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UNIT - I

CIVIL ENGINEERING MATERIALS

CHAPTER 1

Traditional Materials

Stones, bricks, cement, lime and timber are the traditional materials used for civil engineering constructions for several centuries. In this chapter types, properties, tests and uses of these materials is explained.

1.1 STONES

Stone is a 'naturally available building material' which has been used from the early age of civilization. It is available in the form of rocks, which is cut to required size and shape and used as building block. It has been used to construct small residential buildings to large palaces and temples all over the world. Red Fort, Taj Mahal, Vidhan Sabha at Bangalore and several palaces of medieval age all over India are the famous stone buildings.

1.1.1 Type of Stones

Stones used for civil engineering works may be classified in the following three ways:

- Geological
- Physical
- Chemical

Geological Classification

Based on their origin of formation stones are classified into three main groups—Igneous, sedimentary and metamorphic rocks.

(*i*) **Igneous Rocks:** These rocks are formed by cooling and solidifying of the rock masses from their molten magmatic condition of the material of the earth. Generally igneous rocks are strong and durable. Granite, trap and basalt are the rocks belonging to this category, Granites are formed by slow cooling of the lava under thick cover on the top. Hence they have crystalline surface. The cooling of lava at the top surface of earth results into non-crystalline and glassy texture. Trap and basalt belong to this category.

(*ix*) **Seasoning:** Good stones should be free from the quarry sap. Laterite stones should not be used for 6 to 12 months after quarrying. They are allowed to get rid of quarry sap by the action of nature. This process of removing quarry sap is called seasoning.

(*x*) **Cost:** Cost is an important consideration in selecting a building material. Proximity of the quarry to building site brings down the cost of transportation and hence the cost of stones comes down.

However it may be noted that not a single stone can satisfy all the requirements of a good building stones, since one requirement may contradict another. For example, strength and durability requirement contradicts ease of dressing requirement. Hence it is necessary that site engineer looks into the properties required for the inteded work and selects the stone.

1.1.4 Tests on Stones

To acertain the required properties of stones, the following tests can be conducted:

(*i*) crushing strength test

(*ii*) water absorption test

(*iii*) abrasion test

(*iv*) impact test

(*v*) acid test.

(*i*) **Crushing Strength Test:** For conducting this test, specimen of size 40 × 40 × 40 mm are prepared from parent stone. Then the sides are finely dressed and placed in water for 3 days. The saturated specimen is provided with a layer of plaster of paris on its top and bottom surfaces to get even surface so that load applied is distributed uniformly. Uniform load distribution can be obtained satisfactorily by providing a pair of 3 mm thick plywood instead of using plaster of paris layer also. The specimen so prepared in the compression testing machine is loaded at the rate of 14 N/mm^2 per minute. The crushing load is noted. Then crushing strength is equal to the crushing load divided by the area over which the load is applied. At least three specimen should be tested and the average should be taken as crushing strength.

(*ii*) **Water Absorption Test:** For this test cube specimen weighing about 50 grams are prepared and the test is carried out in the steps given below:

(*a*) Note the weight of dry speciment as W_1.

(*b*) Place the specimen in water for 24 hours.

(*c*) Take out the specimen, wipe out the surface with a piece of cloth and weigh the specimen. Let its weight be W_2.

(*d*) Suspend the specimen freely in water and weight it. Let its weight be W_3.

(*e*) Place the specimen in boiling water for 5 hours. Then take it out, wipe the surface with cloth and weigh it. Let this weight be W_4. Then,

$$\text{Percentage absorption by weight} = \frac{W_2 - W_1}{W_1} \times 100 \quad \text{...(1)}$$

$$\text{Percentage absorption by volume} = \frac{W_2 - W_1}{W_2 - W_3} \times 100 \quad \text{...(2)}$$

(*ii*) for bituminous mechadam ≯ 35%

(*iii*) for water bound mechadam ≯ 40%

(*v*) **Acid Test:** This test is normally carried out on sand stones to check the presence of calcium carbonate, which weakens the weather resisting quality. In this test, a sample of stone weighing about 50 to 100 gm is taken and kept in a solution of one per cent hydrochloric acid for seven days. The solution is agitated at intervals. A good building stone maintains its sharp edges and keeps its surface intact. If edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate. Such stones will have poor weather resistance.

1.1.5 Uses of Stones

Stones are used in the following civil engineering constructions:

(*i*) Stone masonry is used for the construction of foundations, walls, columns and arches.

(*ii*) Stones are used for flooring.

(*iii*) Stone slabs are used as damp proof courses, lintels and even as roofing materials.

(*iv*) Stones with good appearance are used for the face works of buildings. Polished marbles and granite are commonly used for face works.

(*v*) Stones are used for paving of roads, footpaths and open spaces round the buildings.

(*vi*) Stones are also used in the constructions of piers and abutments of bridges, dams and retaining walls.

(*vii*) Crushed stones with graved are used to provide base course for roads. When mixed with tar they form finishing coat.

(*viii*) Crushed stones are used in the following works also:

(*a*) As a basic inert material in concrete

(*b*) For making artificial stones and building blocks

(*c*) As railway ballast.

1.1.6 Common Building Stones

The following are the some of commonly used stones:

(*i*) Basalt and trap	(*ii*) Granite
(*iii*) Sand stone	(*iv*) Slate
(*v*) Laterite	(*vi*) Marble
(*vii*) Gneiss	(*viii*) Quartzite.

Their qualities and uses are explained below:

(*i*) **Basalt and Trap:** The structure is medium to fine grained and compact. Their colour varies from dark gray to black. Fractures and joints are common. Their weight varies from 18 kN/m^3 to 29 kN/m^3. The compressive strength varies from 200 to 350 N/mm^2. These are igneous rocks. They are used as road metals, aggregates for concrete. They are also used for rubble masonry works for bridge piers, river walls and dams. They are used as pavement.

(*b*) ***Facing Bricks:*** These bricks are used in the outer face of masonry. Once these bricks are provided, plastering is not required. The standard size of these bricks are 190 × 90 × 90 mm or 190 × 90 × 40 mm.

(*c*) ***Perforated Building Bricks:*** These bricks are manufactured with area of perforation of 30 to 45 per cent. The area of each perforation should not exceed 500 mm^2. The perforation should be uniformly distributed over the surface. They are manufactured in the size 190 × 190 × 90 mm and 290 × 90 × 90 mm.

(*d*) ***Burn't Clay Hollow Bricks:*** Figure 1.4 shows a burnt clay hollow brick. They are light in weight. They are used for the construction of partition walls. They provide good thermal insulation to buildings. They are manufactured in the sizes 190 × 190 × 90 mm, 290 × 90 × 90 mm and 290 × 140 × 90 mm. The thickness of any shell should not be less than 11 mm and that of any web not less than 8 mm.

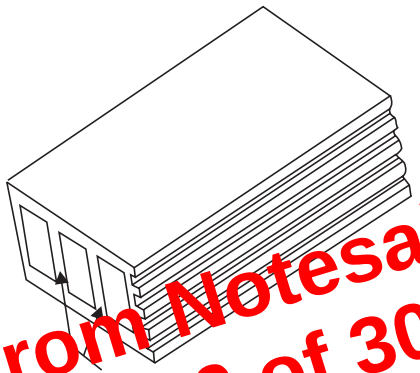


Fig. 1.4 Hollow bricks

(*e*) ***Sewer Bricks:*** These bricks are used for the construction of sewage lines. They are manufactured from surface clay, fire clay shale or with the combination of these. They are manufactured in the sizes 190 × 90 × 90 mm and 190 × 90 × 40 mm. The average strength of these bricks should be a minimum of 17.5 N/mm^2 . The water absorption should not be more than 10 per cent.

(*f*) ***Acid Resistant Bricks:*** These bricks are used for floorings likely to be subjected to acid attacks, lining of chambers in chemical plants, lining of sewers carrying industrial wastes etc. These bricks are made of clay or shale of suitable composition with low lime and iron content, flint or sand and vitrified at high temperature in a ceramic kiln.

1.2.2 Properties of Bricks

The following are the required properties of good bricks:

(*i*) **Colour:** Colour should be uniform and bright.

(*ii*) **Shape:** Bricks should have plane faces. They should have sharp and true right angled corners.

(*iii*) **Size:** Bricks should be of standard sizes as prescribed by codes.

7. Silica of sand contributes to formation of silicates resulting into the hardened mass.

The properties of good sand are:

1. It should be chemically inert.
2. It should be free from organic or vegetable matter.
3. It should be free from salt.
4. It should contain sharp, angular and coarse grains.
5. It should be well graded.
6. It should be hard.

2.2 CEMENT MORTAR

For preparing mortar, first a mixture of cement and sand is made thoroughly mixing them in dry condition. Water is gradually added and mixed with shovels. The cement to sand proportion recommended for various works is as shown is Table 2.1

Table 2.1. Cement to sand proportions for various works

S. No.	*Works*	*Cement : Sand*
1	Masonry works	1:6 to 1:8
2	Plastering masonry	1:3 to 1:4
3	Plastering concrete	1:3
4	Pointing	1:2 to 1:3

Curing: Cement gains the strength gradually with hydration. Hence it is necessary to see that mortar is wet till hydration has taken place. The process to ensure sufficient moisture for hydration after laying mortar/concrete is called curing. Curing is ensured by spraying water. Curing normally starts 6–24 hours after mortar is used. It may be noted that in the initial period water requirement is more for hydration and gradually it reduces. Curing is recommended for 28 days.

Properties of Cement Mortar: The following are the important properties of cement mortar:

1. When water is added to the dry mixture of cement and sand, hydration of cement starts and it binds sand particles and also the surrounding surfaces of masonry and concrete.
2. A mix richer than 1:3 is prone to shrinkage.
3. Well proportioned mortar provides impervious surface.
4. Leaner mix is not capable of closing the voids in sand and hence the plastered surface is porous.
5. The strength of mortar depends upon the proportion of cement and sand. Strengths obtained with various proportion of cement and sand is shown in Table 2.2.

1. Workability
2. Segregation
3. Bleeding
4. Harshness.

The properties of hardened concrete are:

1. Strength
2. Resistance to wear
3. Dimensional changes
4. Durability
5. Impermeability.

Properties of Green Concrete

1. Workability: This is defined as the ease with which concrete can be compacted fully without seggregating and bleeding. It can also be defined as the amount of internal work required to fully compact the concrete to optimum density. The workability depends upon the quantity of water, grading, shape and the percentage of the aggregates present in the concrete.

Workability is measured by

(*a*) The slump observed when the frustum of the standard cone filled with concrete is lifted and removed.

(*b*) The compaction factor determined after allowing the concrete to fall through the compaction testing machine.

(*c*) The time taken in seconds for the shape of the concrete to change from cone to cylinder when tested in Vee-Bee consistometer.

The suggested values of workability for different works are as shown in Table 3.2.

Table 3.2. Suggested values of workability

Application	*Slump*	*Compaction Factor*	*Time in Vee-Bee*
1. Concreting of shallow sections with vibrations	—	0.75 – 0.80	10 – 20
2. Concreting of light reinforced sections with vibrators	—	0.80 – 0.85	5 – 10
3. Concreting of lightly reinforced sections without vibrations and heavily reinforced sections with vibrations	25 – 75 mm	0.85 – 0.92	2 – 5
4. Concreting of heavily reinforced sections without vibration	75 – 125 mm	More than 0.92	—

2. Segregation: Separation of coarse particles from the green concrete is called segregation. This may happen due to lack of sufficient quantity of finer particles in concrete or due to throwing of the

strong to resist the load. However many times flat tiles are used under curved/ribbed tiles. These tiles are not subjected to load directly. They serve in reducing adverse thermal effects. Mangalore, Allahabad tiles, and corrugated tiles are popularly used roofing tiles [Ref. Fig. 5.2].

Allahabad tiles are generally laid side by side and the joints are covered with half round tiles. Mangalore tiles are red in colour and they are of interlocking type. These tiles are manufactured in Mangalore, Calicut, Cochin and Gujarat.

Corrugated tiles satisfy the requirements of appearance and leak proof but they can be easily blown away by wind.

The **desirable properties** of the roofing tiles are:

1. they should not absorb moisture more than 20 per cent by weight.
2. they should give pleasing look.
3. they should be capable of taking load of a man safely, after they are supported on reapers.
4. they should be durable.
5. they should be uniform in shape and size.
6. warpage should not exceed 2% along the edges and 1.5% along the diagonal.

2. **Flooring Tiles and Wall Tiles:** These tiles are manufactured by burning pressed green tiles twice. First they are burnt at 700°C. Then they are dipped in the glaze solution and again burnt at 1250°C to fuse them with glaze. The thickness of these tiles vary from 15 to 20 mm. These tiles are flat and they have pleasing appearance. There are two types of flooring tiles:

(*a*) ***Glazed Tiles:*** These tiles are used as finish surfaces for floors and walls in kitchen and bath-rooms. These tiles are glazed and are provided with attractive colours and designs.

