RAJIV GANDHI PROUDYOGIKI VISHWAVIDYALAYA, BHOPAL

New Scheme Based On AICTE Flexible Curricula

Civil Engineering, IV-Semester

CE402 Construction Technology

Unit-I Design features and construction of Foundations Introduction and essential requirements of foundations, footing types and depth of footings, contact pressure below footings such as strip footings, isolated footings, eccentrically loaded footings, Grillage foundations, , design features and construction detail of combined footing, strap footing, problem of frost heave, its causes and prevention, effect of ground water on footings.

Purpose of pile foundation, classification based on different criterion and types, advantages and disadvantages, selection of pile type, pile action, behavior of pile and pile group under load, definition of load failure.

Unit-II Formwork and Temporary structures Design and construction features of different types of temporary structures, stationary and slip form work techniques, special features of in-situ construction, stripping and removal of formworks, formworks for special structures, e. g. shells bridges towers etc.

Unit-III Masonry and walls Brick masonry, Bonds, Jointing, Stone masonry, casting and laying, masonry construction, brick cavity walls, code provisions regarding load bearing and non load bearing walls, common defect in construction and their effect on strength and performance of walls, Design of brick masonry, precast stone masonry, hollow concrete block and hollow block masonry walls, plastering and pointing, white and colour washing, distempering, dampness and its protection.

Doors windows and ventilators: types based on materials etc. size location fittings, construction sunshades, Sills and jambs, RCC doors/windows frames, Stair types, rules of proportionality, etc., Repair Techniques for masonry, walls, doors and windows.

Unit- IV Construction of Floors Ground floor-introduction, Components of a floor, Materials for construction, Selection of flooring material, Construction of Various types of floorings such as Mud, Brick, Cement, Terrazzo, Mosaic, Tiled, Marble, Rubber, Glass and plastic floorings etc., Upper floor- Introduction, construction of Slab floors, Jack arch floors, RCC floors, Ribbed or Hollow tiled flooring, Filler Joist floors, Pre-cast concrete floors, Timber floors etc. Repair Techniques for floors.

Construction of Roofs Introduction and types of roofs, Construction of Pitched roofs, single roofs, double or purlin roofs, trussed roofs, steel roof trusses etc. roof coverings for pitched roofs and flat terraced roof etc. Repair Techniques for roofs.

Unit- V Construction of Earthquake Resistant Building Planning of earthquake resistant building, Construction of walls – provision of corner reinforcement, construction of beams and columns, Base isolation.

Reference:-

1. Mohan Rai & M. P. Jai Singh, Advances in Building materials and Constructions.
2. S. P. Arora and S. P. Bindra, A text Book of Building Construction-Dhanpat Rai and Sons, New Delhi.
3. S. K. Sarkar and Saraswati, Construction Technology- Oxford University Press, New Delhi.
4. Sushil Kumar, Building Construction.
5. B. C. Punmia , Building Construction.
6. Metchell , Building Construction.
7. Chudley R.., Construction Technology.
8. Dr. K.R. Arora Soil Mechanics & Foundation Engg - Std. Publishers Delhi
9. B.C. Punmia, Soil Mechanics & Foundation Engg. - Laxmi Publications Delhi

List of Experiments:

1. Tests on Bricks
2. Tests on Aggregates (fine and Coarse)
3 Tests on Cements and concrete
4. Tests on tiles

Unit: -1

Design features and construction of Foundations : - Introduction and essential requirements of foundations, footing types and depth of footings, contact pressure below footings such as strip footings, isolated footings, eccentrically loaded footings, Grillage foundations, , design features and construction detail of combined footing, strap footing, problem of frost heave, its causes and prevention, effect of ground water on footings. Purpose of pile foundation, classification based on different criterion and types, advantages and disadvantages, selection of pile type, pile action, behavior of pile and pile group under load, definition of load failure.

Foundation:-

Foundation is a structural part of a building on which a building stands. Foundation transmits and distributes its own load and imposed loads to the soil in such a way that the load bearing capacity of the "foundation bed" is not exceeded. The solid ground at which the foundation is rest called foundation bed. We use various types of footing as a foundation.

Foundations are mainly two categories.

1. Shallow foundation, and
2. Deep foundation.

Shallow Foundation

Shallow foundation is a type of foundation that transfers load to the very near the surface. Shallow foundations typically have a depth to width ratio of less than 1.

Following are the type's shallow foundations –

1. Pad footing or column footing
2. Cantilever or strap footings
3. Mat/Raft footings
4. Wall Footings

Pad footing or column footing

This type of footing can be two types - Isolated and Combined.

- Isolated footing

These are most economical. They are usually in square or rectangle size with the column sitting in the middle of the square. It's a kind of pad footing.

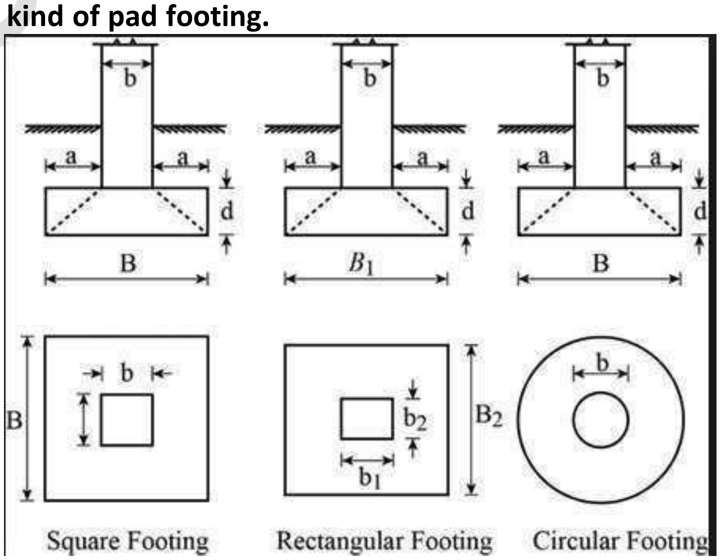


Fig 1 Isolated Footing

- **Combined footing**

A footing, either rectangular or trapezoidal, that supports two columns. It's also a pad footing.

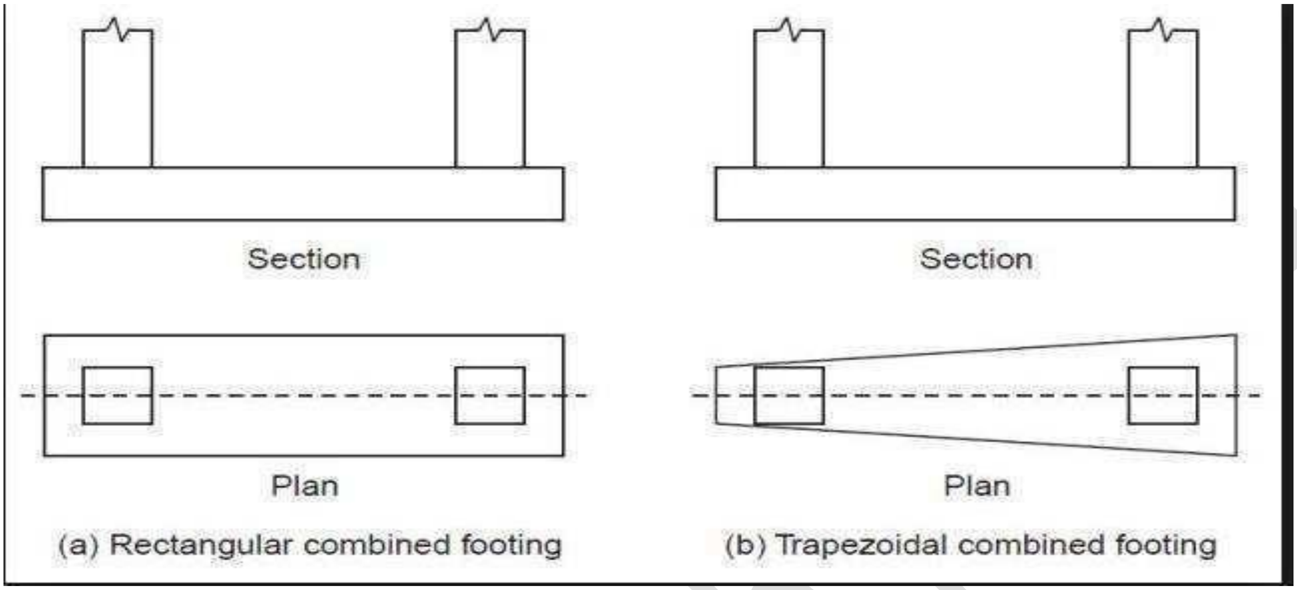


Fig 2 Combined Footing

- **Cantilever or strap footings**

Consist of two single footings connected with a beam or a strap and support two single columns.

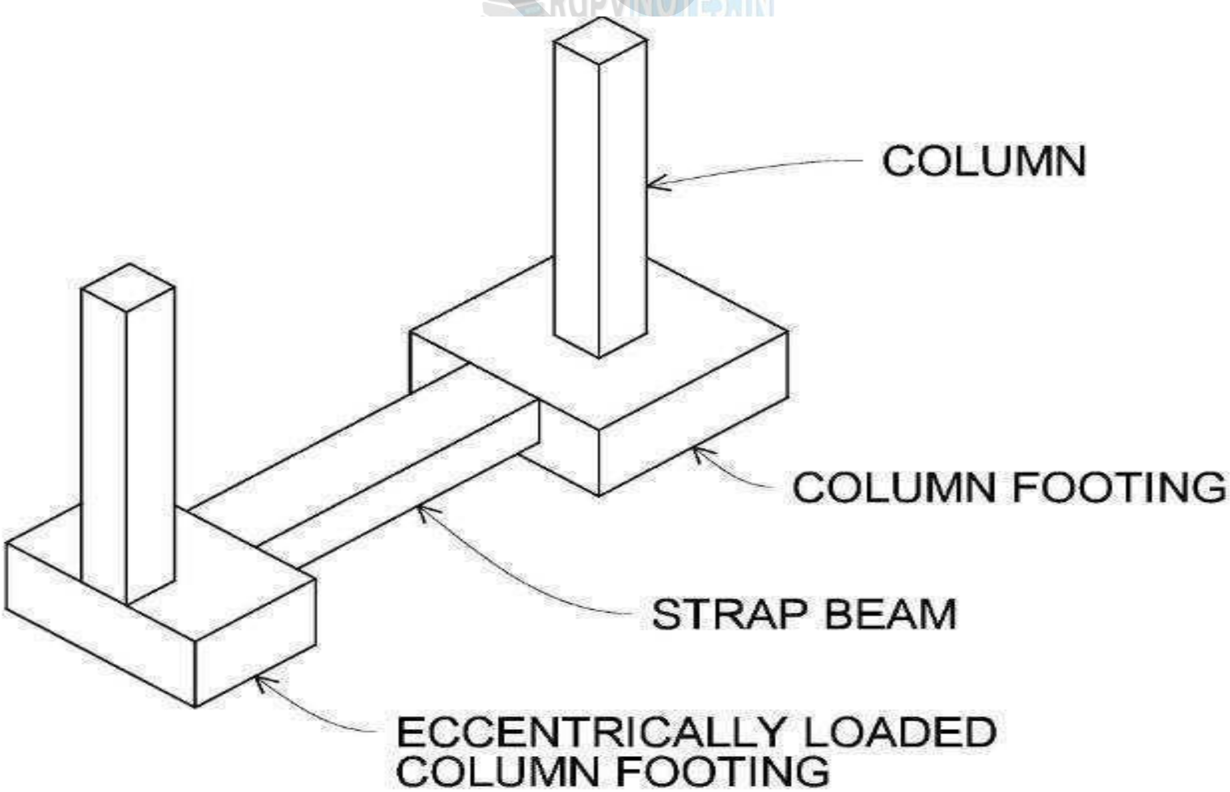


Fig 3 Cantilever or strap footings

- **Mat/Raft footings**

Consist of one footing usually placed under the entire building area. They are used when soil bearing capacity is low, column loads are heavy, single footing can't be used, piles are not used and differential settlement must be reduced.

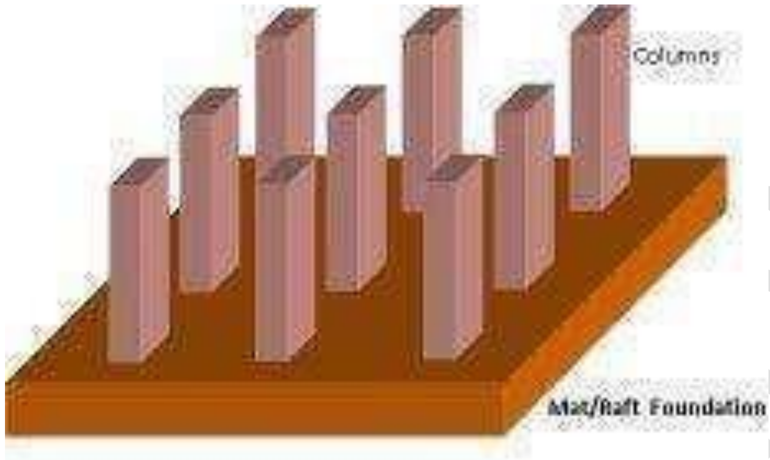


Fig 4 Mat/Raft footings

- **Wall Footings**

Wall footings are used to distribute the loads of structural load-bearing walls to the soil.

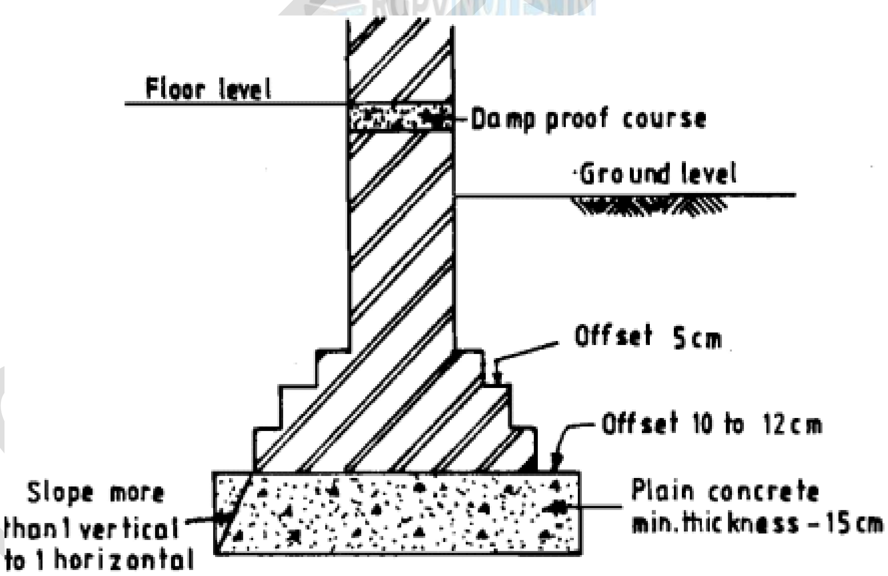


Fig 5 Wall Footings

2. Deep Foundations

Deep foundations are those founding too deeply below the finished ground surface for their base bearing capacity to be affected by surface conditions, this is usually at depths of 3 meter below finished ground level. Deep foundations can be used to transfer the load to deeper, more competent strata at depth if unsuitable soils are present near the surface.

Common Type of Deep Foundation:

Pile foundations are common type of deep foundation. These are relatively long, slender members that transmit foundation loads through soil strata of low bearing capacity to deeper soil or rock strata having a high bearing capacity. They are used when for economic, constructional or soil condition considerations it is desirable to transmit loads to strata beyond the practical reach of shallow foundations. In addition to supporting structures, piles are also used to anchor structures against uplift forces and to assist structures in resisting lateral and overturning forces. Thick slabs are used to tie a group of piles together to support and transmit column loads to the piles.

- **Pile foundations**
- **Caissons**
- **Cylinders**
- **Basements**
- **Hollow Box Foundations (Buoyancy Rafts)**
- **Shaft Foundations**

- **Pile foundations**

Pile foundations are constructed through driving preformed units into the required founding level or by drilling in, driving tubes filled with concrete to the desired depth. The tubes can be filled with concrete in different ways – they can be filled during or before withdrawal, or through drilling unlined, partly lined, or wholly lined boreholes before being filled with concrete.

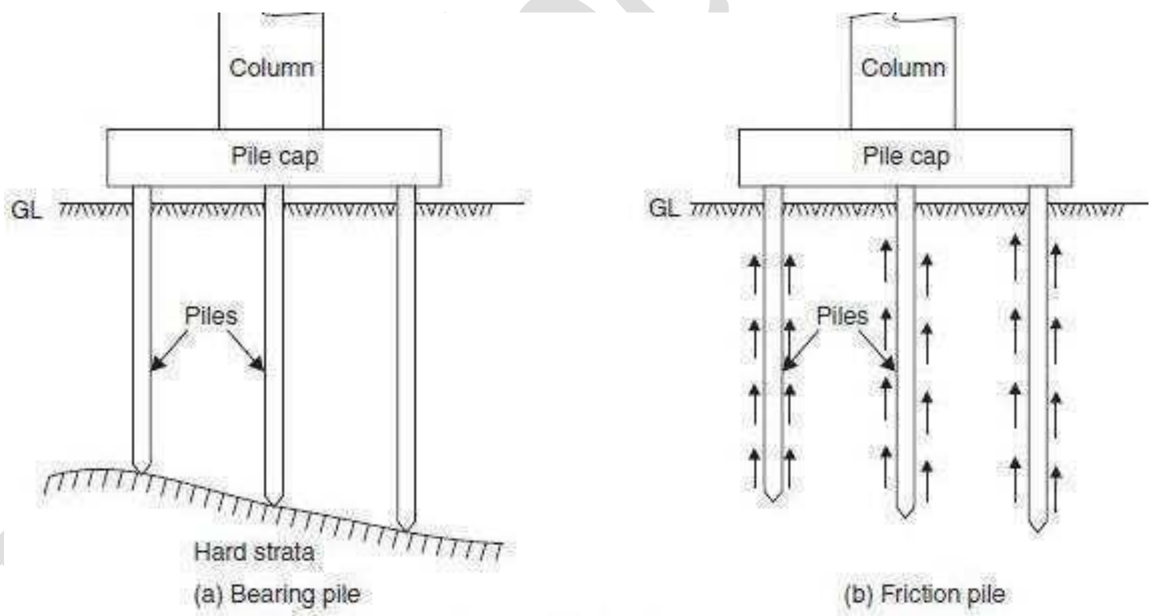


Fig 6 Pile foundation

- **Caissons**

These are hollow substructures that can be constructed near or on the ground surface and are sunk to the desired level as a single unit. They have an enormous load-carrying capacity and are commonly used for bridges.

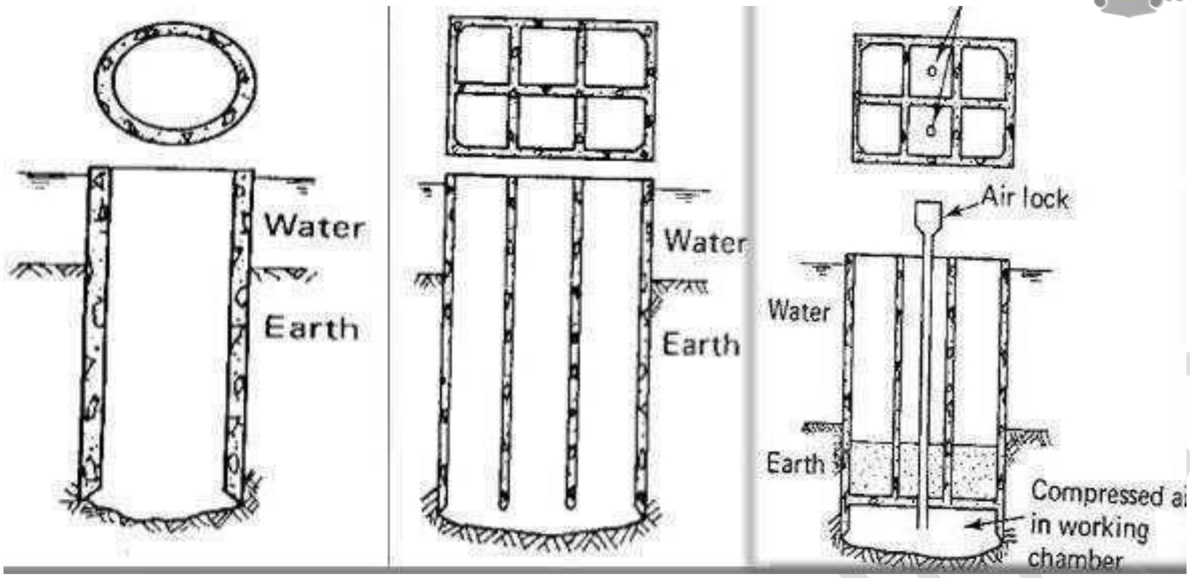


Fig 7 Caissons Foundation

- **Shaft Foundations**

These foundations are constructed by drilling a cylindrical hole within a deep excavation and subsequently placing concrete or another prefabricated load-bearing unit in it. Their length and size can be easily tailored. Drilled shafts can be constructed near existing structures and under low overhead conditions, making them suitable for use in numerous seismic retrofit projects. It may, however, be difficult to install them under certain conditions such as soils with boulders, soft soil, loose sand, and sand under water.

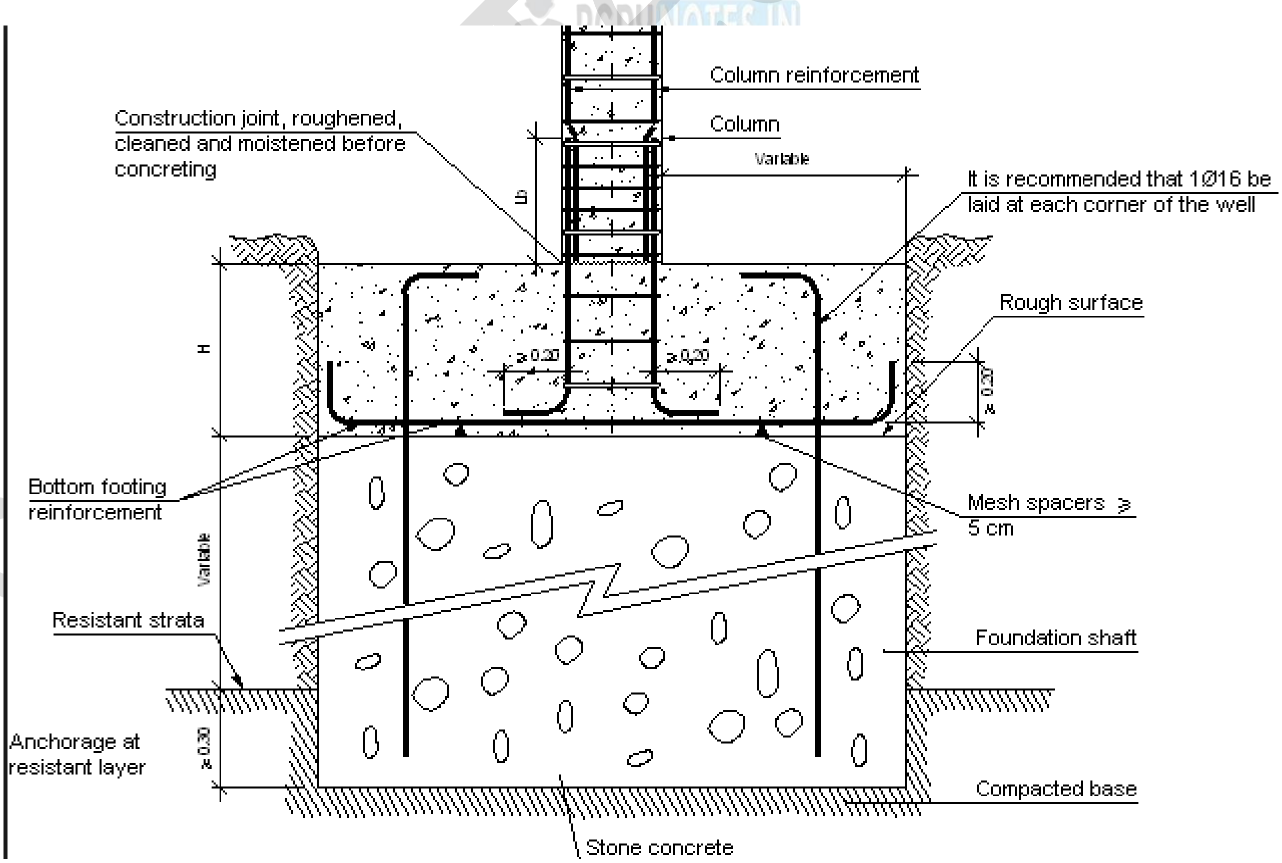


Fig 7 Shaft Foundation

Bearing capacity

In geotechnical engineering, bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil.

Ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity is the ultimate bearing capacity divided by a factor of safety.

TECHNIQUES USED FOR IMPROVING BEARING CAPACITY OF SOIL

The following techniques can be used for improving bearing capacity of soil as per the site condition.

1. **Increasing depth of foundation**
2. **Draining the soil**
3. **Compacting the soil**
4. **Confining the soil**
5. **Replacing the poor soil**
6. **Using grouting material**
7. **Stabilizing the soil with chemicals**
8. **How to improve bearing capacity of soil**

1. INCREASING DEPTH OF FOUNDATION

At deeper depths, the over burden pressure on soil is higher; hence the soil is more compacted at deeper depth. As a result it shows higher bearing capacity. This is applicable only for cohesion less soils such as sandy and gravelly soils. This method of improving bearing capacity of soil is not applicable if the subsoil material grows wetter as depth increase. This method has a limited use because with increase in depth, the weight and cost of foundation also increases.

2. DRAINING THE SOIL

With increase in percentage of water content in soil, the bearing capacity decreases. In case of sandy soil, the bearing capacity may reduce as much as 50% due to presence of water content. Cohesion less soils (i.e. sandy & gravelly soils) can be drained by laying the porous pipes to a gentle slope, over a bed of sand and filling the trenches above the pipes with loose boulders. These trenches subsequently should lead to the nearest well or any water body.

3. COMPACTING THE SOIL

If we compact soil using appropriate method, then there will be increase in its density and shear strength. As a result the bearing capacity of soil also increases. There are many methods of compacting soils on site. Few of them are mentioned below.

By spreading broken stones, gravel or sand and thereafter ramming well in the bed of trenches, using an appropriate roller as per the soil type to move at a specified speed.

4. CONFINING THE SOIL

In this method, the soils are enclosed with the help of sheet piles. This confined soil is further compacted to get more strength. This method is applicable for shallow foundations.

5. REPLACING THE POOR SOIL

In this method the poor soil is first removed and then the gap is filled up by superior material such as sand, stone, gravel or any other hard material. In order to do this, first excavate a foundation trench of about 1.5 m deep, and then fill the hard material is stages of 30 cm. Then compact the hard material at every stage. This method is useful for foundations in black cotton soils.

6. USING GROUTING MATERIAL

This method is applicable for soils where there is presence of pores, fissures or cracks etc. underneath the foundation. In this method, poor soil bearing strata is hardened by injecting the cement grout under pressure, because it scales off any cracks or pores or fissures etc. For proper distribution of the cement grout, the ground is bored and perforated pipes are introduced to force the grout.

7. STABILIZING THE SOIL WITH CHEMICALS

This method of improving bearing capacity of soil is costly and applied in exceptional cases. In this method, chemical solutions, like silicates of soda and calcium chloride is injected with pressure into the soil. These chemical along with the soil particles form a gel like structure and develop a compact mass. This is called chemical stabilization of soil and used to give additional strength to soft soils at deeper depths.

Soil stabilization

The prime objective of soil stabilization is to improve the California Bearing Ratio of in-situ soils by 4 to 6 times. The other prime objective of soil stabilization is to improve on-site materials to create a solid and strong sub-base and base courses. In certain regions of the world, typically developing countries and now more frequently in developed countries, soil stabilization is being used to construct the entire road.

In the past, soil stabilization was done by utilizing the binding properties of clay soils, cement-based products such as soil cement, and/or utilizing the "rammed earth" technique (compaction) and lime.

Some of the renewable technologies are: enzymes, surfactants, biopolymers, and synthetic polymers, co-polymer based products, cross-linking styrene acrylic polymers, tree resins, ionic stabilizers, fiber reinforcement, calcium chloride, calcite, sodium chloride, magnesium chloride and more. Some of these new stabilizing techniques create hydrophobic surfaces and mass that prevent road failure from water penetration or heavy frosts by inhibiting the ingress of water into the treated layer.

However, recent technology has increased the number of traditional additives used for soil stabilization purposes. Such non-traditional stabilizers include: Polymer based products (e.g. cross-linking water-based styrene acrylic polymers that significantly improves the load-bearing capacity and tensile strength of treated soils), Copolymer Based Products, fiber reinforcement, calcium chloride, and Sodium Chloride.

Grillage Foundation

A type of foundation often used at the base of a column. It consists of one, two or more tiers of steel beams superimposed on a layer of concrete, adjacent tiers being placed at right angles to each other, while all tiers are encased in concrete. Grillage foundation is the most economical foundation in case of transferring heavy loads from columns to soil of low bearing capacity.

Definition

Grillage foundations consist of a number of layers of beams usually laid at right angles to each other and used to disperse heavy point loads from the superstructure to an acceptable ground bearing pressure.

The grillage beam can be in any material, the most usual being either steel, precast concrete or timber. In some permanent situations, however, where unusual circumstances exist, such as an abundance of durable timber or the possible re-use of existing rolled steel sections, the grillage can prove both successful and economic. In permanent conditions durability becomes an important design factor and protection and/or the selection of suitable materials is a major part of the design.

The design of the grillage is carried out by calculating the loads and moments applied from the superstructure and determining the required base area using a suitable allowable ground bearing pressure for the condition involved.

From this area, the number and size of each grillage layer can be decided. The layers are then designed to cantilever from the edge of the layer above, which determines the beam sizes required to resist the applied bending moments and shear forces.

If the grillage is encased in concrete and the sequence and method of construction and loading is compatible with the design requirements, the composite action of the beam and concrete can be exploited.

Types of Grillage Foundation

Mostly there are two types of grillage foundation based on type of material used;

a) Steel grillage foundation

b) Timber grillage foundation

Mostly out of these two types the decision is made on the basis of availability of material and overall cost is the deciding factor

Under Reamed Pile

Under reamed piles are bored cast-in-situ concrete piles having one or more number of bulbs formed by enlarging the pile stem. These piles are best suited in soils where considerable ground movements occur due to seasonal variations, filled up grounds or in soft soil strata. Provision of under reamed bulbs has the advantage of increasing the bearing and uplift capacities. It also provides better anchorage at greater depths. These piles are efficiently used in machine foundations, over bridges, electrical transmission tower foundation sand water tanks. Indian Standard IS 2911 (Part III) - 1980 covers the design and construction of under reamed piles having one or more bulbs. According to the code the diameter of under reamed bulbs may vary from 2 to 3 times the stem diameter depending upon the feasibility of construction and design requirements. The code suggests a spacing of 1.25 to 1.5 times the bulb diameter for the bulbs. An angle of 45 0 with horizontal is recommended for all under reamed bulbs. This code also gives Mathematical expressions for calculating the bearing and uplift capacities.

