UNIT – IV

FOUNDATIONS

4.1. Function of foundations

The foundations are provided for the following purposes:

(1) to distribute the total load coming on the structure on a larger area so as to bring down the intensity of load at its base below the safe bearing capacity of sub-soil;
(2) to support the structures,
(3) to give enough lateral stability to the structures against various disturbing horizontal forces such as wind, rain, earthquake, etc.,
(4) to prepare a level and hard surface for concreting and masonry work
(5) to transmit the super-imposed loads through side friction and end bearing in case of deep foundations;
(6) to distribute the non-uniform load of the superstructure evenly to the sub-soil;
(7) to provide the structural safety against undermining or scouring due to animals, flood water, etc.
(8) to prevent or minimize cracks due to movement of moisture in case of weak or poor soils; etc.

4.2. Essential requirements of good foundations

Following are the three basic requirements to be fulfilled by a foundation to be satisfactory:

(1) Location: The foundation structure should be so located that it is able to resist any unexpected future influence which may adversely affect its performance. This aspect requires careful engineering judgement.
(2) Stability: The foundation structure should be stable or safe against any possible failure. The foundation base should be rigid enough to bring down the differential settlements to a minimum extent specially when the superimposed loads are unevenly distributed.
(3) Settlement: The foundation structure should not settle or deflect to such an extent so as to impair its usefulness or the stability of building or the adjoining structures. It is however difficult to define the objectionable amount of settlement or deflection.

4.3. Shallow foundations

If it is possible to construct foundations of a building at reasonable shallow depth, the foundations are termed as the shallow foundations. In such cases, a spread is given under the base of a wall or a column. This spread is known as the footing and the foundation is known as the spread footing. Typical sketches of spread foundations for a masonry wall, a masonry pier and an R.C.C. pier are shown in the fig below.

1. **Wall footing:** A **wall footing** or strip **footing** is a continuous strip of concrete that serves to spread the weight of a load-bearing **wall** across an area of soil. It is the component of a shallow foundation.
2. **Isolated column footing:** A footing that transmits a load from columns to the supporting soil. If the soil is weak or the column loads heavy, isolated spread footings must be larger.

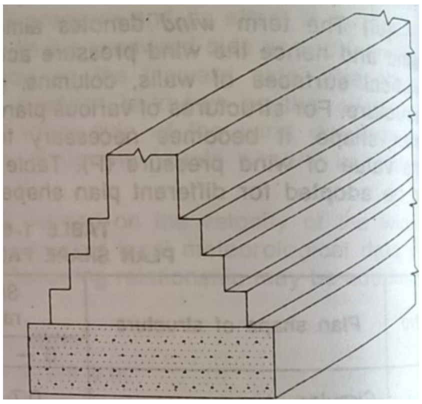


Fig. 4.1. Wall footing

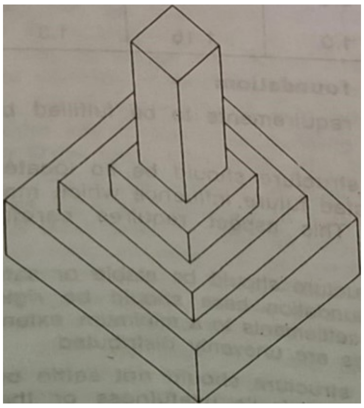


Fig. 4.2. Masonry pier footing

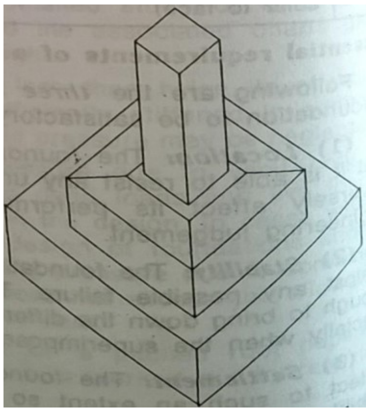


Fig. 4.3. R.C.C. pier footing

3. Combined footing:

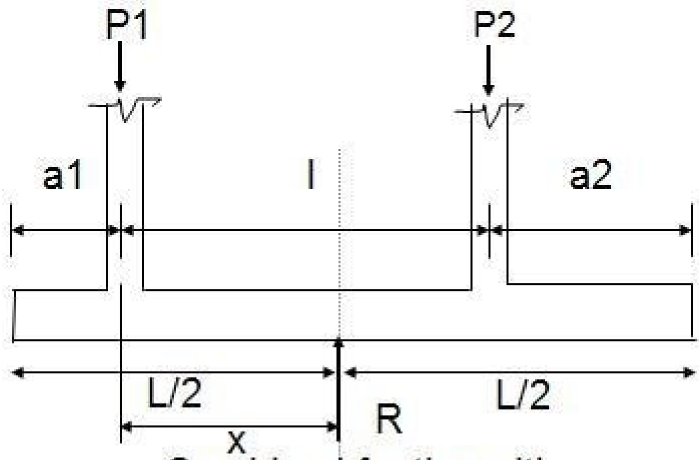
The function of a footing or a foundation is to transmit the load form the structure to the underlying soil. The choice of suitable type of footing depends on the depth at which the bearing strata lies, the soil condition and the type of superstructure.

Combined footing

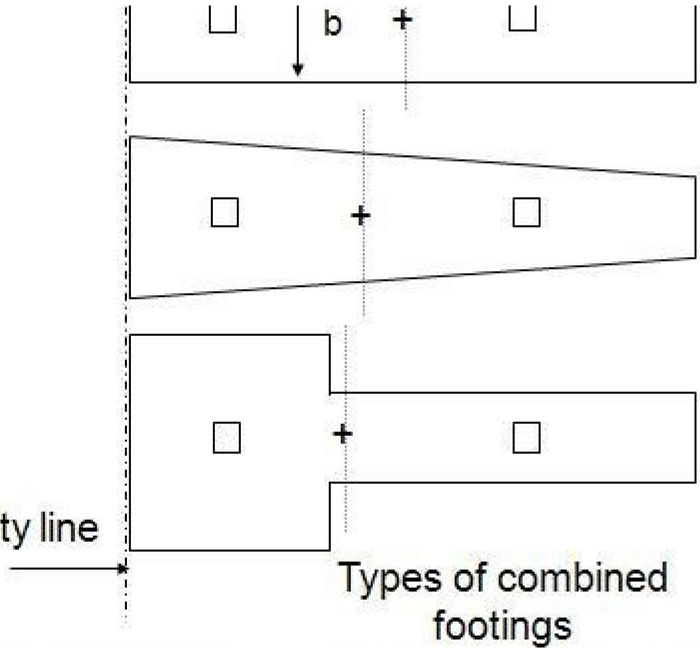
Whenever two or more columns in a straight line are carried on a single spread footing, it is called a combined footing. Isolated footings for each column are generally the economical.

Combined footings are provided only when it is absolutely necessary, as

1. When two columns are close together, causing overlap of adjacent isolated footings
2. Where soil bearing capacity is low, causing overlap of adjacent isolated footings
3. Proximity of building line or existing building or sewer, adjacent to a building column.