(*b*) ***Mosaic Tiles:*** These are precast concrete tiles with marble chips on the top surface. After fixing these tiles, polishing is done.

The desirable properties of flooring and roofing tiles are:

1. Tolerance for length = ± 5 mm.
2. Tolerance for thickness = ± 2 mm.
3. Should be uniform in shape and colour.
4. They should be sound, hard and durable.
5. They should have very low percentage of water absorption.
6. They should give a clear ringing sound when struck with each other.
7. They should show good resistance to abrassion.

QEUSTIONS

1. List the important properties of glass.
2. Write short notes on any four types of glasses.

7.	Loose gravel or sand gravel	250
8.	Soft shale, hard clay	450
9.	Medium clay, readily indented with thumb nail	250
10.	Moist clay, clay and sand mixture	150
11.	Soft clay	100
12.	Black cotton soil, peat and made up of ground	to be found after investigations

(*b*) *Width of Foundation:* Width of wall foundations or size of column footing is determined by first calculating the expected load and then dividing that with SBC. Thus,

$$\text{Width of wall foundation} = \frac{\text{Load per unit length of wall}}{\text{S.B.C. of soil}}$$

$$\text{Area of column footing} = \frac{\text{Load carried by column}}{\text{S.B.C. of soil}}.$$

7.2 CONVENTIONAL SPREAD FOOTINGS

This type of foundations are commonly used for walls and masonry columns. These foundations are built after opening the trenches to required depth. Such footings are economical up to a maximum depth of 3 m. As these foundations are suitable depth, they are grouped under *shallow foundations.*

Figure 7.1 shows a conventional spread footing for a wall and Fig. 7.2 shows it for a masonry column.

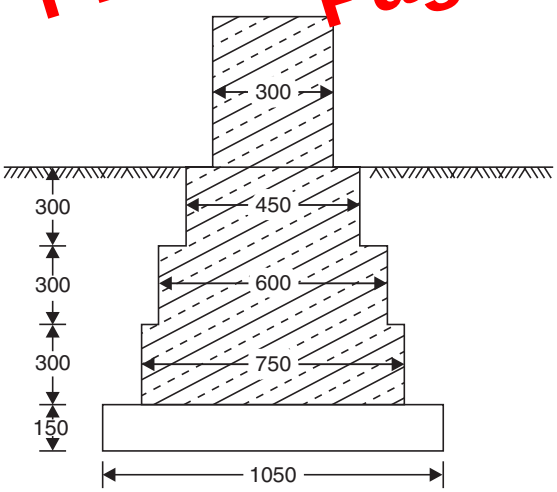


Fig. 7.1. Wall footing

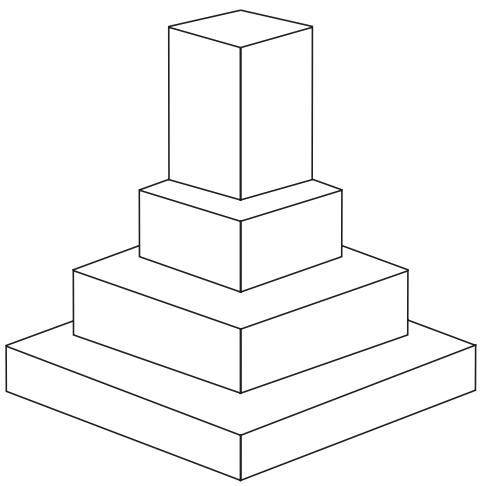


Fig. 7.2. Foundation for masonry pier

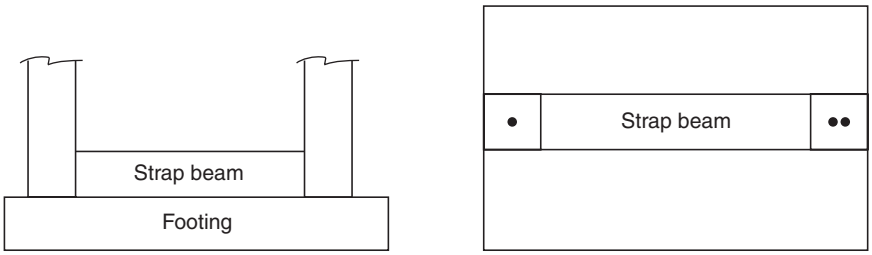


Fig. 7.4. Combined footing [Strap beam may or may not be provided]

(*iii*) **Continuous Footings:** If a footing is common to more than two columns in a row, it is called continuous footing. This type of footing is necessary, if the columns in a row are closer or if SBC of soil is low. Figure 7.5 shows this type of footing.

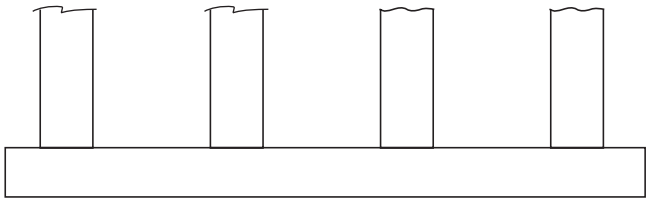


Fig. 7.5. Continuous footing

(*iv*) **Mat Footing/Raft Footing:** If the load on the column is quite high (Multistorey columns) or when the SBC of soil is low, the sizes of isolated columns may work out to be to such an extent that they overlap each other. In such situation a common footing may be provided to several columns as shown in Fig. 7.6. Such footings are known as raft footings. If the beams are provided in both directions over the footing slab for connecting columns, the raft foundations may be called as grid foundation also. The added advantage of such footing is settlement is uniform and hence unnecessary stresses are not produced.

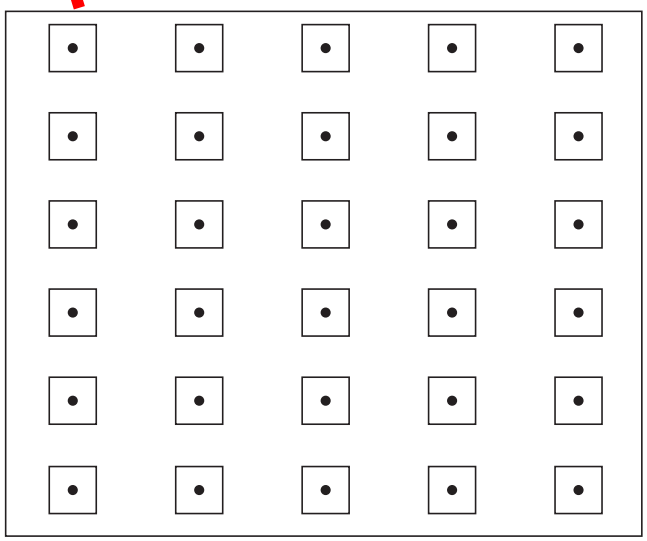


Fig. 7.6. Raft foundation

2. Partition Walls: In framed structures partition walls are built to divide floor area for different utilities. They rest on floors. They do not carry loads from floor and roof. They have to carry only self-weight. Hence normally partition walls are thin. Table 8.4 shows the differences between load bearing walls and partition walls. Depending upon the requirement these walls may be brick partition, clay block partition, glass partition, wood partition, and aluminium and glass partition.

Table 8.4. Differences between load bearing and partition walls

S. No.	*Load Bearing Walls*	*Partition Walls*
1.	They carry loads from roof, floor, self-weight etc.	They carry self-weight only.
2.	They are thick and hence occupy more floor area.	These walls are thin and hence occupy less floor area.
3.	As the material required is more, the construction cost is more.	As the material required is less, the construction cost is less.
4.	Stones or bricks are used for the construction.	Stones are not used for the construction of partition walls.

8.3 STONE MASONRY

Masonry means construction of buildings using building blocks like stone, bricks, concrete blocks etc. Masonry is used for the construction of foundation, plinth, walls and columns. Mortar is the binding material for the building blocks. In this article different types of stone masonry used are explained and points to be observed while supervising stone masonry works are listed.

Types of Stone Masonry

Mainly there are two types of stone masonry:

1. Rubble Masonry
2. Ashlar Masonry.

1. Rubble Masonry: In this type of constructions stones of irregular sizes and shapes are used. To remove sharp shapes they may be hammered. The rubble masonry may be *coursed* or *uncoursed* [Fig. 8.1 and 8.2]. In *uncoursed rubble masonry* the wall is brought to level at every 300 mm to 500 mm. The mortar consumed in these construction is more. Course rubble masonry is used for the construction of public and residential buildings. Uncoursed rubble masonry is used for the construction of foundations, compound walls, garages, labour quarters etc. A skilled mason may arrange the facing stones in *polygonal shapes* to improve the aesthetic of the wall.

13. Brick masonry should be regularly cured for 2 weeks.
14. For carrying out brick work at higher levels, only single scaffolding should be used.

Advantages and Disadvantages of Brick Masonry Over Stone Masonry

Advantages:

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

Disadvantages:

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

8.5 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 : 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 : 2 : 8.

The *objective* of plastering are:

1. to conceal defective workmanship
2. to give smooth surface to avoid catching of dust.

Fig. 8.18. Types of shell roof

Advantages and Disadvantages of Shell Roofs

Advantages of shell roofs are:

(*a*) Good from aesthetic point of view

(*b*) Material consumption is quite less

(*c*) Form work can be removed early

(*d*) Large column free areas can be covered.

Disadvantages are:

(*a*) Top surface is curved and hence advantage of terrace is lost.

(*b*) Form work is costly.

Folded plate roofs may be looked as slab with a number of folds. These roofs are also known as hipped plates, prismatic shells and faltwerke. In these structures also bending is reduced and lot of load gets transferred as membrane compression. However folded plates are not so efficient as shells. Figure 8.19 shows typical folded plate roofs.

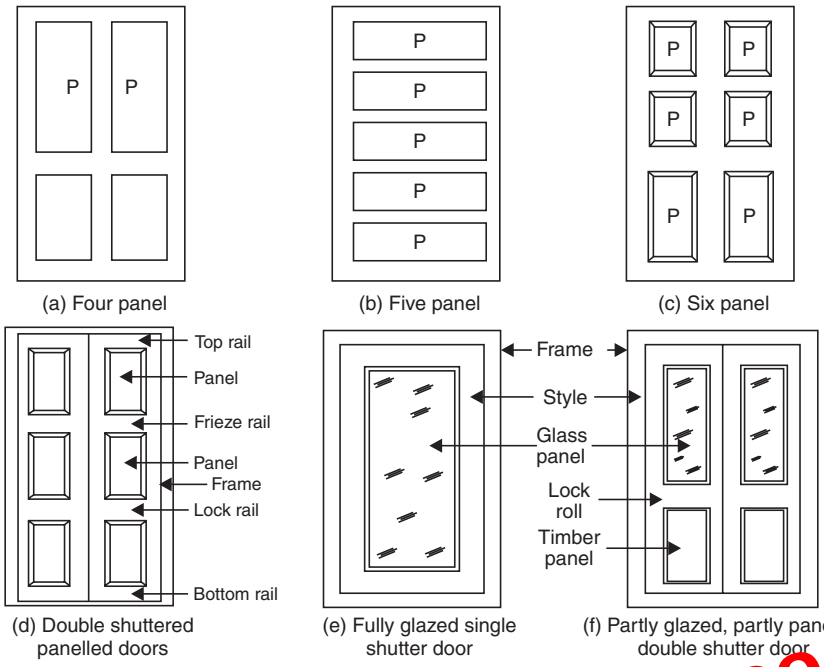


Fig. 8.23. Panelled and lazed doors

4. Flush Doors: The shutters of these doors are made of plywood or block boards. They are of uniform thickness. These shutters are available with different attractive vineer finishes. The time consumed in making such doors at site is quite less. These doors are suitable for interior portion of a building. Nowadays flush doors are commonly used in residential and office buildings. Figure 8.24 shows typical flush door.

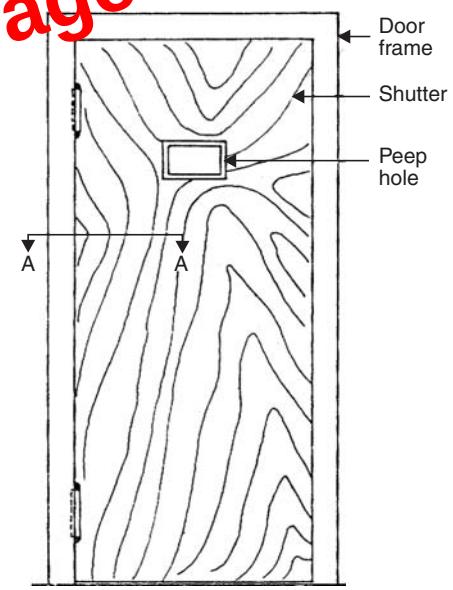


Fig. 8.24. Flush door

Salient Points to be Considered in Locating Stairs

The following points should be considered in locating stairs in a building:

(*a*) They should be located near the main entrance to the building.