Foundation on Black Cotton Soil

Black cotton soils 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. Most of the fine grained clays, including black cotton soils have their grains which are more or less in the form of platelets or sheets (just like leafs of a 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. This increase in volume is commonly known as swelling. If this swelling is checked or restricted (due to the construction of footings over it), high swelling pressure, acting in the upward direction, will be induced. This would result in severe cracks in the walls etc. and may sometimes damage the structural units, such as lintels, beams slabs etc. During summer season, moisture moves out of the soil and consequently, the soil shrinks. Shrinkage cracks are formed on the ground surface. These

shrinkage cracks sometimes also known as tension cracks, may be 10 to 15 cm wide on the ground surface and may be ½ to 2 m deep

In fat clays, having angle of internal friction Ø = 0, the depth z of tension cracks is found to be equal 2c/y, where c is the unit cohesion an y is the unit weight of the soil. These cracks result in loss of support beneath the footings, resulting in high settlements. Some expansive and shrinkable soils stick to the footing base and

Pull the footing down when they shrink. This results in horizontal cracks in the walls and other flexible units of the structure.

Black cotton soils and other expansive soils are dangerous due to their shrinkage and swelling characteristics. In addition to this, these soils have very poor bearing capacity, ranging from 5 t/m2 to 10 t/m2. In designing footings on these soils, the following points should be kept in mind:

1. The safe bearing capacity should be properly determined, taking into account the effect of sustained loading. In absence of tests, the bearing capacity of these soils may be limited to 5 to 10 t/m2.

2. The foundation should be taken at Least 50 cm lower than the depth of moisture movement. This depth should also be much more than depth of tension cracks.

3. Where this soil occurs only in top layer, and where the thickness of this layer does fol exceed 1 to 1.5 m, the entire layer of black cotton soil (or other expansive soil) should be removed, and the foundation should be laid on non-shrinkable non- expansive soil.

4. Where the depth of clay layer is large, the foundation or footing should be prevented from coming in contact with the soil. This can be done by excavating wider and deeper foundation trench and interposing layer of sand around and beneath the footing.

5. Where the soil is highly expansive, it is very essential to have minimum contact between the soil and the footing. This can be best achieved by transmitting the loads through deep piles or piers and by supporting wall loads on capping beams which are kept some distance (5 to 15 cm) above the ground surface, to permit free expansion of the soil.

6. Where the bearing capacity of soil is poor, or soil is very soft, the bed of the foundation trench should be made firm or hard by ramming sand and ballast.

7. The foundations should be constructed during dry season. Also suitable plinth protection around the external wall should be made on the ground surface, with its slope away from the wall, so that moisture does not penetrate the foundation during rainy season.

Types of foundation in black cotton soils

Foundation in black cotton soils may be of the following types:

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 section of shallow footings suitable for black cotton and other expansive soils....

2. Pier foundation 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....

3. Under-reamed pile foundation. An under-reamed pile is a pile of shallow depth (1 to 6 m) having one bulb its lower end. If this bulb is taken or provided at a level lower than the critical depth of moisture movement in expansive soils.

Dewatering

Dewatering is the removal of water from solid material or soil by wet classification, centrifugation, filtration, or similar solid-liquid separation processes, such as removal of residual liquid from a filter cake by a filter press as part of various industrial processes.

Deep wells

A deep well typically consists of a boreholes fitted with a slotted liner and an electric submersible pump. As water is pumped from a deep well, a hydraulic gradient is formed and water flows into the well forming a cone of depression around the well in which there is little or no water remaining in the pore spaces of the surrounding soil. Deep wells work best in soils with a permeability of k = 10-3 m/s to 10-5 m/s; the amount of drawdown that a well can achieve is limited only by the size of the fish pump.

Deep wells can be installed in a ring around an excavation to lower the water level and maintain a safe, dry site. Several equations can be used to design deep well dewatering systems, however many of these are based on empirical data and occasionally fail. Practice and experience, along with a firm understanding of the underlying principles of dewatering, are the best tools for designing a successful system. Some dewatering situations "are so common that they can be designed almost by rule of thumb".

Deep wells are also used for aquifer testing and for groundwater drainage by wells.

Well points

Well points are small-diameter (about 50 mm) tubes with slots near the bottom that are inserted into the ground from which water is drawn by a vacuum generated by a dewatering pump. Well points are typically installed at close centers in a line along or around the edge of an excavation. As a vacuum is limited to 0 bar, the height to which water can be drawn is limited to about 6 meters (in practice). Well points can be installed in stages, with the first reducing the water level by up to five meters, and a second stage, installed at a lower level, lowering it further. The water trickling between the deep wells may be collected by a single row of well point at the toe. This method ensures a much thicker width free from seepage forces.

Well point spears are generally used to draw out groundwater in sandy soil conditions and are not as effective in clay or rock conditions. Open pumps are sometimes employed instead of spears if the ground conditions contain significant clay or rock content.

Horizontal drainage

The installation of horizontal dewatering systems is relatively easy. A trencher installs an un perforated pipe followed by a synthetic or organic wrapped perforated pipe. The drain length is determined by the drain diameter, soil conditions and the water table. In general drain lengths of 50 meters is common. After installation of the drainpipe a pump is connected to the drain. After the water table has been lowered, the intended construction can start. After the construction is finished the pumps are stopped, and the water table will rise again. Installation depths up to 6 meters are common.

Removal of water

Removal of surface and/or groundwater may be necessary for the performance of the specified work, especially where the construction is near or in a lake, stream, or area subjected to frequent or periodic inundation or flow of surface water. If removal of water is needed, it is generally required prior to any significant excavation and backfill operations and will likely be required when preparing the foundation. Removal of water includes impoundment or diversion of surface runoff, exclusion of groundwater or impounded.

Removal of water involves furnishing and installing temporary works, such as water containment facilities, channels, diversions, wells or well points, pumps, Piping, pollution control measures, and other facilities and equipment, that must be monitored and maintained until no longer required.

Methods for controlling water will vary with site condition and location. Unless otherwise specified, the contractor is responsible for designing and constructing the works needed for the removal of water. The contractor must provide and operate all equipment needed to keep foundations, structures, and borrow areas free of excess water. When required, the contractor must furnish, in writing, a plan for removal of water before beginning any construction activities. The plan should include an explanation of all permits required to be obtained by the contractor to conduct work in a stream or near a wetland, including permits to divert water as applicable. This plan is usually reviewed and approved by the responsible engineer who provides a copy and any approval documents to the inspector. The inspector must verify that the plan for removal of water is fully implemented, including the acquisition of permits prior to beginning work. Plan performance should be documented in the diary throughout the construction period. The inspector should discuss with the contractor any concerns of inadequate removal of water efforts. The responsible engineer should be consulted when contractor's efforts fail to adequately remove the water so that the work may be performed as specified or when the quality of work is jeopardized due to wet conditions at the site. The methods and equipment used to divert stream flow or to dewater the site can affect the stability of the foundation and excavated slopes. These methods can also result in surface erosion, which can lead to further instability of slopes or pollution of surface water or groundwater. The inspector should monitor the foundation and excavated slopes for signs of instability and monitor diversions and dewatering operations for signs of pollution of surface water and groundwater. Make the contractor aware of related concerns, and document these concerns and any conversations with the contractor concerning removal of water.

Allowable Settlement for different structures:

The allowable settlement is defined as the acceptable amount of settlement of the structure and it usually includes a factor of safety. The allowable settlement depends on many factors, including the following:

The Type of Construction – For example, wood-frame buildings with wood siding would be much more tolerant than unreinforced brick buildings.

The Use of the Structure – Even small cracks in a house might be considered unacceptable, whereas much larger cracks in an industrial building might not even be noticed.

The Presence of Sensitive Finishes – Tile or other sensitive finishes are much less tolerant of movements.

The Rigidity of the Structure – If a footing beneath part of a very rigid structure settles more than the others, the structure will transfer some of the load away from the footing. However, footings beneath flexible structures must settle much more before any significant load transfer occurs. Therefore, a rigid structure will have less differential settlement than a flexible one.

Aesthetic and Serviceability Requirements – The allowable settlement for most structures, especially buildings, will be governed by aesthetic and serviceability requirements, not structural requirements. Unsightly cracks, jamming doors and windows, and other similar problems will develop long before the integrity of the structure is in danger.

Table below shows the allowable foundation displacement into three categories: total settlement, tilting, and differential settlement. It indicates that those structures that are more flexible (such as simple steel

frame buildings) or have more rigid foundations (such as mat foundations) can sustain larger values of total settlement and differential movement.

Type of Settlement	Limiting factor	Maximum Settlement
Total settlement	Drainage	15 – 30 cm
	Access	30 – 60 cm
	Probability of non-uniform settlement:	
	1. Masonry walled structures	2.5 – 5 cm
	2. Framed structures	5 – 10 cm
	3. Chimneys, silos, mats	8 – 30 cm
Tilting	Stability against overturning	Depends on H and L
	Tilting of chimneys, towers	0.004L
	Rolling of trucks etc.	0.01L
	Stacking of goods	0.01L
	Crane rails	0.003L
	Drainage of floors	0.01 – 0.02 L
Differential settlement	High continuous brick walls	0.0005 – 0.001 L
	One-storey brick mill building, wall cracking	0.001 – 0.002 L
	Plaster cracking	0.001 L
	Reinforced concrete building frame	0.0025 – 0.004 L
	Reinforced concrete building curtain walls	0.003 L
	Steel frame, continuous	0.002 L
	Simple steel frame	0.005 L

Where, L = distance between adjacent columns that settle to different amounts, or between two points that settle differently. Higher values are for regular settlements and more tolerant structures. Lower values are for irregular settlement and critical structures. H = Height and W = width of structure.

Well Foundation: Meaning, Shapes, Forces and Description

Well foundation is a type of deep foundation which is generally provided below the water level for bridges. Cassions or well has been in use for foundations of bridges and other structures since Roman and Mughal periods.
The term 'Cassions' is derives from the French word Caisse which means box or chest. Hence Cassion means a box like structure, round or rectangular, which is sunk from the surface of either land or water to some desired depth.

The Cassions are of three types:
(i) Box Cassion: It is open at the top and closed at the bottom and is made of timber, reinforced concrete or steel. This type of Cassion is used where bearing stratum is available at shallow depth.

(ii) Open Cassion (wells): Open Cassion is a box opened both at top and bottom. It is made up to either timber, concrete or steel. The open Cassion is called well. Well foundation is the most common type of deep foundation used for bridges in India.

(iii) Pneumatic Cassions has its lower end designed as a working chamber in which compressed air is forced to prevent the entry of water and thus excavation can be done in dry conditions.

Shapes of Wells:

The common types of well shapes are:

- **Single circular**
- **Twin circular**
- **Dumb well**
- **Double-D**
- **Twin hexagonal**
- **Twin octagonal**
- **Rectangular.**

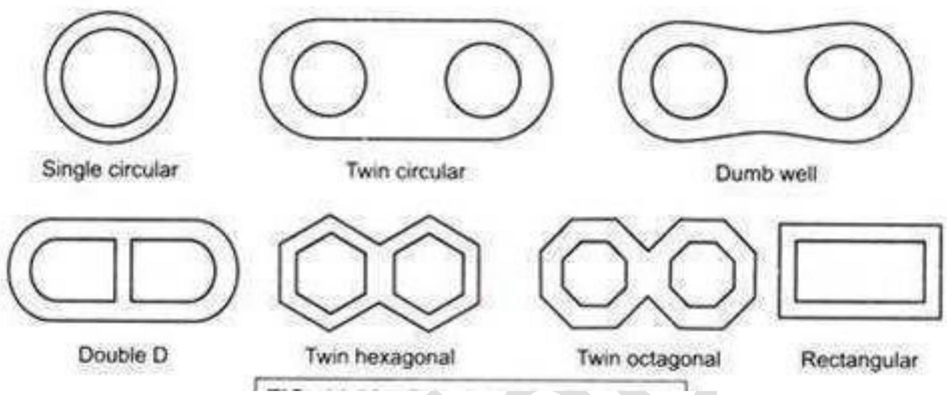


Fig 8 Different shapes of well

The choice of a particular shape of well depends upon the size of the pier, the care and cost of sinking, the considerations of tilt and shift during sinking and the vertical and horizontal forces to which well is subjected.

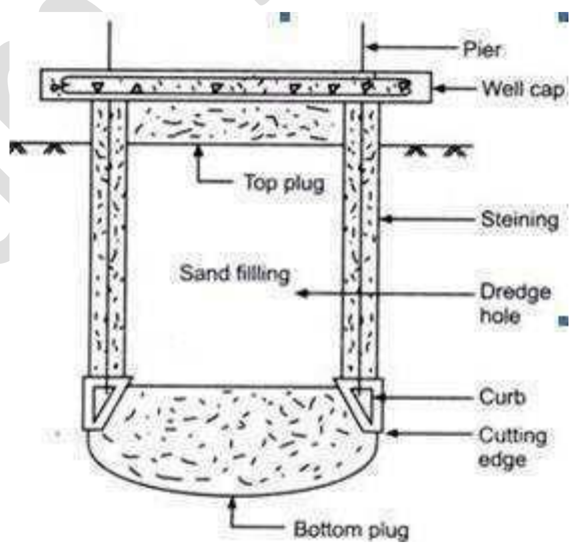


Fig 9 Sinking well foundation

A circular well has the minimum perimeter of a given dredge area. Since the perimeter is equidistant at the points from the centre of dredge hole, the sinking is more uniform than the other shapes. However, the circular well is that in the direction parallel to the span of bridge, the diameter of the well is much more than required to accommodate minimum size of pier and hence circular well obstruct water way much in comparison to other shapes.

Forces Acting On a Well Foundation:

In addition to the self weight and buoyancy, it carries the dead load of superstructure, bearing and piers and subjected to the following horizontal forces:

- **Braking effort of the moving vehicle.**
- **Force due to the resistance of bearings against movement due to temperature variations.**
- **Force of water current**
- **Seismic forces**
- **Wind force**
- **Earth pressure**

Description of Parts (Elements) of Well:

1. Staining: It is the wall or shall of the well, made of R.C.C. and which transfer the load to the curb. It acts as a enclosure for excavating the soil for the penetration of well.

2. Curb: It is a R.C.C. ring beam with steel cutting edge below. The cross- section of the curb is wedge shaped which facilitates the sinking of the well. The curb supports well stoning. The curb is kept slightly projected from the stoning to reduce the skin friction.

3. Cutting edge: It is the lowest part of the well curb which cuts the soil during sinking.

4. Bottom plug: After completion of well sinking the bottom of well is plugged with concrete. The bottom plug which is confined by the well curb acts as a raft against soil pressure from below.

5. Back fill: The well is dewatered after setting of the bottom plug and it is backfilled by sand or excavated material.

6. Top plug: It is a concrete plug provided over the filling inside the well.

7. Well cap: It is a R.C.C. slab provided at the top of stoniness to transmit the load of superstructure to the stoning and over which pier is laid. The minimum thickness of the slab is about 750 mm.

Causes of failures of foundations and remedial measures

The foundations may fail due to the following reasons:

1. Unequal settlement of sub-soil. Unequal settlement of the sub-soil may lead to cracks in the structural components and rotation thereof. Unequal settlement of sub-soil may be due to (i) non-uniform nature of sub-soil throughout the foundation, (ii) unequal load distribution of the soil strata, and (iii) eccentric loading. The failures of foundation due to unequal settlement can be checked by : (i)resting the foundation on rigid strata, such as rock or hard moor, (ii) proper design of the base of footing, so that it can resist cracking, (iii) limiting the pressure in the soil, and (iv)avoiding eccentric loading.

2. Unequal settlement of masonry. As stated earlier, foundation includes the portion of the structure which is below ground level. This portion of masonry, situated between the ground level and concrete footing (base) has mortar joints which may either shrink or compress, leading to unequal settlement of masonry. Due to this, the superstructure will also have cracks.

This could be checked by

(i) using mortar of proper strength

(ii) using thin mortar joints

(iii) restricting the height of masonry to 1 m per day if lime mortar is used and 1.5 m per day if cement mortar is used, and

(iv) Properly watering the masonry.

3. Sub-soil moisture movement. This is one of the major causes of failures of footings on cohesive soil, where the sub-soil water level fluctuates. When water table drops down, shrinkage of sub-soil takes place. Due to this, there is lack of sub-soil support to the footings which crack, resulting in the cracks in the building.

During upward movement of moisture, the soil (especially if it is expansive) swells resulting in high swelling pressure. If the foundation and superstructure is unable to resist the swelling pressure, cracks are induced.

4. Lateral pressure on the walls. The walls transmitting the load to the foundation may be subjected to lateral pressure or thrust from a pitched roof or an arch or wind action. Due to this, the foundation will be subjected to a moment (or resultant eccentric load). If the foundation has not been designed for such a situation, it may fail by either overturning or by generation of tensile stresses on one side and high compressive stresses on the other side of the footing.

5. Lateral Movement of sub-soil This is applicable to very soft soil which are liable to move out or squeeze out laterally under vertical loads, specially at locations where the ground is sloping. Such a situation may also arise in granular soils where a big pit is excavated in the near vicinity of the foundation. Due to such movement, excessive settlements take place, or the structure may even collapse. If such a situation exists, sheet piles should be driven to prevent the lateral movement or escape of the soil.

6. Weathering of sub-soil due to trees and shrubs. Sometimes, small trees, shrubs or hedge is grown very near to the wall. The roots of these shrubs absorb moisture from the foundation soil, resulting in reduction of their voids and even weathering. Due to this the ground near the wall depresses down. If the roots penetrate below the level of footing, settlements may increase, resulting in foundation cracks.

7. Atmospheric action. The behavior of foundation may be adversely affected due to atmospheric agents such as sun, wind, and rains. If the depth of foundation is shallow, moisture movements due to rains or drought may cause trouble. If the building lies in a low lying area, foundation may even be scoured. If the water remains stagnant near the foundation, it will remain constantly damp, resulting in the decrease in the strength of footing or foundation wall. Hence it is always recommended to provide suitable plinth protection along the external walls by
(i) Filling back the foundation trenches with good soil and compacting it,
(ii) Providing gentle ground slope away from the wall
(iii) Providing a narrow, sloping strip of impervious material (such as of lime or lean cement concrete) along the exterior walls.

Timbering of trenches - soils

- **When the depth of trench is large, or when the sub-soil is loose, the sides of the trench may cave in. The problem can be solved by adopting a suitable method of timbering. Timbering of trenches, sometimes also known as shoring consists of providing timber planks or boards and struts to give temporary support to the sides of the trench. Timbering of deep trenches can be done with the help of the following methods:**

  1. Stay bracing.
  2. Box sheeting
  3. Vertical sheeting
  4. Runner system

5. Sheet piling

1. Stay bracing. This method is used for supporting the sides or a bench excavated in fairly firm soil, when the depth of excavation does not exceed about 2 meters. The method consists of placing vertical sheets (called sheathing) or polling boards opposite each other against the two walls of the trench and holding them in position by one or two rows of struts. The sheets are placed at an interval of 2 to 4 meters and generally, they extend to the full height of the trench. The polling boards may have width of about 200 mm and thickness of 44 to 50 mm. The struts may have size 1OO x 100 mm for trench up to 2 m width and 200 x 200 mm for trench up to 4 m width.

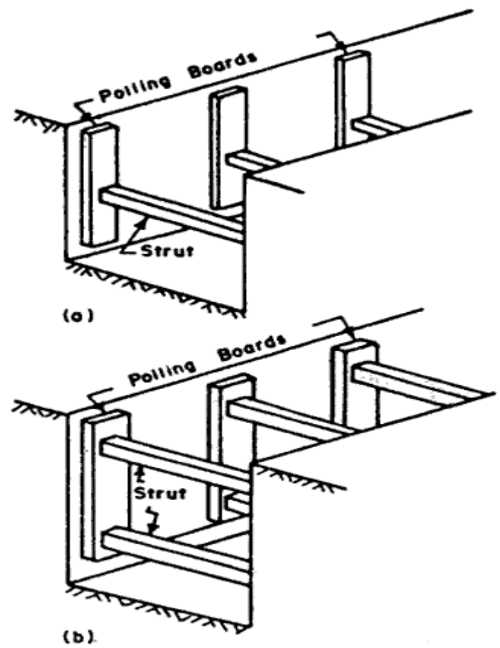


Fig 10 Stay Bracing

2. Box sheeting. This method is adopted in loose soils, when the depth of excavation does not exceed 4 meters. Shows the box like structure, consisting of vertical sheets placed very near to each other (sore times touching each other) and keeping them in position by longitudinal rows (usually two) of Wales. Struts are then provided across the Wales.

Another system of box sheeting is adopted for very loose soils. In this system, the sheeting is provided longitudinally, and they are supported by vertical Wales and horizontal struts [Fig. 2.32 (b)]. If the height is more, braces are also provided along with struts.

3. Vertical sheeting. This system is adopted for deep trenches (up to 10 m depth) in soft ground. The method is similar to the box sheeting [Fig. 2.32 (a)] except that the excavation is carried out in stages and at the end of each stage, an offset is provided, so that the width of the trench goes on decreasing as the depth increases. Each stage is limited to about 3 m in height and the offset may vary from 25 to 50 cm per stage. For each stage, separate vertical sheeting, supported by horizontal wailings and struts are provided.

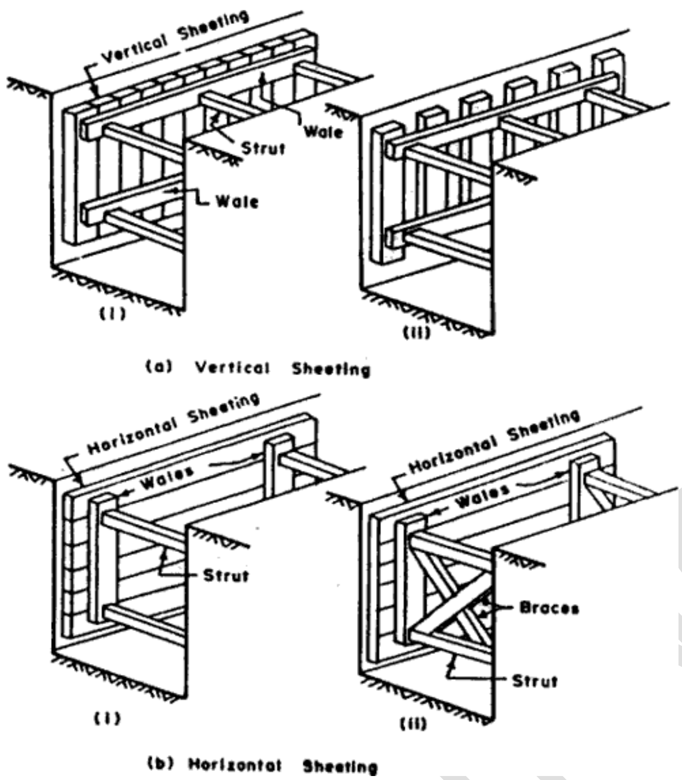


Fig 11 Box Sheeting

4. Runner system. This system is used in extremely loose and soft ground, which needs immediate support as excavation progresses. The system is similar to vertical sheeting of box system, except that in the place of vertical sheeting, runners, made of long thick wooden sheets or planks with iron shoe at the ends, are provided. Wales and struts are provided as usual. These runners are driven about 30 cm in advance of the progress of the work, by hammering

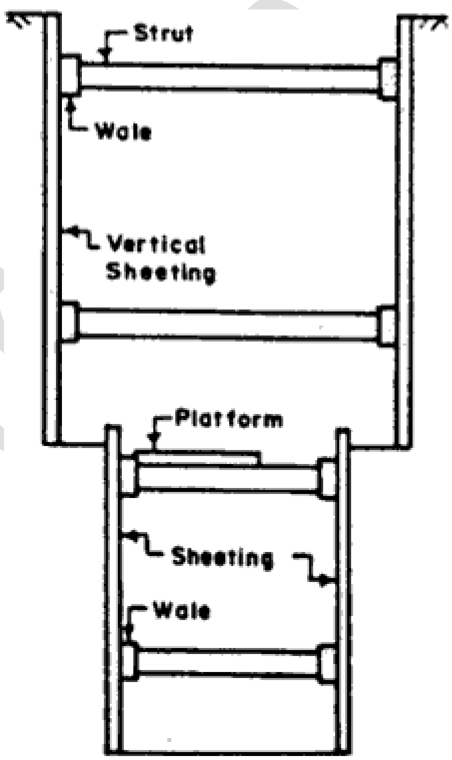


Fig 12.1 Vertical Sheeting

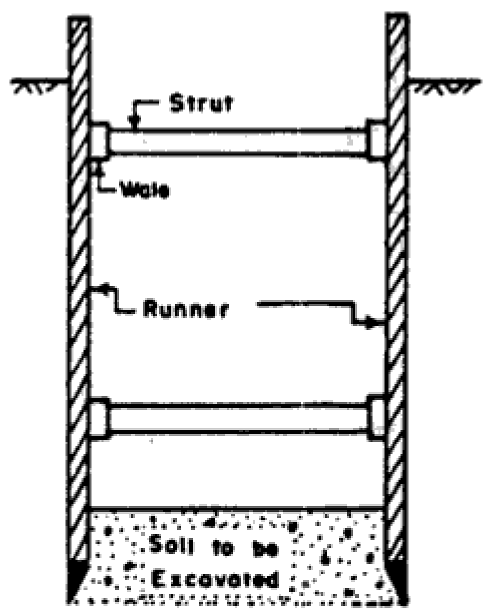


Fig 12.2 Runner System

5. Sheet piling. This method is adopted when

- **(i) Soil to be excavated is soft or loose**
- **(ii) Depth of excavation is large**
- **(iii) Width of trench is also large and**
- **(iv) There is sub-soil water. Sheet piles are designed to resist lateral earth pressure. These are driven in the ground by mechanical means (pile driving equipment). They can be used for excavating to a very large depth.**

Brick foundation and wall problems:

This article explains how to recognize, diagnose, & repair brick foundation & brick wall defects & failures such as cracks, spelling, movement, bulging, leaks, damage due to impact, settlement, frost or water damage, and other problems.

We describe types of brick foundation or wall cracks, crack patterns, differences in the meaning of cracks in different brick wall types (veneer vs. structural or solid brick walls), and where there is brick wall damage, the role of site conditions, building history, and other causes of building movement and damage.

We discuss the following: Examples & list of structural & other failures in brick walls & foundations. Damage caused to brick structures due to thermal expansion of long brick walls lacking expansion joints. Damage to brick veneer walls - cracks, bulges, loose brick. A catalog of types of brick foundation and brick wall damage and defects Types of foundation damage organized by foundation materials. Photographs of brick wall damage patterns and types.

This information helps in recognizing foundation defects and to help the building owner or inspector separate cosmetic or low-risk conditions from those likely to be important and potentially costly to repair.

Guide to Repair Methods for Foundation Cracks

Repair Methods for Foundation Shrinkage Cracks

Before repairing a foundation crack it is important to diagnose the cause of the crack and its effects on the building structure.

The significance of any foundation crack depends on the crack's cause, size, shape, pattern, location, foundation materials, extent of cracking, impact of the crack on the building, and possibly other factors as well. If there is an underlying ongoing problem causing foundation movement or damage, that problem needs to be corrected too.

Cracks in poured concrete walls that are larger than 1/4", cracks which are increasing in size, or cracks which are otherwise indicative of foundation movement should be evaluated by a professional.

At shrinkage cracks in slabs we discuss how we decide if a foundation crack needs repairing the first place.

Suggestions for Repairing Concrete Foundation Shrinkage Cracks

Repairs to foundation cracks which are not traced to building movement, structural problems, site problems, or other conditions which require site or structural repairs may be attempted for cracked foundations and other cracked concrete structural elements using a variety of products and materials such as masonry repair epoxy or sealant products.

These products, some of which include even structural repair epoxies, might be used to seal against water leakage as well, and may be used for repairing certain cracks in concrete foundations following evaluation and advice from a foundation professional. An evaluation of the presence, absence, or condition of reinforcing steel in cracked concrete foundations should be a part of such an inspection.

Shrinkage cracks, which are not normally a structural defect in a building, May nonetheless, need to be sealed against water entry. Common repair methods include chipping out the crack and applying a masonry patching compound to the surface, use of epoxies, or other sealants.

Water entry leaks at foundation cracks: Polyurethane foam sealant is used for foundation crack repairs to stop water entry. (Also find and correct outside water sources). See our article on Polyurethane Foam Injection for details on using this product to seal foundation cracks against leakage.

- **Pile group**

Piles are driven generally in groups in regular pattern to support the structural loads. The structural load is applied to the pile cap that distributes the load to individual piles. If piles are spaced sufficient distance apart, then the capacity of pile group is the sum of the individual capacities of piles. However, if the spacing between piles is too close, the zones of stress around the pile will overlap and the ultimate load of the group is less than the sum of the individual pile capacities specially in the case of friction piles, where the efficiency of pile group is much less.

Group action of piles is evaluated by considering the piles to fail as a unit around the perimeter of the group. Both end bearing and friction piles are considered in evaluating the group capacity. End bearing pile is evaluated by considering the area enclosed by the perimeter of piles as the area of footing located at a depth corresponding to the elevation of pile tips. The friction component of pile support is evaluated by considering the friction that can be mobilized around the perimeter of the pile group over the length of the piles as shown in figure below:

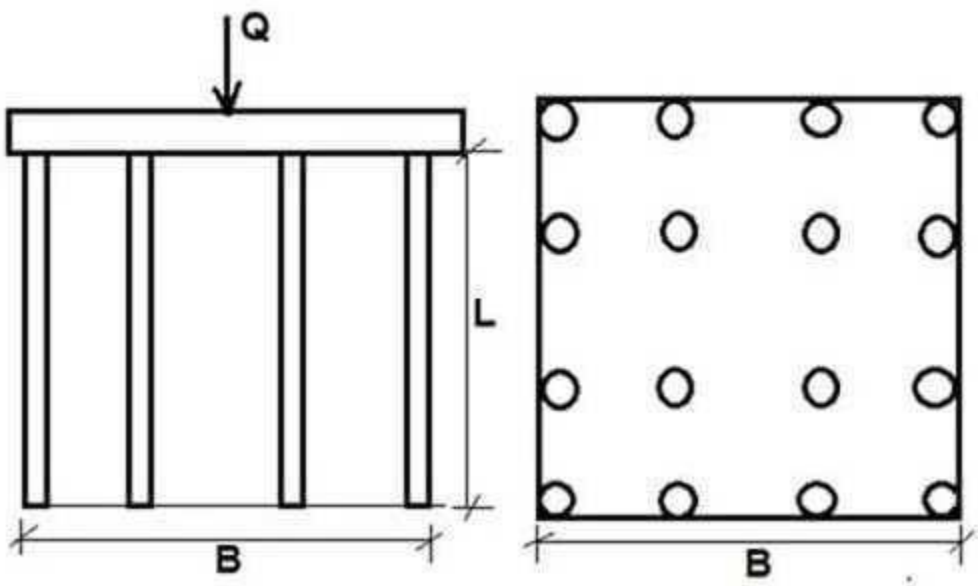


Fig 13 Group of Pile

The efficiency of pile group depends on the following factors:
1. Spacing of piles
2. Total number of piles in a row and number of rows in a group, and
3. Characteristics of pile (material, diameter and length)
The reduction in total bearing value of group of piles is more in case of friction piles, particularly in clayey soils. No reduction in grouping occurs in end bearing piles. The pile groups which are resisting the load by combined action of friction and end bearing, only the load carrying capacity of friction is reduced.