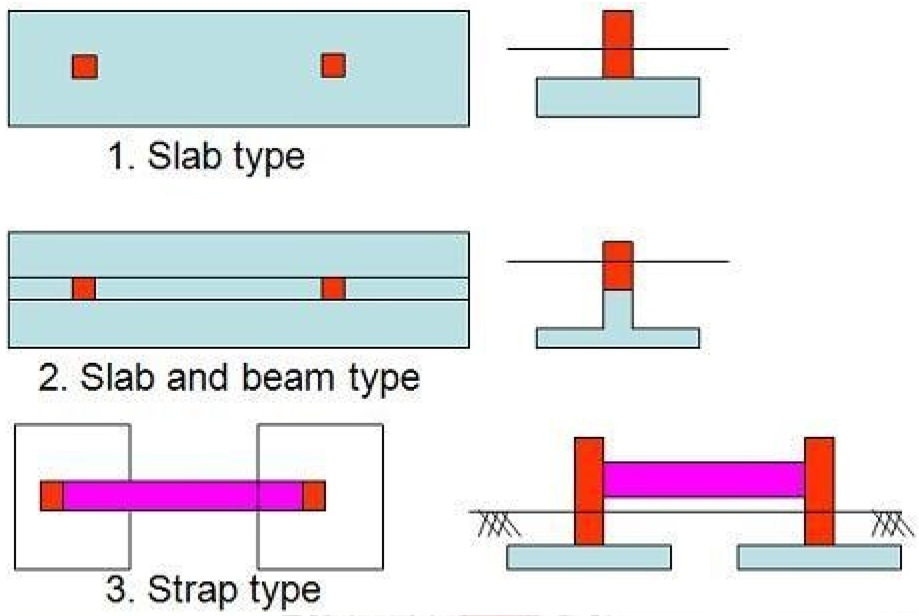


Combined footing with loads



Types of combined footings

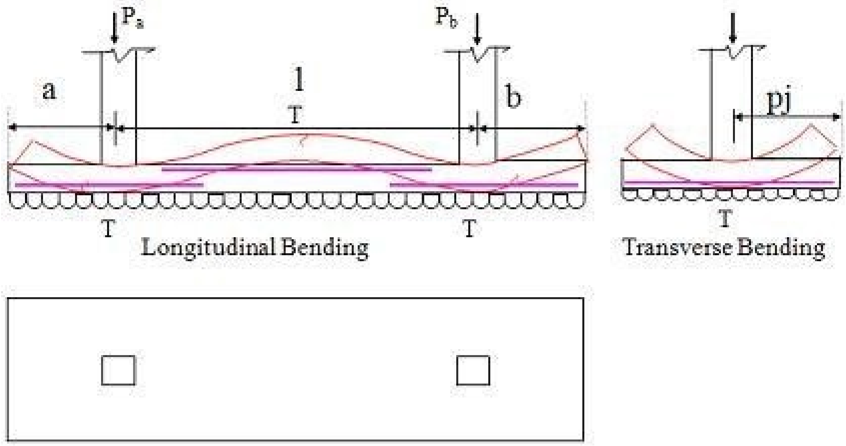
Types of Combined Footing



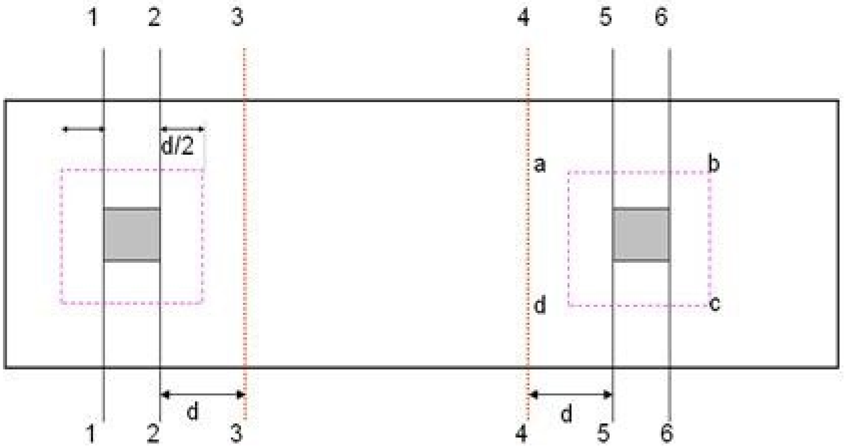
- The combined footing may be rectangular, trapezoidal or Tee-shaped in plan.
- The geometric proportions and shape are so fixed that the centeroid of the footing area coincides with the resultant of the column loads. This results in uniform pressure below the entire area of footing.
- Trapezoidal footing is provided when one column load is much more than the other. As a result, the both projections of footing beyond the faces of the columns will be restricted.
- Rectangular footing is provided when one of the projections of the footing is restricted or the width of the footing is restricted.

Rectangular combined footing

- Longitudinally, the footing acts as an upward loaded beam spanning between columns and cantilevering beyond. Using statics, the shear force and bending moment diagrams in the longitudinal direction are drawn. Moment is checked at the faces of the column. Shear force is critical at distance ‘d’ from the faces of columns or at the point of contra flexure. Two-way shear is checked under the heavier column.
- The footing is also subjected to transverse bending and this bending is spread over a transverse strip near the column.



SLAB TYPE COMBINED FOOTING



Section 1-1, 2-2, 5-5, and 6-6 are sections for critical moments
Section 3-3, 4-4 are sections for critical shear (one way)
Section for critical two way shear is abcd

CRITICAL SECTIONS FOR MOMENTS AND SHEAR

Special Foundations:

The foundations of some important engineering structures require special treatment. Such structures have to be designed for heavy loads and ordinary methods of providing foundations may not be suitable for such structures. In such cases, special treatment is given to the foundations of such structures. These special foundations are as follows:

1. Grillage foundations
2. Raft foundations
3. Inverted arches.

1. **Grillage foundations:** In this method, the depth is limited to 1 m to 1.50 m and the width is increased considerably to bring the pressure on the soil within permissible limits. The superstructure rests on two perpendicular tiers of R.S.J. Fig. 4.4 and fig. 4.5 show typical grillage foundations for a steel stanchion and a wall respectively. Following points should be noted:

(i) The R.S.J. work should be thoroughly embedded in concrete so as to protect it from the atmospheric actions. The bed of concrete should have minimum thickness of 150 mm and at no other point, the depth of concrete should be less than 80 mm.

(ii) The concrete filling does not carry any load. But it maintains the beams in proper position and prevents them from the corrosion.

(iii) Each tier of R.S. joists should be designed to act independently.

(iv) The distance between the flanges of R.S. joists should be equal to 1 1/2 to 2 times the width of flange or 300 mm whichever is less. The tube or pipe separators may be provided to maintain the R.S. joists in proper position.

(v) It is possible to replace the R.S. joists by a number of reinforcement bars of steel of required diameter. This is termed as the mat foundation

(vi) The steel grillage foundations are useful for structures having concentrated loads and hence, are employed for the foundations of the buildings such as theatres, factories, town halls, etc.

(vii) The temporary grillage foundations in the form of timber beams may be provided to timber columns or posts. They can also be -designed oforo supporting light buildings in the soft soil and permanently water-logged areas. The loading on the soil is limited to 55kN/m^2. The timber grillage takes the form of a platform of wooden planks arranged in two layers at right angles to each other. The two layers of planks are separated by rectangular sections of timber placed at a centre to centre distance of about 350mm to 400mm.