(*b*) There should be easy access from all the rooms without disturbing the privacy of the rooms.

(*c*) There should be spacious approach.

(*d*) Good light and ventilation should be available.

QUESTIONS

1. What is super structure ? Distinguish between load bearing and framed structure.

2. Distinguish between load bearing wall and partition wall.

3. Write short notes on

(*i*) partition wall (*ii*) rubble and ashlar masonry.

4. State various points to be kept in mind in supervising

(*i*) stone masonry (*ii*) brick masonry

5. Distinguish between

(*i*) Stretcher and header bond (*ii*) English and Flemish bond

(*iii*) Double flemish and single flemish bonds.

6. Explain different types of bonds used in brick masonry with sketches.

7. State advantages and disadvantages of brick masonry over stone masonry.

8. What is plaster ? State common proportions used in plaster. List the objective of plaster.

9. What are the requirements of good plaster ? State number of coats and their thicknesses used in different types of plasters.

10. Write short note on pointing.

11. Distinguish between plastering and pointing.

12. What are the different types of flooring ? Briefly explain any four of them.

13. Distinguish between terrazo flooring and mosaic flooring.

14. With sketches explain reinforced brick slab and hollow tiled flooring.

15. State advantages and disadvantages of flat roofs.

16. State different types of single roofs and give their sketches.

17. What is a truss ? What are the different materials used for making trusses ? Give sketches of any four types of trusses.

18. Write short notes on

(*i*) Shell roof (*ii*) Folded plate roof.

19. Explain the advantages and disadvantages of

(*i*) Shell roofs over beam-slab construction

(*ii*) Folded plate roof over shell roof.

20. Write short notes on the following roof coverings

(*i*) thatch (*ii*) shingle

(*iii*) tiles (*iv*) slates.

21. Compare between A.C. and G.I. sheet coverings.

22. Write short notes on sizes of doors and windows.

23. Sketch the following types of doors

(*i*) Battened and ledged (*ii*) Battened, ledged and braced

(*iii*) Louvered.

24. Write short notes on

(*i*) revolving doors (*ii*) swing doors

(*iii*) sliding doors

25. Distinguish between

(*i*) Collapsible and rolling shutters (*ii*) Collapsible and revolving door.

26. Explain any four types of windows classified on the basis of their position.

27. Sketch gable, dormer, skylight and clear storey windows.

28. What is lintel ? Where do you use a lintel? Briefly explain different types of lintels used.

29. Explain the terms rise and tread of stairs. Give the desirable relationship between them.

30. Sketch dog legged, open newel and geometric stairs.

31. Write short notes on straight stairs and spiral stairs.

32. What are the salient points to be considered in locating stairs?

9.4 MATERIALS FOR DAMP PROOFING

The materials used for damp proofing are:

1. **Bitumen:** In hot condition it is highly flexible and can be applied with brush to the bedding of concrete or mortar. Thickness of coat provided is about 3 mm.
2. **Mastic asphalt:** It is a semirigid material. It is obtained by heating asphalt with sand and mineral fillers. It is perfectly impervious. It should be laid very carefully.
3. **Bituminous or asphaltic felt:** It is a flexible material which is available in rolls. It is provided on roof slabs and parapet walls with an overlap of 100 mm on sides. The laps are sealed with bitumen. They do not withstand heavy movements.
4. **Bricks:** Good bricks with water absorption less than 5 per cent are sometimes used to make damp proof courses. The bricks are laid in two to four courses in cement mortar.
5. **Stones:** Stones like granite, trap and slates may be laid over wall to its full width as damp proof course.
6. **Mortar:** Cement mortar of proportion 1 : 3 with small quantity of lime and water proofing agents are used to make a water proofing course to foundations, ground floor slabs, top of parapet walls etc. It may be used for plastering external walls.
7. **Concrete:** To check the rise of water into walls a course of 75 mm to 100 mm cement concrete 1 : $1\frac{1}{2}$: 3 or 1 : 2 : 4 is provided before starting constructing walls. These courses may be provided with hot bitumen paint as an additional precaution.
8. **Metal sheets:** Aluminium, copper or lead sheets are provided to seal the construction joints. Over these sheets bituminous seal is provided.
9. **Plastic sheets:** Plastic sheets are very good course for damp proofing. They are made up of black polythene of thickness 1 mm.

9.5 METHODS OF DAMP PROOFING

Various methods of damp proofing are as given below:

1. Providing D.P.C. course
2. Providing cavity walls
3. Surface treatment
4. Integral treatment
5. Guniting and
6. Pressure grouting.

1. **Providing damp proof course:** It consists of providing a damp proof course between the source of dampness and building component. The DPC may be with any water repellant

material like bitumen, mastic asphalt, cement concrete, metal or plastic sheets. DPC should cover full width of wall. It should be laid on levelled surface of mortar. Joints should be minimum and should not be at critical points. When horizontal DPC on roof is continued on vertical face of parapet wall, the junction should be filled with about 75 mm fillet of cement concrete. Figure 9.1 shows details of providing water proof course at plinth level. Whereas Figure 9.2 shows the details of water proofing course for wall and floor. Figure 9.3 shows details of water proofing course for basement.

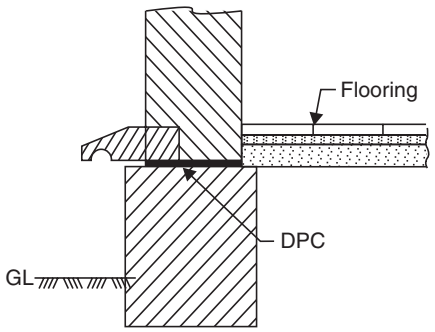


Fig. 9.1. DPC at plinth level

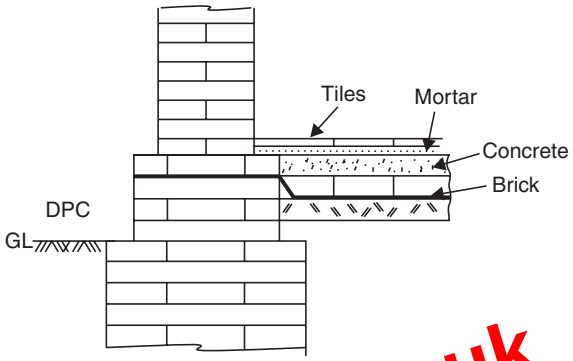


Fig. 9.2. DPC at floor level

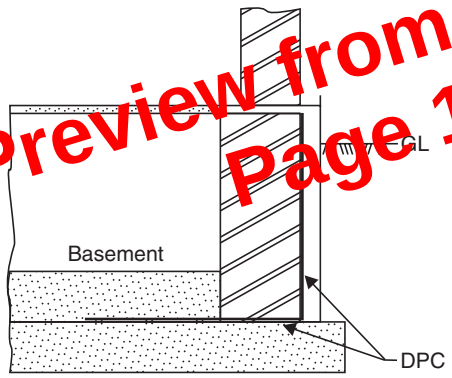


Fig. 9.3. DPC for basement

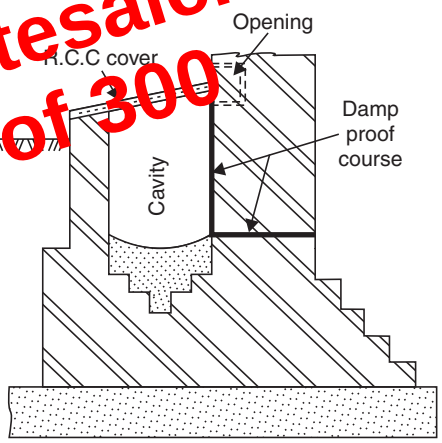


Fig. 9.4. Providing cavity wall

2. **Providing cavity wall:** Cavity wall may be constructed to protect foundation masonry and the wall as shown in Fig. 9.4. The cavity prevents moisture travelling from outer to inner wall.
3. **Surface treatment:** If moisture is only superficial and not under pressure this method is useful. It consists of application of layer of water repellant compounds on the surface. Some of the water proofing agents used for such treatment are silicates of sodium or potassium and sulphates of aluminium, zinc and magnesium.

CHAPTER 10

Cost Effective Construction Techniques In Mass Housing Schemes

Large per cent of the population of India is residing in temporary houses of mud, bamboo, thatched or erected from waste products in a very crude form. The temporary houses (Jhuggi) are not only unsafe but unhygenic to live in. Government of India and all state governments in India are aware of this massive problem and hence have established housing boards for development of housing sites and mass construction of houses. The national housing policy emphasises on the following:

1. Arrangement for selection and promotion of proven technology.
2. Promotion of manufacture of building materials and components through financial assistance, technical help, fiscal concessions.
3. Support extensive network of building centres.
4. Setting up of dedicated organization for technology, research, application and promotion concerning the following areas:
   (*a*) Building materials and components.
   (*b*) Selective approach to technology.
   (*c*) Marketing through building centres.
   (*d*) Franchising of the building centres.
   (*e*) Development of appropriate standards.

As a result of this housing policy, a lot of fund flows to educational institutions and research centres for developing low cost housing technology, establishment of Nirmithi Kendras and good number of mass housing works coming under Ashraya Yojana.

10.1 MINIMUM STANDARDS

It is obvious that cost of construction is directly proportional to the area covered. In low cost housing economy in the construction is a vital factor, but one should not lose sight of the fact that any economies effected are not worth, if the minimum requirements of basic physical comfort in the dwellings are not met. In order to meet these twin requirements of economy and comfort, one has to depend to the maximum extent on the cost effective construction technology to provide minimum standard accommodation. On the recommendations of the planning commission, the Government of India has adopted the following minimum standards:

11.3 FUNDAMENTAL PRINCIPLES OF SURVEYING

To get accurate results in surveying one should follow the following fundamental principles:

(*i*) Work from whole to part

(*ii*) Take extra care in fixing new control points.

11.3.1 Work from Whole to Part

In surveying large areas, a system of control points are identified and they are located with high precision. Then secondary control points are located using lesser precise methods. The details of the localised areas are measured and plotted with respect to the secondary control points. This is called working from whole to part. This principle in surveying helps in localising the errors. If the surveying is carried out by adding localised areas errors accumulated and may become unacceptable when large area is covered.

11.3.2 Extra Care in Fixing New Control Points

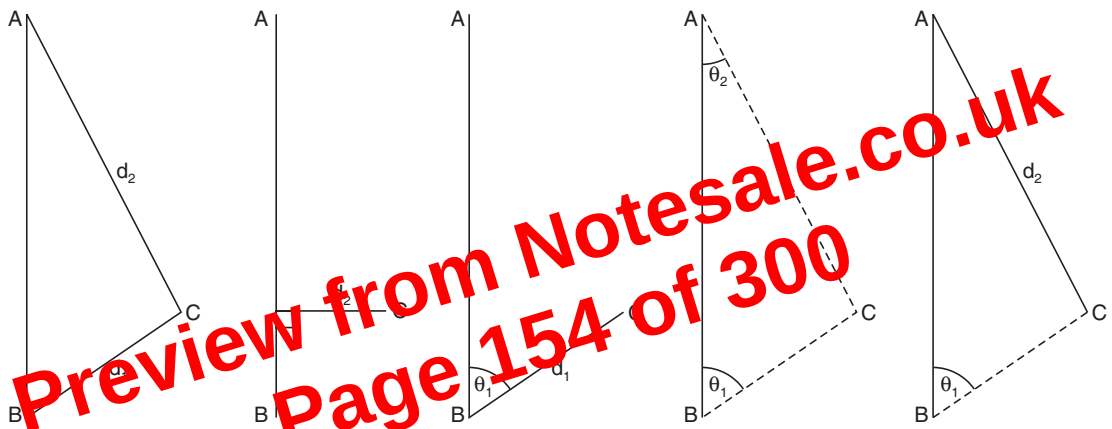


Fig. 11.3. Locating point C w.r.t. points A and B

Figure 11.3 shows the various methods of fixing point *C* with respect to already fixed points *A* and *B* by measuring sides, angles or setting perpendiculars. For fixing new control points (stations) with respect to already fixed points at least two independent process should be followed. If *A* and *B* are already located control points and with respect to them new control point *C* is to be located, apart from the minimum measurements required as shown in Fig. 11.3, one more measurement should be taken. Measuring the lengths of check lines and tie lines will also serve this purpose (Ref. Fig. 11.4).