Unit: -2

Formwork and Temporary structures Design and construction features of different types of temporary structures, stationary and slip form work techniques, special features of in-situ construction, stripping and removal of formworks, formworks for special structures, e. g. shells bridges towers etc.

- **Temporary structures:-**

Temporary structures are critical elements of the overall construction plan. A temporary structure in construction affects the safety of the workers on the job and the general public and there is also the relationship of the temporary structure to the finished structure. Temporary structures are sometimes incorporated into the finished work or are removed at the end of the conclusion of their usefulness. In either case the contractor will have to deal with supervision work, code requirements, contract and legal requirements, and perhaps disputes with others over the work being performed. As far as design, drawings and specifications are concerned, they depend on the temporary structure under consideration. In extremely complex jobs involving such temporary work as cofferdams for bridge piers, the design of the temporary structure will often be done by the designer of the permanent structure. For simpler types of temporary structures, such as temporary ramps used by excavation contractor for building projects, the excavation contractor will do the design. Between these two extremes is the type of temporary structure in which specialty contractors, who make a business of doing a specific type of temporary structure will be employed. The specifications for the temporary structure are usually drawn up by the temporary structure contractor and are required to obtain permits for any work done.

A major emphasis will be placed on concrete formwork construction covering detailed design analysis of both vertical and horizontal timber formwork systems. Any means or methods which provide temporary support, access, enhancement, or otherwise facilitate the construction of permanent structures.

- **Necessity: Temporary structures form the interface between design and construction. Most permanent structures simply could not be built without temporary structures.**

- **Impact on Schedule, Cost, and Quality: Losses in time and money will occur if the temporary structures are not planned and coordinated with the same degree of thoroughness as the permanent structures.**

- **Safety: Failure of temporary structures has been responsible for hundreds of deaths on construction sites. Safety should be the overriding priority of contractors and designers responsible for implementing temporary structures.**

- **Responsibility: The norm in the construction industry is to place the responsibility for temporary structures solely on the general contractor. However, architects and engineers must at least have formulated their own method of construction. Coordinating the design of permanent structure with the temporary structures that will be required can lead to more efficient and cost effective construction.**

- **Design Considerations**
  - **Safety**

    Designers must place the first priority on safety. OSHA codes, as well as other codes in the industry, provides stringent performance specifications (how the system should work) regarding temporary structures.
  - **Cost**

    Temporary structures can be the most expensive part of some construction projects. Designing cost-effective solutions to temporary structures problems could easily be the competitive advantage a contractor has over others. The designer must have a thorough knowledge of all the options which will sufficiently solve the temporary structures problem.
  - **Unique Design Challenges**

    Temporary structures are subject to unique loading conditions which do not apply to a permanent structure (fluctuating or dynamic loads, impact loads, and loads which change position). Working within spatial constraints and cramped sites requires the most efficient temporary structure so that workers still have room to maneuver safely. It is always possible that an unforeseen condition could arise during an excavation due to uncertainty of soil conditions. Designers must include an appropriate factor of safety in their calculations or they may consider contingency plans for changing soil conditions.
  - **The contractor**

    In many cases the contractor is the only member of the construction team with considerable experience and practical knowledge of temporary structures. The contractor must hire his or her own engineer, if the specifications or building codes require one, or self perform the design of temporary structures. The most complex temporary structures are often handled on a design-build basis (design-build approach is a construction technique which allows a single procurement for the design and construction of projects.) The design-build situation is optimal because it guarantees coordination between design and construction. Anyone managing the construction process needs a basic understanding of the engineer's thinking process and the design intentions and the basic understanding of how a structure behaves. Constructor must be able to address a number of technical questions at the project site including structural issues that sometimes are not addressed by the design professionals. Since the safety of construction workers as well as the strength and stability of structures during the construction phase is of paramount importance, construction managers need this knowledge.

- **Structural Design**
  - **Definition: Determination of overall proportions and dimensions of the supporting framework and the selection of individual members.**
  - **Responsibility: The structural engineer is responsible for structural design within the constraints imposed by the architect (number of stories, floor plan, etc.).**

Important factors in design are:

- **Safety (the structure doesn't fall down);**
- **Serviceability (how well the structure performs in term of appearance and deflection);**
- **Economy (an efficient use of materials and labor); and**
- **Several alternative designs should be prepared and their costs compared.**

- **Types of load that structures support are:**

  - **Dead loads – permanent; including self-weight, floor covering, suspended ceiling, partitions, etc.**
  - **live loads – not permanent; the location is not fixed; including furniture, equipment, and occupants of buildings**
  - **Wind load (exerts a pressure or suction on the exterior of a building);**
  - **Earthquake loads (the effects of ground motion are simulated by a system of horizontal forces);**
  - **Snow load (varies with geographical location and drift); other loads (hydrostatic pressure, soil pressure)**

If the load is applied suddenly, the effects of IMPACT must be accounted for.

Design specifications provide guidance for the design of structural members and their connections. They have no legal standing on their own, but they can easily be adopted, by reference, as part of a building code i.e. ACI 318-99 Building Code Requirements for Structural Concrete. The Specifications for Design of Wood Members are by National Design Specifications for Wood Construction by American Forest and Paper Association.

- **Formwork for Concrete**

Formwork development has paralleled the growth of concrete construction throughout the 20th century. The increasing acceptance of concrete as a major construction material presents the form builder a new range of problems in the development of appropriate sheathing materials and maintenance of rigid tolerances. Figure 1 shows a typical concrete wall formwork setup.

Formwork is a classic temporary structure in the sense that it is erected quickly, highly loaded for a few hours during the concrete placement, and within a few days disassembled for future reuse. Also classic in their temporary nature are the connections, braces, tie anchorages, and adjustment devices which form need.

For concrete formworks, the notion of "Temporary Structures" does not quite portray the reality. Forms, its hardware and accessories are used over and over again over their life time. Because of that it is necessary to use materials with high durability and easy to maintain. The form design should be such that it can be erected and disassembled efficiently in order to maximize productivity. The disassembly or stripping of forms depends on factors such as the bond between concrete and the form, rigidity and shrinkage of concrete. Forms should, whenever possible, be left in place for the entire curing period. Since early form removal is desirable for their reuse, a reliable basis for determining the earliest possible stripping time is

necessary. Some of the early signs to look for during stripping are no excessive deflection or distortion and no evidence of cracking or other damage to the concrete due to the removal of the forms or the form supports. In any event, forms must not be stripped until the concrete has hardened enough to hold its own weight and any other weight it may be carrying. The surface must be hard enough to remain undamaged and unmarked when reasonable care is used in stripping the forms.

Traditionally, formwork was erected in place and wrecked after only one time of usage. In the United States, due to high labor costs, it is more efficient and profitable to prefabricate forms, assemble them in large units using mechanical devices, such as cranes to erect the forms and reuse them as much as possible.

Lumber was once the predominant form material, but developments in the use of plywood, metal, plastics, and other materials, together with the increasing use of specialized accessories, have changed the picture. In 1908 the use of wood versus steel formwork was debated at the American Concrete Institute (ACI) convention, the advantages of modular panel formed with its own connecting hardware and good for extensive reuse were also realized. By 1910 steel forms for paving were being produced commercially and used in the field.

Today modular panel forming is the norm. Figure 3 shows steel forms being used for concrete pavement construction.

Figure 1 - Steel modular forms being used in concrete pavement construction

- **Objectives of Form Building**

Forms mold the concrete to desired size and shape and control its position and alignment. But formwork is more than a mold; it is a temporary structure that supports its own weight, plus the freshly placed concrete, plus construction live loads (including materials, equipment, and personnel).

- **Basic objectives in form building are:**

➢ **Quality - In terms of strength, rigidity, position, and dimensions of the forms**

- **Safety - for both the workers and the concrete structure**
- **Economy - the least cost consistent with quality and safety requirements**

- **Causes of Formwork Failure**

Formwork failures are the cause of many accidents and building failures that occur during concrete construction, usually when fresh concrete is being placed. Generally some unexpected event causes one member to fail, then others become overloaded or misaligned and the entire formwork structure collapses. The main causes of formwork failure are:

- **Improper stripping and shore removal**
- **Inadequate bracing**
- **Vibration**
- **Inadequate control of concrete placement**
- **Lack of attention to formwork details.**

- **Planning for Formwork**
  - **The contractor should plan for formwork at the time of making bid considering the following factors:**
  - **Placing schedule and stripping time requirements;**
  - **Capacity of equipment available to handle form sections and materials; capacity of mixing and placing equipment;**
  - **Construction joints;**
  - **Reuse of forms as affected by stripping time;**
  - **Relative merits of job-built, shop-built and ready-made forms; and weather (protection requirements and stripping time)**
  - **Compare alternative methods to determine the most efficient plan.**

- **Areas of Cost Reduction**

- **Planning for maximum reuse – A form designed for max reuse is stronger and more expensive, but it can save on the total form cost.**

- **Economical form construction use shop-built-forms provides greatest efficiency in working conditions and in the purchase and use of materials and tools; create shop area on the site- to form sections too large or transportation cost too high; use job-built- for small jobs, or where forms must be fitted to terrain; buy prefabricated forms(large number of reuses rent prefab forms(better flexibility in regulating volume of work).**
- **Setting and stripping repeat the same functions to increase the crew efficiency as the job progresses use metal clamp or special wedge pin connections that are secure, yet easy to assemble and dismantle; and add extra features that make handling, erection, and stripping easier such as handles, lifting eyes.**
- **Cranes and Hoists Size of form sections should be limited to the capacity of the largest crane planned for the job. Stair towers may be completed early in the schedule to be used for**

moving men and materials. Leave one bay open to permit mobile crane and concrete truck movement.

- **Bar Setting** Form design can permit the rebar to be pre assembled before installation (more favorable condition)
- **Concrete Placement** High lifts in wall construction make placing and vibration difficult. Placing rate is limited by form design.

- **Form Materials and Accessories**

Practically all formwork jobs require some lumber. A local supplier will advise what material and sizes are in stock or promptly obtainable, and the designer or builder can proceed accordingly. Southern yellow pine and Douglas fir, sometimes called Oregon pine are widely used in structural concrete forms. They are easily worked and are the strongest in the softwood group. Both hold nails well and are durable. They are used in sheathing, studs, and wales. Figure 5 shows a typical wall form with its components.

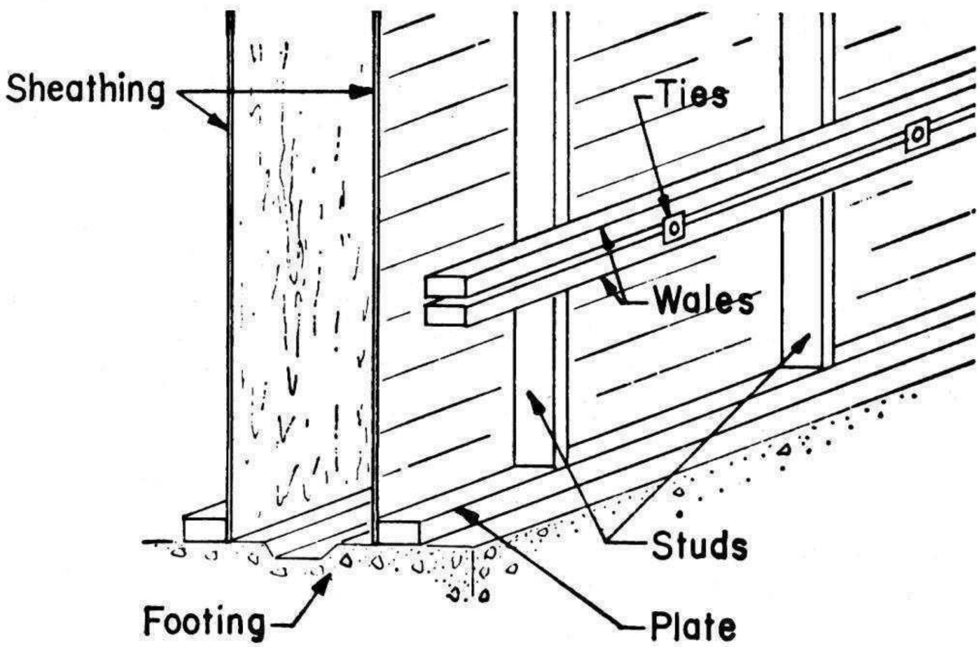


Figure 2 - Typical wall form with components identified.

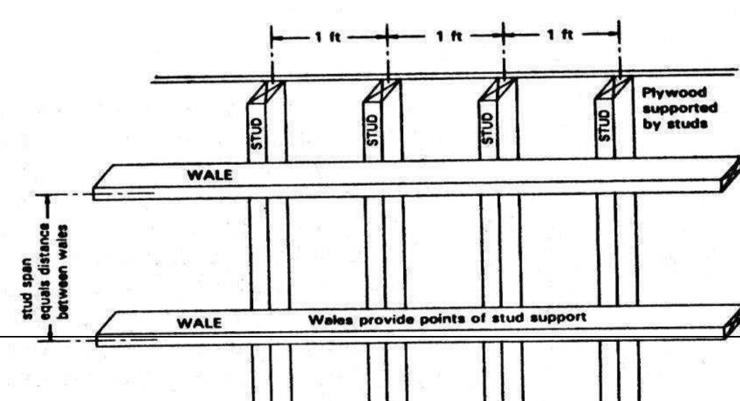


Figure 3 - Parts of a typical wall form

- **Ties**

In order to secure concrete forms against the lateral pressure of unhardened concrete, a tensile unit called concrete form tie is used (they are also referred to as form clamps, coil ties, rod clamps, snap ties, etc.). They are ready-made units with safe load ratings ranging from 1000 lb to more than 50000 lb and have an internal tension unit and an external holding device. Figure 7 shows a typical single member tie.

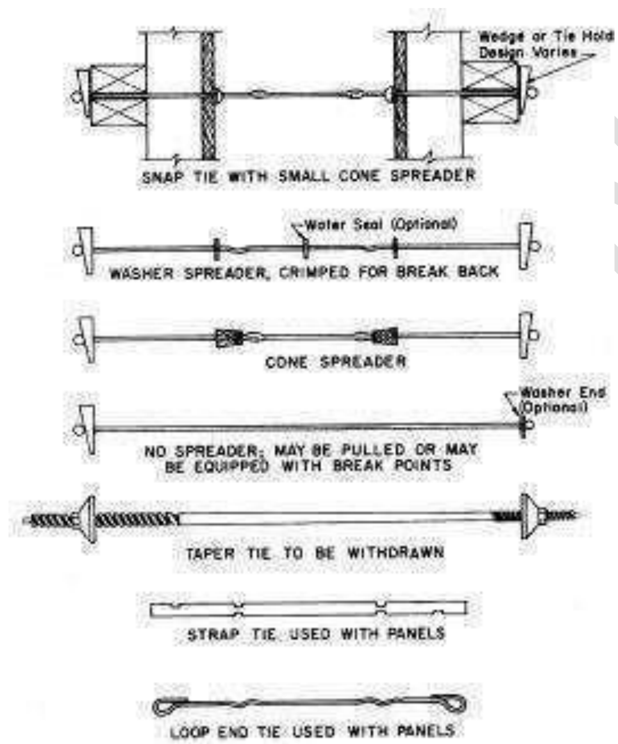


Figure 4 – A typical single member ties

- **Ties are manufactured in two basic types:**

Continuous single member ties; in which the tensile unit is a single piece, have a special holding device added for engaging the tensile unit against the exterior of the form Some single member ties may be pulled as an entire unit from the concrete; others are broken back a predetermined distance. Some are cut flush with the concrete surface. It is generally used for lighter loads, ranging up to about 5,000 lb safe load

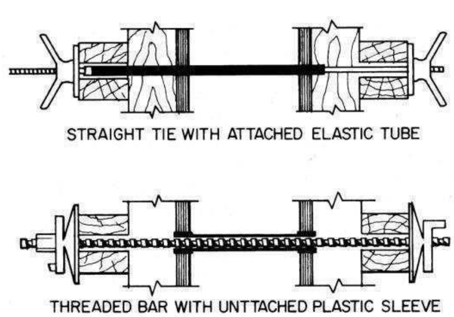


Figure 5 – A continuous single member tie

Internal disconnecting type ties, in which the tensile unit has an inner part with threaded connections to removable external members generally remain in the concrete (Figure 9). It is available for light or medium loads, but finds its greatest application under heavier construction loads up to about 70,000 lb.

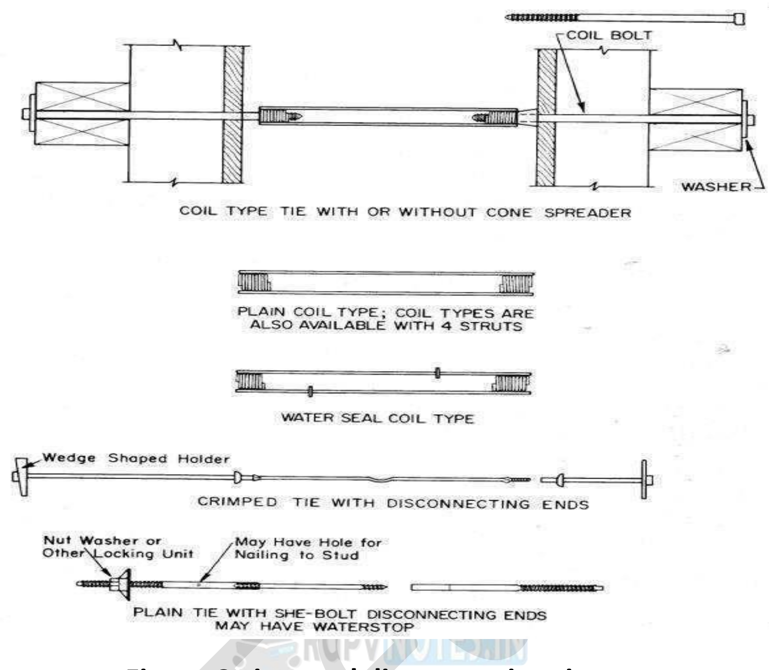


Figure 6 - internal disconnecting ties

- Different types of temporary structures
  - Scaffolding Scaffolding provides a temporary safe working platform for:
    - Erection.
    - Maintenance
    - Construction
    - Repair
    - Access
    - Inspection

- There are two main types of scaffolding:
  - Freestanding scaffolds, such as independent towers,
  - Independent tied scaffolds, such as independent towers tied to an adjacent structure.

The most common piece of structure used in scaffolding is the scaffold tube. The tube generally comes in two thicknesses, 3.2mm or 4mm. The tubes are galvanized due to their exposure to the elements and axial capacity loads are given either 'as new' or 'used.' Capacities of tubes used in tension are usually limited by the safe slip load capacity of the coupler, which is far lower than the actual tensile resistance of the tube.

Scaffolding is designed support its own self-weight, i.e. the weight of the boards, tubes, guardrails, toe boards etc. and imposed loads such as wind. The imposed load applied to

the scaffolding depends on its use. The wind load applied to scaffolding will change depending on whether sheeting or debris nets are used.

- **Formwork**

Formwork is the term used for a temporary mould into which concrete is poured and formed.

Traditional formwork is fabricated using timber, but it can also be constructed from steel, glass fiber reinforced plastics and other materials.

Timber formwork is normally constructed on site using timber and plywood. It is easy to produce, although it can be time consuming for larger structures. It is used when the labour costs are lower than the cost of producing re-usable formwork from materials such as steel or plastic.

Re-usable plastic formwork is generally used for quick pours of concrete. The formwork is assembled either from interlocking panels or from a modular system and is used for relatively simple concrete structures. It is not as versatile as timber formwork due to the prefabrication requirements and is best suited for lost-cost, repetitive structures such as mass housing schemes.

Stay-in-place structural formwork is generally assembled on site using prefabricated fiber-reinforced plastic. It is used for concrete columns and piers and stays in place, acting as permanent axial and shear reinforcement for the structural member. It also provides resistance to environmental damage for both the concrete and reinforcing bars.

Proprietary systems are used to support vertical formwork while concrete cures, consisting of a series of tubes and ties.

When selecting formwork, the type of concrete and temperature of the pour are important considerations as they both affect the pressure exerted.

Once the concrete has gained sufficient strength the formwork can be struck (removed). A minimum value of 5 N/mm2 is recommended in all cases when striking vertical formwork as so not to damage the permanent concrete in the process.

High quality workmanship and inspection are necessary to ensure a high standard and appearance of the resulting concrete structure.

- **Trench support**

A trench is defined as an excavation when its length greatly exceeds its depth. Shallow trenches are usually considered to be less than 6 m deep and deep trenches greater than 6m. Depending on the dimensions of a trench, excavation can either be carried out by hand or using a mechanical digger. Trenches are commonly required to allow services, pipelines or foundations to be laid.

Water ingress into the trench is often a major issue and ground water table locations and soil strata should be investigated before any extensive excavation takes place.

Over short periods of time for relatively shallow depths most soil types will stand almost vertically without any problems. However, trenches other than those which are relatively shallow may require a trench support scheme.

- **Timber supports**

Historically, trenching involved using timber to support horizontal and vertical soil loads and this technique is still used today. Timber trenching is generally used for low risk, narrow trenches, shafts or headings. The timber solutions require good workmanship and are reasonably labour-intensive, however they are versatile and the equipment required is easy to handle and transport.

- **Trench boxes**
  Trench boxes are suitable for low-risk situations in stable, dry ground and can be placed in pre-excavated trenches or installed using the 'dig and push' technique. The system requires at least two struts at each panel for stability which must be considered when access is required for construction work or piping.

- **Trench sheets**
  Trench sheets are the most adaptable of the systems available, and are most commonly used to retain poorer soil. They can support deeper trenches with larger surcharges and provide a continuous support. They require multiple levels of strut support and the slenderness of the sheets can often limit the depth of the trench as they are installed by light machinery and could buckle under large vertical loads.

- **Slip form work techniques**
  - **Slip forming or slip form construction is a construction method in which concrete is poured into a continuously moving form.**
  - **Slip forming is used for tall structures (such as bridges, towers, buildings, and dams), as well as horizontal structures, such as roadways.**
  - **Concrete needs to be workable enough to be placed into the form and consolidated (via vibration), yet quick-setting enough to emerge from the form with strength.**

- **Types of Slip forming**

  - **Vertical Forming**
  - **In vertical slip forming the concrete form may be surrounded by a platform on which workers stand, placing steel reinforcing rods into the concrete and ensuring a smooth pour.**
  - **Together, the concrete form and working platform are raised by means of hydraulic jacks.**
  - **Construction of Silos, Chimneys.**

  - **Horizontal Slip Forming**
  - **In horizontal slip forming for pavement and traffic separation walls concrete is laid down, vibrated, worked, and settled in place while the form itself slowly moves ahead.**
  - **This method was initially devised and utilized in Highway construction.**

  - **Structural units of Slip Formwork :- Slip formwork includes**
    - **Steel panels attached to frames,**

- **Working platforms,**
- **Hydraulic jacks,**
- **Rods,**
- **Pumps,**
- **Distribution Centre and other connecting elements.**

- **Structure of Slip Formwork**
  - **Slip formwork system is a system in which slip forms are continuously raised by hydraulic equipment. By this means the rising from 150 to 300 mm per hour depending on the concrete hardening rate as the cast concrete can become self-supporting very rapidly.**
  - **The system uses steel panels of special height, which are fixed to working carcass consisting of steel frames (yokes), trusses and fixing devices.**
  - **Carcass provide stability of the system design and is a reliable base for the wooden flooring used as a working platform for placement of concrete, reinforcement and embedded parts for doors and windows on its surface.**
  - **A hydraulic jack is placed on the top of each frame. A high tensile steel jacking rod is passed through the jack and is casted into the walls as it rises. The jack consists of a cylinder and a pair of upper and lower clamp mechanisms gripping the rod and working in cycles.**
  - **The principle is that the jack works against the lower clamp to lift the frame. When the pressure is released upper clamp grips the rod and the lower clamp is released and come up by spring action.**
  - **Vertical reinforcement is retained in the correct position using guides, which are fixed on the top of the frames. Horizontal reinforcement is laid under the frames and is bounded with the vertical reinforcement.**
  - **High speed of erection (works' execution speed increases) and as a result, rapid completion of the project - considerable saving of time.**
  - **Minimal use of a crane, as formwork is lifted by hydraulic jacks.**
  - **Uniformity of wall sections with the project drawings, smooth wall surfaces are achieved by the use of slip formwork.**
  - **Reduced labor costs due to the intensity of the working process.**

- **Stripping and removal of formworks**

The removal of concrete formwork also called as strike-off or stripping of formwork should be carried out only after the time when concrete has gained sufficient strength, at least twice the stress to which the concrete may be subjected to when the formworks are removed. It is also necessary to ensure the stability of the remaining formwork during formwork removal.

  - **Concrete Formwork Removal Time**

The rate of hardening of concrete or the concrete strength depends on temperature and affects the formwork removal time. For example, time required for removal of concrete in winter will be more than time required during summer.

Special attention is required for formwork removal of flexural members such as beams and slabs. As these members are subjected to self-load as well as live load even during construction, they may deflect if the strength gained is not sufficient to handle to loads. To estimate the strength of concrete before formwork removal, the tests on concrete cubes or cylinders should be carried out. The concrete cubes or cylinders should be prepared from the same mix as that of the structural members and cured under same circumstances of temperature and moisture as that of structural member.

When it is ensured that the concrete in the structural members has gained sufficient strength to withstand the design load, only then formworks should be removed. If possible, the formworks should be left for longer time as it helps in curing.

Removal of formwork from concrete section should not make the structural element to:

- Collapse under self load or under design load
- deflect the structural member excessively in short or the long term
- Physically damage the structural member when formwork is removed.
- The following points must be kept in mind during formwork removal whether the structure will be prone to:
- freeze thaw damage
- cracks formation due to thermal contraction of concrete
- After formwork striking. If there is a significant risk of any of the above damages, it is better to delay the removal time of formwork. If formwork has to removed for optimizing the concrete construction activities, then these structures must be insulated well to prevent such damages.

- Calculation of Safe Formwork Striking Times:

Structural members are constructed based on designed load. But before a structure is complete and subjected to all loads assumed during structural design, the structural members are subjected to its self weight and construction loads during construction process.

So, to proceed with construction activities at a quicker rate, it is essential to calculate the behavior of structure under is self load and construction load. If this can be done and structural member is found to be safe, formwork can be stripped-off.

If these calculations are not possible, then following formula can be used for calculation of safe formwork striking times:

Characteristic strength of cube of equal of maturity to the structure required at time of formwork removal.

Unit - 3

Masonry and Walls: Brick masonry, Bonds, Jointing, Stone masonry, casting and laying, masonry construction, Brick cavity walls, code provisions regarding load bearing and non-load bearing walls. Common defects in construction and their effect on strength and performance of walls, designed Brick masonry, precast stone masonry block, Hollow concrete block, plastering and pointing, white and color washing, distempering, dampness and its protection, Design of hollow block masonry walls. Doors, Windows and Ventilators: Types based on material etc., size location, fittings, construction sunshades, sills and jambs, RCC doors/windows frames. Stairs types, rule of proportionality etc., Repairs techniques for masonry, walls, doors & windows.

Masonry is defined as the art of construction in which building units, such as clay bricks, sand-lime, bricks, stones, Pre-cast hallow concrete blocks, concrete slabs, glass bricks, combination of some of these building units etc are arranged systematically and bonded together to form a homogeneous mass in such a manner that they can with stand point to other loads and transmit then through the mass without fail or disintegration.

Masonry can be classified into the following categories

1. Stone masonry
2. Brick masonry
3. Hallow block concrete masonry
4. Reinforced masonry
5. Composite masonry

These can be further sub-divided into varies types depending upon workmanship and type of materials used.

Definitions of terms

- Course: A course is a horizontal layer of bricks stones
- Bed: the surface of a stone perpendicular to the line of pressure of (lower surface of bricks or stones in each course)
- Back: The inner surface of wall not exposed is called back. The material forming back is known as backing
- Face: The exterior of the wall exposed to weather is known as face. The material used in the facing of wall is known as facing'
- Hearting: It is the interior portion of a wall between facing and backing
- Head: It is a brick or stone, which lies with its greatest length at right angles to the face of the work.
- Stretcher: Itis a brick or a stone which lies with its congest side parallel to the face of the work
- Bond: The method of arranging bricks so that the individual units are tiedtogether
- Spalls: The chips of stones used for filling the interstices in stone masonry
- Quoins: The stones used for the corners of walls of structure
- Bat: It is a portion of a brick cut across the width.
- Closer: It is the portion of a brick cut in such a manner that its one long face remains uncut
- Queen closer: it is the portion of a brick obtained by cutting a brick length-wise into twoportions
- King closer: It is the portion of brick obtained by cutting off the triangular piece between the centre of one end and the centre of one side.
- Beveled closer: It is the portion of a brick in which the whole length of the brick is beveled for maintaining half width at one end and full width at the other

- Frog: It is an indentation or depression on the top face of a brick made with the object of forming a key for the mortar.
- Sill: It is a horizontal stone, concrete or wood, employed for the purpose of shedding off rain water from the face of wall immediately below the window opening
- Corbel: It is the extension of one or more course of stone or brick from the face of a wall to serve as a support for wall plates
- Templates: Pieces of stones placed under the end of a beam to distribute load over a greater area.
- Coping: It is the course placed upon the exposed top of an external wall to prevent the seepage of water
- Buttress: It is a sloping or stepped masonry projection from a tall wall intended to strengthen the wall against the thrust of a roof as shown in fig 4.1

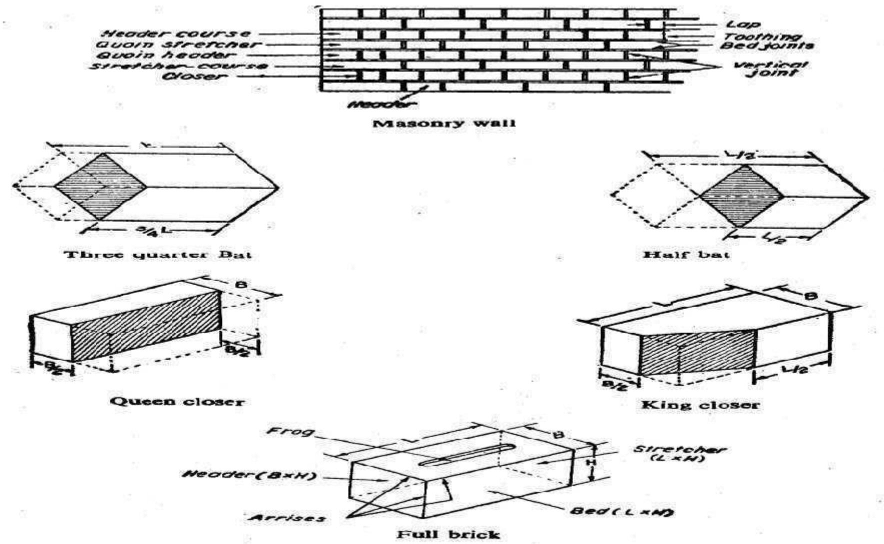


Fig 4.1 Definitions of terms

Stone masonry: The construction of stones bonded together with mortar is termed as stone masonry where the stones are available in a 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, beams etc.