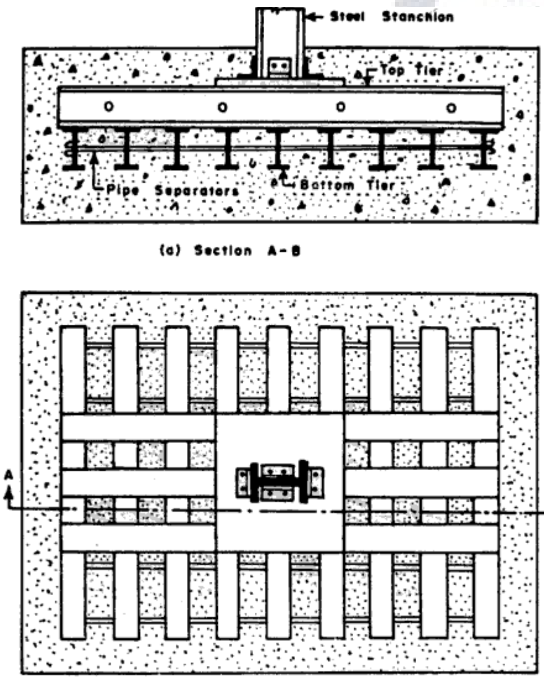


Fig. 4.4. Grill foundation for steel stanchion

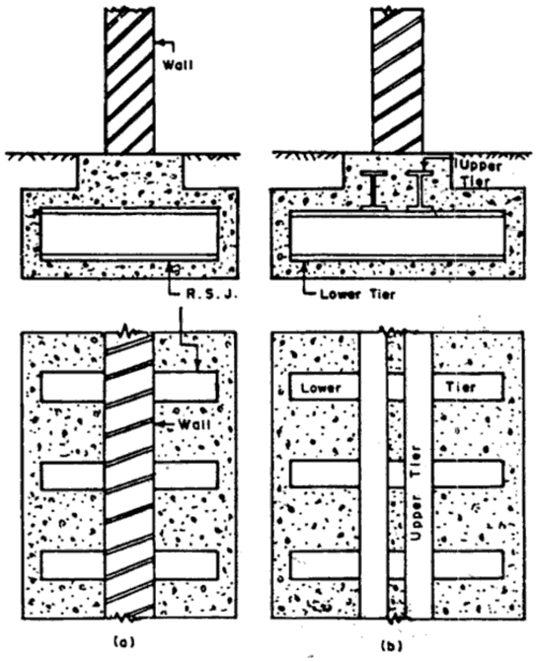


Fig. 4.5. . Grill foundation for wall

2. **Raft foundations:** This method of increasing the bearing power of soil becomes very useful when the load coming on the soil is practically uniform, while the soil is of yielding nature (e.g. soft clay or reclaimed soil).

The method consists of providing an R.C.C. slab of suitable thickness and with necessary reinforcement. The raft is designed in such a way that the allowable bearing power of the soil is not exceeded. If required, beam and slab construction in R.C.C. can also be carried out. The raft is designed as an inverted R.C.C. roof with uniformly distributed load of the soil pressure and supported by walls, beams and columns. Fig. 4.6 shows an R.C.C. raft with slab only. Fig. 4.7 shows an R.C.C. raft with slab and beam.

Sometimes the design of the raft is so adjusted that the weight of the excavated earth is just equal to the total load of the building. Thus the loading on the soil remains practically the same after the construction of the building. This is known as a floating foundation and in such a case, the settlement is reduced to a minimum extent.

The design of raft foundations requires careful attention. Usually, the raft is so shaped and proportioned, wherever possible, that the centre of gravity of the imposed load is vertically under the centre of area of the bearing ground. Also, in cases where there is fear of ground water pressure to damage the raft foundations, suitable holes are provided in the raft to release the water pressure.

The raft foundations are useful for public buildings, office buildings, school buildings, residential quarters, etc.

This method of increasing the bearing power of soils becomes useful, especially when there are large number of openings in ground floor in a structure.

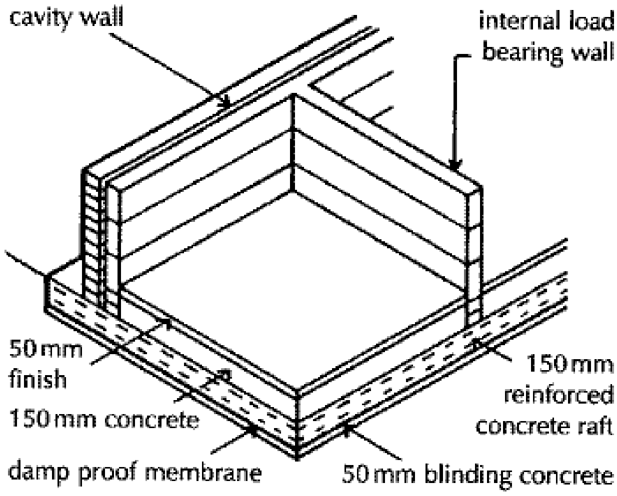


Fig. 4.6. RCC raft with slab only

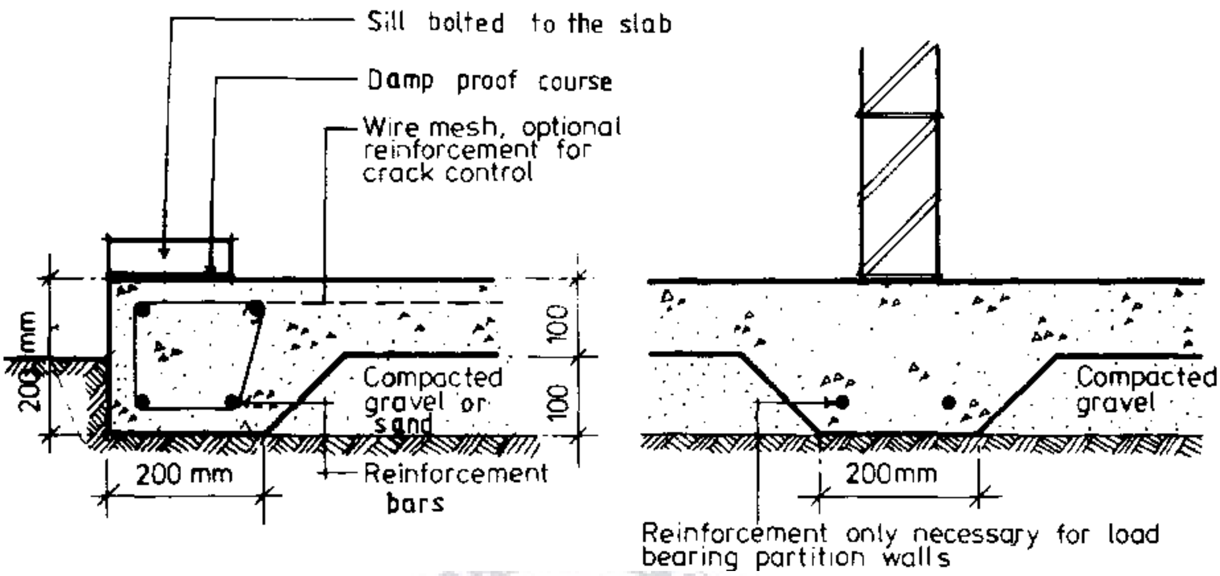


Fig. 4.7. RCC raft with slab and beams

3. **Inverted arches:** The method consists in constructing the inverted arches between the piers as shown in fig. 4.8. The rise of the inverted arch is about 1/5 to 1/10 of the span and the inverted arch is invariably built in half-brick rings.