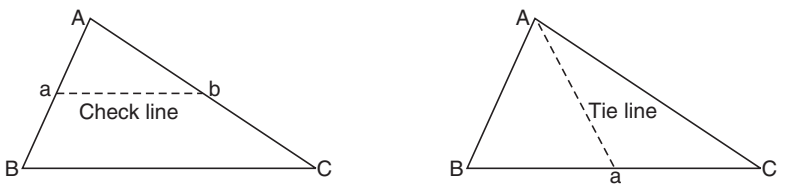


Fig. 11.4. Check line and tie line

■ **Example 11.1:** *Construct a plain scale of RF =* $\frac{1}{500}$ *and indicate 66 m on it.*

Solution. If the total length of the scale is selected as 20 cm, it represents a total length of 500 × 20 = 10000 cm = 100 m. Hence, draw a line of 20 cm and divide it into 10 equal parts.

Hence, each part correspond to 10 m on the ground. First part on extreme left is subdivided into 10 parts, each subdivision representing 1 m on the field. Then they are numbered as 1 to 10 from right to left as shown in Fig. 11.6. If a distance on the ground is between 60 and 70 m, it is picked up with a divider by placing one leg on 60 m marking and the other leg on subdivision in the first part. Thus field distance is easily converted to map distance.

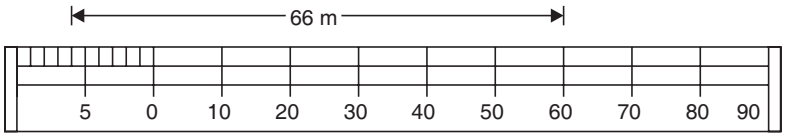


Fig. 11.6

IS 1491—1959 recommends requirements of metric plain scales designated as A, B, C, D, E and F as shown in Table 11.2. Such scales are commonly available in the market. They are made of either varnished cardboard or of plastic materials. Such scales are commonly used by surveyors and architects.

Table 11.2. Recommended plain scales

Designation	*Scale*	*RF*
A	Full size	1/1 (1:1)
	50 cm to a metre	1/2 (1:2)
B	40 cm to a metre	1/2.5 (1:25)
	20 cm to a metre	1/5 (1:5)
C	10 cm to a metre	1/10 (1:10)
	5 cm to a metre	1/20 (1:20)
D	2 cm to a metre	1/50 (1:50)
	1 cm to a metre	1/100 (1:100)
E	5 mm to a metre	1/200 (1:200)
	2 mm to a metre	1/500 (1:500)
F	1 mm to a metre	1/1000 (1:1000)
	0.5 mm to a metre	1/2000 (1:2000)

11.7.2 Diagonal Scale

In plain scale only unit and tenths can be shown whereas in diagonal scales it is possible to show units, tenths and hundredths. Units and tenths are shown in the same manner as in plain scale. To show hundredths, principle of similar triangle is used. If *AB* is a small length and its tenths are to be shown, it can be shown as explained with Fig. 11.7 below.

(*i*) **Cloth or Linen Tape:** 12 to 15 mm wide cloth or linen is varnished and graduations are marked. They are provided with brass handle at the ends. They are available in length of 10 m, 20 m, 25 m and 30 m. These tapes are light and flexible. However because of the following disadvantages they are not popular:

(*i*) Due to moisture they shrink.

(*ii*) Due to stretching they extend.

(*iii*) They are not strong.

(*iv*) They are likely to twist.

(*ii*) **Metallic Tape:** They are made up of varnished strip of waterproof linen interwooven with small wires of brass, copper or bronze. End 100 mm length of tapes are provided with leather or suitable strong plastic materials. Tapes of length 10 m, 20 m, 30 m and 50 m are available in a case of leather or corrosion resistant metal fitted with a winding device. Red and black coloured markings are used for indicating full metres and its fractions in centimetres. A typical metallic tape is shown in Fig. 12.2. These tapes are light, flexible and not easily broken. These tapes are commonly used in surveying.

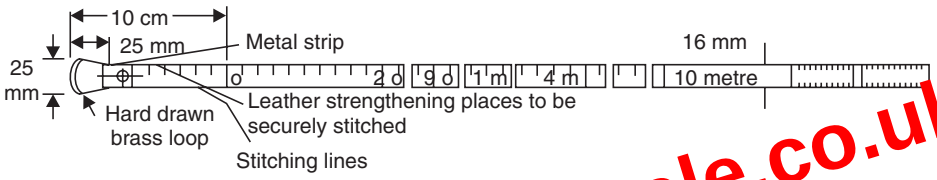


Fig. 12.2. Metallic tape

(*iii*) **Steel Tape:** A steel tape consists of 6 mm to 10 mm wide strip with metal ring at free end and wound in a leather or corrosion resistant metal case. It is provided with a suitable winding device. Tapes are marked indicating 5 mm, centimetres, decimetres and metres. The end 10 cm length is marked with millimetres also. 10 m, 20 m, 30 m, or 50 m tapes are used in surveying. Figure 12.3 shows a typical steel tape (Ref. Plate 12.1 also). Steel tapes are superior to metallic tapes as far as accuracy is concerned. However they are delicate. Care should be taken to wipe clean before winding. They should be oiled regularly to prevent corrosion.

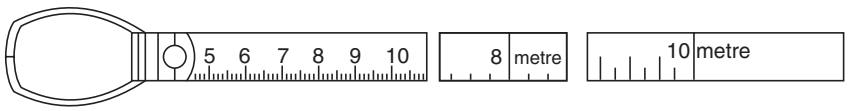


Fig. 12.3. Steel tape

(*iv*) **Invar Tape:** Invar is an alloy of nickel (36%) and steel. It's coefficient of thermal expansion is low. Hence errors due to variation in temperature do not affect measurements much. The width of tape is 6 mm. It is available in length 30 m, 50 m and 100 m. It is accurate but expensive.

12.1.3 Measurements by Optical Means

In this system, the telescope of the angle measuring instrument called theodolite (to be explained in Ch. 16) is provided with two additional cross hairs at *a* and *b* which are at distance '*i*' [Ref. Fig. 12.4]. To measure distance 'D' between two point P and Q instrument is set at P and a graduated staff is held vertically at Q and vertical intercept AB is recorded. Then distance D can be computed as explained below:

12.2 INSTRUMENTS USED IN CHAINING

The following instruments are required for measurements with chain and tape:

(*i*) Arrows
(*ii*) Pegs
(*iii*) Ranging rods and ranging poles
(*iv*) Offset rods
(*v*) Laths
(*vi*) Whites
(*vii*) Plumb bobs and
(*viii*) Line ranger.

12.2.1 Arrows

When the length of the line to be measured is more than a chain length, there is need to mark the end of the chain length. Arrows are made up of 4 mm diametered steel wire with one end sharpened and other end bent into a loop. Length of an arrow is approximately 400 mm.

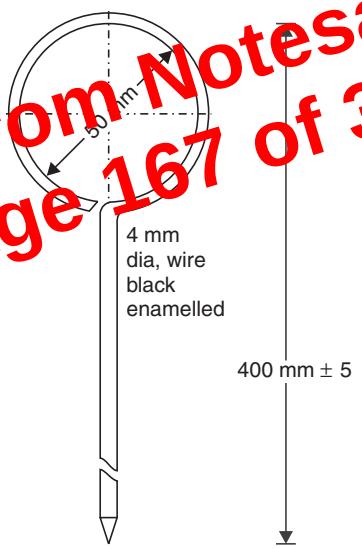


Fig. 12.5. Arrows

12.2.2 Pegs

Wooden pegs are used in measuring a length of a line to mark the end points of the line. The pegs are made of hard wood of 25 mm × 25 mm section, 150 mm long with one end tapered as shown in Fig. 12.6. When driven in ground to mark station points they project about 40 mm.

Check lines: These are the lines connecting main station and a substation on opposite side or the lines connecting to substations on the sides of main lines. The purpose of measuring such lines is to check the accuracy with which main stations are located.

12.3.2 Selection of Stations

The following points should be considered in selecting station points:

(*i*) It should be visible from at least two or more stations.

(*ii*) As far as possible main lines should run on level ground.

(*iii*) All triangles should be well conditioned (No angle less than 30º).

(*iv*) Main network should have as few lines as possible.

(*v*) Each main triangle should have at least one check line.

(*vi*) Obstacles to ranging and chaining should be avoided.

(*vii*) Sides of the larger triangles should pass as close to boundary lines as possible.

(*viii*) Tresspassing and frequent crossing of the roads should be avoided.

12.3.3 Offsets

Lateral measurements to chain lines for locating ground features are known as offsets. For this purpose perpendicular or oblique offsets may be taken (Ref. Fig. 12.12). If the object to be located (say road) is curved more number of offsets should be taken. For measuring offsets tapes are commonly used.

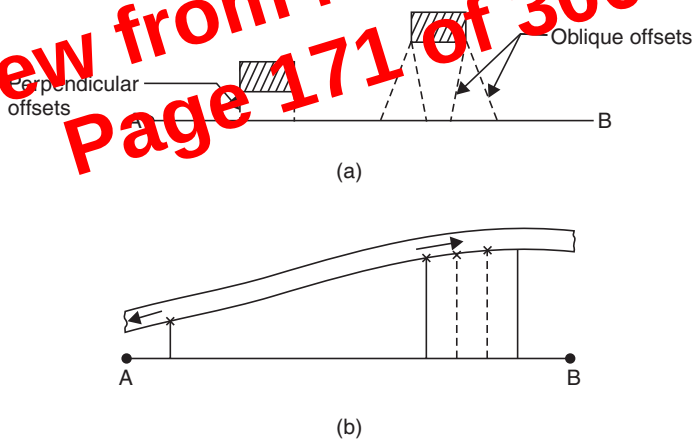


Fig. 12.12. Offsets

For setting perpendicular offsets any one of the following methods are used:

(*i*) Swinging

(*ii*) Using cross staffs

(*iii*) Using optical or prism square.

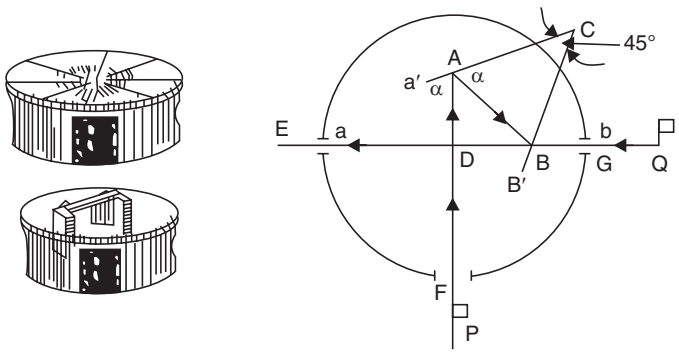


Fig. 12.15. Optical square

Optical square consists of a metal box about 50 mm in diameter and 125 mm deep. In the rim of the box there are three openings:

(*i*) a pin hole at E

(*ii*) a small rectangular slot at G, and

(*iii*) a large rectangular slot at F.

A and B are the two mirrors placed at 45° to each other. Hence the image of an object at F which falls on A gets reflected and emerge at E which is at right angles to the line FA. The mirror A which is opposite to the opening at F is fully silvered. It is fitted to a frame which is attached to the bottom plate. If necessary this mirror can be adjusted by inserting a key on the top of the cover. The mirror B which is in the line with EG is silvered in the top half and plain in the bottom half. It is firmly attached to the bottom plate of the box.

The ranging rod at G is directly sighted by eye at E in the bottom half of the B which is a plain glass. At the same time in the top half of B, the reflected ray of the object at P is sighted. When the image of P is in the same vertical line as the object at Q, then the lines PA is at right angles to the line EB.

This instrument can be used for finding foot of the perpendicular or to set a right angle.

In prism square, instead of two mirrors at 45° to each other a prism which has two faces at 45° to each other is used [Fig. 12.16.]. Its advantage is it will not go out of adjustment even after long usage.

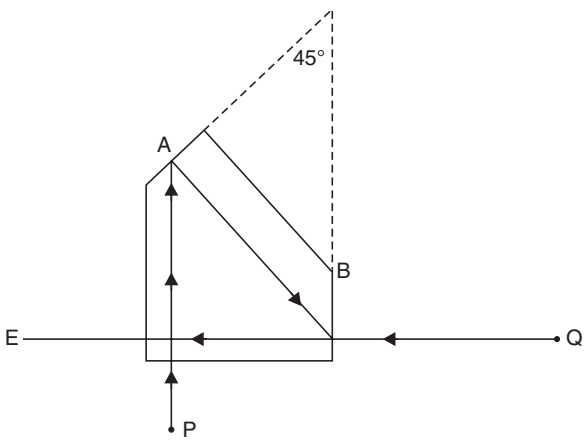


Fig. 12.16. Prism square

12.3.4 Field Book

All observations and measurements taken during chain surveying are to be recorded in a standard field book. It is a oblong book of size 200 mm × 120 mm, which can be carried in the pocket.