Uses of stone masonry:

Stone masonry construction is used in

(i) Building foundations, dams, monumental structures
(ii) Building walls, piers, columns, pillars, light houses and architectural works.
(iii) Arches, domes, lintels and beams
(iv) Roofs, flames, paving jobs
(v) Railway, ballast, black boards and electrical switch boards

Selection of stone for stone masonry:

The selection of stones for stone masonry depends upon

a. Availability
b. Ease of working
c. Appearance
d. Strength and stability
e. Polishing characteristics
f. Economy
g. Durability

The table 4.1 given broadly outlines the different types of stones used for different purposes

S. No.	Purpose	Stones used
1.	Heavy engineering works Ex: stocks, break waters, light houses, bridges, piers	Granite, gneiss
4.2.	Buildings situated in industrial towns	Granite and compact sandstone
3.	Pavements, railway ballast, doors its and steps	Granite slabs and slate
4.	Electrical switch board	Marble slabs and slate
5.	Fire resistance works	Compact sandstone
6.	Carving and ornamental works	Marble and late rite
7.	Face work and architectural purposes	Marble, granite closer gained sand stone

Tools required for stone masonry construction:

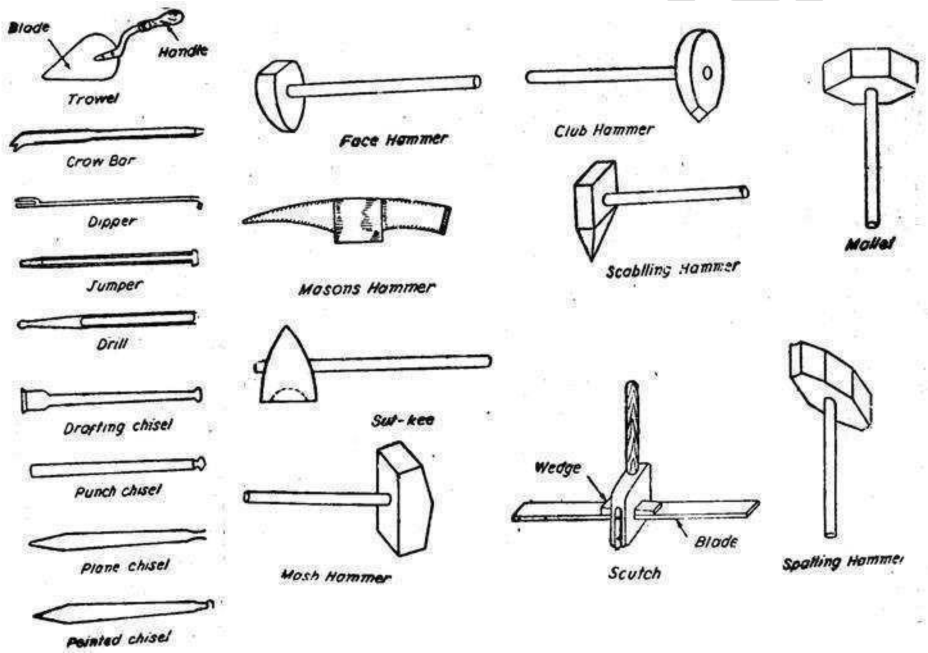


Fig 4.2 Tools for Stone Masonry

- Trowel : This is used to lift and spread mortar
- Square: This is made of flat steel having each arm about 0.5m long
- Plumb rule and bob: This is used to check the vertically of walls
- Spirit level: this is used to chick the horizontality of walls
- Line and pin: This is used to maintain the alignment of the work in progress
- Bevel: The instrument used to set right angles
- Pick axe: This is employed for dressing of rough stone and split the stones in thequarry
- Crowbar: This is used to make stones in query
- Chisels: They are used to dress stones
- Spall hammer: This is heavy hammer used for rough dressing of stones
- Mallet: The wooden hammer used for driving of wooded headed chisels
- Iron hammer: This is used for carving of stones
- Scrabbling hammer: This is used to break small projections of stones

- Pitching tool: This is used to make the stones of required size
- Gauge: this is employed to dress stones for spring course, comics, coping etc
- Claw tool: This is employed for dressing the surface of stones
- Necker: This is employed to draw fine chisel lines on the stone surface
- Jumper: They are used for boring holes
- Wedge and feathers: They are employed for cutting the stones after they have been bored with jumper.
- Gad: A small steel wedge used for splitting of stones
- Drag: This is employed to level a stone surface
- Punch: This is employed to dress roughly the stones
- Handsaw: This is used to cut soft stones
- Cross-cut saw: This is used to cut hard stones
- Frame saw: This is used to cut large blocks of stones.

Masonry:

Masonry is art of construction in which buildings units bricks, stones etc are arranged systematically and banded with cement & sand mixture

- The masonry is classified as
- Stone masonry
- Brick masonry
- Hallow Masonry
- Re-forced masonry
- Composite Masonry

The stone masonry is useful for foundations, dams, walls, piers, columns, arches, domes, lintels, beams, roofs, floors, railway ballets, black boards and electrical switch boards

- Stone masonry is divided

(i) Rubble masonry
(ii) Ashlars masonry

- The brick masonry is a unified mass obtained by systematically arrangement of laying brick and bonded together with mortar.
- The brick mortar generally the following types
- Mud mortar
- Cement mortar
- (iii)Cement lime mortar
- (iv) Lime Surkhi mortar
- Bonding is a process of arranging bricks and mortars to tie them together in a mass of brickwork
- The bonds can be classified as
    - Stretcher bond
    - Header bond
    - English bond
    - Double Flemish bond
    - Single Flemish bond
    - Garden wall bond
    - Fading bond
    - Dutch bond
    - Raking bond
    - Zig Zag bond

- English cross bond
- Bonds in columns

(i) Brick on edge bond or soldier course
(ii) Bonds at junction and squint junction

Based on the arrangement of the stone in the construction and degree of refinement in the surface finish, the stone masonry can be classified broadly in the following two categories

1. Rubble masonry
2. Ashlars masonry

General principles in the stone masonry construction

- The stones to be used for stone masonry should be hard, tough and durable.
- The pressure acting on stones should be vertical
- The stones should be perfectly dressed as per the requirements
- The heads and bond stones should not be of a dumb bell shape.
- In order to obtain uniform distribution of load, under the ends of girders, roof trusses etc large flat stones should be used
- The beds of the stones and plan of the course should be at right angles to the slope in the case of sloping retaining wall
- Wood boxing should be filled into walls having fine dressed stone work to protect it during further construction
- The mortar to be used should be good quality and in the specified faces.
- The instruction work of stone masonry should be raised uniformly.
- The plumb bob should be used to check the vertically of erected wall
- The stone masonry section should always be designed to take compression and not the tensile stresses
- The masonry work should be properly cured after the completion of work for a period of 4.2 to 3 weeks
- As per as possible broken stones or small stones chips should not used
- Double scaffolding should be used for working at higher level
- The masonry hearting should be properly packed with mortar and chips if necessary to avoid hallows
- The properly wetted stones should be used to avoid mortar moisture being sucked

1) Rubble masonry: In this category, the stones used are either undressed or roughly dressed having wider joints. This can be further subdivided as uncared, coursed, random, dry, polygonal and bent.

- Uncoarsed rubble masonry: This is the cheapest, roughest and poorest form of stone masonry. The stones used in this type of masonry very much vary in their shape and size and are directly obtained from quarry. Uncoarsed rubble masonry can be divided into the following.
- Uncoarsed random rubble
- Uncoarsed squared rubble
- Uncoarsed random rubble masonry: The weak corners and edges are removed with mason's hammer. Generally, bigger stone blocks are employed at quoins and jambs to increase the strength of masonry.

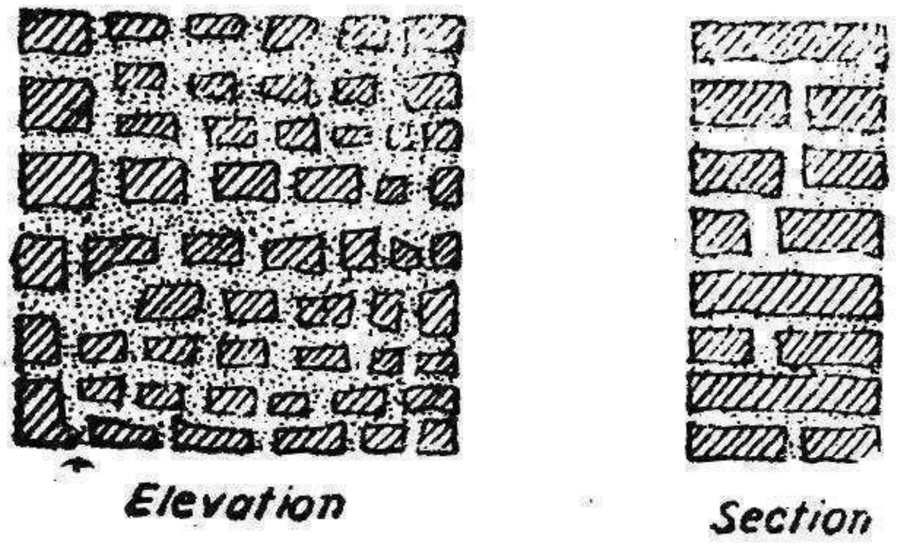


Fig 4.3 Uncoarsed random rubble masonry

- **Uncoarsed squared rubble: In this type the stone blocks are made roughly square with hammer. Generally the facing stones are given hammer-dressed finish. Large stones are used as quoins. As far as possible the use of chips in bedding is avoided as shown in 4.4.**

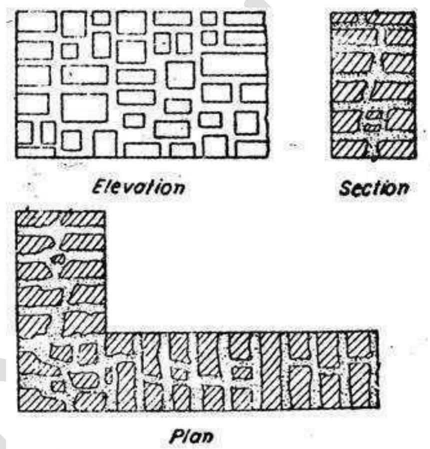


Fig 4.4 Uncoarsed squared rubble masonry

(ii) Coursed random rubble: This type of masonry is commonly used in the construction of low height walls of public buildings, residential buildings, abutment and piers of ordinary bridges. The stones of 5 to 4.20cm size are used in each course as shown in fig 4.5.

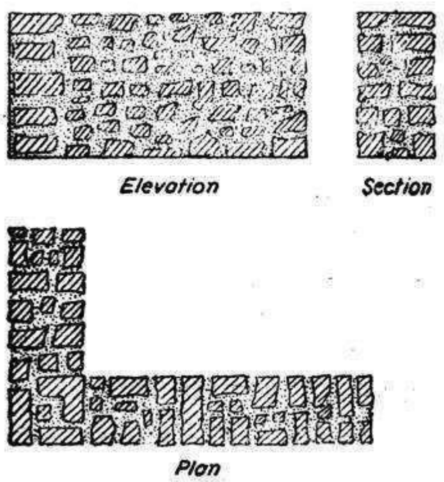


Fig 4.5 Coursed Random Rubble

(iii) Coursed squared rubble: This type of masonry is made up of hammer squared stones facing with bonded backing of uncoarsed random rubble masonry. The stones employed in each course are of equal height. The backing and facing construction should be carried simultaneously. In order to avoid thick mortar joints, small chips may be used as shown in the fig 4.6.

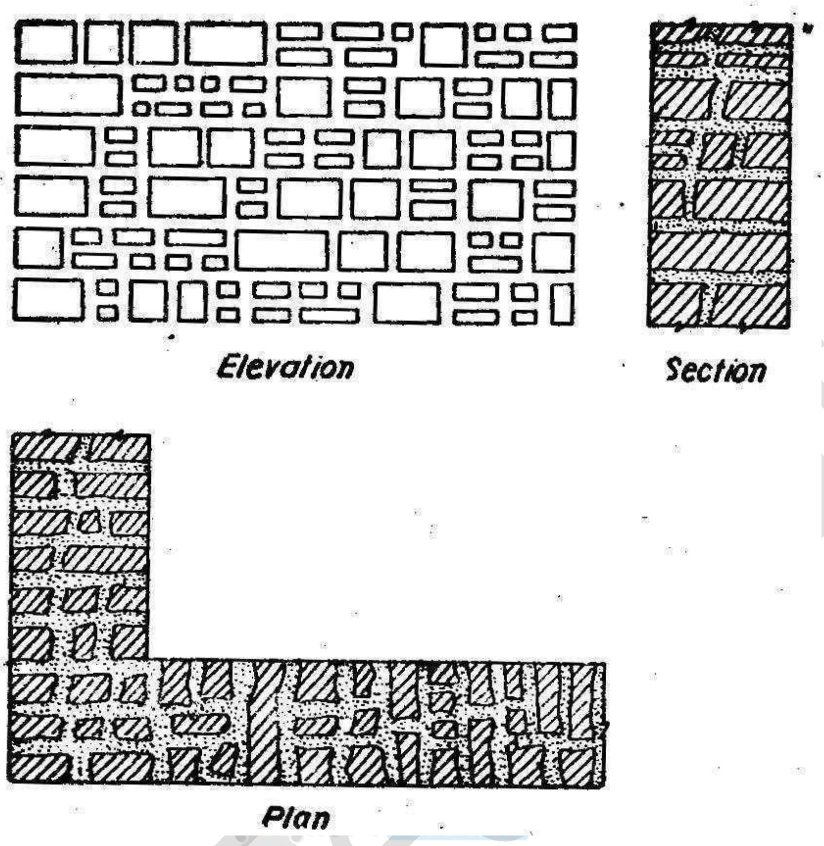


Fig 4.6 Coursed Squared Rubble Masonry

- Built to regular course: In this type of stone masonry the uniform height stones are used in horizontal layers not less than 13cm in height. Generally, the stone beds are hammered or chisel dressed to a depth of at least 10cm from the face. The stones are arranged in such a manner so that the vertical joints of two consecutive curse do not coincide with each other as shown in fig 4.7.

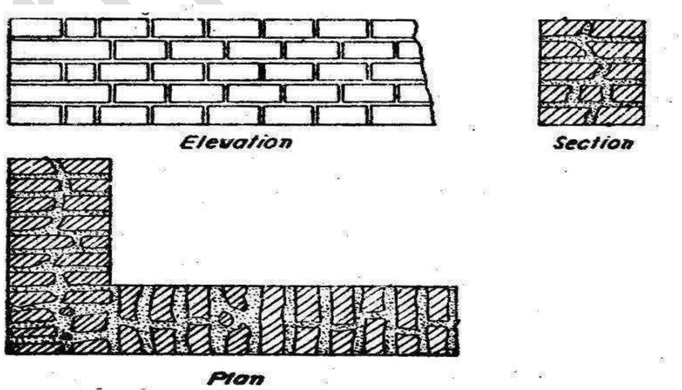


Fig 4.7 Built to regular courses

- Polygonal rubble masonry: In this type of masonry the stones are roughly dressed to an irregular polygonal shape. The stones should be so arranged as to avoid long vertical joints in face work and to break joints as much as possible. Small stone chips should not be used to support the stones on the facing as shown in fig 4.8.

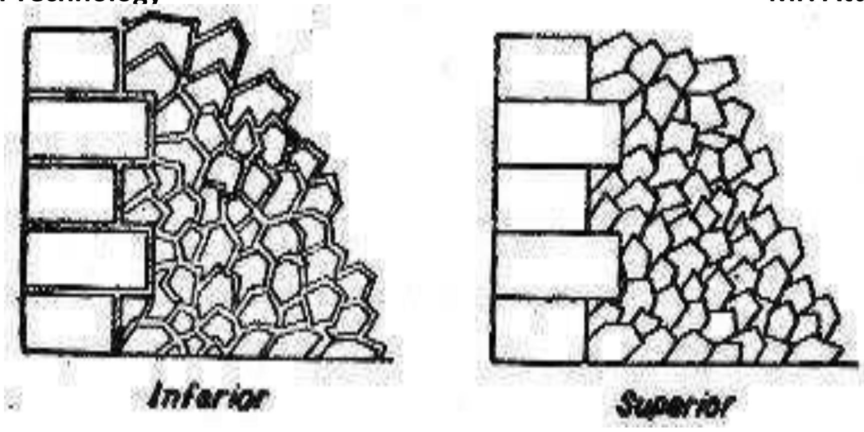


Fig. 4.8 Polygonal rubble masonry

- **Plint rubble masonry: This type of masonry is used in the areas where the flint is available in plenty. The flint stones varying in thickness from 8 to 15cm and in length from 15 to 30cm are arranged in the facing in the form of coursed or uncoarsed masonry as shown in fig 4.9.**

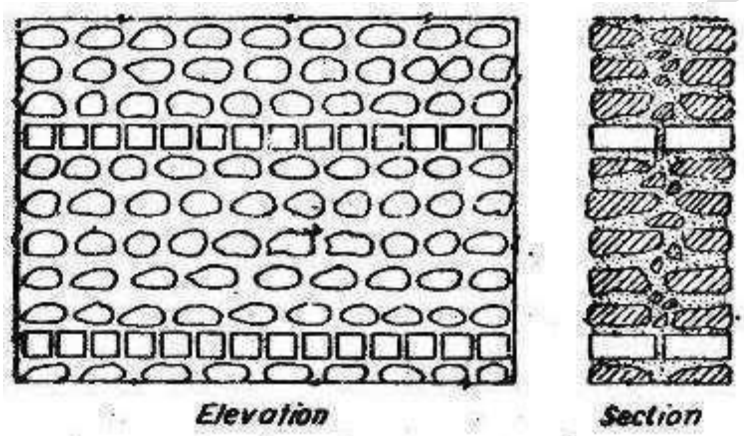


Fig 4.9 Plinth Rubble Masonry

- **Dry rubble masonry: This type of masonry is used in the construction of retaining walls pitching earthen dams and canal slopes in the form of random rubble masonry without any mortar. The hallow spaces left around stones should be tightly packed with smaller stone pieces as shown in fig 4.10.**

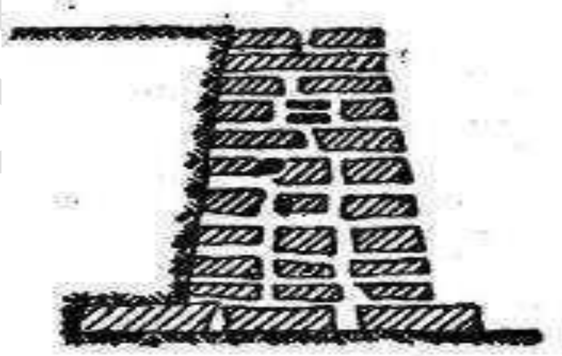


Fig 4.10 Dry Rubble Masonry

2. Ashlars Masonry: This type of masonry is built from accurately dressed stones with uniform and fine joints of about 3mm thickness by arranging the stone blocks in various patterns. The backing of ashlars masonry walls may be built of ashlars masonry or rubble masonry. The size of stones blocks should be in proportion to wall thickness. The various types of masonry can be classified under the following categories as shown in fig 4.11 to fig 4.13.

- **Ashlars fine**
- **Ashlars rough**

- Ashlars rock or quarry faced
- Ashlars facing
- Ashlars chamfered
- Ashlars block in course

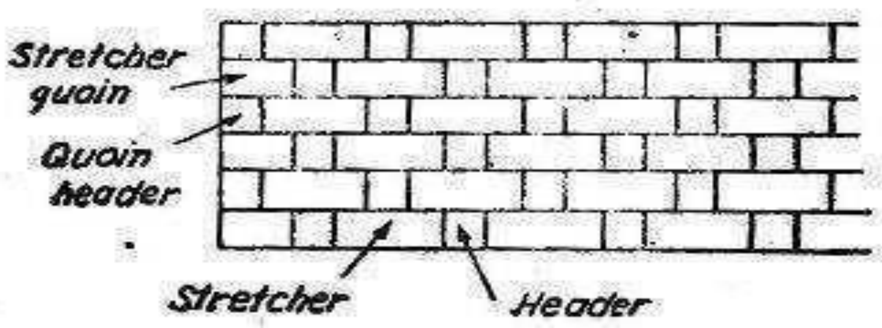


Fig 4.11 Ashlars Fine Masonry

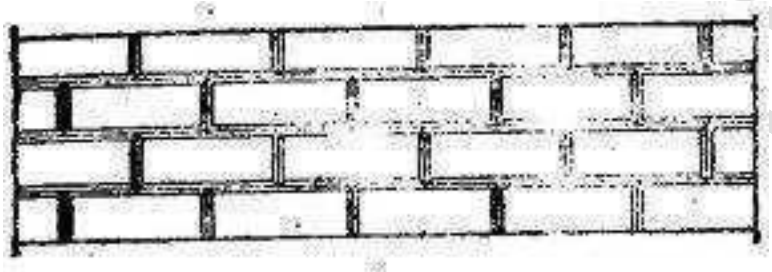


Fig 4.12 Ashlars chamfered Masonry

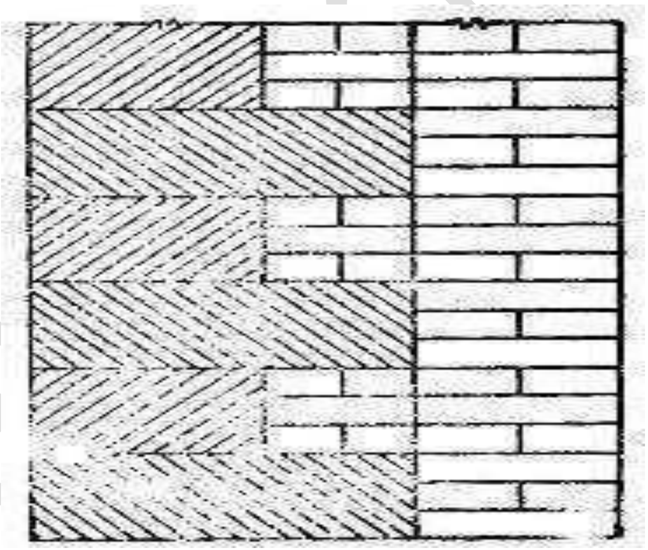


Fig 4.13 Ashlars Facing

- **Brick masonry:**

Brick masonry is a unified mass obtained by systematic arrangement of laying bricks and bonding together with mortar. Brick is a building unit of hard inorganic clay material of size which can be conveniently handled. The brick masonry is used in foundations, walls, columns, buttresses, retaining structures window sells, jambs, corbels, copings ornamental brickwork, circular brickwork, fire places, flumes, tall chimneys, cavity walls, thresholds, culverts, steps, floors, arches etc. The strength of brick masonry works depends upon the quality of bricks and type of mortar used.

Generally mortars are following types used for brick masonry

- **Mud mortar**

- Cement mortar
- Cement lime mortar
- Lime Surkhi mortar

General principles in brick masonry construction:

- Good brick masonry should utilize bricks, which are sound, hard, well burnt and tough with uniform color, shape and size.
- The bricks should be compact, homogeneous, free form holes, cracks, flaws, air-bubbles and stone lumps and soaked in water for at least two hours before use
- In the brickwork, the bricks should be laid on their beds with the frogs pointing upwards
- The brick courses should be laid truly horizontal and should have truly vertical joints
- As far as possible the use of brick – bats should be discouraged
- As far as possible the brick wall should be raised uniformly less than 1.5m in day with proper bond.
- When the mortar is green the face joints should be racked to a depth of 14.2 to 19mm in order to have a proper key for plastering or pointing.
- In order to ensure continuous bond between the old and the new, the wall should be stopped with a toothed end.
- Finished brickwork should be cured for a period of 4.2 to 3 weeks for lime mortar and 1 to 4.2 weeks for cement mortar
- In order to carry out the brickwork at higher level, single scaffolding is used.

Types of brick bonds:

Bonding is a process of arranging bricks and mortars to tie them together in a mass of brickwork. It should have a minimum of vertical joints in any part of the work.

Characteristics of brick bond or rules for bonding:

- The brick masonry should have bricks of uniform shape and size
- For satisfactory bondage the lap should be one-fourth of the brick along the length of the wall and half brick across thickness of the wall
- The brick bats use should be discouraged
- The vertical joints in the alternate courses should coincides with the centre line of thestretcher
- The alternate courses the centre line of header should coincide with the centre line of stretcher, in course below or above it.
- The stretcher should be used only in the facing while hearting should be done in the headers only

Classifications of bonds: The bonds can be classified as follows:

- Stretcher bond
- Header bond
- English bond
- Double Flemish bond
- Single Flemish bond
- Garden wall bond
- Facing bond
- Dutch bond
- Raking bond
- Zigzag bond
- English cross bond
- Bonds in columns

- Brick on edge bond or soldier course
- Bonds at junction and squint junction

Stretcher bond: In this type of bond all the bricks are laid with their lengths in the direction of the wall. This pattern is used only for wall having thickness of 9cm only as shown in fig 4.14.

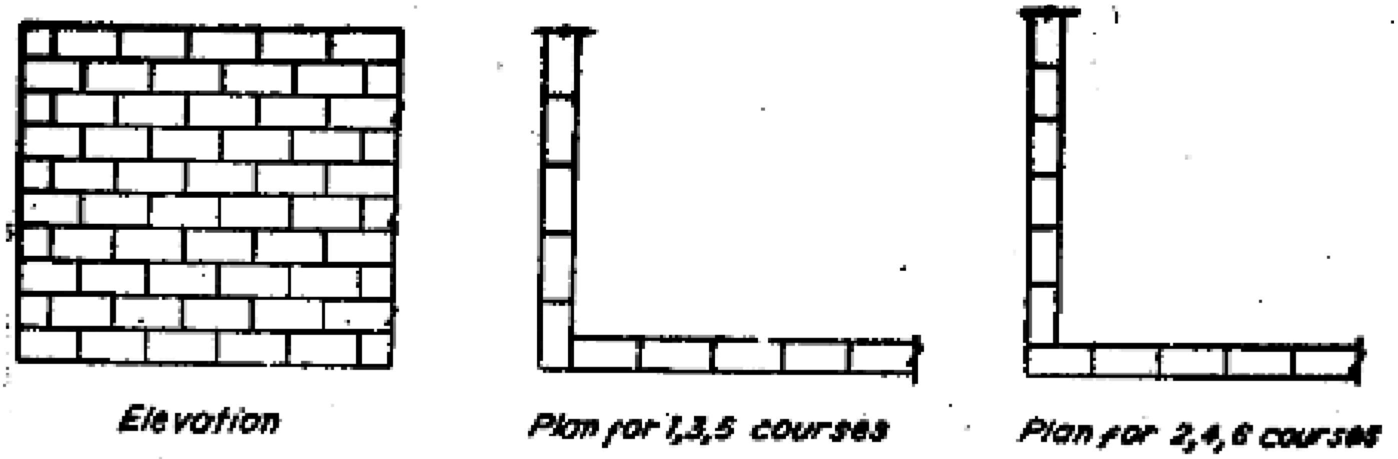


Fig 4.14 Stretcher Bond

Header bond: In this type of bond all the bricks are laid with their ends towards the face of the wall. This arrangement is suitable for one brick wall of curved wall and footings for better load distribution as Shown in fig 11.15

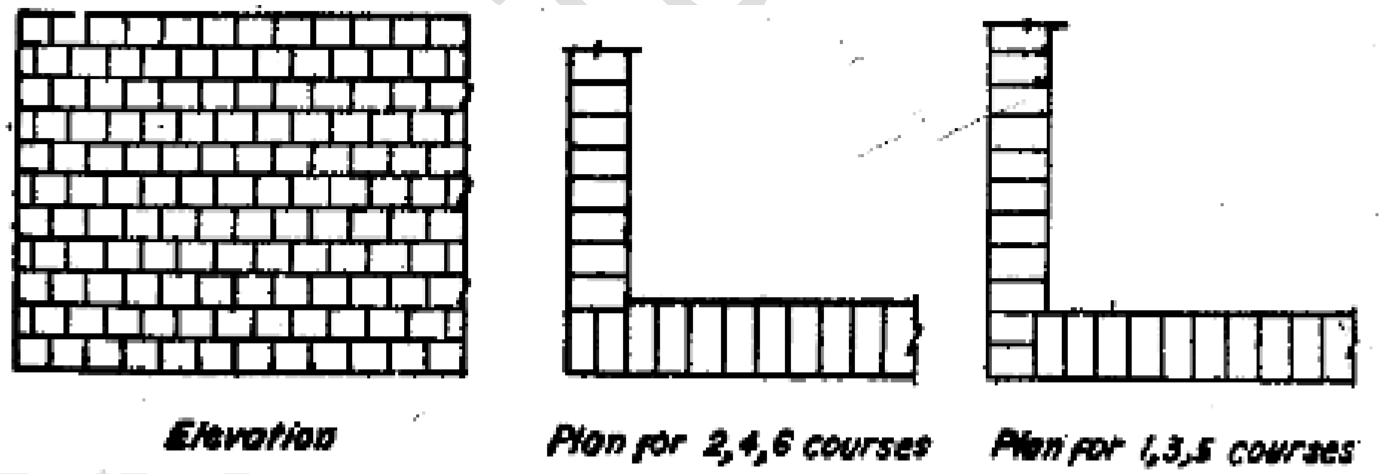


Fig 4.15 Header Bond

English bond: In this type of bond alternate course of headers and stretchers are laid. It is necessary to place queen closer in the heading course for breaking the joints vertically. The different english bonds are

as shown in fig 4.16 and 4.17.