Following points should be noted:

(i) The inverted arch should be set in cement mortar.
(ii) The end pier should be designed to resist the outward pressure caused by arch action.
(iii) The position of the inverted arches may be either along row of piers or across the row of piers or in both the direction. The selection of method will mainly depend on the nature of soil and the type of load.
(iv) The depth of foundations is considerably reduced when this method is adopted and hence, it proves to be economical in of foundations in soft soils.
(v) This method of spreading the load over a large area is not common for the construction of foundations of buildings. But it suitable for the foundations of the structures such as bridges, reservoirs, support of drainage lines, tanks etc.

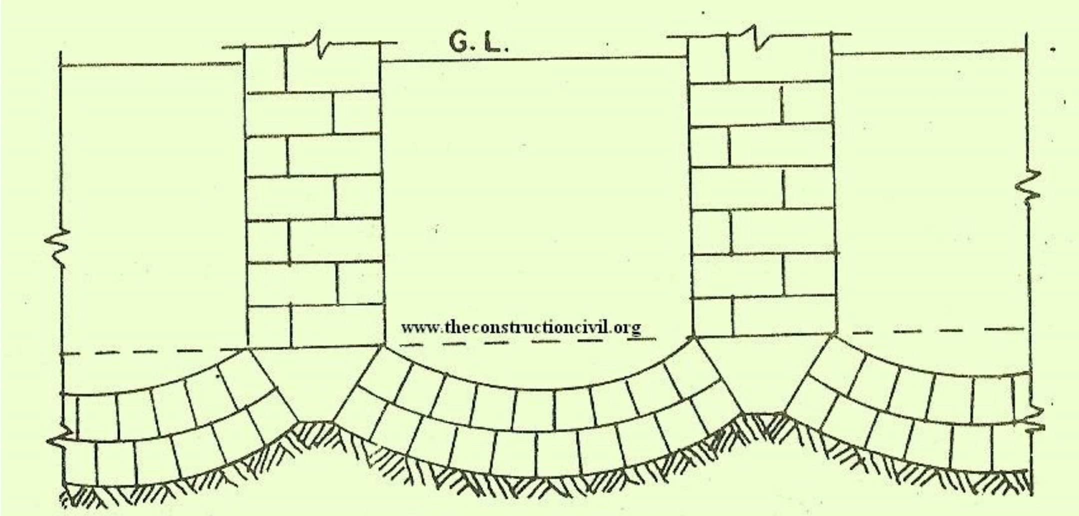


Fig. Inverted Arch Foundation

4.4. Deep foundations

Deep foundations are required to carry loads from a structure through weak compressible soils or fills on to stronger and less compressible soils or rocks at depth, or for functional reasons. These 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 >3 m below finished ground level. Deep foundations can be used to transfer the loading to a deeper, more competent strata at depth if unsuitable soils are present near the surface.

The types of deep foundations in general use are as follows:

1) Basements
2) Buoyancy rafts (hollow box foundations)
3) Caissons
4) Cylinders
5) Shaft foundations
6) Piles

Basement foundations:

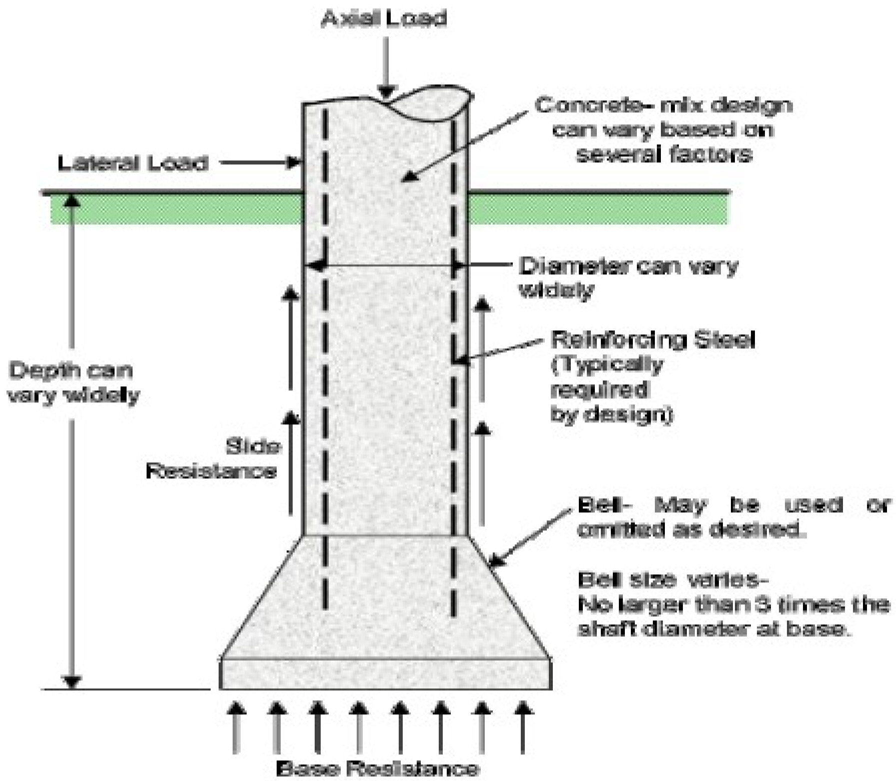
These are hollow substructures designed to provide working or storage space below ground level. The structural design is governed by their functional requirements rather than from considerations of the most efficient method of resisting external earth and hydrostatic pressures. They are constructed in place in open excavations.

Buoyancy rafts (hollow box foundations)

Buoyancy rafts are hollow substructures designed to provide a buoyant or semi-buoyant substructure beneath which the net loading on the soil is reduced to the desired low intensity. Buoyancy rafts can be designed to be sunk as caissons, they can also be constructed in place in open excavations.

<u>Caissons foundations</u>:

Caissons are hollow substructures designed to be constructed on or near the surface and then sunk as a single unit to their required level.



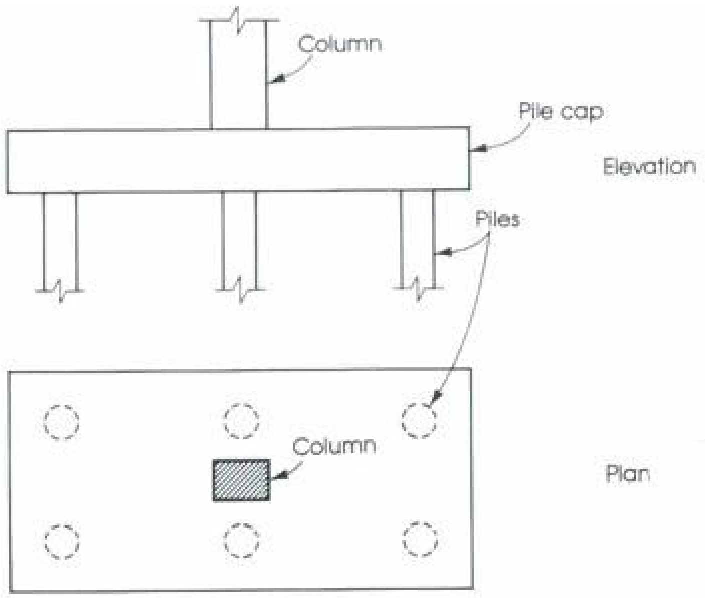
Cylinders:

Cylinders are small single-cell caissons.