There are two forms of the book (*i*) single line and (*ii*) double line. The pages of a single book are having a red line along the length of the paper in the middle of the width. It indicates the chain line. All chainages are written across it. The space on either side of the line is used for sketching the object and for noting offset distances. In double line book there are two blue lines with a space of 15 to 20 mm is the middle of each book. The space between the two lines is utilised for noting the chainages. Figure 12.17 shows typical pages of a field books.

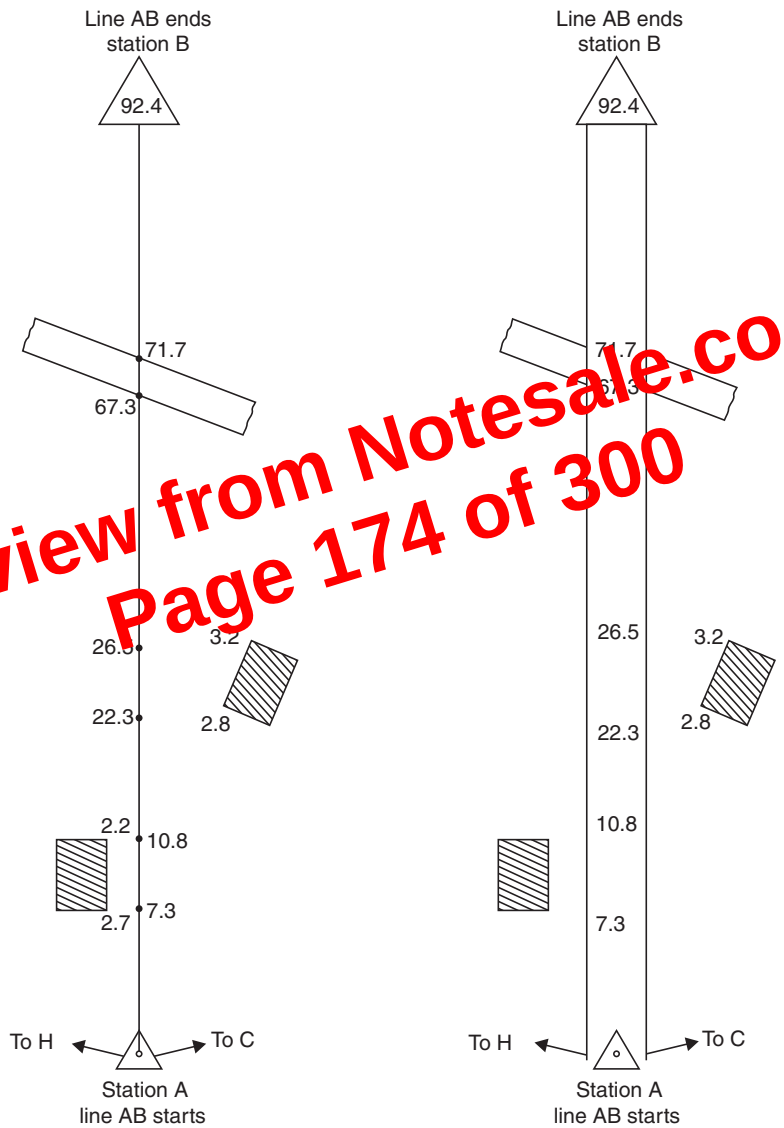


Fig. 12.17

Various obstacles to chaining may be grouped into:

(*i*) Obstacles to ranging (chaining free-vision obstructed)
(*ii*) Obstacles to chaining (chaining obstructed-vision free)
(*iii*) Obstacles to both ranging and chaining.

Various methods of overcoming these obstacles are explained is this article.

12.5.1 Obstacles to Ranging

These obstacles can be further classified into the following categories:

(*a*) Both ends of the line are visible from some intermediate points. Intervening ground is an example of such obstacle. By resorting to reciprocal ranging this difficulty can be overcome.

(*b*) Both ends of the line may not be visible from intermediate points on the line, but may be visible from a point slightly away from the line. Intervening trees and bushes are the examples of such obstacles. This obstacle to chaining may be overcome by measuring along a random line as shown in Fig. 12.20. In this case required length

$$EB = \sqrt{EC^2 + CB^2}$$

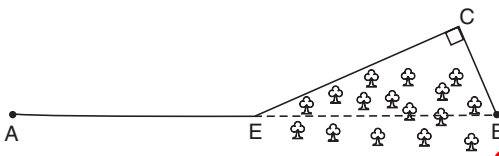


Fig. 12.20. Obstacle to ranging

12.5.2 Obstacles to Chaining

In this type the ends of lines are visible but chaining is obstructed. Examples of such obstructions are ponds, lakes, marshy land etc. Various geometric properties may be used to find obstructed length CB as shown in Fig. 12.21.

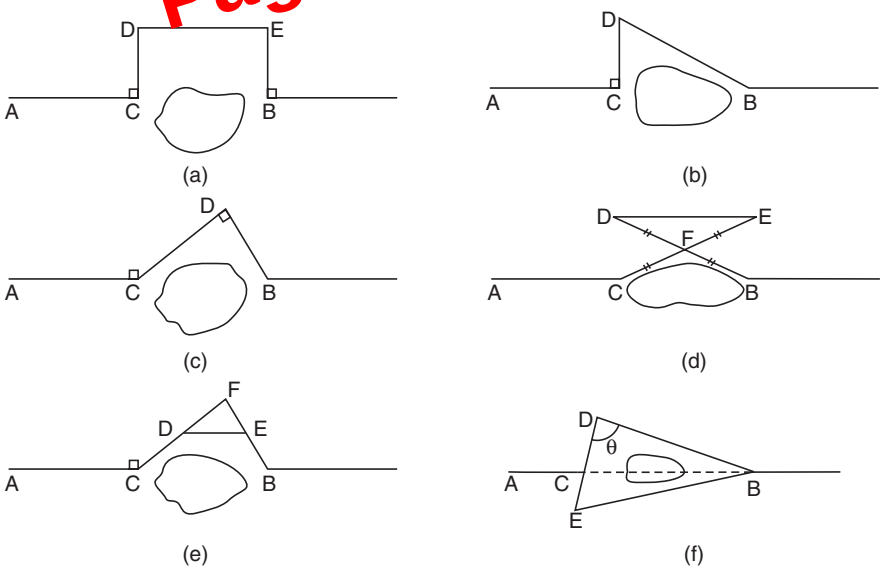


Fig. 12.21. Obstacles to chaining

$$= \frac{(150 - 80) \times 30}{2 \times 10^5 \times 8}$$

$$= 1.3125 \times 10^{-3} \text{ m}$$

[*Note:* Unit of AE comes out to be Newton only, if A is in cm^2 or mm^2 and E in N/cm^2 or N/mm^2].

∴ Total correction for temperature and pull

$$= C_t + C_p = 3.360 \times 10^{-3} + 1.3125 \times 10^{-3}$$

$$= 4.6725 \times 10^{-3} \text{ m per chain length}$$

■ **Example 12.6:** *Calculate sag correction for a 30 m steel tape under a pull of 80 N, if it is suspended in three equal spans. Unit weight of steel is 78.6 kN/m^3. Area of cross-section of tape is 8 mm^2.*

Solution: Length of each span = 10 m

W = wt. of taper per span length

$$= 78.6 \times 10 \times (8 \times 10^{-6})$$

$$= 6288 \times 10^{-6} \text{ kN} = 6.288 \text{ N}$$

[*Note:* 1 $mm^2 = (0.001)^2$ $m^2 = 1 \times 10^{-6}$ m^2]

P = 80 N L = 10 m

∴ Correction for each span

$$= \frac{1}{24}\left(\frac{6.288}{80}\right)^2 \times 10$$

$$= 2.574 \times 10^{-3} \text{ m}$$

∴ **Correction for three spans**

$$= 3 \times 2.574 \times 10^{-3} \text{ m}$$

$$= \mathbf{7.722 \times 10^{-3} \text{ m}} \quad \textbf{Ans.}$$

■ **Example 12.7:** *A 30 m steel tape was standardised under 60 N pull at 65° F. It was suspended in 5 equal span during measurement. The mean temperature during measurement was 90° F and the pull exerted was 100 N. The area of the cross-section of the tape was 8 mm^2. Find the true length of the tape, if,*

$\alpha = 6.3 \times 10^{-6}$/°F, $E = 2 \times 10^5$ *N/mm^2 and unit weight of steel = 78.6 kN/m^3.*

Solution: *Correction for temperature:*

$$C_t = l \, \alpha \, (T_m - T_0)$$

$$= 30 \times 6.3 \times 10^{-6} \, (90 - 65)$$

$$= 4.725 \times 10^{-3} \text{ m}$$

Correction for pull:

$$C_p = \frac{(P - P_0)\, l}{AE} = \frac{(100 - 60) \times 30}{8 \times 2 \times 10^5} = 0.75 \times 10^{-3} \text{ m}$$

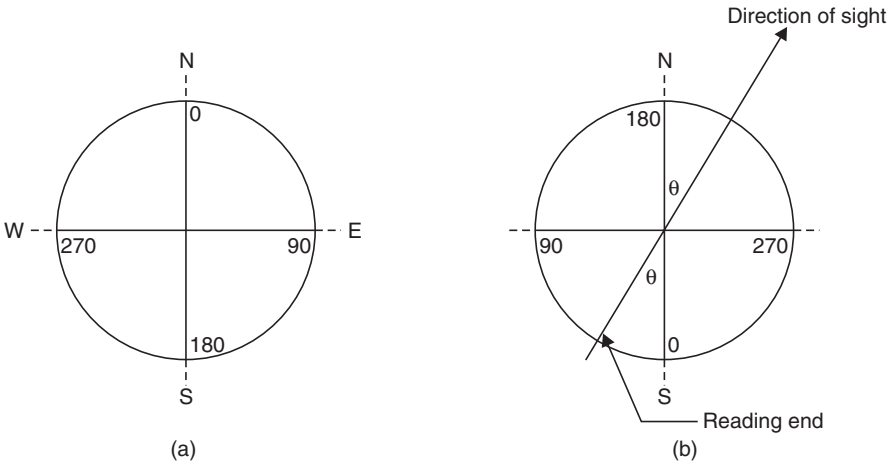


Fig. 13.2

The line of sight consists of object unit and the reading unit. Object unit consists of a slit metal frame (5) hinged to the box. In the centre the slit is provided with a horse hair or a fine wire or thread (6). The metal frame is provided with a hinged mirror (7), which can be placed upward or downward on the frame. It can be slided along the frame. The mirror can be adjusted to view objects too high or too low from the position of compass. Reading unit is provided at diametrically opposite edge. It consists of a prism (8) with a sighting eye vane (9). The prism magnifies the readings on the graduation disk just below it. For focussing, the prism is lowered or raised on the frame carrying it and then fixed with the stud (10). Dark sunglasses (11) provided near the line of sight can be interposed if the object to be sighted is bright (*e.g.,* sun).

The bottom of the box (12) which is about 85 mm to 110 mm supports the pivot of needle firmly at its centre. The object vane and the prism are supported on the sides of the box. The box is provided with a glass (13) lid which protects the graduation disc at the same time permit the direct reading from the top. When the object vane is folded on the glass top it presses a lifting pin (14) which activates lifting lever (15) lifts the needle off the pivot. Thus, it prevents undue wear of pivot point. While taking reading, if graduation disc vibrates, it can be dampened with a spring (16). For pressing spring a knob or brake pin (17) is provided on the box. When not in use prism can be folded over the edge of the box. The box is provided with a lid to close it when the compass is not in use. The box is provided with a socket to fit it on the top of a tripod.

13.1.2 Surveyors Compass

In this type of compass graduation disc is fixed to the box and magnetic needle is free to rotate above it. There is no prism provided at viewing end, but has a narrow slit. After fixing the line of sight, the reading is directly taken from the top of the glass cover. Hence, graduations are written directly (not inverted). In this compass graduations are from zero to 90°, zero being to north or south and 90° being to east and west. An angle of 20° to north direction to the east is written as N 20° E, and an angle of 40° to east from south is written as S 40° E. Always first direction indicated is north or south and the last letter indicates east or west direction. In this system graduated circle rotates with line of sight and magnetic needle is always towards north. The reading is taken at the tip of needle. Hence, on the compass east and west are marked interchanged and marked [Ref. Fig. 13.3] Plate 13.2 shows the photograph of a surveyors compass.

(*iv*) Since it is in NW quadrant,

$$32° 42' = 360° - \theta$$

or $$\theta = 360° - 32° 42' = \mathbf{327° 18'}$$ **Ans.**

■ **Example 13.2:** *The following fore bearings were observed for lines, AB, BC, CD, DE, EF and FG respectively. Determine their back bearings:*

(*i*) *148°* (*ii*) *65°*

(*iii*) *285°* (*iv*) *215°*

(*v*) *N 36° W* (*vi*) *S 40° E*

Solution: The difference between fore bearing and the back bearing of a line must be 180°. Noting that in WCB angle is from 0° to 360°, we find back bearing = fore bearing ± 180°

+ 180° is used if θ is less than 180° and

– 180° is used when θ is more than 180°.