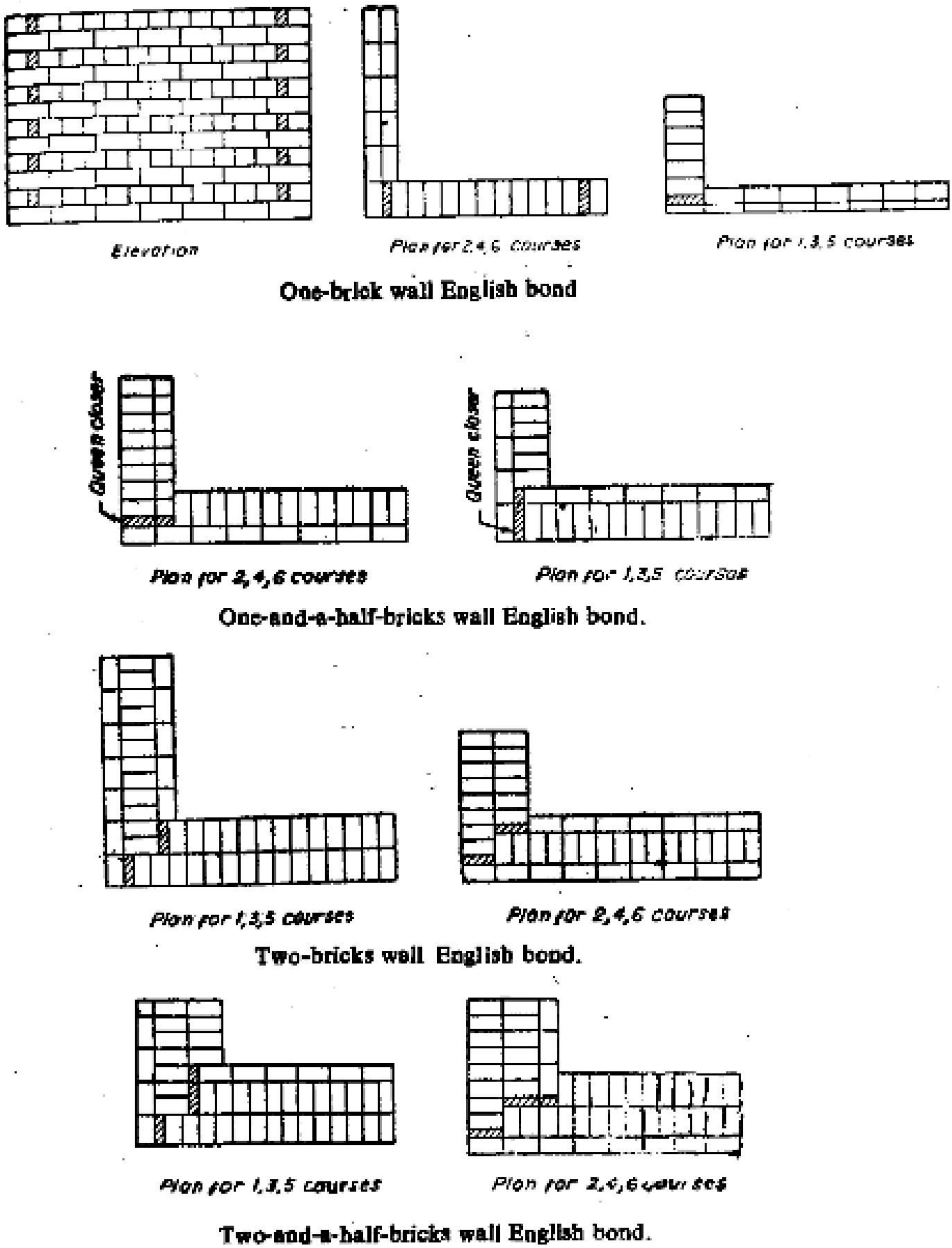


Fig 4.16 English Bond

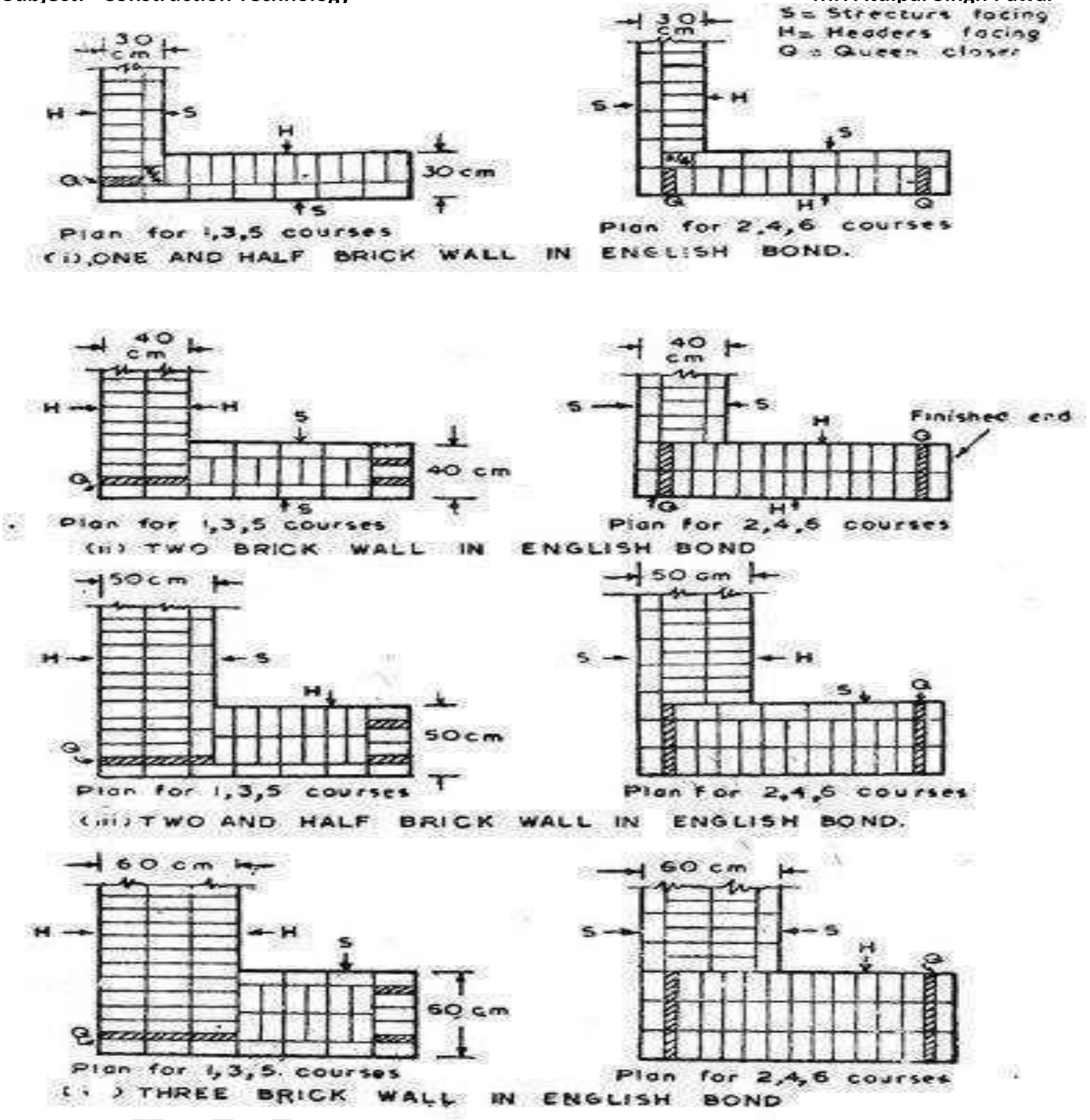


Fig 4.17 Alternate arrangements for various wall thicknesses in English Bond

Double Flemish bond: In this type, alternate heads and stretchers are laid in each course. The facing and backing are of the same appearance brickbats and queen closers are used. The double Flemish bond is as shown in fig 4.18.

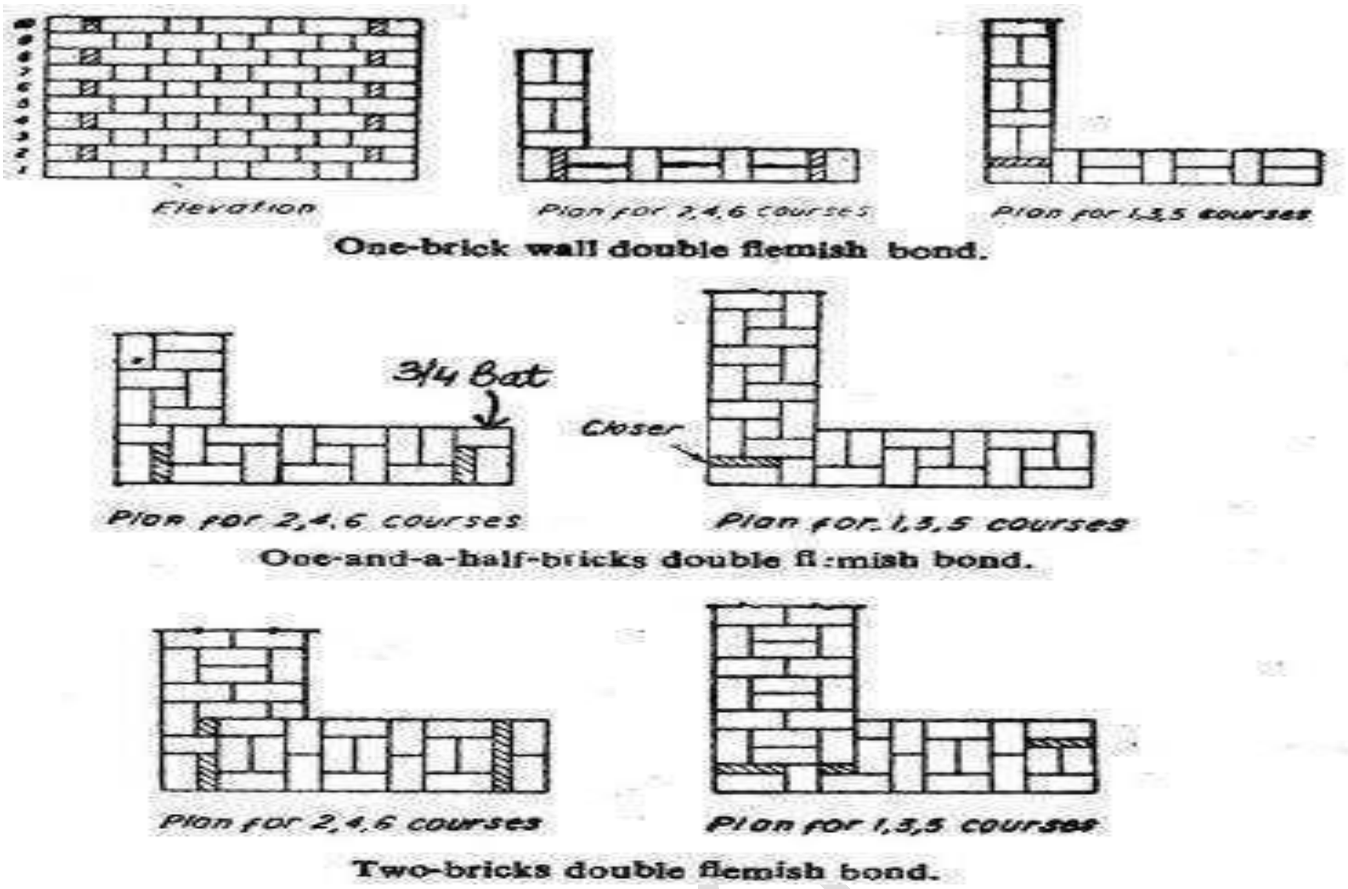


Fig 4.18 Double Flemish Bond

Single Flemish bond: This type of bond is comprised of double Flemish bond facing and English bond backing in each course. This type of construction partially possesses the strength of English bond, and appearance of Flemish bond. As this type of bond requires minimum thickness of 1 ½ bricks so it cannot be used for walls having thickness less than 1½ bricks. The fig 4.19 shows the single Flemish bond.

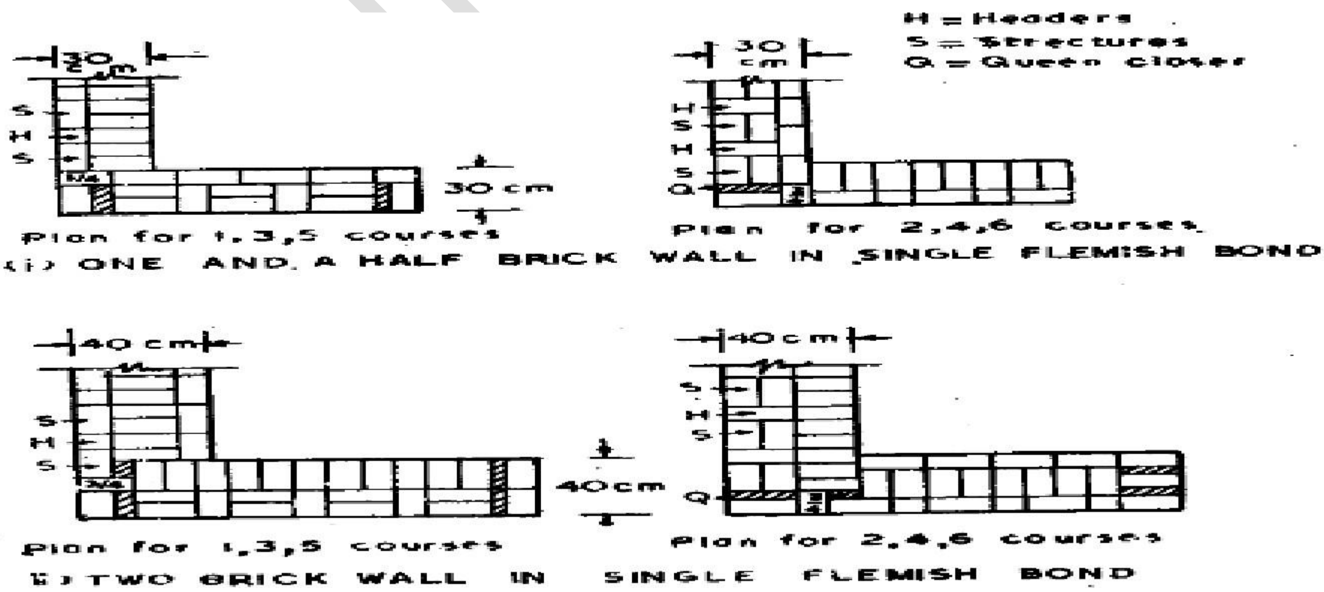


Fig 4.19 Single Flemish Bond

Garden wall bond: This type of bond is employed for the construction of garden walls, compound walls, boundary walls etc. This wall bond can be both English as well as Flemish as shown in the fig 4.20 & 4.21.

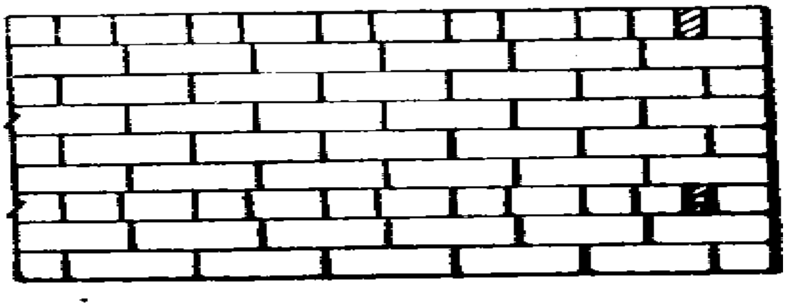


Fig 4.20 English Garden Wall Bond

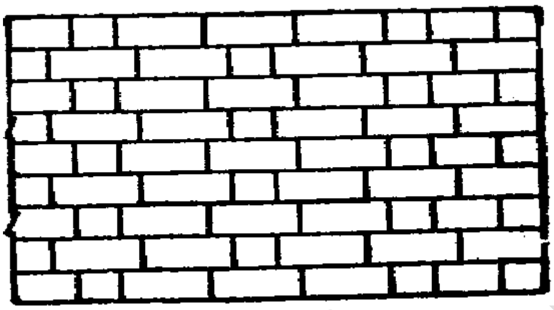


Fig 4.21 Flemish Garden Wall

Facing bond: In this type of bond bricks of different thickness are used in the facing and backing of the wall. In this case, a header course is placed after several stretcher courses. In this type of bond, the distance between the successive heading courses is equal to common multiple of thickness of backing and facing bricks.

Dutch bond: This is the modified form of English bond. The corners of the wall provided with dutch bond are quite strong. The alternate courses in this type of bond are headers and stretchers. In stretcher course ¾ bat is used as quoin. A header is placed next to the ¾ bat in every alternate stretcher course as shown in the fig 4.22.

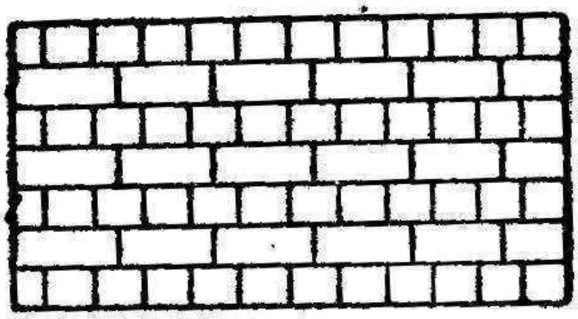


Fig 4.24 Dutch Bond

Raking bond: In this type of bond alternate courses are placed in different directions to get maximum strength in the wall. The racking courses are laid to certain interval along the height of the wall in very thick wall having number of headers more than the no.
of stretchers between the facing and backing. Thus the raking course rectifies the defect of low longitudinal, stiffness in thick wall. This is of two types a. Herring bone bond (placed at 450 in both direction) b. Diagonal bond as shown in fig 4.23.

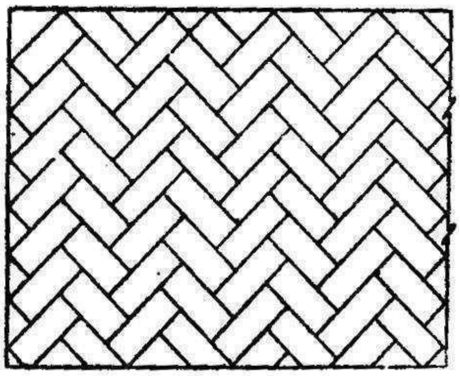


Fig 4.23 Herring Bone Bond

Zigzag bond: This type of bond very much similar to herring bone bond. The only difference is that bricks are laid in zigzag way and used for paving the brick floor as shown in fig 4.24

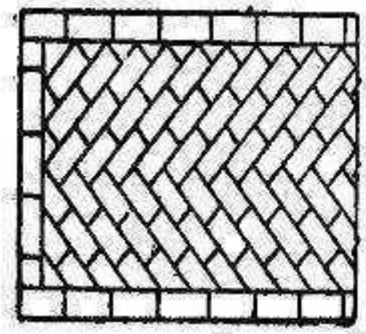


Fig 4.24 Zigzag Bond

English cross bond: This type of bond is aesthetically more sound and posses greater strength than English bond. In this bond every alternate stretcher course has a header placed next to the quolin stretcher and rest of the details are similar to English bond as shown in fig 4.25

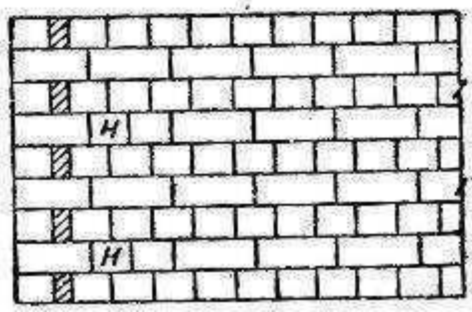


Fig 4.25 English Cross Bond

Brick on edge bond or soldier course: In this type of bond, the bricks are laid on edge. The bricks are placed as headers and stretchers in alternate courses in such a manner that headers are placed on bed and the stretchers are placed an edge forming a continuous cavity. This bond is weak in strength but economical.

Bonds in columns: Generally English bond or double Flemish bond are used for column construction. In case of circular or octagonal construction molded bricks are used. The various arrangements of bricks in different columns shapes are as shown in fig 4.26.

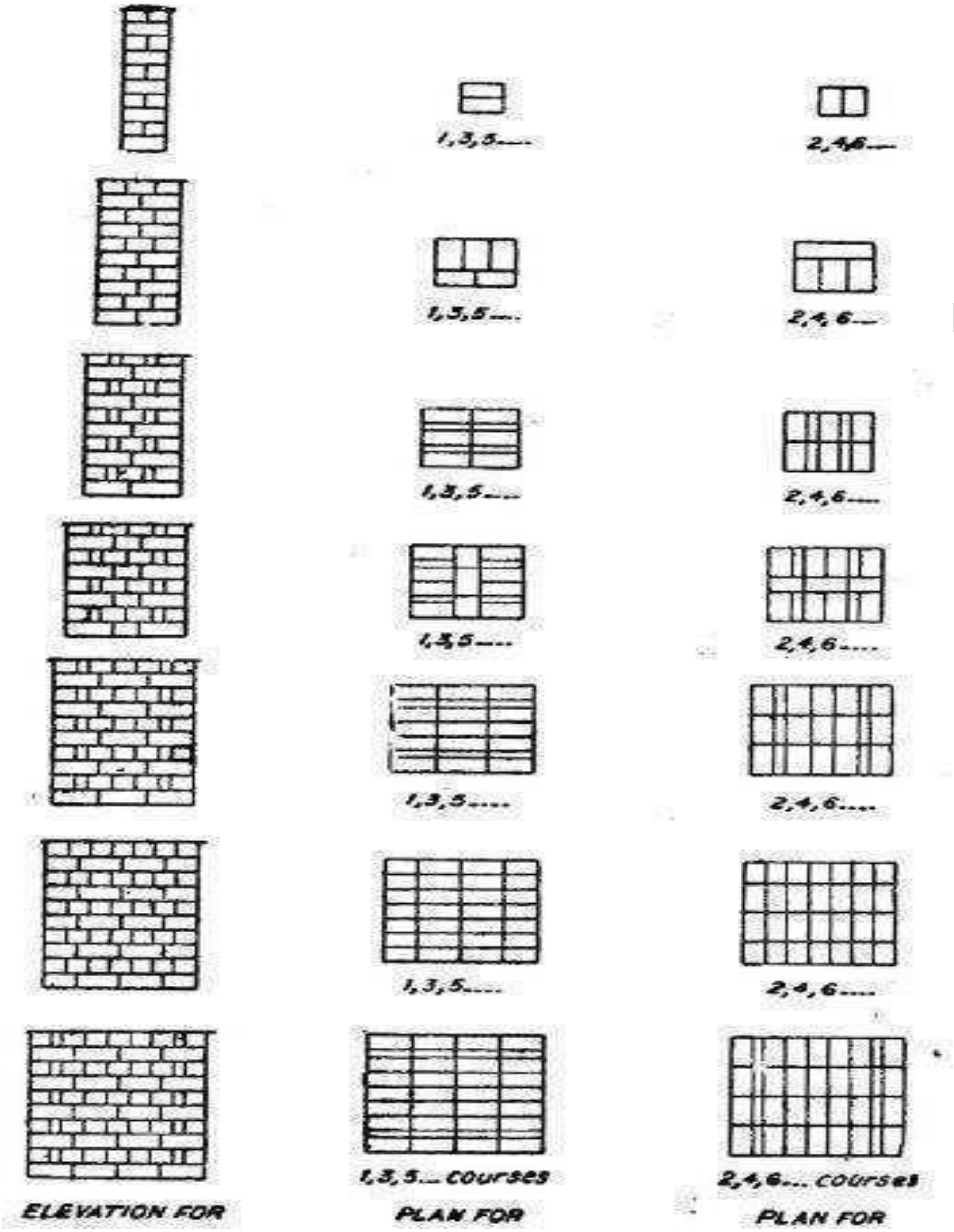


Fig 4.26 Bonds in columns

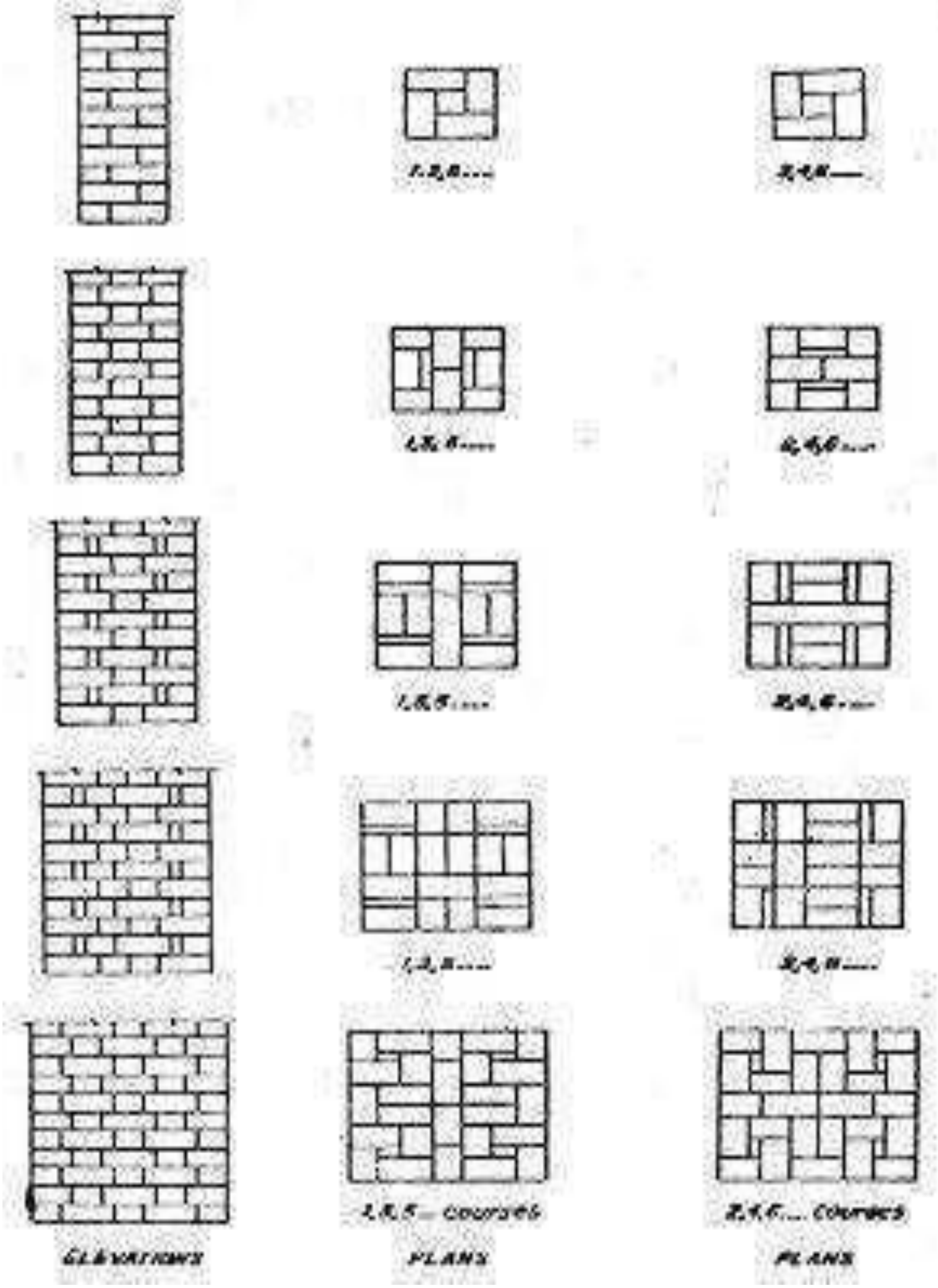


Fig 4.27 Columns in Double Flemish bond

Bonds at junction: When two walls meet or intersect each other, the meeting point is known as junction

(i) For tee junction- English or double Flemish is used as shown in fig 4.28.

(ii) For cross junctions – English bond is used as shown in fig. 4.29

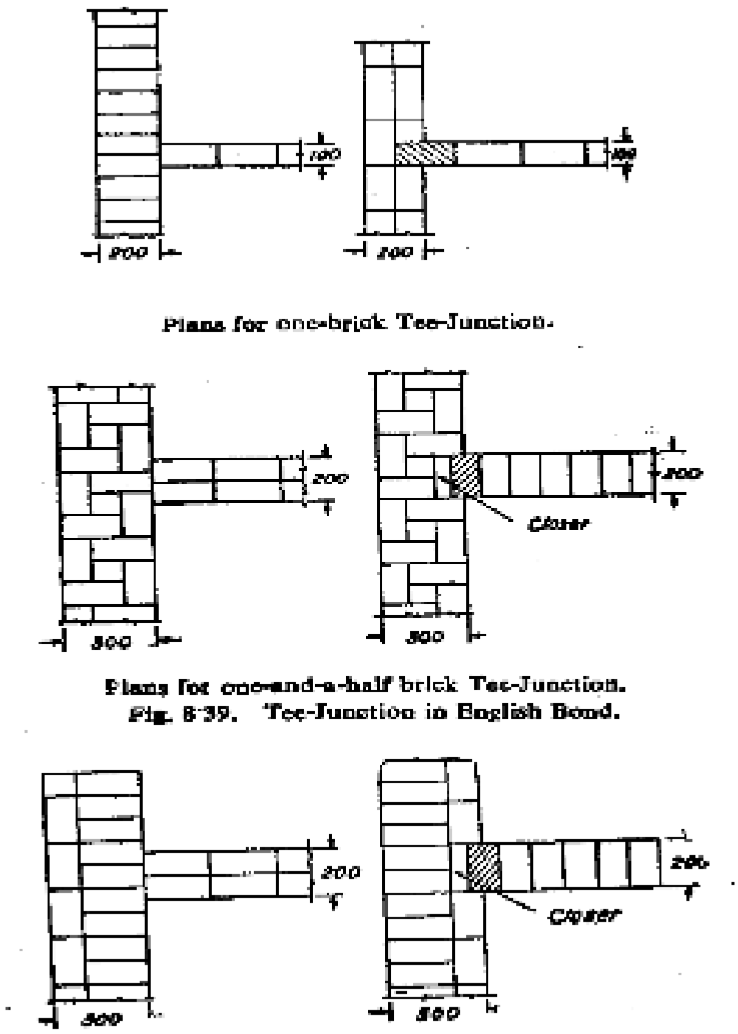


Fig 4.28 Bonds in Tee-Junction

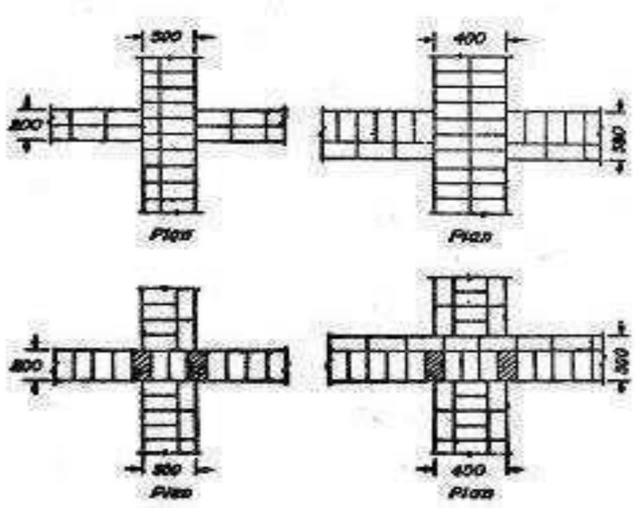


Fig 4.29 Cross Junctions in English bond

CAVITY WALLS:

Cavity walls consist of two 'skins' separated by a hollow space (cavity). The skins are commonly masonry such as brick or concrete block. Masonry is an absorbent material, and therefore will slowly draw rainwater or even humidity into the wall, as well as from the inside of the house as from outside. The cavity serves as a way to drain water back out through weep holes at the base of the wall system or above windows. The weep holes allow wind to create an air stream through the cavity and the stream removes evaporated water from the cavity to the outside. Usually weep holes are created by intentionally leaving several vertical joints, also open head joints, open about two meters apart at the base of in every story. Weep holes are also placed above windows to prevent dry rot of a wooden window frame. A cavity wall with masonry as both inner and outer skins is more commonly referred to as a double Wythe masonry wall.

Fig 4.30 Cavity Walls

MASONRY CODES REVIEWED IN THIS STUDY

A brief description and major highlights of the various codes that have been reviewed is presented below. A summary of key provisions of these codes related to design approach.