Shaft foundations:

Shaft foundations are constructed within deep excavations supported by lining constructed in place and subsequently filled with concrete or other pre-fabricated load-bearing units.

Pile foundations:



Pile foundations are relatively long and slender members constructed by driving preformed units to the desired founding level, or by driving or drilling-in tubes to the required depth – the tubes being filled with concrete before or during withdrawal or by drilling unlined or wholly or partly lined boreholes which are then filled with concrete.

4.5. Introduction to damp proofing

Causes of dampness:

The dampness in a building is a universal problem and the various causes which are responsible for the entry of dampness in a structure are as follows:

1. Rising of moisture from the ground: The ground on which the building is constructed may be made of soils which easily allow the water to pass. Usually the building materials used for the foundations, absorb moisture by capillary action. Thus the dampness finds its way to the floors through the substructure.
2. Action of rain: If the faces of wall, exposed to heavy showers of rain, are not suitably protected, they become the sources of entry of dampness in a structure. Similarly the leaking roofs also permit the rain water to enter a structure.
3. Exposed tops or walls: The parapet walls and compound walls should be provided with a damp-proof course on their exposed tops. Otherwise the dampness entering through these exposed tops of such walls may lead to serious results.
4. Condensation: The process of condensation takes place when warm humid air is cooled. This is due to the fact that cool air can contain less invisible water vapour than warm air. The moisture is deposited on the walls, floors and ceilings. This is the main source causing dampness in badly designed kitchens.
5. Miscellaneous: There are various miscellaneous causes of dampness as mentioned below:
   a. If the structure is located on a site which cannot be easily drained off, the dampness will enter the structure.
   b. The orientation of a building is also an important factor. The walls obtaining less sunshine and heavy showers of rain are liable to become damp.
   c. The newly constructed walls remain damp for a short duration.
   d. Very flat slope of a roof may also lead to the penetration of rain water which is temporarily stored on the roof.
   e. The dampness is also caused due to bad workmanship in construction such as defective rain water pipe connections, defective joints in the roofs, improper connections of walls, etc.

Effects of dampness:

The structure is badly affected by dampness. The prominent effects of dampness are as follows:

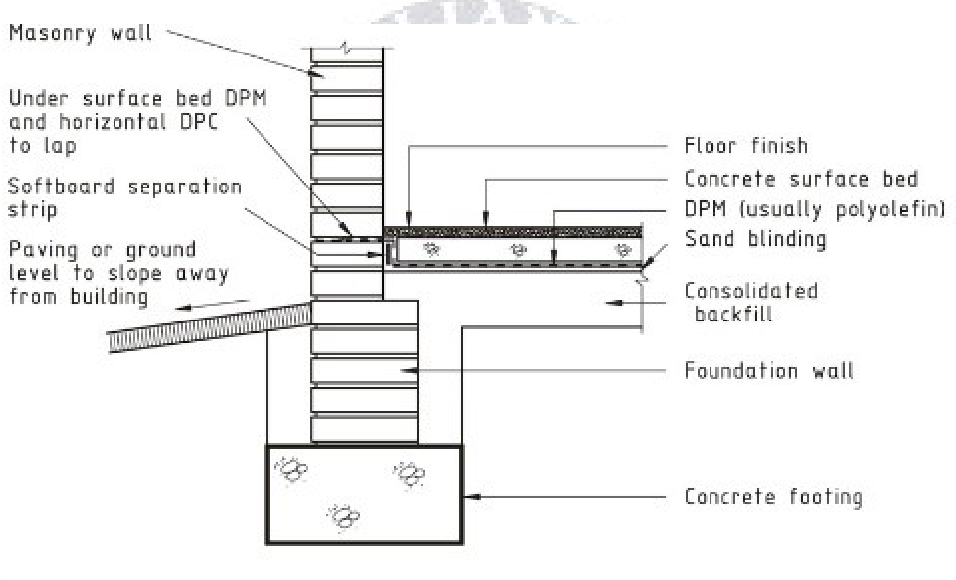
1. A damp building gives rise to breeding of mosquitoes and creates unhealthy conditions for those who occupy it.
2. The metals used in the construction of the building are corroded.
3. The unsightly patches are formed on the wall surfaces and ceilings.
4. The decay of timber takes place rapidly due to dry-rot in a damp atmosphere.
5. The electrical fittings are deteriorated and it may lead to leakage of electricity and consequent danger of short circuiting.
6. The materials used as floor coverings are seriously damaged.
7. It promotes and accelerates the growth of termites.
8. It results in softening and crumbling of the plaster.
9. The materials used for wall decoration are damaged and it leads to difficult and costly repairs.
10. The continuous presence of moisture in the walls may cause efflorescence which may result in disintegration of stones, bricks, tiles, etc. and the strength of wall is then reduced.

11. The floorings get loosened because of reduction in the adhesion when moisture enters through the floor.
12. The dampness combined with warmth and darkness breeds germs of dangerous diseases such as tuberculosis, rheumatism, etc. and the occupants may also become asthmatic.

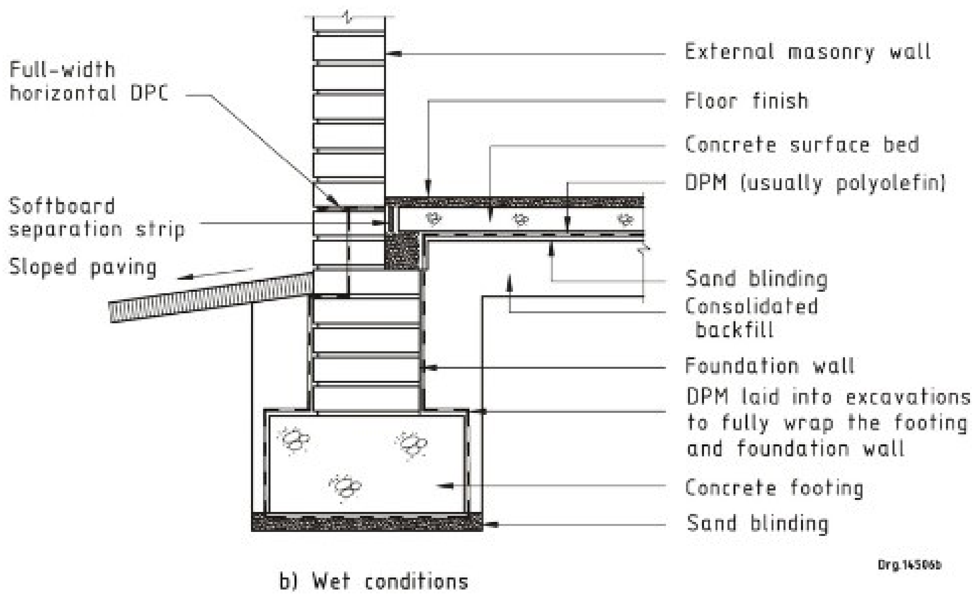
Methods of damp-proofing:

There are various methods of damp-proofing and depending upon the nature of surface, situation of the structure and amount of dampness, the proper method is selected. Following are the methods or measures adopted to prevent entry of dampness:

1. In the level of the ground floor is in the level of the ground surface or just above it, the damp proofing course is provided as shown in fig below. The materials should be flexible and it should be stepped vertically through the wall to meet the damp-proofing course of the solid floor.