Hence

(*i*) BB of AB = 145° + 180° = 325°

(*ii*) BB of BC = 65° + 180° = 245°

(*iii*) BB of CD = 285° – 180° = 105°

(*iv*) BB of DE = 215° – 180° = 35°

In case of RB, back bearing of a line can be obtained by interchanging N and S at the same time E and W. Thus

(*v*) BB of EF = S 36° E

(*vi*) BB of FG = N 40° W.

13.5 COMPUTATION OF ANGLES

At any point, if bearings of any two lines are known, the angle between these two lines can be easily found by drawing a neat sketch, and then noting the difference. The procedure is illustrated with the examples given below.

■ **Example 13.3:** *In a closed traverse the following bearings were observed with a compass. Calculate the interior angles.*

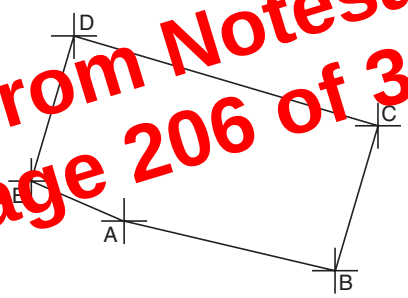
Line	*Fore bearing*
AB	*65° 00′*
BC	*125° 30′*
CD	*200° 00′*
DE	*265° 15′*
EA	*330° 00′*

QUESTIONS

1. Explain with a neat sketch construction of a prismatic compass.
2. Bring out the differences between prismatic compass and surveyor's compass.
3. Distinguish between
   (*a*) Magnetic meridian and true meridian.
   (*b*) Whole circle bearing and quadrantal bearing.
   (*c*) Declination and dip.
   (*d*) Fore bearing and back bearing.
   (*e*) Isogonic and agonic lines.
4. What is meant by magnetic declination? List the different types of its variations.
5. What is local attractions? How it is detected in the field?
6. What are the precautions to be taken while taking bearing of a line with a compass.
7. In traversing in anticlockwise direction, the following readings were observed:

Line	AB	BC	CD	DE	EA
FB	105° 15′	20° 00′	316° 30′	187° 15′	122° 45′

Draw a neat sketch of the traverse. Determine the interior angles of the traverse and apply check.



$\angle A = 162° 30'$ $\angle B = 94° 45'$

$\angle C = 116° 30'$ $\angle D = 50° 45'$

$\angle E = 115° 30'$ $\Sigma\theta = 540°$ Checked. **Ans.**

8. The following bearings were taken in running a compass traverse:

Line	*FB*	*BB*
AB	124° 30′	304° 30′
BC	68° 15′	246° 00′
CD	310° 30′	135° 15′
DA	200° 15′	17° 45′

At what stations do you suspect local attraction? Find the correct bearings of the lines and also compute the included angles.

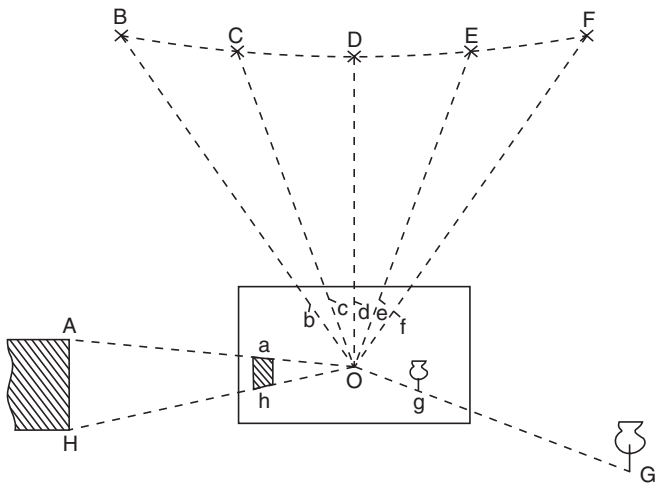


Fig. 14.7. Radiation method of plane tabling

14.3.2 Intersection

In this method the plotted position of an object is obtained by plotting rays to the object from two stations. The intersection gives the plotted position. Thus it needs the linear measurements only between the station points and do not need the measurements to the objects. Figure 14.8 shows the method for locating objects A and B from plane table positions O_1 and O_2.

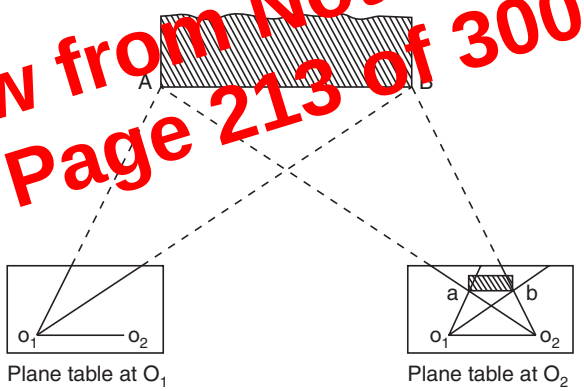


Fig. 14.8. Intersection method of plane tabling

This method is commonly employed for locating:

(*a*) details

(*b*) the distant and inaccessible points

(*c*) the stations which may be used latter.

14.3.3 Traversing

This is the method used for locating plane table survey stations. In this method, ray is drawn to next station before shifting the table and distance between the stations measured. The distance is scaled

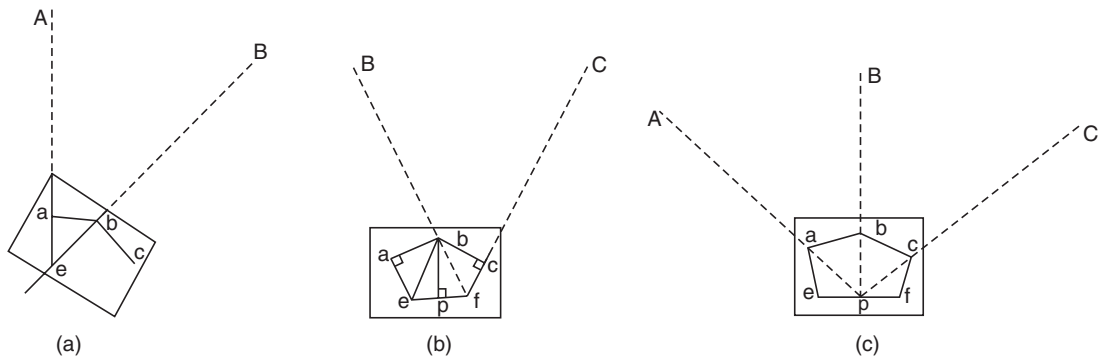


Fig. 14.15. Method of perpendiculars of solve three point problem

3. Join *cf* drop *bp* perpendicular to *ef* to get the plotted position '*p*'.
4. Orient the table such that *pb*B are in a line. Clamp the table to place it in correct orientation. Resections A*a* and C*c* may be used to check the orientation.

Trial and Error Method

This method is also known as *'triangle of error method'* and '*Lehman's Method'*. It involves the following steps:

1. Set the table over point P and orient the table approximately just by observation.
2. Draw the rays *a*A, *b*B and *c*C [Fig. 14.16]. If the orientation was perfect, the three rays would have intersected at a single point, *i.e.* at point '*p*'. Otherwise a triangle of error is formed.
3. To eliminate the triangle of error an approximate position, ray *p′*, is selected near the triangle of error. Then keeping alidade along *p′a* object A is sighted and the table is clamped. Draw the resectors *c*C and *b*B to check the orientation.
4. Above step is repeated till triangle of error is eliminated.

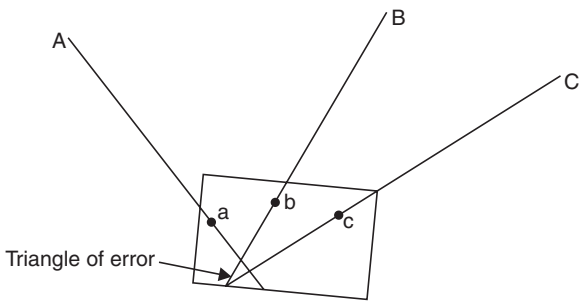


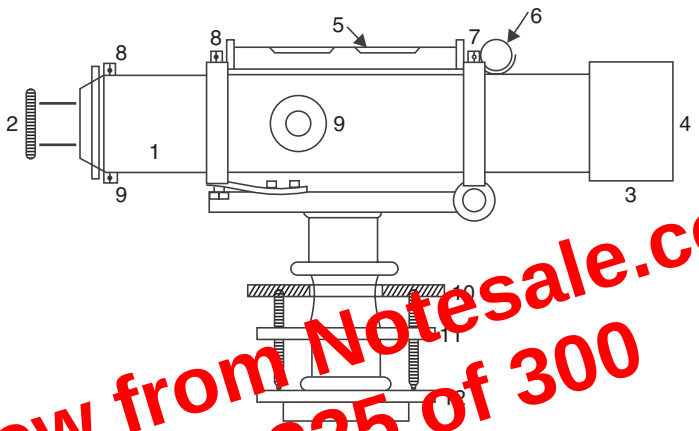
Fig. 14.16

Lehman presented the following guidelines to select '*p′*' so that triangle of error is eliminated quickly.

Rule 1: The distance of point sought '*p*' is in the same proportion from the corresponding rays as the distance of those from the plane table station.

dumpy level. The telescope rotates in horizontal plane in the socket of the levelling head. A bubble tube is attached to the top of the telescope. Figure 15.3 shows a typical dumpy level. Plate 15.1 shows its photograph.

Plate 15.1 Dumpy level



1. Telescope
2. Eyepiece
3. Shade
4. Objective end
5. Longitudinal bubble tube
6. Transverse bubble tube
7. Bubble tube adjusting screws
8. Diaphragm adjusting screws
9. Focusing screws
10. Foot screws
11. Upper parallel plate (tribrach)
12. Foot plate (Trivet stage)

Fig. 15.3. Dumpy level

Telescope is a tube with object glass and eyepiece. Object glass can be adjusted using the focussing screw before sighting the graduated staff held on the object. Eyepiece can be adjusted by rotating it to see that parallel is removed and cross hairs appears distinctly. Eyepiece once adjusted needs no change as long as the same person takes the readings.

Level tube is a glass tube with slightly curved shape provided over the level tube. The tube is filled with ether or alcohol leaving a little air gap, which takes the shape of a bubble. The air bubble is always at the highest point. The level tube is fixed with its axis parallel to telescope tube, so that when bubble is centred, the telescope is horizontal. The tube is graduated on either side of its centre to estimate how much the bubble is out of centre. The glass tube is placed inside a brass tube which is open from top and on lower side it is fixed to telescope tube by means of capston headed nuts. The bubble tube is adjusted with these nuts, if it is out of order.

Levelling head consists of two parallel plates with three foot screws. The upper plate is known as tribratch plate and the lower one as the trivet. The lower plate can be screwed on to the tripod stand. By adjusting the screws the instrument can be levelled to get perfect horizontal line of sight.

Dumpy level is to be fitted to a tripod stand to use it in the field. The tripod stand consists of three legs connected to a head to which the lower plate of level can be fitted. The lower side of the legs are provided with metal shoes to get good grip with ground. Plate 15.2 shows typical level stands.

Plate 15.2 Levelling stands (adjustable and non-adjustable)

15.3.2 Wye or Y-Level

In this type of level, the telescope is supported in two Y-shaped supports and can be fixed with the help of curved clips. Clips can be opened and telescope can be reversed end to end and fitted. The advantage of this level is some of the errors eliminated, if the readings are taken in both the direction of telescope.

15.3.3 Cooke's Reversible Level

In this instrument the telescope is supported by two rigid sockets into which telescope can be introduced from either end and then screwed. For taking the readings in the reversed position of telescope, the screw is slackened and then the telescope is taken out and reversed end for end. Thus it combines the rigidity of dumpy level and reversibility of Y-level.

15.3.4 Cushing Level

In this reversing of telescope end for end is achieved by interchanging the eyepiece and the objective piece since both collars are exactly the same.

15.3.5 Tilting Level

In this, telescope can be tilted through about four degrees with the help of a tilting screw. Hence bubble can be easily centered. But it needs centering of the bubble before taking every reading. Hence it is useful, if at every setting of the instrument number of readings to be taken are few.

15.3.6 Auto Level

The auto-level or the automatic-level is a self aligning level. Within a certain range of tilt automatic levelling is achieved by an inclination compensating device. The operational comfort, high speed and precision are the advantages of this instrument.