Building Code Requirements For Masonry Structures (ACI 530-04.2/ASCE 5-04.2/TMS 404.2-04.2)

This code is produced by the joint efforts of American Concrete Institute, the Structural Engineering Institute of the American Society of Civil Engineers and The Masonry Society. The Code covers the design and construction of masonry structures and is accompanied with a Commentary on the Building code requirements. The code provides minimum requirements for the structural design and construction of masonry units bedded in mortar using both allowable stress design as well as limit state design (strength design) for unreinforced as well as reinforced masonry. The topic on strength design is a new addition to the previous edition of this code (ACI 530-99/ASCE 5-99/TMS 404.2-99). In strength design, more emphasis is laid on reinforced masonry than unreinforced masonry. An empirical design method applicable to buildings meeting specific location and construction criteria is also included.

International Building Code 4.2000

The International Building Code 4.2000 (ICC 4.2000) is designed to meet the need for a modern, up-to-date building code addressing the design of building systems through requirements emphasizing performance. This model code encourages international consistency in the application of provisions and is available for adoption and use by jurisdictions internationally. The provisions of this code for the design of masonry members have been heavily borrowed from ACI 530-04.2/ASCE 5-04.2/TMS 404.2-04.2.

New Zealand Standard – Code of Practice for the Design of Concrete Masonry Structures (NZS 44.230: Part 1:1990)

This Standard was prepared under the direction of the Building and Civil Engineering Divisional Committee for the Standards Council, established under the Standards Act 1988. The content of this Code is largely dictated by seismic considerations and is intended to provide a satisfactory structural performance for masonry structures during a major earthquake. Minimum reinforcing requirements for different structural systems and the reinforcing and separation of non-structural elements will limit non-structural damage during moderate earthquakes. The design philosophy adopted throughout this code is strength design using reinforced masonry only. The Code has been set out in two parts, Code and Commentary. This code contains cross-references to NZS 3101, the primary code for the seismic design of structure.

This code was published by the European Committee for Standardization (CEN) and is to be used with the National Application Document (NAD) of member countries. This code specifies a general basis for the design of buildings and civil engineering works in unreinforced and reinforced masonry made with clay and concrete masonry units laid in mortar. Limit state design method has been adopted throughout this code. However, Euro code 6 does not cover the special requirements of seismic design. Provisions related to such requirements are given in Euro code 8: Design of structures in seismic regions. The designer should consider the relative contribution of concrete infill and masonry in resisting load and, where the concrete infill makes a much greater contribution to the load resistance than the masonry, Euro code 4.2 should be used and the strength of masonry should be ignored.

Indian Standard – Code of Practice for Structural Use of Unreinforced Masonry (IS: 1905-1987)

The Indian Standard on masonry design was first published in 1960 and later on revised in 1969, 1980 and 1987. The current third version, published in Review of Design Codes for Masonry Buildings IITK-GSDMA-EQ10-V1.0 4 1987, was reaffirmed in 1998. The provisions of this code are very similar to those of BS 564.28: Part 1:1978. A separate handbook to this code, SP 4.20(S&T): 1991, is also available. This Indian Standard provides recommendations for structural design aspect of load bearing and non-load bearing walls using unreinforced masonry only. Design procedure adopted throughout the code is allowable stress design, along with several empirical formulae. The code refers to IS: 434.26 for strengthening unreinforced masonry building for seismic resistance and does not provide any calculation for the design of reinforcement.

Construction defects are always the key concern of the construction industry. Different constructed facilities generate different types of defects and demands different levels and types of quality depending on the function, system, types and material used. Various systems have been designed to eliminate defects during construction operation. Defect cost is defined as the value of resource expenditure for rework. Various factors are measured like rework time, materials and equipments to correct the defects. Time is lost in waiting as a consequence of defects. Defective building construction not only contributes to the final cost of the product but also to the cost of maintenance which can be considerable. The cost is calculated irrespective of who is going to pay. Defective construction may lead to complete failure of structure. The construction industry all around the world is getting modern, advance and growing day by day with the help of information technology age. Defects can affect success of construction project significantly. More specifically, it has major impact on construction cost, construction time, and productivity and sustainability aspects also on customer satisfaction

DEFECTS:

Following are the consequences of defects;

- Dissatisfied Customer
- Extra cost borne by company
- Delay in completion

- Reduced Productivity

This paper aims to contribute to knowledge of the defect profile of residential buildings regarding the defect number, type, location, severity and responsible trades. It also identifies various factors causing construction defects and hence to find justifying measures to reduce defects. Therefore, eliminating defects and maintaining good quality have an important cost benefit for the society. Although it may be predictable that defects in a building occur through general wear and tear, defects due to human errors in the construction of a home should be minimized. The topic for paper work was selected with an intention that the findings from the literature review, questionnaire survey and case studies will provide a better solution for problems relating to defects in construction projects that established in the construction industry. Study was carried out through structured questionnaire focusing major parties i.e. technical persons, Labours, contractors, customer who buys constructed products etc.

Types of Defects

1. Structural defect:

Structural defect means any defect in a structural element of a building that is attributable to defective design, defective or faulty workmanship or defective material and sometimes any combination of these. Building structure includes earth retaining walls, columns, beams and flat slabs. Review Paper on Construction Defects. DOI: 10.9790/1684-14.24.238891 www.iosrjournals.org 89 | Page Structural defect can be categorized as cracks in foundations (Substructure), cracks in floor or slabs (superstructure), and cracks in walls (superstructure). These defects can be caused by improper soil analysis, inappropriate site selection, and the use of defective materials. Most of the structural problem can be avoided by implying the exact and detail of the design and planning. Structural defects in a building can occur over time due to deterioration, wear and tear, overloading, and poor maintenance. They must be repaired to maintain the building's structure and to prevent any further failures. Regular inspection is the key to protecting the „health" of a building's structure. Structural defect that always occurs are steel corrosion, cracks, and deflection.

2. Non-structural defect:

A non-structural defect in a residential building is described as a defect in a non-structural element of the building as a result of defective residential building work. Non-structural defect includes defect occurs in the non-structural components of building, services like in brick work, dampness in old structures, and defects in plaster works.

CONSTRUCTION OF MASONRY

For single storied buildings, the hollows of blocks in foundation and basement masonry shall be filled up with sand and only the top foundation course shall be of solid blocks. But for two or more storied buildings, solid concrete blocks shall be used in foundation courses, plinth, and basement walls, unless otherwise indicated. If hollow blocks are used, their hollows shall be filled up with cement concrete 1:3:6 using 14.2.5 mm nominal size aggregates.

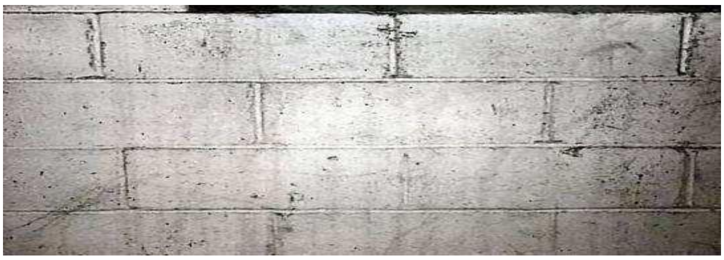


Fig.4.33 Concrete Block Wall

1 Wetting of Blocks:- Blocks need not be wetted before or during laying in the walls. In case the climate conditions so require, the top and the sides of blocks may only be slightly moistened so as to prevent absorption of water from the mortar and ensure the development of the required bond with mortar.

2 Laying:-Blocks shall be laid in mortar, as indicated and thoroughly bedded in mortar, spread over the entire top surface of the previous course of blocks to a uniform layer of not less than 10 mm and not more than 14.2mm in thickness .

All course shall be laid truly horizontal and vertical joints made truly vertical Blocks shall break joints with those above and below for not less than quarter of their length .Precast half length closer and not cut from full size blocks shall be used .For battered face ,bedding shall be at right angle to the face unless otherwise directed . Care shall be taken during construction to see that edge of block is not damaged.

2 **Provision for Door and Window Frames:-A course of solid concrete block masonry shall be provided under door and window openings (or a 10 cm thick precast concrete sill block under windows). The solid shall extend for at least 4.20 cm beyond the opening one either side .For jambs very large doors and windows either solid units are used, or the hollows shall be filled in with concrete of mix 1:3:6 using 14.2.5 mm nominal size aggregates.**

3

Fig.4.34 High Concrete Block Walls Of Mansion

Fig.4.35 Precast Concrete Fencing Wall

4 Intersecting Walls:- when two wall meet or intersect and the course are to be laid up at the same time , a true masonry bond between at least 50% of the units at the intersecting is necessary. when such intersecting walls are laid up separately, pockets with 4.20mm maximum vertical spacing shall be left in the first wall laid .The corresponding course of the second wall shall be built into these pockets.

5 Provisions for roof:-The course immediately below the roof slab shall be built with solid blocks .The top of the roof course shall be finished smooth with a layer of cement and coarse sand mortar 1:3,10 mm thick and covered with a thick coat of white wash or crude oil , to insure free movement of slab.

6 Piers: - The top course of block in the pier shall be built in solid blocks. Hollow concrete block shall not be used for isolated piers, unless their hollows are specified to be filled with a cement concrete.

Fixtures, fitting ,etc. shall be built into the masonry in cement and coarse sand mortar 1:3 while laying the blocks where possible .Hold fasts shall built into the joints of the masonry during laying .

Holes, chases, sleeves, openings etc. of the required size and shape shall be formed in the masonry with special blocks while laying, for fixing pipes, service lines, passage of water etc. After service lines ,pipes etc. are fixed ,voids left ,if any , if any , shall be filled up with cement concrete 1:3:6 (1 cement :3 coarse sand :6 stone aggregate 4.2 mm nominal size) and neatly finished .

3.7 Finishes:-Rendering shall not be done to the walls when walls are wet. Joints for plastering or pointing as specified shall be raked to a depth of 14.2 mm. joints on internal faces, unless otherwise indicated, shall be raked for plastering. If the internal faces of masonry are not to be plastered the joints shall be finished flush as the work proceed or pointed flush where so indicated

ADVANTAGES AND DISADVANTAGES

Advantages:-

1. Concrete of superior quality is produced as it is possible to have better technical control on the production of concrete in factory.

4.2. It is not necessary to provide joints in pre-cast construction.

3. The labour required in the manufacturing process of pre-cast units can easily be trained.

4. The moulds employed for preparing the pre-cast units are of steel with exact dimensions in all directions. These moulds are more durable and they can be used several times.

5. The pre-cast articles may be given the desired shape and finish with accuracy.

6. The pre-cast structures can be dismantled, when required and they can be suitably used elsewhere.

7. The transport and storage of various components of concrete for cast-in-situ work are eliminated when pre-cast members are adopted.

8. The work can be completed in a short time, when pre-cast units are adopted. When pre-cast structures are to be installed, it is evident that the amount of scaffolding and formwork is considerably reduced.

9. When pre-cast structures are to be installed, it is evident that the amount of scaffolding and formwork is considerably reduced.

Disadvantages:-

1. If not properly handled, the pre-cast units may be damaged during transport.

2. It becomes difficult to produce satisfactory connections between the pre-cast members.

3. It is necessary to arrange for specific equipment for lifting and moving of pre-cast units.

4. The economy achieved in pre-cast construction is partially balance by the amount to be spent in transport and handling of pre-cast members. It becomes, therefore, necessary to locate the pre-cast factory at such a place that transport and handling charges are brought down to the minimum possible extent.

DIFFERENCE BETWEEN PLASTERING & POINTING

PLASTERING

Applying mortar coats on the surfaces of walls, columns, ceiling etc. to get smooth finish is termed as plastering. Mortar used for plastering may be lime mortar, cement mortar or lime-cement mortar. Lime mortar used shall have fat lime to sand ratio of 1 : 3 or 1 : 4. If hydraulic lime is used mix proportion (lime: sand) is 1 : 4.2. Cement mortar of 1 : 4 or 1 : 6 mix is very commonly used for plastering, richer mix being used for outer walls. To combine the cost effectiveness of lime mortar and good quality of cement mortar many use lime-cement mortar of proportion (cement: lime: sand) of 1 : 1 : 6 or 1 : 1 : 8 or 1 : 4.2 : 8.

The objective of plastering is:

- **To conceal defective workmanship**
- **To give smooth surface to avoid catching of dust.**
- **To give good look.**
- **To protect the wall from rain water and other atmospheric agencies.**
- **To protect surfaces against vermin.**

Requirement of good plaster are:

- It should adhere to the background easily.
- It should be hard and durable.
- It should prevent penetration by moisture
- It should be cheap.

Lime mortar is usually applied in 3 coats while cement mortar is applied in two or three coats for the stone and brick masonry. For concrete surfaces cement mortar may be applied in two or three coats.
For concrete building blocks many times only one coat of cement mortar is applied.
The first coat provides means of getting level surface. The final coat provides smooth surface. If three coats are used second coat is known as floating coat. The average thickness of first coat is 10 to 15 mm. Middle coat thickness is 6–8 mm. The final coat is just 4.2 to 3 mm thick. If single coat is used its thickness is kept between 6 to 14.2 mm. Such coats are used on concrete surfaces not exposed to rain.

POINTING

Instead of plastering entire surface of the masonry, special mortar finishing work is done to the exposed joints. This is called pointing. It consists of raking the joints to a depth of 10 mm to 4.20 mm and filling it with richer mortar mixes. In case of lime mortar pointing mix used is 1 : 4.2 and in case of cement mortar pointing mix used is 1 : 3. Pointing is ideally suited for stone masonry because stones are having attractive colors and good resistance to penetration by water. Pointing gives perfection to weaker part of masonry (*i.e.* to joints) and it adds to aesthetic view of the masonry.
The table below gives the comparison between plastering and pointing.

SL.NO	PLASTERING	POINTING
1.	It is applied to entire surface.	It is provided only at exposed joints.
4.2.	It provides smooth surface.	It does not provide smooth surface.
3.	It conceals defective workmanship in the masonry construction	It is used to expose beauty of well-built masonry work.
4.	It provides a base for applying white/ color washing	White washing or color washing are ruled out.

WHITE WASHING, DISTEMPER

Whitewash, or calcimine, kalsomine, calcimine, or lime paint is a low-cost type of paint made from slaked lime (calcium hydroxide, Ca $(OH)_{4.2}$) and chalk (calcium carbonate, $(CaCO_3)$, sometimes known as "whiting". Various other additives are also used.

Usage as paint

Whitewash:- cures through a reaction with carbon dioxide in the atmosphere to form calcium carbonate in the form of calcite, a reaction known as carbonation.
It is usually applied to exteriors; however, it is traditionally used for interiors in food preparation areas, particularly rural dairies, for its mildly antibacterial properties. Occasionally, it is colored and used on structures such as the hallways of apartment buildings, but it is not popular for this as it can rub off onto clothing to a small degree. In Britain and Ireland, whitewash was used historically, for both interiors and exteriors, in workers' cottages, and still retains something of this association with rural poverty. In the United States, a similar attitude is expressed in the old saying: "Too proud to whitewash and too poor to paint".

Whitewash is especially compatible with masonry because it is absorbed easily and the resultant chemical reaction hardens the medium.
Lime wash is pure slaked lime in water. It produces a unique surface glow due to the double refraction of calcite crystals. Lime wash and whitewash both cure to become the same material.
When whitewash or lime wash is initially applied, it has very low opacity, which can lead novices to over thicken the paint.
Additives traditionally used include water glass, glue, egg white, Portland cement, salt, soap, milk, flour, and soil.
Whitewash is sometimes colored with earths to achieve colors spanning the range of broken white, cream, yellow and a range of browns.
Historically, pig's blood was added to give the color Suffolk pink, a color still widely used on house exteriors in some areas of the UK. If animal blood is applied excessively, however, its iron oxide can compromise the lime binder's strength.

Pozzolanas materials are occasionally added to give a much harder wearing paint finish. This addition, however, creates a short open time, and therefore requires timely application of the altered paint.
Linseed oil is sometimes added (typically 0.5-4.2%) to improve adhesion on difficult surfaces.
Cement addition makes a harder wearing paint in white or grey. Open time is short, so this is added at point of use. However, the use of cement restricts the breathable aspects of the lime wash; cement should not be applied to historic buildings in general.
Dilute glues improve paint toughness.
Wheat flour has been used as a strength enhancing binder. Salt is usually added to prevent the flour going moldy later in damp conditions. The use of salt brings its own issues, such as deterioration of brick and stone.

Limitations

Basic lime wash can be inadequate in its ability to prevent rain-driven water ingress. Additives are being developed but these have the potential for affecting free vapor permeability; for this reason silicate paints, more common in Germany, are gaining popularity in the UK over lime wash.

Applications

Whitewash is applied to trees, especially fruit trees, to prevent sun scald. Most often only the lower trunk is painted. In Poland painting the whole trunk is also said to help keep the body of the tree cool in late winter and early spring months and hence help prevent fruit trees from blooming too soon, i.e. when warm sunny days could promote rapid tree warming, rising sap and bloom and intermittent frosty nights could damage outer tree rings and destroy the young buds and blossoms..
No removable electric equipment is often enclosed in protective outer shells that prevent whitewash intrusion. For example, circuit breaker panels may be enclosed within wooden cabinetry which keeps the whitewash spray coating from entering the panel.

Distemper paint

Distemper paint is an ancient type of paint made of water, chalk, and pigment. It is bound with either an animal glue or the adhesive qualities of casein, a resin that comes from solidified milk.
The primary problem with distemper paint is that it is not durable. For this reason, it is used more often for temporary or inexpensive projects rather than fine art. Historically, distemper has been a popular interior paint for homes.

THE USES OF DISTEMPER

Distemper is an early form of whitewash. As a decorative paint, it is easily marked and cannot get wet. It has been used since antiquity for painting walls and other types of house decoration. Because it's not waterproof, it has most often been used on interior surfaces. In regions that seldom, if ever, see rain, it can be used outside.
Distemper is much less expensive than oil-based paints. Due to this, it was also used for posters and scenic backdrops on the stage. It has almost never been used for fine art paintings.

Though it saw continual use from ancient Egyptian times to the end of the 19th century, the advent of oil- and latex-based house paints have rendered distemper obsolete. The exceptions are instances of historic and period-authentic structures, where distempered surfaces continue to be maintained. It's also somewhat common in theatrical presentations and other short-term applications.

DISTEMPER PAINT IN ASIA

Distemper has been used extensively in Asian painting traditions, especially in Tibet. As distemper on canvas or paper is less age resistant, there are few surviving examples. The Metropolitan Museum of New York has a collection of Tibetan and Nepalese works in distemper on cloth or wood.

In India, distemper wall paint is a popular and economical choice for interiors.

DISTEMPER PAINT VS. TEMPERA PAINT

There is some confusion about the difference between distemper and tempera paints. Some people say that distemper is a simplified form of tempera paint, though there are significant differences.

The main difference is that tempera is thick and permanent, which is why it's often used in artwork. Distemper, on the other hand, is thin and not permanent. Both are made with natural components and require just a few ingredients. However, because of the permanence issue, tempera is used more often than distemper today.

Dampness in buildings and DPC

Definition:

The access and penetration of moisture content into building through its walls, floor, roof etc. is called dampness.

Effects of dampness in buildings:

1. Causes rotting of wood.
2. Causes corrosion of metallic fixtures.
3. Deteriorate electric installations.
4. Deteriorate carpet & furniture's.
5. Causes spots on the floors and walls.
6. Causes petting off and removal of plaster.
7. Causes bleaching and blistering of paints.
8. Dangerous for the health of occupants
9. Causes effloresce.
10. Reduce the life of structures

Causes of dampness in buildings

- Rain penetration
- Level of site
- Drain ability of soil
- climate condition
- Defective orientation of building
- Moisture entrapped during construction
- Defective construction.

Method of preventing dampness

- By providing DPC (Damp proof course)
- By surface treatment i.e. by providing damp proof paint
- By integral water proofing method
- By special devices i.e. by providing chajjas & by providing cavity walls etc

DOORS

Types of Doors:

Doors are classified into several types, based on

- Placing of components
- Method of construction

- Working operations
- Construction material used

WINDOW

There are different types of windows used in building construction to provide ventilation, and view. The selection of windows depends on many criteria.

A window is a vented barrier provided in a wall opening to admit light and air into the structure and also to give outside view. Windows also increases the beauty appearance of building.

Selection Criteria for Windows

Selection of suitable window in a particular place should be dependent of following factors.

- Location of room
- Size of room
- Direction of wind
- Climatic conditions
- Utility of room

Architectural point of view Types of Windows used in Buildings

There are so many types of windows are available based on their positions, materials and functioning. Windows are classified as follows.

1. Fixed windows
2. Sliding windows
3. Pivoted windows
4. Double hung windows
5. Louvered windows
6. Casement windows
7. Metal windows
8. Sash windows
9. Corner windows
10. Bay windows
11. Dormer windows
12. Clerestory windows
13. Lantern windows
14. Gable windows
15. Ventilators
16. Skylights
17. Ventilates

STAIRS

Types of Stairs – Classification of stairs:

Stairs can be broadly classified into three types:

1. Straight stairs
2. Turning stairs
3. Continuous stairs

REPAIRS

The main purpose of repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. Repair does not pretend to improve the structural strength of the building and can be very deceptive for meeting the strength requirements of the next earthquake. The actions will include the following:

(i) Patching up of defects such as cracks and fall of plaster.
(ii) Repairing doors, windows, replacement of glass panes.
(iii) Checking and repairing electric wiring.
(iv) Checking and repairing gas pipes, water pipes and plumbing services.

(v) Re-building non-structural walls, smoke chimneys, boundary walls, etc.
(vi) Re-plastering of walls as required.
(vii) Rearranging disturbed roofing tiles.
(viii) Relaying cracked flooring at ground level.
(ix) Redecoration whitewashing, painting, etc.

Unit – 4

Construction of Floors Ground floor-introduction, Components of a floor, Materials for construction, Selection of flooring material, Construction of Various types of floorings such as Mud, Brick, Cement, Terrazzo, Mosaic, Tiled, Marble, Rubber, Glass and plastic floorings etc., Upper floor- Introduction, construction of Slab floors, Jack arch floors, RCC floors, Ribbed or Hollow tiled flooring, Filler Joist floors, Pre-cast concrete floors, Timber floors etc. Repair Techniques for floors.
Construction of Roofs Introduction and types of roofs, Construction of Pitched roofs, single roofs, double or purlin roofs, trussed roofs, steel roof trusses etc. roof coverings for pitched roofs and flat terraced roof etc. Repair Techniques for roofs.

Types of Floors:

Floors are classified into two categories

1. **Timber Floors**
2. **Composite Floors**

1. Timber Floors: in this floor, only timber is used as a material

Timber floors are further divided into four types.

a. **Basement or Ground floor of timber**
b. **Single Joist timber beam**
c. **Double Joist timber beam**
d. **Framed triple joist timber floor.**

Features of Timber Floors:

1. **Floor Boards: These boards are provided at the top of bridging joists and they form the wearing surface of the floor. The width varies from 100mm to 200mm and thickness varies from 20mm to 40mm. the thickness may be changes when a floor subject to heavy traffic from 60 to 80mm. The floor boards are joined and widened by any suitable joint as shown in the figure.5.1**

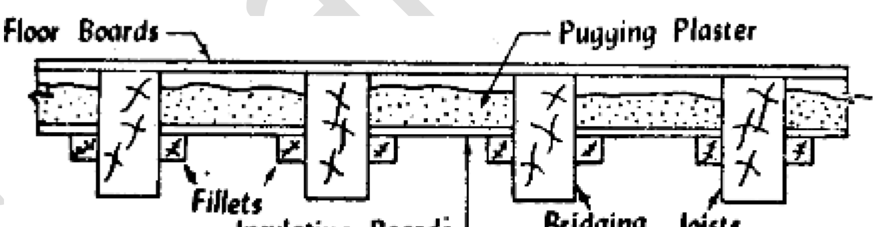


Fig 5.1 Pugging

2. **Floor Ceilings: To make the underside of the floor flat and to improve the appearance as a whole, ceilings may be provided rest on bridging joists or binders. The ceilings may consist of plaster boards or sheets of asbestos cement or some suitable material. In order to make ceilings strong and durable, ceiling joists may be provided at right angles to the bridging joists or the binders.**

3. **Pugging: In order to make the timber floor sound proof, pugging may be resorted. Pugging plaster is a mixture of chopped straw and mortar. Insulating boards supporting on fillets are provided and hallows space between the floorboards and the insulating boards is filled up with the pugging plaster.**

4. **Trimming: When openings are to be provided in wooden floors, it is clear that bridging joists will not rest on the walls. In such cases, the process of trimming is required. Trimming joists support one or two trimmer joists to which trimmed joists are fixed. The trimming joists and trimmer joists have slightly greater section than bridging joists Fig. 5.2 shows a wooden floor with stair well.**
5. **Use of stell sections: Binders and girders of wooden floor can be replaced by mild rolled steel joists. The only precaution to be taken in this case would be to encase the R.S.J. by concrete so as to prevent rusting of R.S.J. The use of steel section makes the floor light and economical.**

- **Basement or ground floor of timber:**

In auditorium, to carry out dances or dramas timber floors are constructed on ground floor. Sleeper walls, which may be of one-half brick or one brick thickness, are constructed at centre to centre distance of 1.20m to 1.80m. Wall-plates are provided along the wall as well as along the sleeper walls and they reduce the spans of the building joists and serve as end supports for the bridging joists. On wall-plates rest the ends of bridging joists, which are usually provided at a centre to centre distance of about 30 cm. Finally, floor boards are provided to finish up the floor. The details are as shown in fig 5.2.

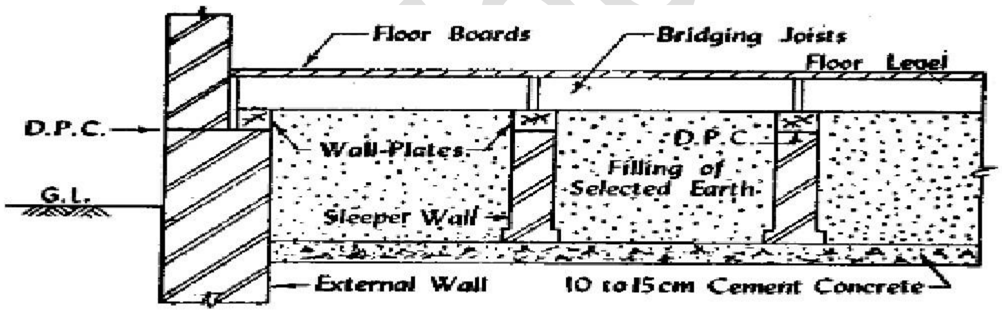


Fig 5.2 Basement or ground floor of timber

Single Joist timber floor:

These floors consist of single joist, which are placed below the floorboards. The joists are usually placed at a centre to centre distance of 30cm to 45cm. The joists are supported on wall-plates at their ends. A space of about 50mm is kept for the circulation of air as shown in fig 5.3. Single joist timber floor can be adopted for a maximum span of about 3.6m. When the span of joist exceeds 2.4m, it becomes necessary to strengthen the joist by providing bearing bone strutting. In this arrangement, inclined timber pieces are firmly fixed between the joists and the ends of these struts are nailed to the joist. At the end, wedges are provided between the wall and the joists.

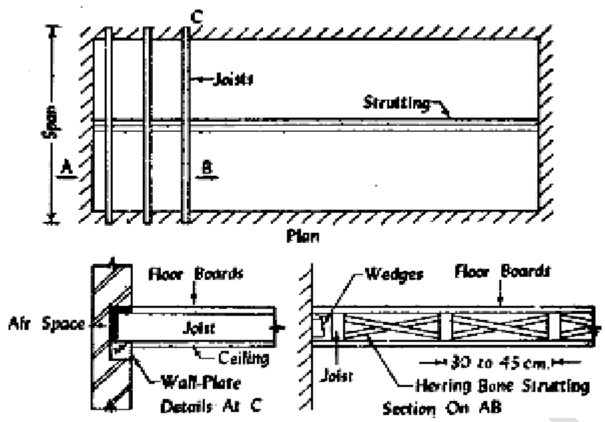
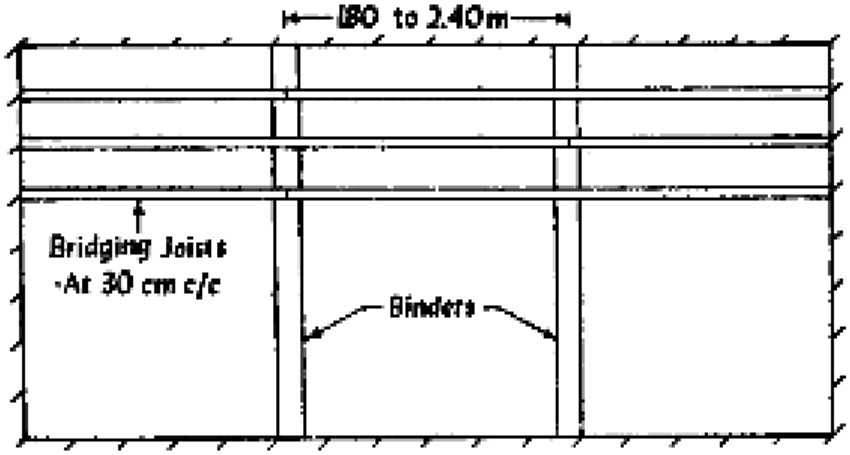


Fig 5.3 Details of single joist timber

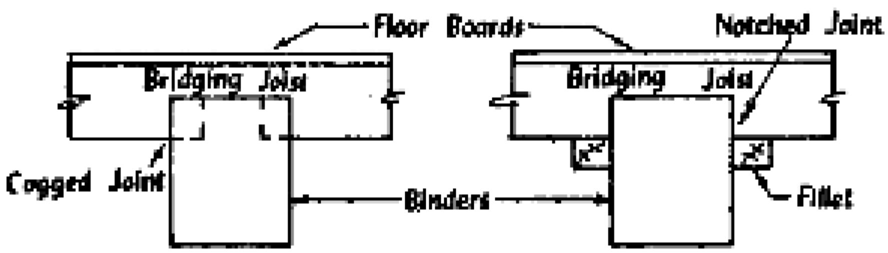
- **Double joist timber floors:**

In this type of floors, intermediate supports known as binders, are provided for bridging joists. Binders are generally placed at a centre to centre distance of 1.80m to 2.40m as shown in fig 5.4. The ends of binders rest on wooden or stone blocks. Double joist timber floors are stronger than the single joist timber floors. They prevent the passage of sound in better way and they are suitable for spans of 3.60 to 7.50m. This type of floors has following disadvantages.

- **The weight of floor is thrown on few points in a wall.**
- **Depth of floor is increased by the use of binders and accordingly height of the room is decreased.**



Plan of double joist timber floor



Methods of fixing binders with joists

Fig 12.4

- **Framed or triple joist timber floor:**

In this type of floors, intermediate supports, known as girders, are provided for the binders. Thus, this type of floor consists of girders, binders, bridging joists and floor boards as shown in fig 5.5. Girders are generally placed at a centre to centre distance of 3 meters. Binders are staggered and connected to girders by tusk and tendon joints. Alternatively, the ends of binders are supported on the iron stirrups, which are fixed to the girders. The ends of girders rest on

spans greater than 7.50.