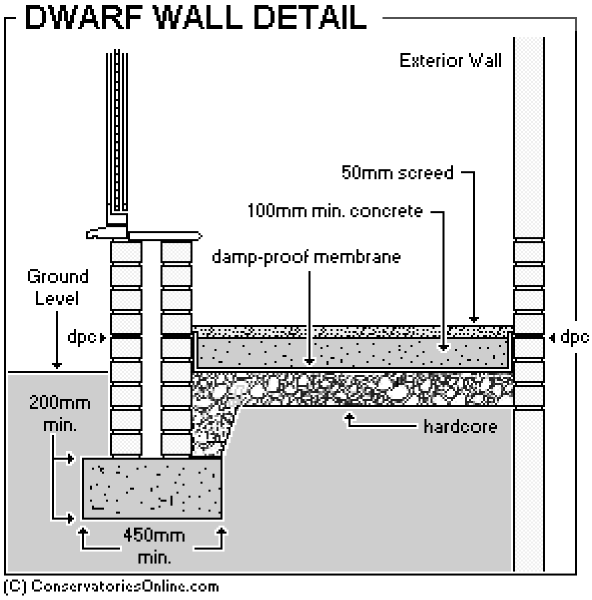


a) Dry conditions



b) Wet conditions

2. If two ground floors at different levels are connected by an internal wall, the damp-proofing course may be provided as shown in fig. below. It should be noted that the damp-proofing course on the internal wall is in level with the lower floor level.



3. In order to prevent the rising of moisture from the adjacent ground, the air drains may be provided as shown in fig. below. An air drain is a narrow hollow space which is constructed parallel to the external wall. The width of air drain is about 200 mm to 300 mm. The openings with gratings are provided at regular intervals for the passage of air. The wall forming the air drain rests on the foundation concrete of the main wall and is carried about 150mm above the ground level. The top of air drain is covered either by an RCC slab or a stone and necessary arrangements are provided for the inspection of the air drain. The vertical and horizontal damp proofing courses are provided as shown in the fig. below.

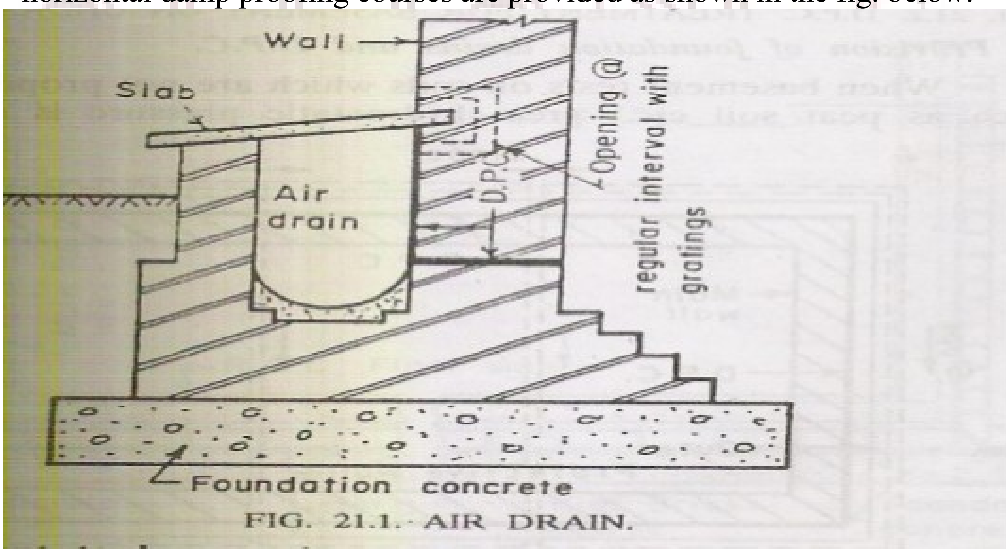
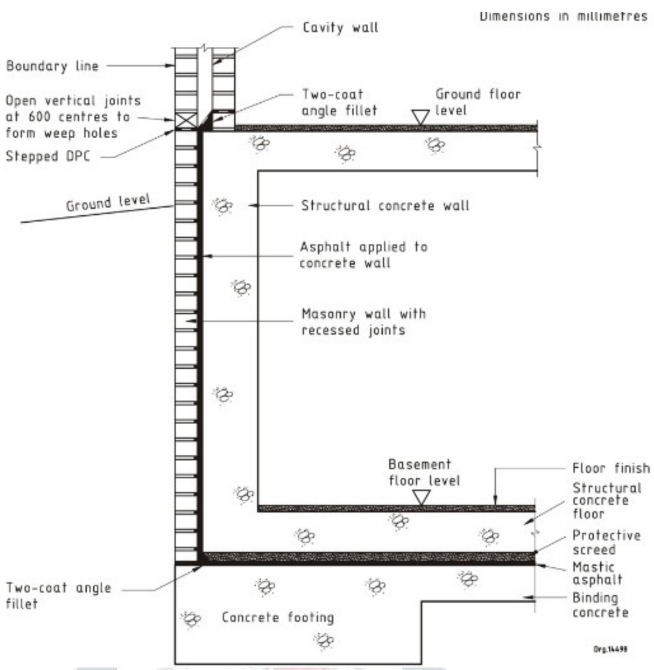


FIG. 21.1. AIR DRAIN.

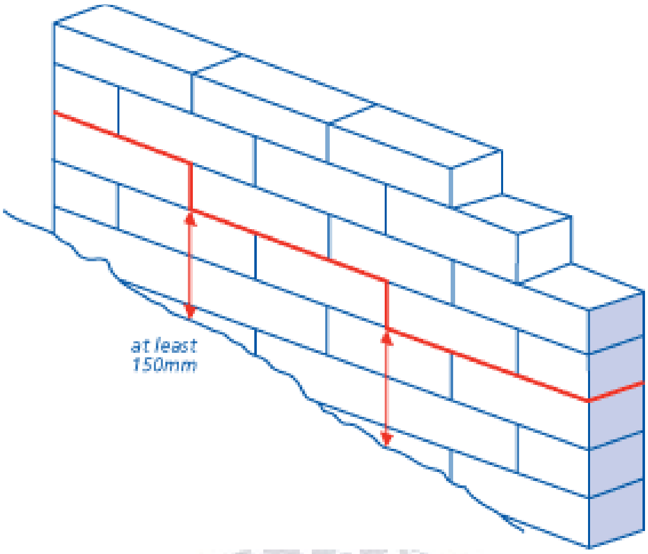
4. In case of basement, the damp proofing course should be properly provided. Otherwise the basements become useless except for the materials unaffected by damp. The usual process of providing asphalt tanking is shown in figure below.



The important facts to be observed in case of asphalt tanking are as follows:

(i) The layer of asphalt should be continuous.
(ii) The vertical end of asphalt layer may end in a horizontal damp-proofing course, if necessary.
(iii) The vertical damp-proofing course should be taken above ground level for a minimum distance of 150 mm.
(iv) The sequence of construction should be: inner wall, asphalt layer and protective wall. The reverse sequence may also be adopted but with less success.
(v) The thickness of horizontal asphalt layer at basement floor is 30 mm and it is laid in three coats. The thickness of vertical layer is 20 mm and it is laid in three coats.