15.4 LEVELLING STAFF

Along with a level, a levelling staff is also required for levelling. The levelling staff is a rectangular rod having graduations. The staff is provided with a metal shoes at its bottom to resist wear and tear. The foot of the shoe represents zero reading. Levelling staff may be divided into two groups:

R_3			9						
		20							
L_1	3								
L_2	6								
L_3	9								
R_1			3						
R_2			6						
R_3			9						
									Checked.

15.8.6 Reciprocal Levelling

In levelling, it is better to keep distance of back sight and fore sight equal. By doing so the following errors are eliminated:

(*i*) Error due to non-parallelism of line of collimation and axis of bubble tube.

(*ii*) Errors due to curvature and refraction.

But in levelling across obstacles like river and ravine, it is not possible to maintain equal distances for fore sight and back sight. In such situations reciprocal levelling as described below is used:

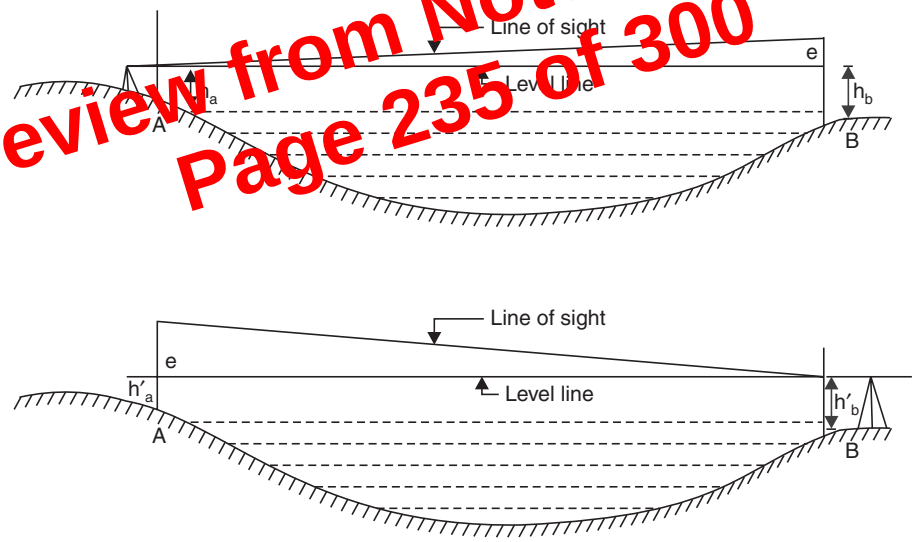


Fig. 15.10

(*i*) Referring to Fig. 15.10 (*a*).

Since A is very close, error in reading at A is negligible. Hence h_a is correct reading.

Let error in h_b be '*e*',

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18.1.1 Computation of Areas of Regular Figures

The following expressions for calculating areas may be noted:

(*a*) **Triangle:**

(*i*) If base width is *b* and height is '*h*',

$$A = \frac{1}{2} bh \qquad ...(18.1)$$

(*ii*) If *a, b* and *c* are the sides of a triangle,

$$A = \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$$

where $$s = \frac{a+b+c}{2} \qquad ...(18.2)$$

(*b*) **Rectangle:** If *b* and '*d*' are the dimension of a rectangle,

$$A = bd \qquad ...(18.3)$$

(*c*) **Trapezium:**

$A = d\,\frac{h_1 + h_2}{2}$, where *d* is the distance between two parallel sides and h_1 and h_2 lengths of parallel sides. ...(18.4)

18.1.2 Areas of Irregular Shapes

For this purpose from a survey line offsets are taken at regular intervals and area is calculated from any one of the following methods:

(*a*) Area by Trapezoidal rule

(*b*) Area by Simpson's rule

(*a*) **Area by Trapezoidal Rule:**

If there are '$n + 1$' ordinates at *n* equal distances '*d*', then total length of line is $L = nd$, Area of each segment is calculated treating it as a trapezium. Referring to Fig. 18.2,

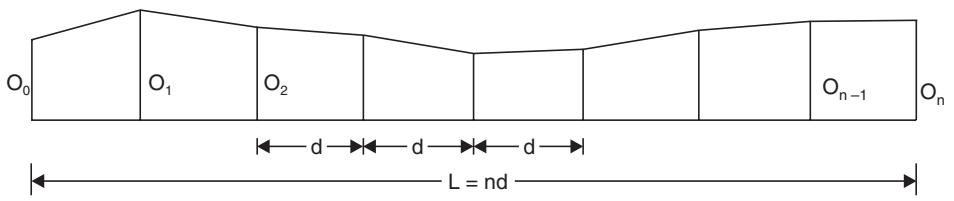


Fig. 18.2

Area of first segment = $\frac{O_0 + O_1}{2}\,d$

$$= \frac{1}{2} \times 22 \times 15 + \frac{1}{2} \times 45 \times 21 + \frac{1}{2} (15 + 20) (60 - 22) + \frac{1}{2} (13.8 + 21.0) (85 - 45)$$

$$+ \frac{1}{2} \times 20 (120 - 60) + \frac{1}{2} \times 13.8 (120 - 8.5)$$

Area = 2840 m^2 **Ans.**

■ **Example 18.2:** *The perpendicular offsets taken at 10 m intervals from a survey line to an irregular boundary are 2.18 m, 3.2 m, 4.26 m, 6.2 m, 4.8 m, 7.20 m, 8.8 m, 8.2 m and 5.2 m. Determine the area enclosed between the boundary, survey line, the first and the last offsets by*

(*i*) *Trapezoidal rule* (*ii*) *Simpson's rule.*

Solution: d = 10 m, n = number of segments = 8 number of ordinates = 9.

Length of survey line = 8 × 10 = 80 m.

(*i*) **Area by trapezoidal rule**

$$A = \left(\frac{O_0 + O_8}{2} + O_1 + O_2 + \cdots + O_7 \right) d$$

$$= \left[\frac{2.18 + 5.2}{2} + 3.2 + 4.26 + 6.2 + 4.8 + 7.2 + 8.8 + 8.2 \right] 10$$

Area = 463.5 m^2 **Ans.**

(*ii*) **Area by Simpson's method**

$$= \frac{d}{3} [(O_0 + O_8) + 4 (O_1 + O_3 + O_5 + O_7) + 2(O_2 + O_4 + O_6)]$$

$$= \frac{10}{3} [2.18 + 5.2 + 4 (3.2 + 6.2 + 7.2 + 8.2) + 2 (4.26 + 4.8 + 8.8)]$$

= 474.333 m^2 **Ans.**

■ **Example 18.3:** *The following offsets were taken to a curved boundary from a survey line:*

0, 2.46, 3.78, 3.26, 4.40, 3.28, 4.24 and 5.20 m.

Compute the area between curved boundary, survey line and end offsets, if the offsets were at a regular interval of 10 m, using Simpson's rule and trapezoidal rule. Compare the results.

Solution: Number of offsets = 8

Number of intervals = 7

O_0 = 0.0, O_1 = 2.40, O_2 = 3.78, O_3 = 3.26, O_4 = 4.40, O_5 = 3.28,

O_6 = 4.27, O_7 = 5.20

d = 10.0 m

(*i*) **From trapezoidal rule**

$$A = \left[\frac{O_0 + O_7}{2} + O_1 + O_2 + O_3 + O_4 + O_5 + O_6 \right] d$$

(*b*) **Subdivisions into squares:** Similar to a graph sheet, squares are marked on a transparent tracing sheet, each square representing a known area. Full squares are counted. Fractional squares are counted by give and take approximation. Then the number of squares multiplied by area of each square gives the area of the map Fig. 18.6 shows such a scheme. Finer the mesh better is the accuracy.

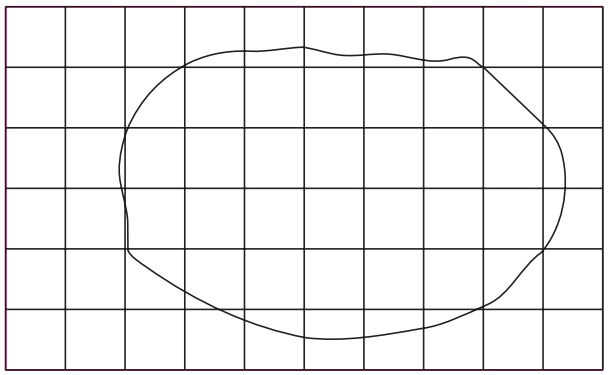


Fig. 18.6

(*c*) **Subdivisions into rectangles:** In this method, a set of parallel lines are drawn at equal spacing on a transparent paper. Then that sheet is placed over the map and slightly rotated till two parallel lines touch the edges of the tap. Then equalising perpendiculars are drawn between the consecutive parallel line. Thus given area is converted to equivalent set of rectangles and then area is calculated (Ref. Fig. 18.7).

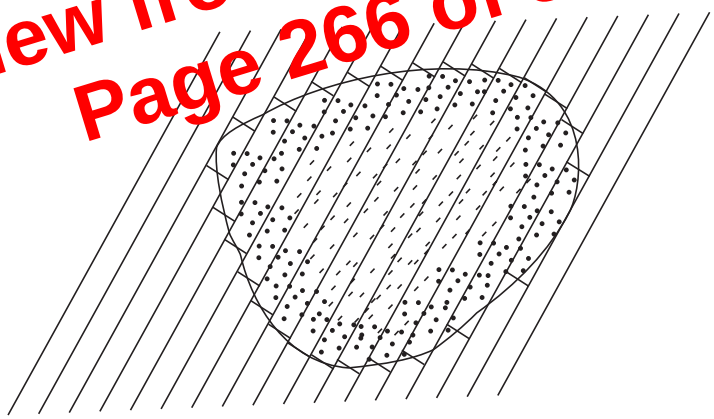


Fig. 18.7

18.2.2 Computing Area Using Planimeter

Planimeter is a mechanical instrument used for measuring area of plan. The commonly used planimeter is known as Amsler planimeter (Fig. 18.8). Its construction and uses are explained in this article.

Let 'h' be the depth at the centre line of the alignment and 1 : n be the side slopes. Then

$$w = b + 2nh$$

$$\therefore \quad A = \frac{1}{2}(w + b)\, h$$

$$= \frac{1}{2}(b + 2nh + b)\, h$$

$$= (b + nh)\, h \qquad ...(18.8)$$

(b) If it is a multilevel section [Fig. 18.10]

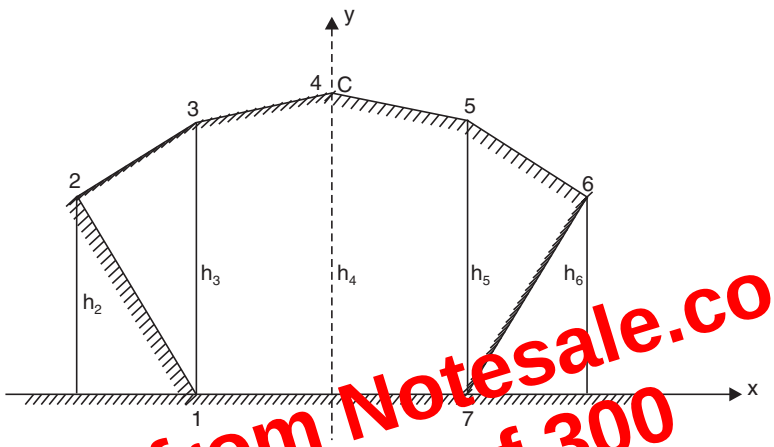
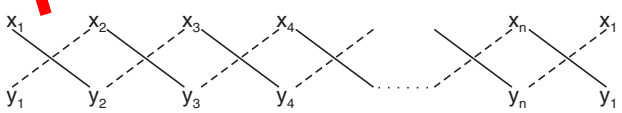


Fig. 18.10

Let the coordinates of points be (x_1, y_1), (x_2, y_2), ..., (x_n, y_n), then arrange the coordinates in the following order



Then area of the figure

$= \frac{1}{2}$ [Σ Product of pair of coordinates connected by continuous lines – Σ Product of coordinates connected by dotted lines] ...(18.9)

The above formula can be easily proved by taking a simple example of a quadrilateral [Ref. Fig. 18.11]. Let the coordinates of A, B, C and D be (x_1, y_1), (x_2, y_2), (x_3, y_3) and (x_4, y_4). Then area of ABCD

= Area of a AB b + Area of b BC c + Area of c CD d – Area of a AD d.

$$= \frac{1}{2}(x_1 + x_2)(y_2 - y_1) + \frac{1}{2}(x_2 + x_3)(y_3 - y_2) + \frac{1}{2}(x_3 + x_4)(y_4 - y_3) - \frac{1}{2}(x_1 + x_4)(y_4 - y_1)$$

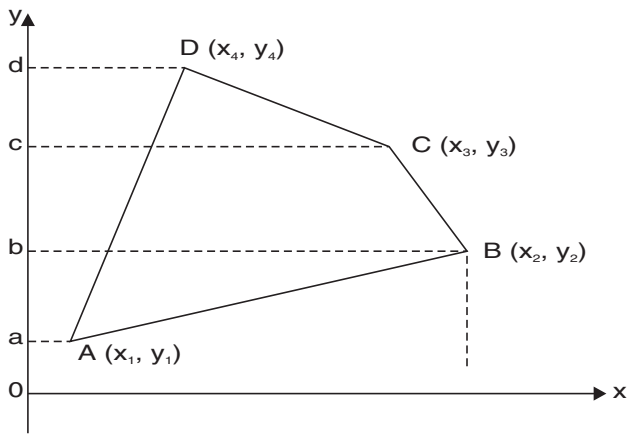


Fig. 18.11

$$= \frac{1}{2}\,[x_1y_2 - x_1y_1 + x_2y_2 - x_2y_1 + x_2y_3 - x_2y_2 + x_3y_3 - x_3y_2 + x_3y_4 - x_3y_3 + x_4y_4 - x_4y_3 - x_1y_4 + x_1y_1 - x_4y_4 + x_4y_1]$$

$$= (x_1y_2 + x_2y_3 + x_3y_4 + x_4y_1) - (x_2y_1 + x_3y_2 + x_4y_1 + x_1y_4)$$

[Note terms with same subscript appear in pairs and cancell each other].