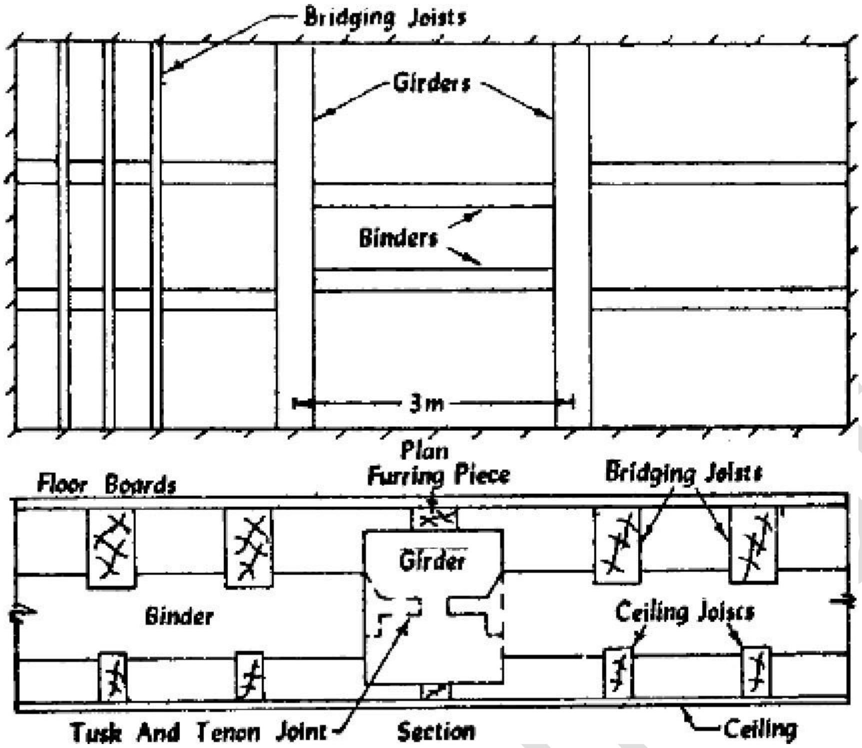


Fig 5.5 Details of framed timber floors

walls on stone or concrete templates. This type of timber floor is suitable for

Composite Floors:-

Floors composed of more than one material are known as composite floors and they found to possess the following advantages.

- **(i)** **Resist fire and sound in better way than timber floors**
- **(ii)** **Better hygienic because can be easily cleaned**
- **(iii)** **Adopted for greater spans.**

The following are the types of composite floors

- **(a)** **Double flag stone floors**
- **(b)** **Filler Joists floors**
- **(c)** **Jack arch floor**
- **(d)** **R.C.C. floors**
- **(e)** **Hallow block and rib floors**

- **Double flagstone floors:**

In this type of floors, flagstones are used in two layers as shown in fig 5.6. If span is about 4m, only rolled steel joists are provided and span exceeds 4m, a framework consists of rolled steel beams and joists is formed. Steel beams are placed at a distance of about 3m centre to centre and joists are placed at right angles to beams. Flagstones of about 40mm thickness and of suitable width are fixed on the lower flanges and upper flanges. The joints of top layer of flagstones are finished in a better way to give a nice appearance. Filling of selected earth or concrete is done in the space between the

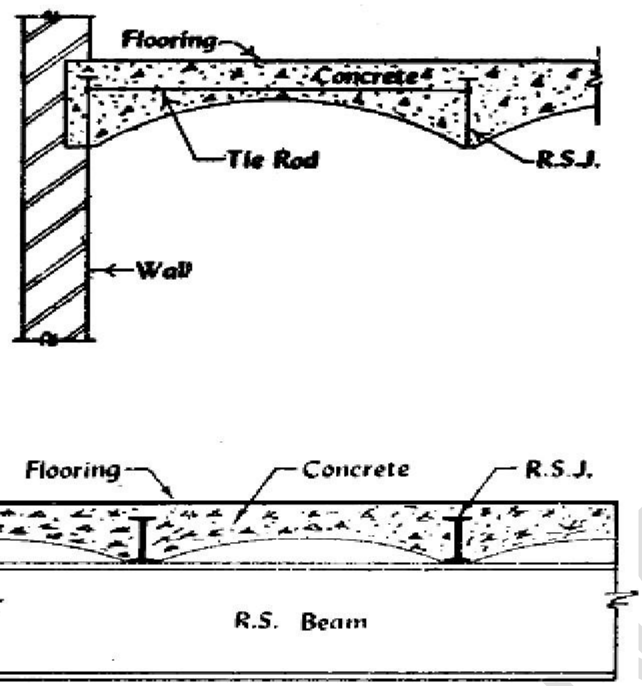


Fig 5.8 (b) Concrete jack floor

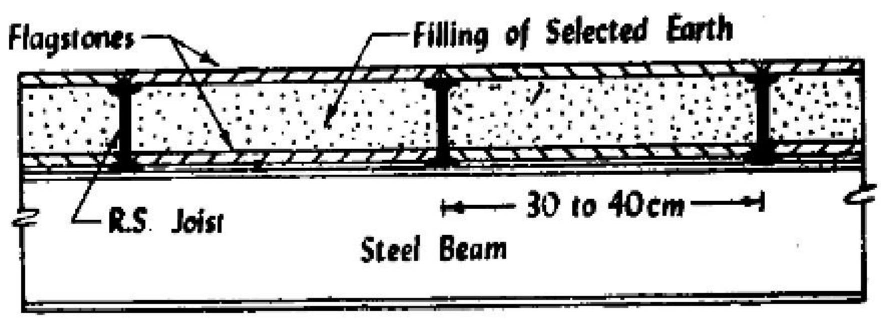


Fig 5.6 Double Flagstone floor

- **Filler Joist floors:**

In this type of floors, small sections of rolled steel joists are placed in concrete, this joists may either rest on wall or on steel beam as shown fig 5.7. The joists act as a reinforced and are spaced at a centre to centre distance of 60cm to 90cm. Concrete should completely surround the rolled steel / joists

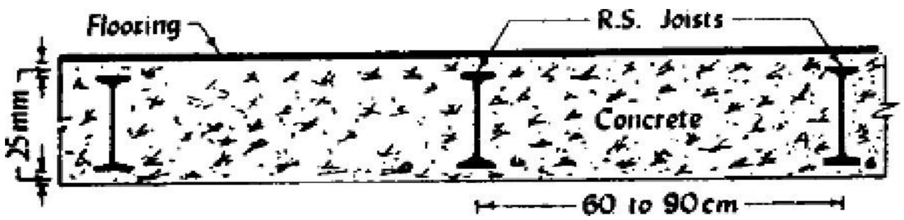


Fig 5.7 Filler Joist Floor

- **Jack arch floors:**

In this type of floor, brick arches or cement concrete arches are constructed and these arches rest on the lower flanges of mild steel joists. The joists in turn rest either on wall or on beam. The joists are placed at a distance of about 80cm to 50cm center to center. The rise of arch should be 10cm to 20cm. and the minimum depth of concrete at the crown should be 15cm. The only disadvantage of this floor is that it does not give plain ceiling surface as shown in the fig 5.8. (a & b)

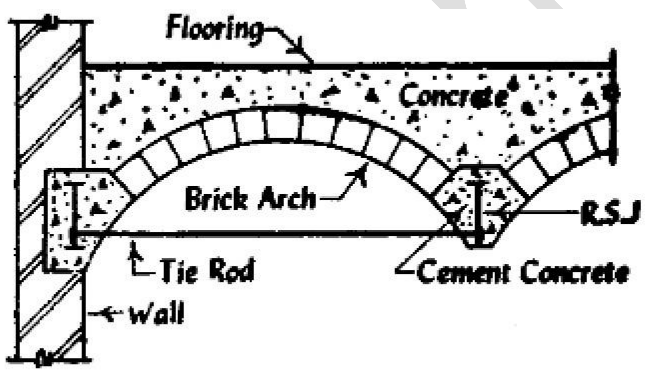


Fig5.8 (a) Brick Jack arch floor

Floor: In this type of floors steel bars and concrete are used to form a floor. This type of floor is widely used in modern construction. The slab and beam are designed as per loading coming on the floor and proper reinforcement is placed at a suitable place. In case of R.C.C. slab thickness varies from 80mm to 150mm and the main reinforcement is generally in the form of mild steel bars of diameter varying from 9mm to 12 mm as shown in fig. The reinforced concrete may be cast-in-situ or pre-cast, the former being very common. R.C.C. floors are less costly, durable, easy to construct and fire-proof. However, they are likely to transmit sound.

In any case R.C.C. floors are fast replacing other types of floors.

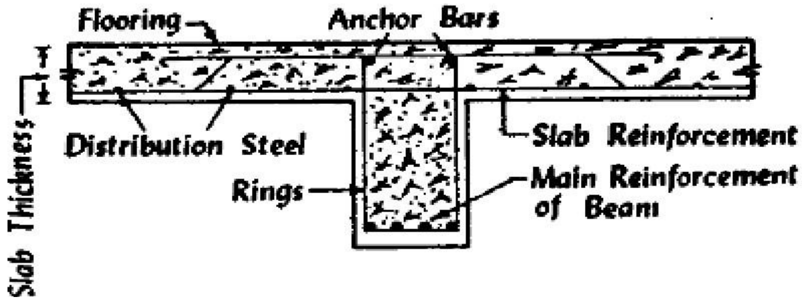


Fig 5.9 R.C.C. Floor

- **Hallow Block and Rib Floors: In this type of floors, hallow blocks of clay or concrete are used to reduce the total weight of the floor. In one form, the blocks are placed 10cm apart and in this space, mild steel bars are placed as shown in the fig 5.10.A minimum cover of 80mm is kept at the top. Suitable flooring at the top and sealing finish are provided. The blocks are provided with rough or grooved surface so that they can develop enough bond with the concrete. This type of floor is economical, fire proof, sound proof and light in weight. If properly designed, this type of floor can even be used to carry heavy loads.**

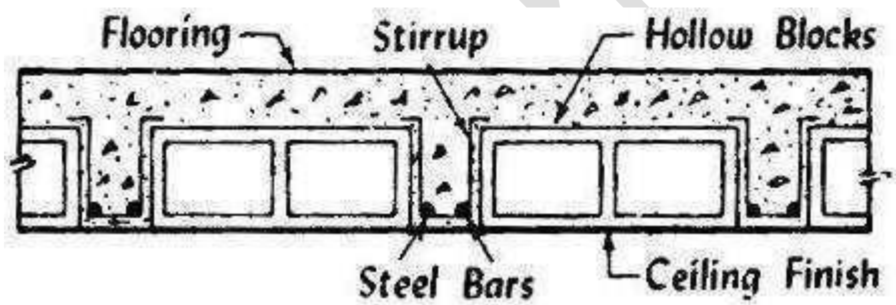


Fig 5.10 Hallow Block and Rib floor

- **ROOFS**

A roof is defined as the uppermost part of a building which is constructed in the form of a frame work to given protection to the building against rain, heat, snow, wind etc. A roof basically consists of structural elements provided at the top of building for the support of roof coverings.
Following are the requirements of well-planned roof:

(i) **It should be durable against the adverse effects of various agencies such as wind, rain, sun etc.**
(ii) **It should grant the desirable insulation against sound and heat.**
(iii) **It should be structurally stable and sound, it should be capable of taking the loads likely to come over it.**
(iv) **It should be well-drained**
(v) **It should have efficient water-proofing arrangement.**

Types of roofs-Methods of construction:
The roofs classified into the following three categories;

(i) **Pitched roofs**
(ii) **Flat roofs**
(iii) **Curved roofs**

- **Pitched roofs: A sloping roof is known as pitched roof as shown in the fig 5.1.1. The technical terms in connection with the pitched roof are given below**

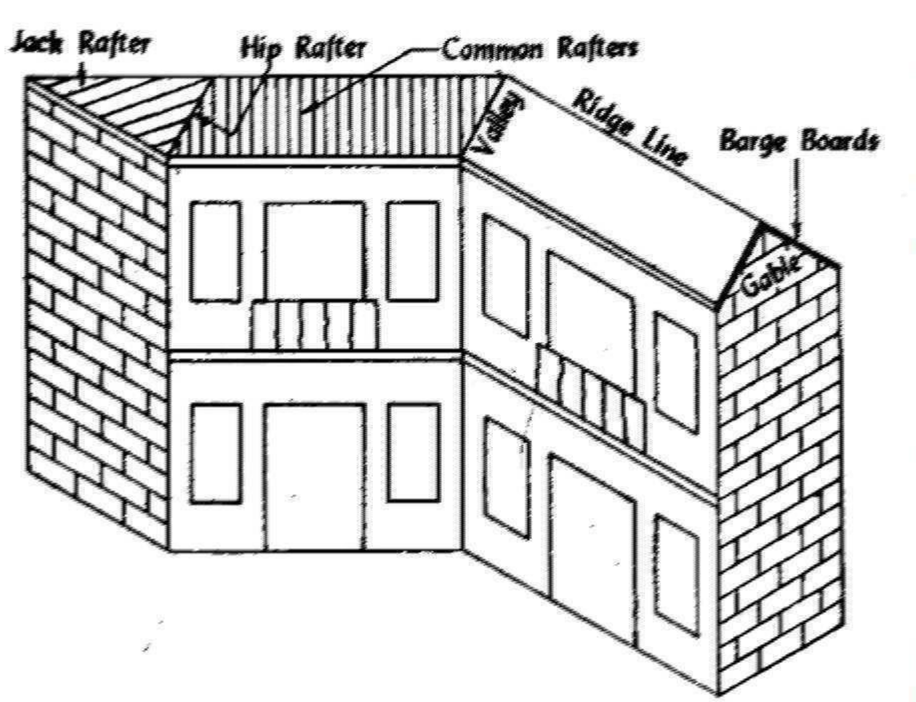


Fig 5.1..1 Building with pitched roof

(i) **Barge Boards: Wooden planks or boards which are fixed on the gable end of the roof**
(ii) **Battens: Thin strips of wood which are fixed on rafters or ceiling to support the roof ceiling.**
(iii) **Cleats: Small blocks of wood which are fixed on truss to prevent the sliding of purlins.**
(iv) **Dragon beam: The diagonal piece of wood which is laid across the corner of the wall.**
(v) **Eaves: The lower edge of a roof which are resting upon or projecting beyond the supporting walls are known as eave as shown in the fig 5.1.2**
(vi) **Gable: The triangular upper part of a wall formed at the end of a pitched roof is known as gable.**
(vii) **Hip: The angle formed at the intersection of two roof slopes is known as hip.**
(viii) **Pitch: The inclination of sides of a roof to the horizontal plane is known as pitch, expressed in degrees or as a ratio of rise to span.**
(ix) **Purlins: The wooden pieces which are placed horizontally on principal rafters to carry the common rafters are known as purlins.**
(x) **Rafters: There are the pieces of timber which extend from the caves to the ridge**
a) **Common rafters: These are the intermediate rafters, which give support to the roof coverings a shown in the fig 5.1.2.**
b) **Hip rafters: Which is provided at the junction of two roof slopes?**
c) **Jack rafters: Any rafters, which is shorter than common rafters, is known as Jack Rafters.**
d) **Principal rafters: These are the inclined members of a truss**
(xi) **Ridge: A wooden piece provided at the ridge line of a sloping roof is known as ridge or ridge board or ridge piece**

(xii) Span: The horizontal distance between the internal faces of walls or supports is known as span or clear span.

(xiii) Template: A bidding block generally provided at the end of a truss. This block is known as template and it helps in spreading load over a large area. A template may be of wood or stone or R.C.C.

(xiv) Verge: The edge of a gable, running between the caves and ridge is known as a verge

(xv) Valley: When two roof surfaces meet together and form an internal angle, a valley is formed

(xvi) Wall-plate: These are long wooden members which are embedded on top of walls to receive the common rafters.

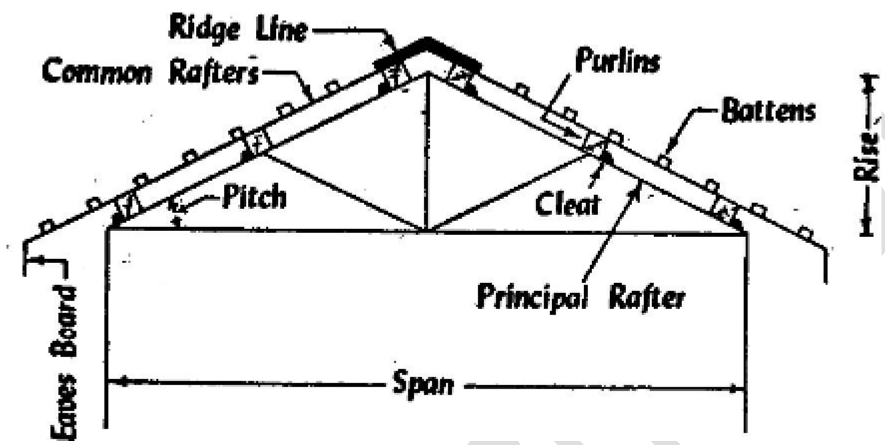


Fig 5.1.2 Truss

Types of pitched roofs:

(i) Single roof
(ii) Double or purlin roof
(iii) Trussed roofs

(i) Single roof: In this type of roofs, common rafters are provided to each slope without any intermediate support. The following are the varieties of single roof.

a) Lean to roof
b) Couple roof
c) Couple close roof
d) Collar beam roof

a) Lean to roof: It is the simplest form of a pitched roof and it is known as pent roof or Aisle roof. In this type of roof, one wall is carried up sufficiently higher than the other to give necessary slope to the roof. A lean-to roof is generally used for sheds, out-houses attached to main buildings verandah etc. This is suitable for a maximum span of 2.40m as shown in fig 5.1.3.

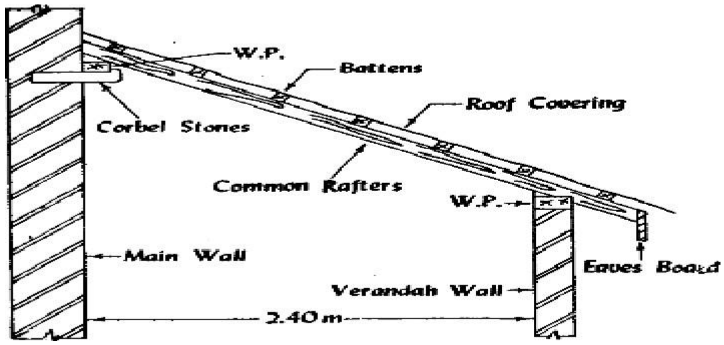


Fig 5.1.3 Lean-to roof

b) **Couple roof: In this type of roof the common rafters slope upwards from the opposite walls and they meet on a ridge piece in the middle as shown in the fig 5.1.4. A couple roof is suitable for span upto 6m.**

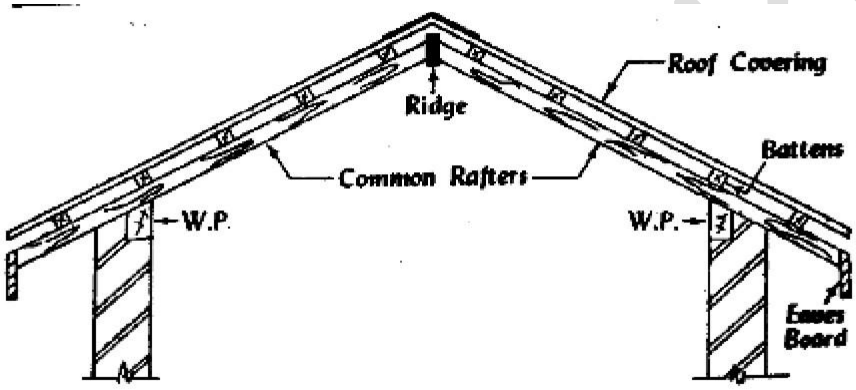


Fig 5.1.4 Couple roof

c) **Couple close roof: This roof is just similar to couple roof except that the legs of the common rafters are connected by a tie beam as shown in the fig 5.1.5. The tie beam prevents the tendency of rafters to spread out and thus danger of overturning of the walls is avoided. This roof can be adopted economically upto the span of 4.2m.**

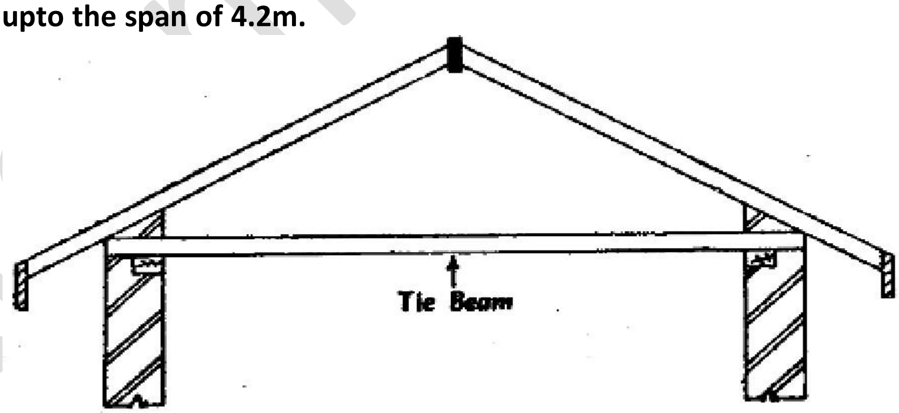


Fig 5.1.5 Couple close roof

d) **Collar beam roof: The tie beam is raised and placed at a higher level as shown in fig 5.1.6 known as collar or collar beam. This beam roof is adapted to economies the space and to increase the height of a room. This roof can be adopted up to a maximum span of 4.8m.**

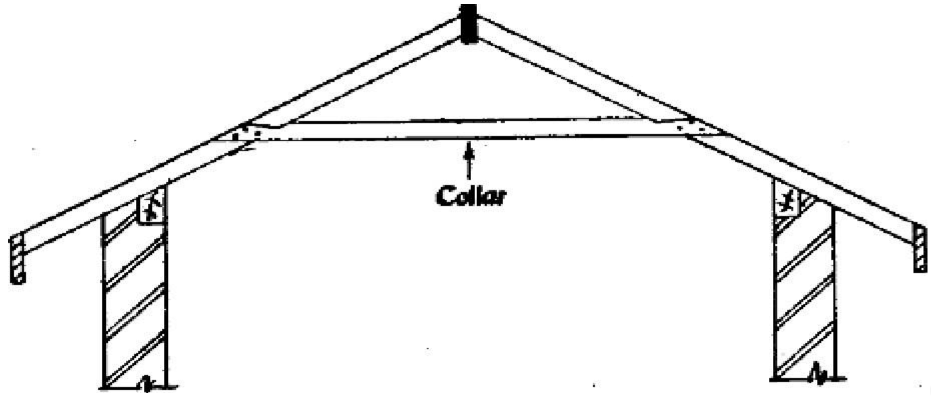


Fig5.1.6 Collar beam roof

e) **Double or purlin roofs:** When the span exceeds 2.4m, the necessary size for the rafters becomes uneconomical. Hence in order to reduce the size of rafters, intermediate supports called purlins are introduced under the rafters as shown in fig 5.1.7. This roof can be adopted economically up to 4.8m.

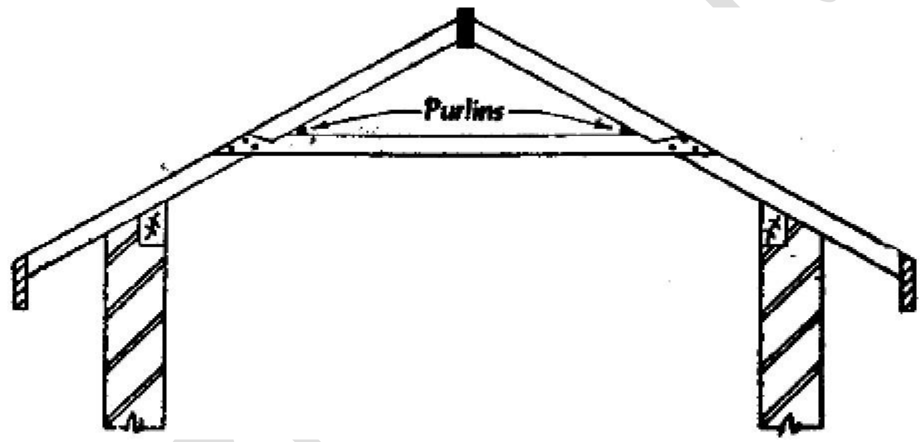


Fig 5.1.7 Double or Purlin roof

f) **Trussed roofs:** When the span exceeds 4.8m and when there are no inside supporting walls or partitions for purlins, framed structure known as trusses are on the roof, position of cross walls, span and material of the truss. The spacing is 3m for wooden trusses. Trusses carry the ridge piece and purlins on which the common rafters rest. Some of the usual forms of roof truss are givenbelow.

a) King-post truss
b) Queen post truss
c) Mansard truss
d) Truncated truss
e) Bel-fast truss
f) Steel trusses
g) Composite trusses

a) **King post truss:** In this type of truss, the central post known as king-post forms support for the tie beam. The inclined member, known as structs, prevents the principal rafters from bending in the middle. A king-post truss suitable for roofs of span varying from 5 to 8 m as shown in fig 5.1.8.

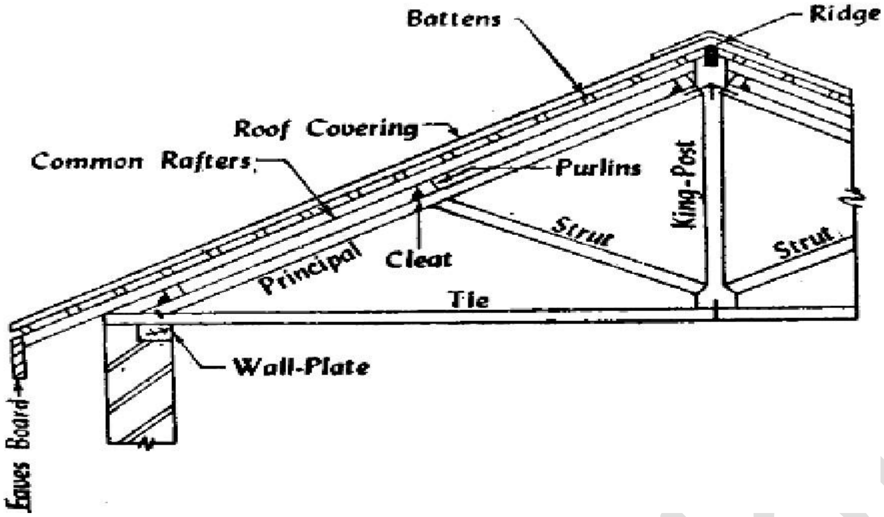


Fig 5.1.8 King post truss roof

b) Queen post truss: This truss is differ from a king-post truss in having two vertical members known as queen posts. The upper ends of the queen posts are kept in position by means of a horizontal member known as straining beam. Additional purlins are supported on the queen posts. A queen post truss is suitable for roof spans varying 8 to 5 m as shown in fig 5.1.9.

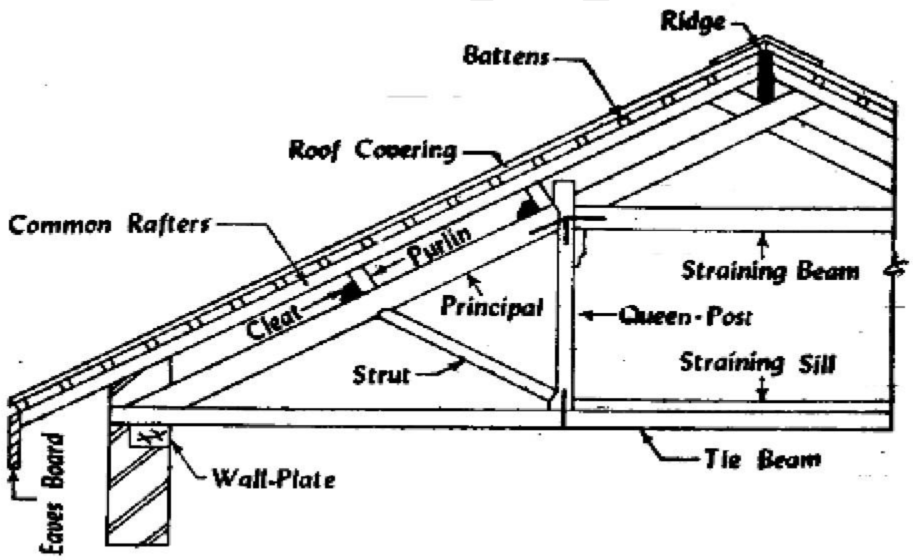


fig 5.1.9 Queen post truss

c) Mansard truss: this is a combination of king post and queen post trusses. Lower queen post & upper king post trusses. Use of mansard trusses results in the economy of space and room may be provided in the room.

d) Steel trusses: For spans greater 5m, it becomes economical to use steel trusses. For smaller spans, steel trusses consist of angles riveted or welded together through plates known as gusset plates. As steel resists both compression and tension stresses, the design of steel truss is simplified various types of steel trusses are shown in fig 5.1.10.