5. The rain water gutters, in case of pitched roofs, may be constructed in cement concrete and standard rain water fittings may be used. Further the gutters may be lined with bituminous materials or burnt clay products.
6. The cement paints, when applied suitably, act as effective vertical damp-proofing courses.
7. For cheaply constructed buildings, the damp-proofing course may be provided in the form of a layer of well burnt bricks which are dipped in hot tar and pitch
8. In case of a sloping ground, the damp-proofing course should be stepped such that it remains at a minimum vertical distance of 150 mm above ground as shown in fig. below. The damp-proofing course may be of any suitable flexible material such as bituminous felt, etc.



9. The construction of cavity walls considerably prevents the entry of damp inside the building. Suitable damp-proofing courses may be provided on these walls.
10. The provision of coping on a wall prevents considerably the entry of damp from the top surface of the wall.
11. The good workmanship and use of materials of better quality on face of the walls immensely help in preventing the entry of damp inside the building.
12. For providing damp-proof course in an existing wall, the following procedure is adopted:
    (i) The level at which the damp-proof course is to be provided is carefully decided after considering the ground level and the floor level. It is usually kept about 150 mm above the ground level or floor level, whichever is higher.

    (ii) A special saw made of steel blades is used to make a cut at the corner of the wall.
    (iii) The loose bricks from the course just above the cut are carefully removed.
    (iv) The damp-proof membrane, usually bituminous felt, is inserted immediately after the cut is made.
    (v) The cycle of cutting the slot and inserting the damp proof membrane is repeated till the entire length of wall is completed.
    (vi) The removed bricks are re-laid and the surface is finished with plaster or pointing.

4.6. Shoring

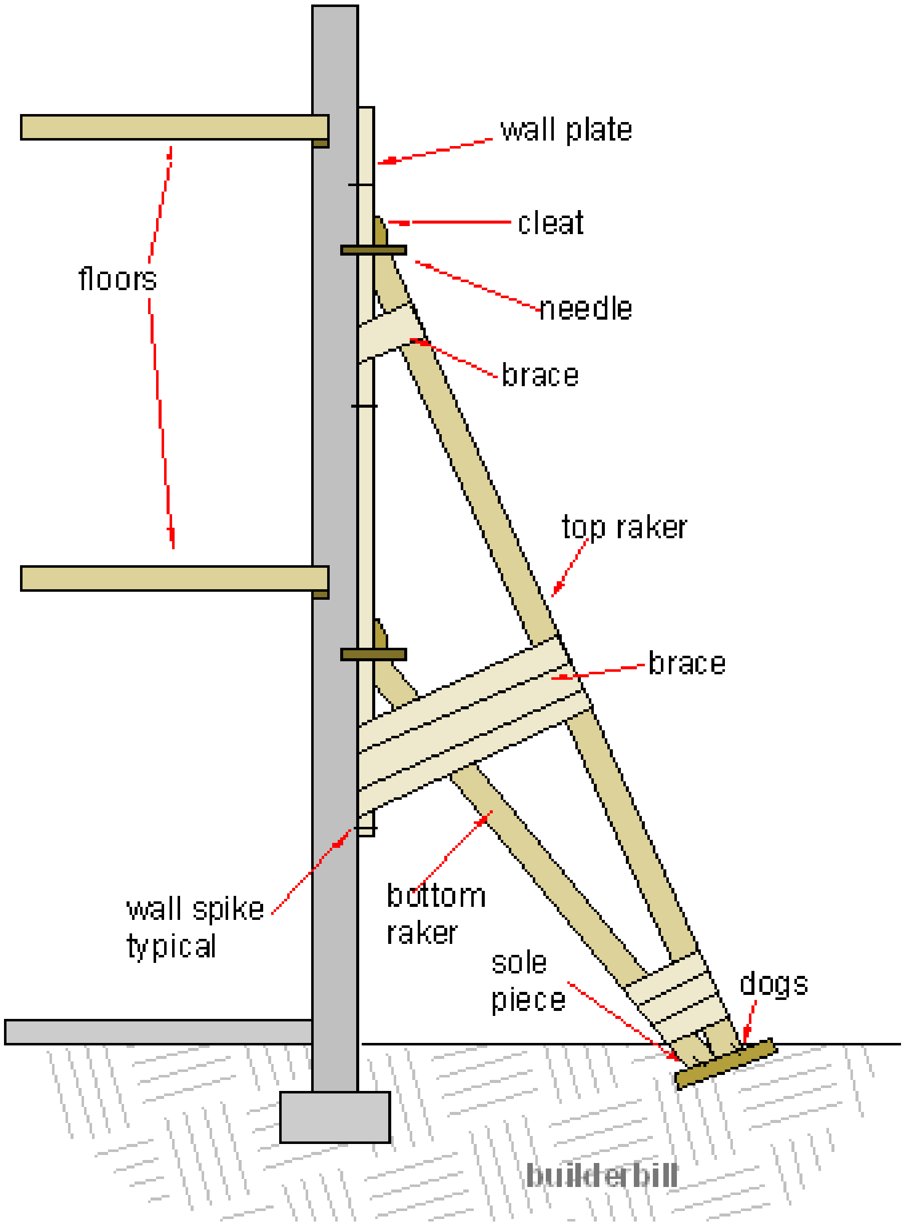
Shoring is the construction of a temporary structure to support temporarily an unsafe structure. These support walls laterally. They can be used under the following circumstances:

1. When walls bulge out
2. When walls crack due to unequal settlement of foundation and repairs are to be carried out to the cracked wall.
3. When an adjacent structure needs pulling down.
4. When openings are to be newly made or enlarged in a wall.

Types of shoring

1. Raking shores
2. Flying shores
3. Dead shores

Raking shores (fig below)



A Double Raking Timber Shore

In this method, inclined members known as rakers are used to give lateral supports to walls. A raking shore consists of the following components:

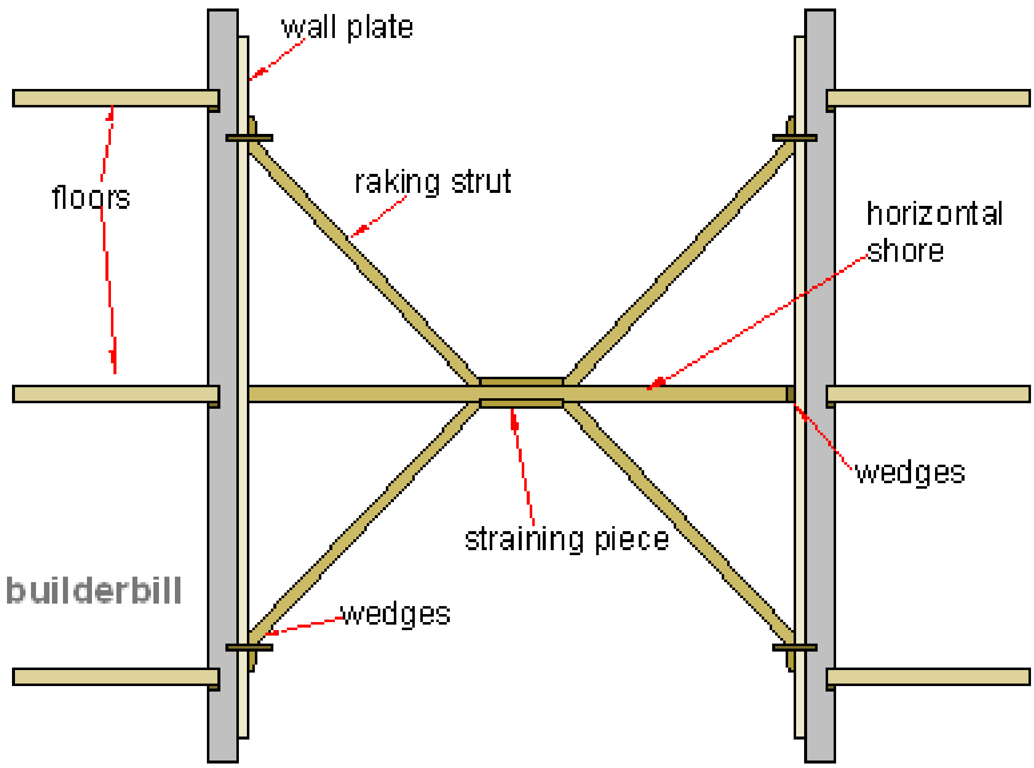
1. Rakers or inclined member
2. Wall plate
3. Needles
4. Cleats
5. Bracing
6. Sole plate

