This system is suitable for temporary installations.

- Installation and dismentalling is easy.
- low cost.
- Inspection work is easy.
- Not good appearance.
- Life is very short.

2. Casing and capping wiring :-

↳ This system which was popular in the early days of wiring. The cables used in this type of wiring were either VIR or pvc or any other approved insulated cables. The cables were carried through the wooden or pvc Casing enclosures. Then it is covered with capping structure..

- low cost
- good appearance
- Inspection, installation and maintenance is very easy.

3. CTS or TRS or Batten wiring :-

↳ In this type of wiring the cables used may be single core, twin core or three core TRS cables with a circular oval shape. TRS cables are run on teak wood batten of thickness 10 mm at least. The width of the batten depends upon the number and size of cables to be carried by it. The battens are available in width of 13, 19, 25, 31, 38, 44, 50, 56, 63, 69 and 75 mm.

The wooden battens are screwed to the walls or ceiling by flat-head wood screws to wood or other approved plugs at an interval not exceeding 75 cm. The cables are held on the wooden batten by means of tinned brass link clips already fixed on the batten with brass pins and spaced at an interval of 10 cm in case of horizontal runs and 15 cm in case of vertical runs.

4. Lead sheathed wiring or metal sheathed wiring:-

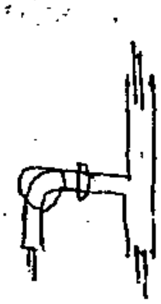
↳ This type of wiring employs conductors insulated with VIR and is covered with an outer sheath of lead aluminium alloy containing about 95% lead. This metal sheath gives protection to the cable from mechanical injury, dampness and atmospheric corrosion.

5. Conduit wiring:-

↳ In this system of wiring steel tubes known as conduits, are installed on the surface of walls by means of pipe hooks or buried under plaster and PVC cables are drawn afterwards by means of a GI wire of size of about 18 SWG. In damp situations the conduits can be spaced from the walls by means of small wooden blocks fixed below the pipes at regular intervals. In order to facilitate drawing of wires number of inspection fittings are provided along its length.

↳ workshop and public buildings.

↳ High cost.



or ceiling by flat-
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length.

Busbar :-

- It is made up of copper or aluminium.
- It is circular or flat type.
- It carries the full load current.

Electrical services :- Electricity is playing an important role in modern everyday life, because of its cleanliness, easy to control, reliability, steady output etc. Electricity has increased production, reducing work fatigue, protecting their health and reducing accidents.

Importance :-

1) lightening purpose.
2) powering kitchen & other house hold utensils eg; washing machine, Refrigerator, computer as well as other electrical appliances.

The general rules which are to be kept in mind for wiring system are :-

1) Every installation is to be properly protected near the point of entry of supply cables by Main switch and a fuse units.
2) The conductor used are to be of such a size that it may carry load current safely.
3) Every subcircuit is to be connected to a distribution fuse board
4) Switch board is to be installed so that its bottom lies 1.25m above the floor.
5) Adequate no. of socket outlet is to be provided at suitable places in all room, so as to avoid use of long flexible cords.
6) Socket outlets are to be installed either 25 cm or 1.3 m above the floor level as desired. No socket outlet is to be provided in bathroo

of a height less than 1.3 m.

7) All lamps unless otherwise required are to be hung at a height of 2.5 m above the floor level and ceiling fans are hung 2.27 m above the floor.

8) In any building light, fan wiring and power wiring are to be kept separate.

Safety and protection:-

1.) Fuse :- Fuse is a wire of short length or thin strip of material having low melting point and is inserted in electric ckt and protects the ckt when excessive current flow through the ckt. i.e. when current > maxm current allowed to flow through the socket in normal condition.

Under normal working condition the current flowing through the ckt is within limits but when some fault such as short ckt occurs when load more than ckt capacity is connected to it, the current exceeds the limiting value and fuse wire gets heated, hence it melts and break the ckt. It thus, protect a machine or apparatus from damaged due to excessive current.

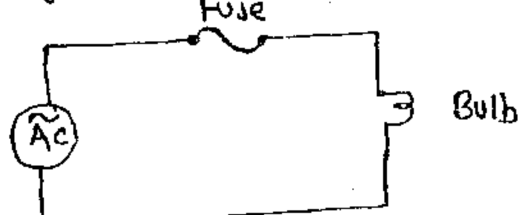

fig: Ele-ckt

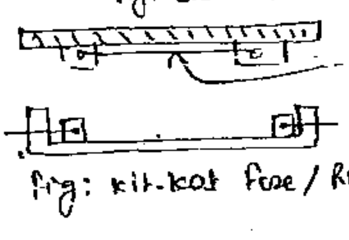

fig: kit-kat fuse / Rewirable fuse.

height of
2.27 m

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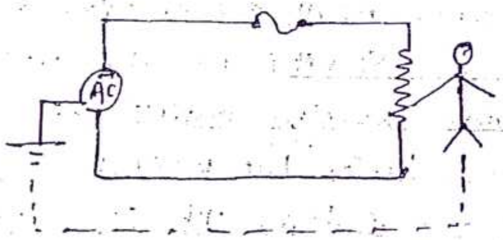
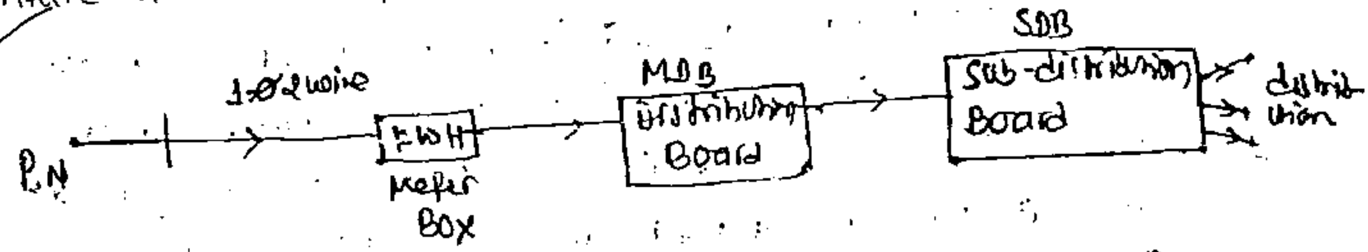
2. MCB (Miniature circuit Breaker) :-