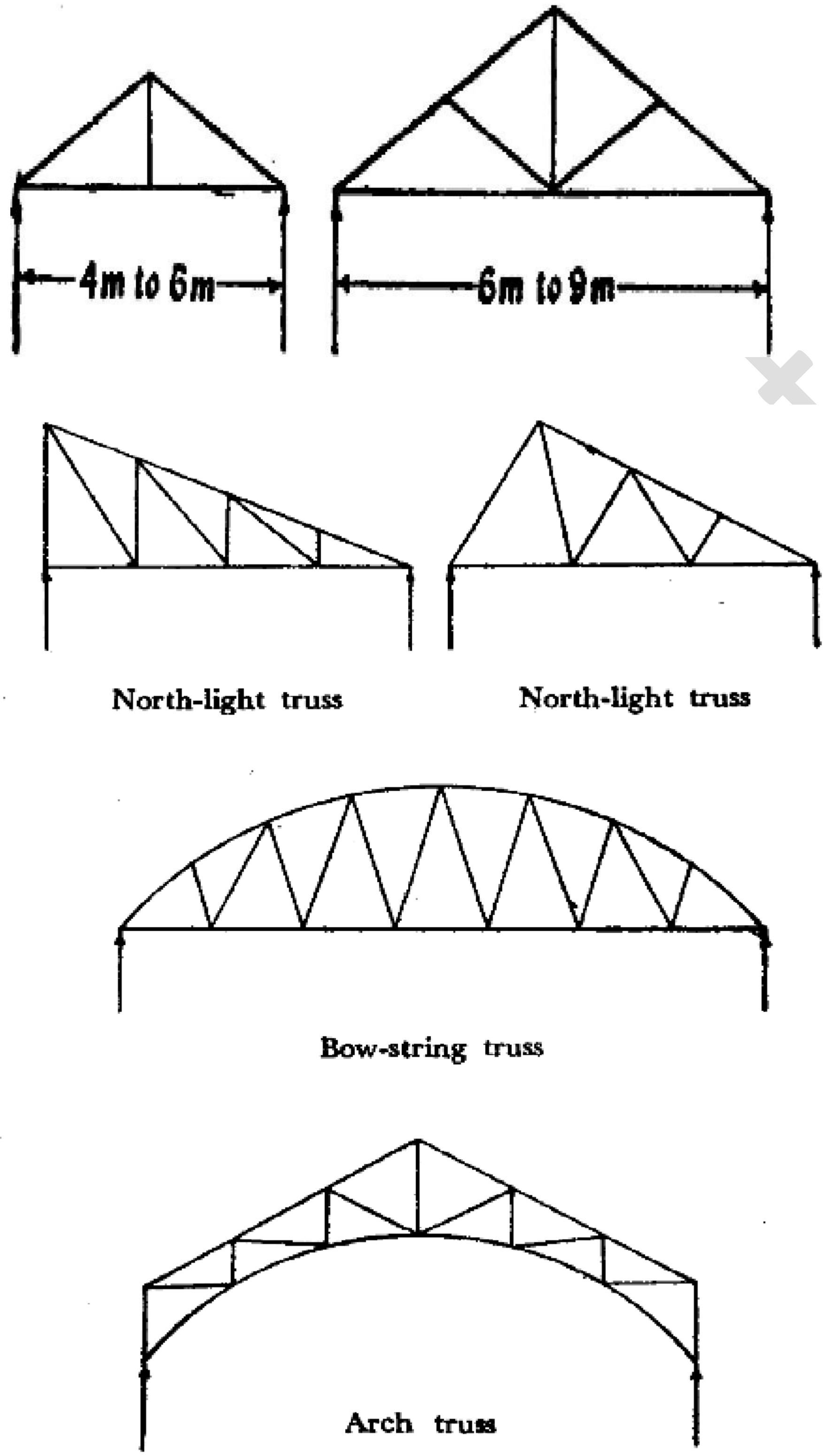


Fig 5.1.11 Steel trusses

e) **Composite stress: This truss composed of wooden members and steel. Steel members resist tension. A composite truss is light and economical as shown in the fig 5.1.12.**

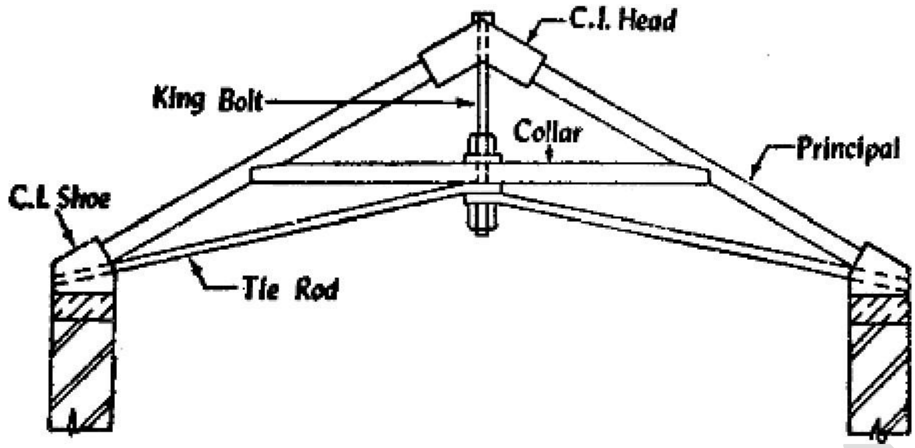


Fig 5.1.12 Composite stress

The factors should be considered before selecting the type of roof covering for pitched roof

- **Climate of the locality**
- **Nature of the building**
- **Initial cost and maintenance cost**
- **Resistance to fire and heat**
- **Special features of the locality**

Flat Roofs

A roof which is nearly flat is known as flat roof. It should be noted that no roof can be laid perfectly level. The roof must slope in one direction or the other to cause rain water to flow off rapidly and easily. The construction of flat roof is same as that of floors except that the top surface is made slightly.

Sloping in case of flat roofs the types of flat roofs commonly used are

1. **Madras terrace roof**
2. **Bengal terrace roof**

1. Madras Terrace Roof:

Procedure of construction:

1. **Teak wood joists are placed on rolled steel joists with a furring piece between the joists and rolled steel joists. The furring is placed sloping and gives necessary slope to the flat roof**
2. **A course of specially prepared terrace bricks of 150x75x25mm is laid diagonally across the joists with lime mortar**
3. **After the brick course, has set, a course of brick bat concrete of 75mm thick with 3 parts of brick bats, one part of gravel and sand and 50 percent of lime mortar by volume is laid.**
4. **The concrete is well rammed for three days and allowed to set**
5. **Flat tiles are laid over the layer of concrete of thickness 50mm**
6. **Finally, the surface of roof is finished with three coats of plaster given a slope of 1 in 30.**
7. **As this type of flat roof is widely used in madras state, it is known as madras terrace roof as shown in fig 5.1.13.**

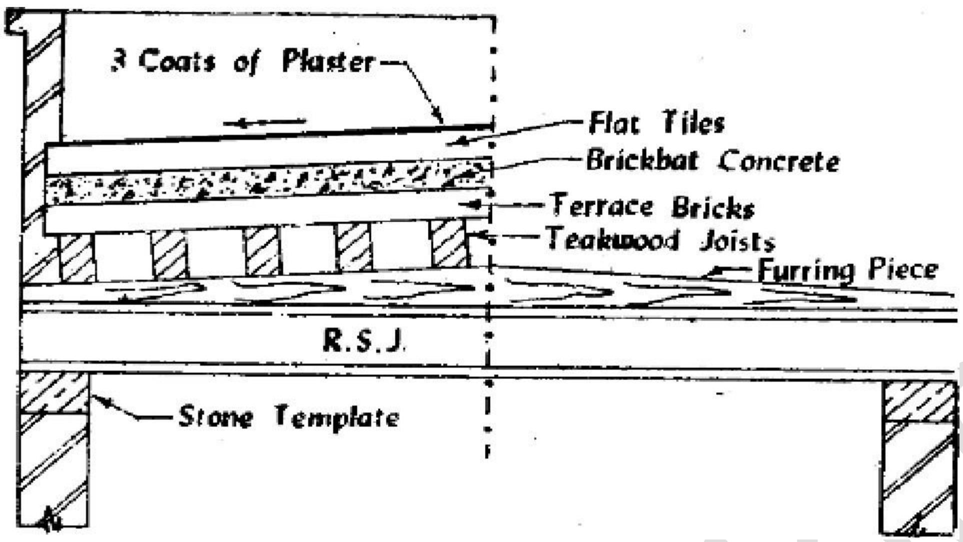


Fig 5.1.13 Madras Terrace Roof

2. **Bengal terrace roof:**

Procedure of construction:

1. **Rafters are placed, with a slight inclination, at 30cm to 50cm c/c. one end of the rafters is inserted into the main wall to a depth of 20cm and its other end is supported on a verandah wall.**
2. **Battens are placed at right angles to the rafters at a centre to centre distance of about 15cm**
3. **A course of flat tiles is then laid in mortar over the battens.**
4. **Finally, the surface of the roof is finished in any one of the following methods**

(i) **Two or more courses of flat tiles may be laid and the surface of roof is rubbed and polished with two or three coats of plaster**

(ii) **A layer of jelly concrete of 40mm thick may be laid over the first course of files. On this layer of concrete, another course of flat tiles is laid and the surface of roof is rubbed and polished with two or three coats of plaster**

5. As this type of roof is mainly used in Bengal state to cover verandahs, it is known as Bengal Terrace roof as shown in fig 13.15

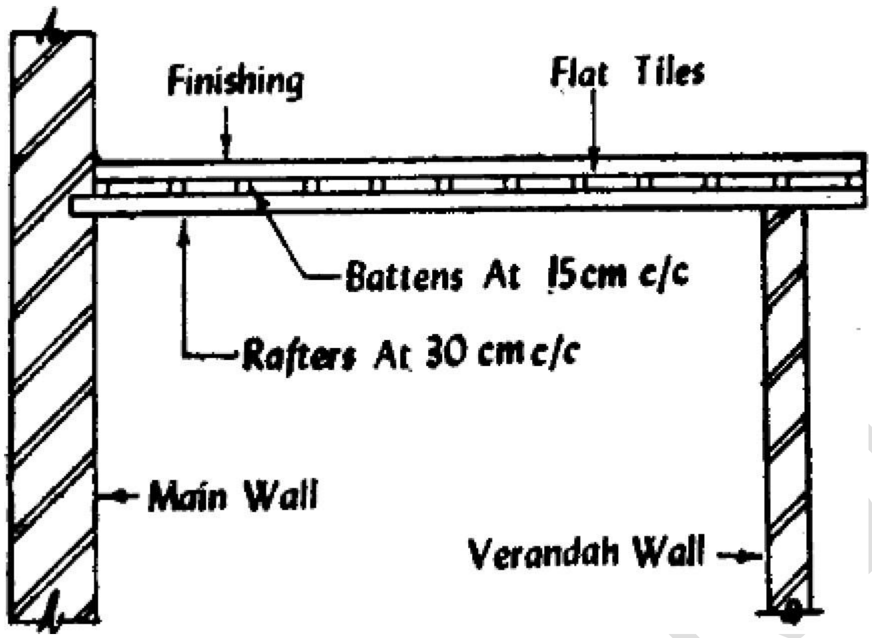


Fig 5.1.14 Bengal Terrace roof

Advantages of flat roofs:

- (i) The construction of roof is simplified
- (ii) It is easier to make a flat roof fire-proof than a sloping roof
- (iii) The roof are can be utilized as roof garden, drying yards and conveniently be used for sleeping in hot season.
- (iv) The construction of work of upper floors can be easily started where as pitched roof, the entire roof is to removed and is to be replaced by a new floor under such circumstances
- (v) Flat roofs is found to be economical than pitched roof.

Disadvantages

1) Flat roofs cannot be used for long spans without introduction of intermediate pillars and beams
2) Cracks are developed on the surface of the roof due to the variation in temperature
3) Pockets of water are formed on the surface of the roof if slope is not sufficient and leads to leakage of roof
4) Flat roofs are not suitable, where rainfall is heavy
5) The dead weight of flat roof is considered and hence it proves to be more expensive, Initial cost is higher than pitched roof.

Curved roofs

These are the just the modifications of pitched roofs and are frequently employed in modern age to cover large areas shed/roofs and domes are the varieties of curved roofs. They are useful for big structures such as factories, monumental works etc curved roofs may be constructed of timber or R.C.C. the latter material being very common now-a-days. They are two common forms of a shell roof

i) A north-light shell roof ii) A barrel vault shell roof are as shown in fig

13.1 & 13.17

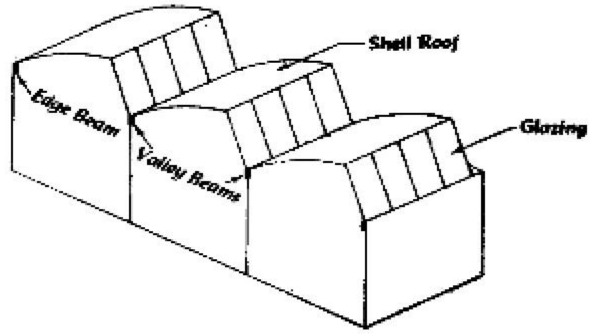


Fig 5.1.15 North-light shell

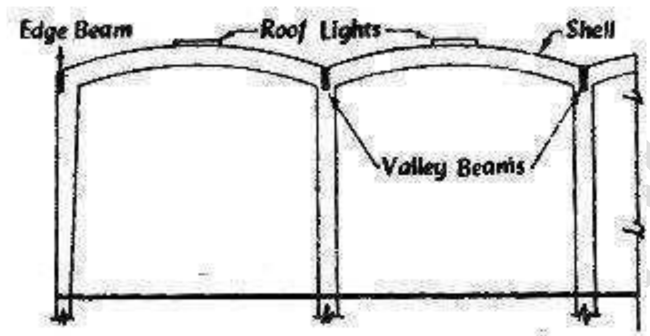


Fig 5.1.16 Barrel vault shell roof

A dome is a round vault forming a roof. It is useful when roof is to be provided on circular brick work or regular polygon shaped walls.
Curved roofs afford pleasing appearance and due to arch action, the stresses are considerably reduced which results in thin sections for a curved roof.

Procedure of construction

- **(i)** **Pre-cast units of cement concrete tills of size 70 x 70cm with a uniform minimum thickness of 20mm in the form of domes with a rise of about 50mm are used**
- **(ii)** **Pre-cast units of R.C.C. 1:2:4 beams are prepared as per design usually 90mm deep and 5.10mm wide as per design usually 90mm deep and 5.10mm wide**
- **(iii)** **The beams are suitably laid across the supporting walls**
- **(iv)** **The tiles are placed in position after spreading some mortar on the edges of beams. The minimum bearing of tiles on beams should be 25mm and that on walls should be 50mm to 70mm**
- **(v)** **The haunches between the humps of tiles are filled up with cement concrete of proportion 1:2:4**
- **(vi)** **Suitable water-proofing treatment to the roof is given at the top. The roof thus exhibits a flat surface at the top and curved surface at bottom.**

Advantages

1. **It can be constructed in short time**
2. **It does not require skilled supervision**
3. **It is cheap in construction**
4. **It requires less frame work**

A roof is defined as uppermost part of a building which is constructed in the form of a frame work to give protection to the building against rain, heat, snow, wind etc

1. A well planed roof requires following requirements
    - Durable against adverse effects
    - Insulation against sound and heat
    - Stable
    - Well drained
    - Efficient water-proofing
2. The types of roofs are
    - Pitched roofs
    - Flat roofs
    - Curved roofs
3. A sloping roof is known as pitched roof are the following types
    - Single roof
    - Double or purlin roof
    - Trussed roof
4. Single roof common rafters are provided to each slope without any intermediate support is the following types.
    - Lean to roof
    - Couple roof
    - Couple close roof
    - Collar beam roof
5. When the span exceeds 2.4m, intermediate supports called purlins are provided in double or purlin roof up to 4.8m.
6. When the span exceeds 4.8m and when there are no inside supporting walls or partitions for purlins, framed structure known as truss of following types
    - King post truss
    - Queen post truss
    - Truncated truss
    - Be-fast truss
    - Steel truss
    - Composite truss
7. A roof which is nearly flat is known as flat roof commonly used flat roofs are
    - Madras terrace roof
    - Bengal terrace roof
8. Curved roof are the just modified of pitched roofs to cover large areas.

- Building services

Building services are the systems installed in buildings to make them comfortable, functional, efficient and safe.

Building services might include:

- Building control systems.
- Energy distribution.
- Energy supply (gas, electricity and renewable sources such as solar, wind, geothermal and biomass).
- Escalators and lifts.
- Facade engineering (such as building shading requirements).
- Fire safety, detection and protection.

- **Heating, ventilation and air conditioning (HVAC).**
- **Information and communications technology (ICT) networks.**
- **Lighting (natural and artificial).**
- **Lightning protection.**
- **Refrigeration.**
- **Security and alarm systems.**
- **Water, drainage and plumbing (including sustainable urban drainage systems (SUDS)).**

Specialist building services might also include systems for bacteria and humidity control, specialist lighting and security, emergency power, specialist gas distribution, fume cupboards, operating theatres and so on.

Building services play a central role in contributing to the design of a building, not only in terms of overall strategies and standards to be achieved, but also in façade engineering, the weights, sizes and location of major plant and equipment, the position of vertical service risers, routes for the distribution of horizontal services, drainage, energy sources, sustainability, and so on.

This means that building services design must be integrated into the overall building design from a very early stage, particularly on complex building projects such as hospitals. Whilst it is usual for a building design team to be led by an architect, on buildings with very complex building services requirements a building services engineer might be appointed as the lead designer.

The detection of clashes between building services and other building components is a significant cause of delays and variations on site, not just in terms of the physical services themselves, but also access to allow the builders work in connection with those services. The use of 3D computer aided design (CAD) systems and building information modeling (BIM) should help reduce the occurrence of such problems.

Increasingly, building services engineers are central to the design and assessment of sustainable systems, assessing the life cycle of buildings and their component services to minimize the resources consumed and the impact on the environment during fabrication, construction, operation and dismantling.

According to the Chartered Institute of Building Services Engineers (CIBSE):

'In any new construction project, building services typically account for 30-40% of the total cost.' (Ref. CIBSE fact sheet) and buildings account for almost 50% of carbon emissions (Ref. CIBSE).

As a consequence, many aspects of building services design are regulated (the building regulations, the energy related products regulations, and so on), and clients may impose their own standards on top of these regulations or seek certification under schemes such the Building Research Establishment's (BRE) Environmental Assessment Method (BREEAM).

Ensuring that building services meet the standards set can involve the use of sophisticated simulation tools to predict the likely performance of buildings during the design stages (including the assessment and comparison of different options), as well as monitoring actual performance in use.

However, clients and designers are becoming increasingly aware of a disparity between the predicted and actual performance of buildings, with many buildings using considerably more energy than had been expected (up to 5 times as much according to the Carbon Trust's Low Carbon Buildings Accelerator and the Low Carbon Buildings Programme).

This may be as a result of the following:

A lack of proper understanding of building design and the interaction between components

- **Poor prediction tools.**
- **Inadequate detailing.**
- **Discrepancies between specifications and actual construction.**
- **Poor build quality.**
- **The use of idealized performance data for products.**

- **Improper user behavior or operation.**

Unexpected power loads (such as additional ICT equipment, external lighting, and so on).
The collection of more data to feedback information about performance in use will be necessary to rectify this problem.
NB: Building services will have to be upgraded and equipment replaced a number of times in the life of most buildings, building services engineers should consider this throughout design development as well as ease of maintenance and running costs.
Water supply and Drainage Systems in Buildings
Home » Building Technology » Types of Plumbing and Drainage Systems in Buildings
Plumbing system is used for water supply in building .It supplies water to kitchen toilet outlets via distribution system of pipes. Drainage system is used to get rid of human wastes through well-arranged network of drainage pipes.

For distribution system pipes generally used are GI, copper, HDPE, CPVC, mostly now a days CPVC plastic pipes are used as they don't get rusted, light weight, easy installation and maintenance and economic.
Types of Plumbing Systems in Buildings
Plumbing system in buildings consists of underground tank which is supplied water via municipal or water department supply lines, from there with the help of pumps and piping distribution system water is supplied to overhead tank and thereby due to gravity water reaches to home outlets.
The overhead tank can however be eliminated if water is supplied directly from underground tank to kitchen toilet outlets, there comes the need of pumps which can give uninterrupted supply of water with required pressure to outlets so that when one opens the tap he gets continuous supply of water. Such pumps are called hydro-pneumatic system.
Such pumps consists of small steel tank with water on one side and air on another separated by a rubber membrane .As the pump starts it supplies water to the wet side thus causing rubber membrane to expand and air compresses on other side thus causing extra pressure on wet side which is connected to water supply line. So as one opens the tap , gets the required quantity of water. This causes the pressure to drop and the pump is automatically switched on again thereby maintaining the pressure of water and at same time supplying the water to outlets.

The advantage of such plumbing system in buildings is that requirement of overhead tanks is eliminated. Secondly these pumps are designed to get the required equal pressure to all floors, unlike in traditional way water flows from underground tanks to overhead tanks and the upper floors gets water with less pressure and lower& ground floor gets high pressure due to gravity and more height.
This gives energy conservation also because it eliminates the need of supply of water ten or twenty floors to overhead tank and then supply by gravity to all floors.
1. Waste water is from showers, basins, kitchen sinks, washing machines, and the like this is also called grey water. Normally a minimum of 75 mm dia. pipes are used for drainage of waste water.
2. Soil water or sewage is from WCs and urinals. This is also called black water. Minimum of 100 mm diameter pipes are used for waste water. When run horizontally, soil water pipes should be run at a steeper slope, such as 1:40, as they have solids. These can be of cast iron or of PVC.

A grease trap should be used when draining waste from kitchens, grease should not be allowed to enter the normal drainage system. A grease trap is nothing but a small inspection chamber. The grease floats, and should be removed manually on a daily basis. The inlets and outlets into this chamber should be designed in a way that minimizes disturbance of the floating grease layer.

Stone ware (ceramic) pipes are used when soil and waste water is to be transported in external soil. An inspection chamber is used to clean blockage in the line and change direction of pipes. Inspection chamber is a short version of manholes which are used on the streets.

If municipal government drainage is not available on a small project, or exterior of city, provide a septic tank and a soak pit. A septic tank is a rectangular underground tank with compartments. It is always full of sewage that can be removed manually. The less water put into a septic tank, the better it will function. The effluent that flows out of this, which is about 70% purified, is then put into a soak pit. A soak pit is a cylindrical tank with porous brick walls surrounded by a layer of gravel.

A soak pit should not be placed near any occupied structure, water body, or water supply pipe. It also cannot be used where the water table is high, as groundwater will then enter and flood the pit through the porous walls.

An overall view of complete sewage treatment of a complete city

A sewage treatment plant is recommended for the disposal of large amounts of sewage. This is a plant that will process sewage and produce sludge and (relatively) clean water from it. This water may then be used for landscaping, or even perhaps for HVAC cooling towers – not for drinking or washing.

Unit V

Construction of Earthquake Resistant Building: - Planning of earthquake resistant building, Construction of walls – provision of corner reinforcement, construction of beams and columns, Base isolation.

- **Introduction: - the fabrication of a building or structure that is able to withstand the sudden ground shaking that is characteristic of earthquakes, thereby minimizing structural damage and human deaths and injuries. Suitable construction methods are required to ensure that proper design objectives for earthquake-resistance are met. Construction methods can vary dramatically throughout the world, so one must be aware of local construction methods and resource availability before concluding whether a particular earthquake-resistant design will be practical and realistic for the region.**

There is a fundamental distinction between the design of a building and the construction methods used to fabricate that building. Advanced designs intended to withstand earthquakes are effective only if proper construction methods are used in the site selection, foundation, structural members, and connection joints. Earthquake-resistant designs typically incorporate ductility (the ability of a building to bend, sway, and deform without collapsing) within the structure and its structural members. A ductile building is able to bend and flex when exposed to the horizontal or vertical shear forces of an earthquake. Concrete buildings, which are normally brittle (relatively easy to break), can be made ductile by adding steel reinforcement. In buildings constructed with steel-reinforced concrete, both the steel and the concrete must be precisely manufactured to achieve the desired ductile behavior.

Building failures during earthquakes often are due to poor construction methods or inadequate materials. In less-developed countries, concrete often is not properly mixed, consolidated, or cured to achieve its intended compressive strength, so buildings are thus extremely susceptible to failure under seismic loading. This problem is often made worse by a lack of local building codes or an absence of inspection and quality control.

- **Planning of earthquake resistant building**

i. **Symmetry: The building as a whole or its various blocks should be kept symmetrical about both the axes. Asymmetry leads to torsion during earthquakes and is dangerous; Symmetry is also desirable in the placing and sizing of door and window openings, as far as possible.**

ii. **Regularity: Simple rectangular shapes, behave better in an earthquake than shapes with Tensional effects of ground motion are pronounced in long narrow rectangular blocks. Therefore, it is desirable to restrict the length of a block to three times its width. If longer lengths are required two separate blocks with sufficient separation in between should be provided.**

iii. **Separation of Blocks: Separation of a large building into several blocks may be required so as to obtain symmetry and regularity of each block. For preventing hammering or pounding damage between blocks a physical separation of 3 to 4 cm throughout the height above the plinth level will be adequate as well as practical for up to 3 storied buildings. The separation section can be treated just like expansion joint or it may be filled or covered with a weak material which would easily crush and crumble during earthquake shaking. Such separation may be considered in larger buildings since it may not be convenient in small buildings.**

iv. Simplicity: Ornamentation invo1ving large cornices, vertical or horizontal cantilever projections, facia stones and the like are dangerous and undesirable from a seismic viewpoint. Simplicity is the best approach. Where ornamentation is insisted upon, it must be reinforced with steel, which should be properly embedded or tied into the main structure of the building. Note: If designed, a seismic coefficient about 5 times the coefficient used for designing the main structure should be used for cantilever ornamentation.

v. Enclosed Area: A small building enclosure with properly interconnected walls acts like a rigid box since the earthquake strength which long walls derive from transverse walls increases as their length decreases. Therefore structurally it will be advisable to have separately enclosed rooms rather than one long room. For unframed walls of thickness t and wall spacing of a, a ratio of $a/t = 40$ should be the upper limit between the cross walls for mortars of cement sand 1:6 or richer, and less for poor mortars. For larger panels or thinner walls, framing elements should be introduced.

vi. Separate Buildings for Different Functions: In view of the difference in importance of hospitals, schools, assembly halls, residences, communication and security buildings, etc., it may be economical to plan separate blocks for different functions so as to affect economy in strengthening costs.

- **Construction of walls – provision of corner reinforcement**

Earthquake resistant design is inadequate to prevent collapse of masonry buildings due to out-of-plane failure of walls. Two important aspects of any earthquake resistant feature are ductility and integral connectivity of the various structural components of the building. It is rather easy to derive both these in the case of reinforced concrete framed structures than in load bearing masonry buildings.

Unreinforced brick masonry, generally has poor flexural strength and practically no ductility in flexure. The masonry wall behaves like a plate in two-dimensional bending, when subjected to lateral load during earthquakes. Hence there is a need to reinforce the wall in both horizontal and vertical directions to impart ductility to the wall. It is rather easy to introduce reinforcement and embed it in a thin layer of concrete in the horizontal direction through the bed joints of the masonry, which results in horizontal bands at various levels. These R.C. bands also integrally connect the various walls of the building together. The provision of vertical reinforcement poses certain difficulties. The conventional approach is to provide reinforcement in the middle of the wall enclosed by concrete. This will be inefficient since half of the wall thickness will be ineffective during the bending of the wall and the ductility of the wall will be limited to compressive strain capacity of the masonry. Further, the interface between the concrete enclosing the vertical steel and the masonry will create a vertical joint which is contrary to the concept of masonry construction. Such an interface between two materials having significantly different elastic properties will facilitate formation of vertical cracks. In order to overcome the above difficulties a new and an innovative way of providing vertical reinforcement on the surface of masonry wall has been developed which is called as “containment reinforcement”.

In this technique the steel rod is wrapped around the wall in the vertical direction with reinforcement anchored at the top and bottom to the roof and plinth R.C. bands. Further the rods on either faces of the wall are held together at intermittent levels by steel ties/links passing through the bed joints of the masonry. The links are necessary to prevent the buckling of the steel rod present on the compression side of the wall. For the containment reinforcement to be effective, it is essential for it to remain hugged to the wall at all times during an earthquake.

- Construction of beams and columns

Beam-column joint is an important component of a reinforced concrete moment resisting frame and should be designed and detailed properly, especially when the frame is subjected to earthquake loading. Failure of beam-column joints during earthquakes is governed by bond and shear failure mechanism which are brittle in nature1. Therefore, current international codes give high importance to provide adequate anchorage to longitudinal bars and confinement of core concrete in resisting shear2.

Since joints are subjected to large shear force during earthquake, shear strength in this region should be adequate to carry this large amount of shear force. Therefore, the current code needs to be upgraded to incorporate shear design provisions of beam-column joints. Moreover, under cyclic lateral loading, The overhead tank can however be eliminated if water is supplied directly from underground tank to kitchen toilet outlets, there comes the need of pumps which can give uninterrupted supply of water with required pressure to outlets so that when one opens the tap he gets continuous supply of water. Such pumps are called hydro-pneumatic system.

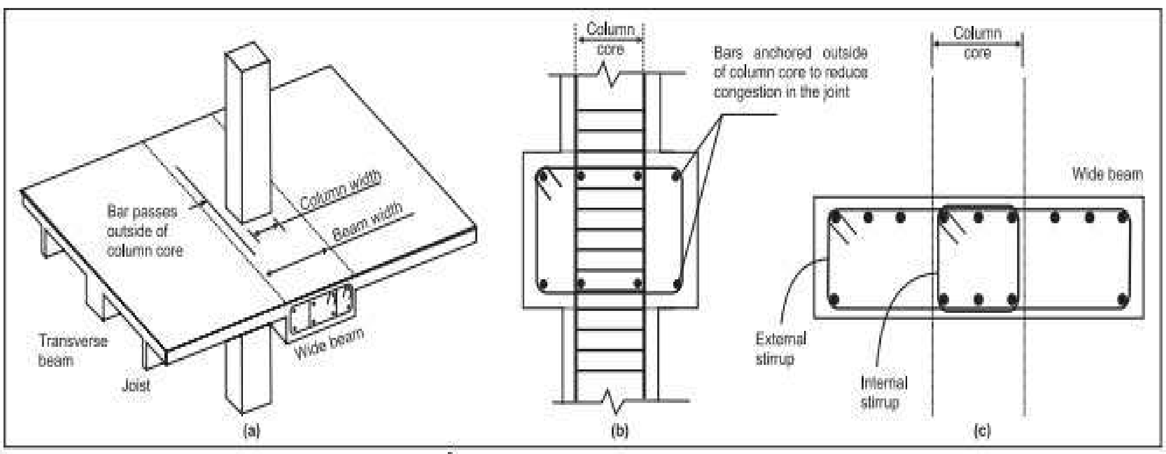


Fig 2 Connection between wide beam and column[8]

Such pumps consists of small steel tank with water on one side and air on another separated by a rubber membrane .As the pump starts it supplies water to the wet side thus causing rubber membrane to expand and air compresses on other side thus causing extra pressure on wet side which is connected to water supply line. So as one opens the tap , gets the required quantity of water. This causes the pressure to drop and the pump is automatically switched on again thereby maintaining the pressure of water and at same time supplying the water to outlets.

For an interior joint this anchorage length can only be provided through adequate column width and depth. Therefore, the code must have a provision for minimum dimension of column. The current code should also include confinement provisions on connection between columns and wide-beams, which are often found in one-way concrete joist systems and in buildings where floor-to-ceiling heights are restricted.

- **Base Isolation**

Base isolation, also known as seismic base isolation or base isolation system, is one of the most popular means of protecting a structure against earthquake forces. It is a collection of structural elements which should substantially decouple a superstructure from its substructure resting on a shaking ground thus protecting a building or non-building structure's integrity.

Base isolation is one of the most powerful tools of earthquake engineering pertaining to the passive structural vibration control technologies. It is meant to enable a building or non-building structure to survive a potentially devastating seismic impact through a proper initial design or subsequent modifications. In some cases, application of base isolation can raise both a structure's seismic performance and its seismic sustainability considerably. Contrary to popular belief base isolation does not make a building earthquake proof.

Base isolation system consists of isolation units with or without isolation components, where:

1. **Isolation units are the basic elements of a base isolation system which are intended to provide the aforementioned decoupling effect to a building or non-building structure.**
2. **Isolation components are the connections between isolation units and their parts having no decoupling effect of their own.**

- **Isolation units could consist of shear or sliding units.**
- **This technology can be used for both new structural design and seismic retrofit. In process of seismic retrofit, some of the most prominent U.S. monuments, e.g. Pasadena City Hall, San Francisco City Hall, Salt Lake City and County Building or LA City Hall were mounted on base isolation systems. It required creating rigidity diaphragms and moats around the buildings, as well as making provisions against overturning and P-Delta Effect.**

- **Base isolation is also used on a smaller scale—sometimes down to a single room in a building. Isolated raised-floor systems are used to safeguard essential equipment against earthquakes. The technique has been incorporated to protect statues and other works of art—see, for instance, Rodin's Gates of Hell at the National Museum of Western Art in Tokyo's Ueno Park.**

- **Base isolation is one of the most widely accepted seismic protection systems in earthquake prone areas.**

Seismic isolation is a design strategy, which uncouples the structure for the damaging effects of the ground motion.