The following points are to be kept in view for the use of the raking shores:

1. Rakers are to be inclined in the ground at 45^0. However the angle may be between 45^0 and 75^0.
2. For tall buildings, the length of the raker can be reduced by introducing rider raker.
3. Rakers should be properly braced at intervals.
4. The size of the rakers is to be decided on the basis of anticipated thrust from the wall.
5. The centre line of a raker and the wall should meet at floor level.
6. Shoring may be spaced at 3 to 4.5m spacing to cover longer length of the bar.
7. The sole plate should be properly embedded into the ground on an inclination and should be of proper section and size.
8. Wedges should not be used on sole plates since they are likely to give way under vibrations that are likely to occur.

FLYING SHORES (fig below)

It is a system of providing temporary supports to the party walls of the two buildings where the intermediate building is to be pulled down and rebuilt. All types of arrangements of supporting the unsafe structure in which the shores do not reach the ground come under this category. They flying shore consists of wall plates, needles, cleats, horizontal struts (commonly known as horizontal shores) and inclined struts arranged in different forms which varies with the situation. In this system also the wall plates are placed against the wall and secured to it. A horizontal strut is placed between the wall plates and is supported by a system of needle and cleats. The inclined struts are supported by the needle at their top and by straining pieces at their feet. The straining piece is also known as straining sill and is spiked to the horizontal shore. The width of straining piece is the same as that of the strut.

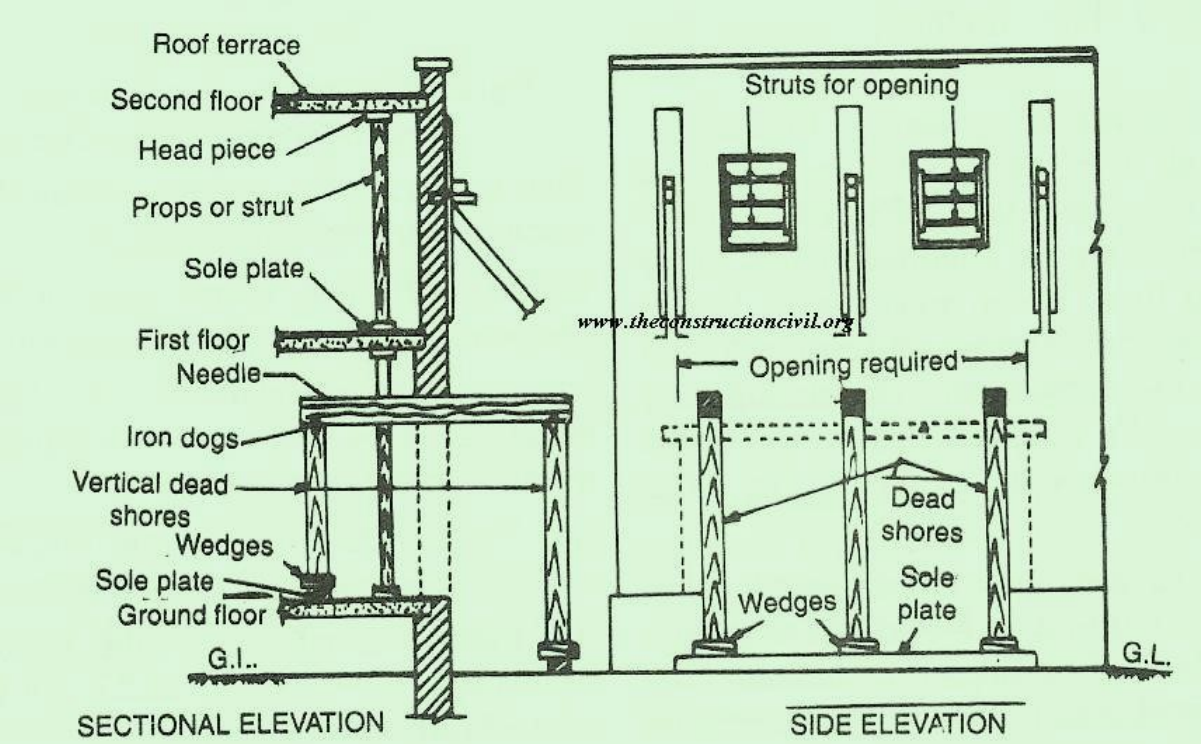


Part Elevation Through Two Buildings With A Single Flying Timber Shore

When the distance between the walls (to be strutted apart) is considerable, a horizontal shore cannot be safe and a trussed framework of members is necessary to perform the function of flying shore.

DEAD SHORES

This is the system of shoring which is used to render vertical support to walls and roofs, floors, etc when the lower part of a wall has been removed for the purpose of providing an opening in the wall or to rebuild a defective load bearing wall in a structure. The dead shore consists of an arrangement of beams and posts which are required to support the weight of the structure above and transfer same to the ground on firm foundation below.



Use of dead shores in making an opening in the existing wall.

When opening in the wall are to be made, holes are cut in the wall at such a height as to allow sufficient space for insertion of the beam or girder that will be provided permanently to carry the weight of the structure above. Distance at which the holes are cut depends upon the type of masonry and it varies from 1.2m to 1.8m centre. Beams called needles are placed in the holes and are supported by vertical props called dead shores at their ends on either side of the wall. The needles may be of timber or steel and are of sufficient section to carry the load above.

The dead shores stand away from wall on either side so as to allow for working space when the needle and the props are in position. The props are tightened up by folding wedges provided at their bases while the junction between the prop and the needle is secured with the help of dogs. Before the dismantling work is started, all the doors, windows or other openings are well strutted. In order to relieve the wall of load of floors and roof above, they are independently supported. Vibrations and shocks are bound to occur when wall cutting is done as such a measure of safety raking shores are sometimes erected before commencement of wall cutting operation.

4.7. Underpinning

Underpinning may be necessary for a variety of reasons:

1. The original foundation is simply not strong or stable enough, e.g. due to decay of wooden piles under the foundation.
2. The usage of the structure has changed.
3. The properties of the soil supporting the foundation may have changed (possibly through subsidence) or were mischaracterized during planning.
4. The construction of nearby structures necessitates the excavation of soil supporting existing foundations.
5. It is more economical, due to land price or otherwise, to work on the present structure's foundation than to build a new one. Underpinning is accomplished by extending the foundation in depth or in breadth so it either rests on a stronger soil stratum or distributes its load across a greater area. Use of micro piles and jet grouting are common methods in underpinning. An alternative to underpinning is the strengthening of the soil by the introduction of a grout. All of these processes are generally expensive and elaborate.