↳ MCB is an advanced type of fuse which turns off automatically under overload and short ckt condition. It is not necessary to replace it again and again after ever operation as fuse element. MCB is more reliable than fused wire.

3. Earthing:



Intake structure and provision :-



The electric supply authority supplies power as primary distribution system (11 kv or 33kv) to consumers or buildings through low voltage 220 or 380 volt, 3Ø, 4 wire distribution system called secondary distribution system. For large consumer like industry, large commercial building are however supplied at higher voltage through primary system for small consumer i.e. residential building receive power from 3-Ø, 4-wire low voltage distribution system.

The suppliers distribution system brings power to the consumers through over head lines or by under ground cable to the outside of the consumers.

Busbar :-

✓ Busbar term as used for main bar or conductor carrying and electric current to which many connection may be made thus electrical busbar is the collector of electrical energy at one location. Busbar used are usually Rectangular section bar but they can be of round or square tubes. Busbar are of Aluminium and most common size of busbars are 40x4 mm, 50x6 mm, 60x8 mm, 80 x 8 mm, 100 x 10 mm.

A Trunking is a large size of conduit when we need to run a number of electric conduit along each other for a significant distance than trunking is used in place of small conduit

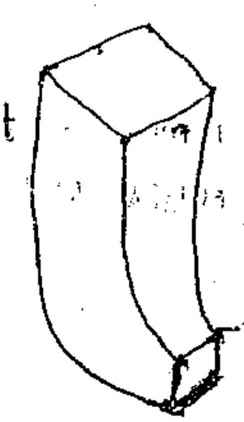


fig: Trunk.

3.6 Types of roofs – shape, material

Introduction

A roof is the uppermost part of a building which is supported on structural members and covered with a roofing material. The main function of roof is to enclose the space of the building and to protect it from the damaging effects of the weather elements such as rain, wind, heat, snow etc. The structural element may be trusses, beams, slabs etc. The roofing materials or roof coverings may be A.C sheets, tiles, slats, slab etc. Roof and roof coverings receive rain & snow more directly and in much greater quantity than walls. It must, therefore, provide a positive barrier to the entry or rain and vigorous (strong) weather proofing is most important. The structural component must have adequate strength and stability. A roof must have thermal insulation, fire resistance & sound insulation.

The functions of any roof are:

1. To keep out rain, wind, snow and dust.
2. To prevent excessive heat loss in winter
3. To keep the interior of the building cool in summer.
4. It is designed to accommodate all stresses encountered.
5. It is designed to accept movement due to changes in temperature and moisture content.
6. It is designed for strength and stability of building.
7. It is designed for durability and free from maintenance.
8. It is designed to provide resistance to the passage of sound.
9. T provides safety for occupants
10. It has aesthetic beauty

Requirements of a roof: To be a good roof, it should have the following properties (requirements)

1. **Adequate strength**
It should have adequate strength to carry the super imposed load (dead loads & live loads)
2. **Effective protection**
It should effectively protect the building against rain, sun; window etc and it should be durable against adverse effects of such agencies.
3. **Water proof**
It should be water proof and should have efficient drainage arrangement.
4. **Thermal insulation**
It should have adequate thermal insulation.
5. **Fire resistance**
It should be fire resistant.
6. **Sound insulation**
It should provide insulation against external sounds.

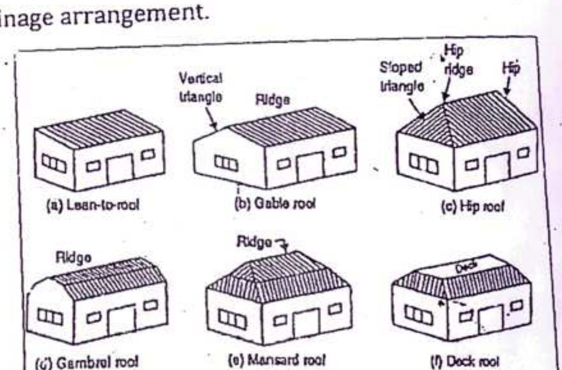


FIG. 15.1. VARIOUS FORMS OF SLOPING ROOFS

Types of roofs or classification of roof

Types of roofs may be as follows:

1. Pitched or sloped roof
2. Flat roof
3. Shelled roof
4. Domed roof

1. Pitched or sloped roof:

A roof with sloping surface is known as a pitched roof. Pitched roofs are considered suitable for buildings in coastal regions or in areas where rainfall and snowfall is very heavy. Normally the sloped roof has the slope from 1 in 3 to 1:1 or $1{:}1^1/_2$. The pitch of the roof is determined by the types of coverings and the basic form of roof is governed by the load and span. Pitched roofs are basically of the following forms or shape:

a. Lean to roof
b. Gable roof
c. Hip roof
d. Gambrel roof
e. Mansard or curb roof
f. Deck roof

Materials used for pitched roofs may be Thatch, Wood singles, Slates, Tiles, G.I. and A.C. sheets etc.