Hence equation 18.9 is proved.

Calculation of Volumes

Once cross-sectional areas at various sections are known volume can be found from trapezoidal or prismoidal rule as given below.

Trapezoidal Rule

$$V = d\left[\frac{A_0 + A_n}{2} + A_1 + A_2 + \cdots + A_{n-1}\right] \qquad ...(18.10)$$

where 'n' are number of segments at interval of 'd', Area at L = nd, being A_n.

Prismoidal Rule

$$V = \frac{d}{3}\,[(A_0 + A_n) + 4\,(A_1 + A_3 + \cdots + A_{n-1}) + 2\,(A_2 + A_4 + \cdots + A_{n-2})] \qquad ...(18.11)$$

where n is number of even segments.

If number of segments are odd, (n is odd), for $n - 1$ segments prismoidal rule may be applied and for the last one trapezoidal rule is applied. Or else for the last segment area at middle of last segment found and prismoidal formula applied for A_{n-1}, A_m and A_n.

■ **Example 18.6:** *A railway embankment of formation width 12 m is to be built with side slopes of 1 vertical to 1.5 horizontal. The ground is horizontal in the direction transverse to the centre line. Length of embankment is 200 m. The centre height of embankment at 25 m interval are as given below:*

1.6, 2.4, 3.4, 3.8, 4.2, 3.6, 2.8, 2.2, 1.2 m. Calculate the volume of earth filling.

Solution: Since the section is level,

$A = (b + nh)\,h$ where $n = 1.5$

Point	1	2	3	4	5	1
x	–6.0	–8.0	0	12.5	6.0	–6
y	0.0	2.5	3.1	5.4	0	0.0

$$\therefore \quad 2A_m = (-6 \times 2.5 - 8 \times 3.1 + 0 \times 5.4 + 12.5 \times 0 + 6 \times 0.0) - \{0 \times (-8) + 2.5 \times 0 + 3.1 \times 12.5 + 5.4 \times 6.0 + 0 \times (-6)\}$$

$$= 110.95$$

$$A_m = 55.475 \text{ m}^2$$

Now $d = \frac{40}{2} = 20$ m, between two consecutive sections.

$$V = \frac{20}{3}(42.0 + 4 \times 55.475 + 70.7)$$

$V = 2230.67 \text{ m}^3$ **Ans.**

18.3.2 Computation of Earth Work from Spot Levels

This method is used to calculate volume of earth work for the elevations of basements, large tanks and borrow pits. In this method the whole area is divided into a number of rectangles or triangles (Fig. 18.13). The levels are taken at corner points before and also after excavation. The depth of excavation at each corner point is measured. Then for each simple figure (rectangle or triangle),

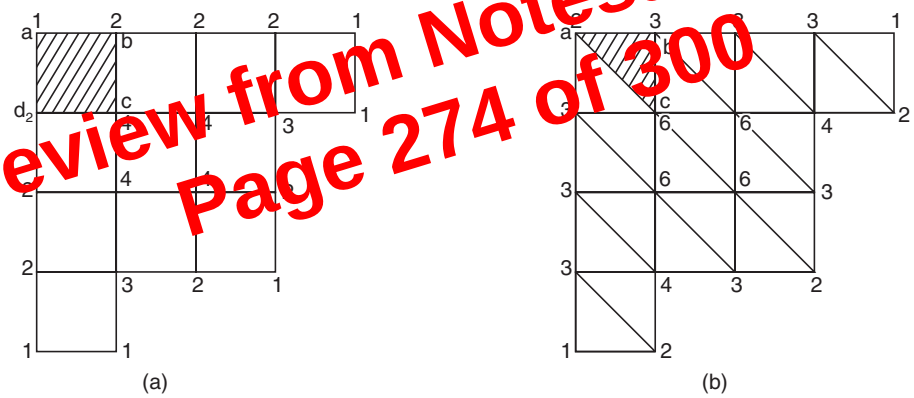


Fig. 18.13

V = Area of the figure × average depth.

Thus for a rectangle with corner depth h_a, h_b, h_c and h_d,

$$V = \text{Area of rectangle} \times \frac{h_a + h_b + h_c + h_d}{4}$$

For a triangle,

$$V = \text{Area of triangle} \frac{h_a + h_b + h_c}{3}$$

All such volumes, when added give total volume of work.

4. Cantilever projections should be avoided.
5. Roof and parapet wall should be properly anchored to the columns and walls.
6. Height of the buildings should be restricted.
7. Suitable wind load should be considered in the building design.
8. Openings in the wall should be less.
9. Structure should not rest on loose soil.

20.10 FIRE RESISTANT BUILDING

It is reported that in USA fire kills more people each year than all other natural disasters combined including floors, cyclones and earthquake. The **fire load** in a building should be kept to the minimum possible. The term fire load indicates the amount of heat liberated in kilo joules per square metre (kJ/m^2) of floor area of any compartment by the combustion of the content of the building including its own combustible part. It is determined by multiplying the weights of all combustible materials by their respective calorific values and dividing that with floor area.

A building may be made more fire resistant by

1. Using suitable materials
2. Taking precautions in building construction
3. By providing fire alarm systems and fire extinguishers.

20.10.1 Using Suitable Materials

The fire resisting material is having the following characters:

(*a*) It should not disintegrate under the effect of heat

(*b*) It should not expand under heat so as to introduce unnecessary stresses in the building

(*c*) The material should not catch fire easily

(*d*) It should not lose its strength when subjected to fire.

Fire resisting characters of some of the commonly used building materials are given below:

Stone: It is a bad conductor of heat. Sand stones with fire grains can resist fire moderately. Granite disintegrate under fire. Lime stone crumbles easily. Most of the stones disintegrate during cooling period after heated by fire.

Brick: Bricks can resist heat up to 1200°C. At the time of construction, if good quality mortar is used, fire resistance is extremely good.

Timber: Any structure made of timbers is rapidly destroyed in fire. Timber enhances the intensity of fire. Use of heavy sections of timber in buildings is not desirable. To make timber more fire resistant the surface of timber is coated with chemicals such as ammonium phosphate and sulphate, boric acid and borax. Sometimes fire resistant paint is applied to timber used in the building.

Fire extinguishers should be provided at all strategic points in the buildings. The common fire extinguishers are as follows:

(*a*) Manual: Carbon dioxide type portable fire extinguishers are commonly used. Sometimes buckets of water, sand and asbestos blankets are kept ready at all possible places where fire is likely to catch.

(*b*) Internal Hydrant: The hydrant should be located in and around the buildings so that water is available easily for fire fighting.

(*c*) Automatic Water Sprinkler: In the buildings vulnerable for fire like textile mills, paper mills automatic water sprinklers are installed. As the fire takes place the sprinkling of water is automatically activated from the piping system containing water under pressure.

QUESTIONS

1. What do you understand by the term earthquakes? What are its causes? State different types of earthquake.

2. Define and explain the following terms with a neat sketch:

(*a*) Focus (*b*) Epicentre

(*c*) Focal length and (*d*) Epicentral distance of earthquake.

3. Write short notes on

(*a*) Magnitude (*b*) Intensity of earthquake and

(*c*) Seismograph

4. Describe the various provisions to be made to make a medium size building earthquake resistant.

5. Explain the different hazards to be given in a building to make it earthquake resistant.

6. Write short notes on

(*a*) Base isolators (*b*) Seismic dampers.

7. What special cares are to be taken to make buildings cyclone resistant?

9. Write short note on cyclones.

10. Describe the characteristics of an ideal fire proofing material and discuss fire resistant properties of any four building materials.

11. How a building can be made fire resistant? Describe in short.

12. Write short notes on

(*a*) Fire alarm system (*b*) Fire extinguishers

(*c*) Fire load.

have been controlled to a great extent. Spreading the awareness of building earthquake, cyclone and fire resistant structures can prevent disasters. Major and minor irrigation projects aim at controlling drought.

21.2 EARLY WARNING SYSTEM

Space technology plays an important role in efficient mitigation of disaster. Indian Meteorological Department has developed a four stage warning system for a cyclone. The system works on the observation of development of low pressures in ocean 48 hours prior to the time of expected cyclone to hit land the alert warning is given. 24 hours prior to the anticipated time of arrival of cyclone, warning is given. Then 12 hours early cyclone arrival warning is given. Warnings about storms, their intensity and the likely path on regularly given through radio and television until the storm passes over.

21.3 DISASTER PREPAREDNESS

At all levels of civil administration committees are established and responsibilities and urgently required finance entrusted. At national level Ministry of Home Affairs, Government of India, a national disaster management division is established. It has prepared guidelines for disaster management. The national disaster management authority is responsible for

- Providing necessary support and assistance to State Governments.
- Coordinating and managing Government policies for disaster mitigation.
- Ensure adequate preparedness at all levels.
- Coordinating response to a disaster when it strikes.
- Assisting the provisional Governments in coordinating post disaster relief and rehabilitation.
- Monitor and introduce a culture of building a requisite features of disaster mitigation in all development plan and programmes.

In India all states have been asked to set up Disaster Management Authorities. Chief Minister heads this authority. He is assisted by senior officers from various departments like Water Resources, Agriculture, Water Supply, Environment, Forest, Urban and Rural development.

At district level district magistrate/deputy commissioner heads the committee. He is assisted by the officers from various departments in the district. At block levels also disaster management committees have been established. Every concerned person is informed about his duties and responsibilities in disaster management. The committees have major role in

- Community involvement and awareness generation.
- Close interaction with the corporate sector, Non-Governmental Organisations (NGO) and the media.
- Train the disaster managers.

Training the concerned people in facing national disaster is very important part of disorder preparedness. Training programmes are organised in Administrative Training Institutions and at various places for different target groups. In CBSE curriculum also lessons are added on disaster mitigation.

The masons and engineers should be trained to build earthquake, cyclone and fire resistant buildings. Hospital staff should be trained to take the challanges of disaster management. Disaster prone areas are to be identified and at suitable places good hospitals should be built, communication facility provided including helicopter landings. Sufficient medicines should be stored.

21.4 DISASTER MITIGATION

Disaster mitigation means minimizing the painfulness which occur due to disaster. After the disaster the people face the following problems:

1. Shelters are completely or partially damaged
2. Food is not available when required
3. Drinking water shortage is felt.
4. Diseases spread.
5. Communication systems are affected.

To mitigate the misery of the affected people the following steps are to be taken:

1. Provide temporary accommodation with water supply, sanitary and electricity facilities.
2. Extend manpower, material and financial assistance to repair/build their houses.
3. During the expected period of cyclones and floods, store up at least seven day stock of essential food articles, medicines and water supply.
4. Continue to listen to warning bulleting and keep in touch with local officials.
5. Be ready to evacuate people to places of safety when advised.
6. Remove damaged and decayed parts of trees to make them resist wind and reduce the potential for damage.
7. Before cyclone season starts carry out all necessary repairs to the building.
8. Keep valuables and documents in containers which cannot be damaged by water.
9. Talk to children and explain about cyclone/floor. Remain calm.
10. Fishermen are advised not to venture into the sea during cyclone warning period.
11. Avoid taking shelter near old and damaged building or near trees.
12. Do not touch power lines.

21.5 DISASTER RESCUE AND RELIEF MEASURES

Disaster rescue and relief means taking steps to face the distress situation after the disaster has taken place. Volunteer groups, police force or military teams are organised to