Rajsons Publications Pvt. Ltd.

Civil Engineering
Building Construction

T.D. AHUJA
G.S. BIRDI

STANDARD BOOK HOUSE (SINCE 1960)

CIVIL ENGINEERING

(For Degree, Diploma and A.M.I.E. Students)

By

T.D. Ahuja

Formerly Head of Civil Engineering Deptt.
Allahabad Polytechnic, Allahabad

and

G.S. Birdi

Formely Head of Structural Engg. Deptt.
Allahabad Polytechnic, Allahabad

STANDARD BOOK HOUSE

unit of : **RAJSONS PUBLICATIONS PVT. LTD.**

1705-A, Nai Sarak, PB.No. 1074, Delhi-110006 Ph.: +91-(011)-23265506
Show Room: 4262/3, First Lane, G-Floor, Gali Punjabian, Ansari Road, Darya Ganj,
New Delhi-110002 Ph.: +91-(011)43551085 Tel Fax : +91-(011)43551185, Fax: +91-(011)-23250212

E-mail: sbh10@hotmail.com www.standardbookhouse.com

Preface to the Eighth Edition

The present edition of the book is mostly overhauled and revised. One chapter on Temperary Structure is added in the Part of Building Construction. Now the book is quite up-to-date in shape and style. The edition of the book is entirely new and different from its previous editions.

We hope, the book will prove more useful and will serve its purpose better. Any suggestions for the improvement of the book will be gratefully acknowledged by the publishers.

Allahabad **T.D. Ahuja**
2013 **G.S. Birdi**

Preface to the First Edition

This book on 'Civil Engineering' is meant for second year students preparing for Diploma Examination in Civil, Electrical and Mechanical Engineering courses. It comprises Building Construction, Roads, Water-Supply and Sanitary Engineering. There are many good books on Building Construction, Roads, Water-Supply and Sanitary Engineering separately, but there is hardly any book covering the four subjects in one. This attempt has been made to facilitate studying of the subject in one volume.

We claim no originality in this work, but sufficient pain have been taken in preparing it. We have tried to explain the sjubject-matter lucidly with the help of numerous sketches which have been prepared by us. The subject-matter has been treated on a descriptive basis as is required in the syllabus and as such all numerical problems have been omitted. We feel that with the publication of this work, teaching the subject to the students will present no difficulty.

We take this opportunity to express our deep appreciation to our friends and colleagues for their encouragement and help in preparing the work.

In spite of all our efforts, misprints or errors might have crept in. Any suggestions for the improvement of the book will be gratefully acknowledged.

Allahabad Polytechnic, **T.D. Ahuja**
July, 1966 **G.S. Birdi**

Published by:
RAJINDER KUMAR JAIN
Standard Book House
Unit of: Rajsons Publications Pvt. Ltd.
1705-A, Nai Sarak, Delhi - 110006
Post Box: 1074
Ph.: +91-(011)-23265506 Fax: +91-(011)-23250212

Showroom:
4262/3, First Lane, G-Floor, Gali Punjabian
Ansari Road, Darya Ganj
New Delhi-110002
Ph.: +91-(011)-43551085, +91-(011)-43551185
E-mail: sbhl0@ hotmail.com
Web: www.standardbookhouse.com

Eighth Edition : 2013

Price: **₹ 220.00**

ISBN: 978-81-89401-47-4

Typeset by:
C.S.M.S. Computers, Delhi.

Printed by:
Radha Press, Kailsh Nagar, Delh-110031

Contents

PART 1

Building Construction

PART 2

Road Engineering

PART 3

Water Supply Engineering

PART 5

General Surveying

PART 1

BUILDING CONSTRUCTION

Chapter 1

Foundations

1.1 GENERAL

Building Construction is an Engineering Science, which deals with the technique of construction of buildings. A building is defined as an enclosed space covered by a roof. Building in general can be classified into two categories *viz. Public Buildings* and *Residential Buildin*gs. *Public buildings* are those which are primarily meant for the use of the general public, such as an office, a school, a college, a hospital, a cinema house, etc. whereas a residential building is only meant either for a single individual or group of individuals, such as an ordinary dwelling house or a bungalow. As far as techniques of construction are concerned, for an engineer both are the same. This chapter is particularly devoted to the most important part of a building, that is, its foundation.

1.2 DEFINITION OF FOUNDATIONS

Every structure has two component parts. One is called *foundation* and the other *super-structure*. Foundation is that part of the structure which is generally constructed below the ground level. It is often confused that foundation is constructed to take up the load of the structure or to support it. But actually this is not the case. No doubt the structure rests over the foundation but it is not supported by the foundation. The foundation transmits the load of the structure to the sub-soil below it, over a larger area uniformly. The word foundation as applied to buildings is defined as the extended *base* of walls and pillars carried below the ground level, to *distribute* the load of the structure over a large area of the sub-soil.

The foundation is the most important part of a structure. The strength and stability of the structure depends upon its foundation. If the foundation fails, the super-structure however strong it may be, cannot stand. Hence for stable structure, a good foundation is essential.

1.3 OBJECTS OF FOUNDATION

As stated above, the foundation are constructed to keep the structure in position. However the following are the objectives of the foundations :

1. To distribute the load of the structure over a larger area of substratum and prevent overloading.
2. To prevent tilting and over-turning of the structure and increasing its stability.
3. To prevent the lateral escape of the supporting material.
4. To provide a levelled base for the super-structure.
5. To prevent unequal settlement of the soil and super-structure by loading the sub-soil evenly.

1.4 CAUSES OF FAILURE OF FOUNDATIONS AND PRECAUTIONS TO PREVENT SUCH FAILURES

1.4.1 Causes

1. Unequal settlement of sub-soil. All soils, except rock and muram, yield under the load of the structure. If this yielding is uniform and within a particular limit, it is harmless, but unequal yielding will cause cracks in the structure and ultimately cause the failure of the structure and the foundation.

2. Unequal settlement of masonry. This is caused by shrinkage and compressibility of mortar joints and the poor quality material used in the foundation.

3. Withdrawal of sub-soil moisture below the foundations. This occurs when the soil is wet. In dry weather when the moisture of the soil is evaporated, the soil becomes compressed and cracked and thereby causes the failure of the structure.

4. Lateral pressure on the super-structure. When the structure is subjected to lateral pressure due to wind or the lateral thrust of arches or a sloping roof or wide cantilever projections, a tendency of tilting or overturning is developed, which causes eccentricity of the loads due to which foundations can fail.

5. Lateral escape of soft soil from underneath the foundation. When the building is situated near a deep cutting or a river or a nallah, the soil below the foundation may escape laterally and cause the settlement of the foundation. Similarly, if the depth of the foundation is small or the sub-soil below the foundation is of a sliding nature, it may slip away under the loads and cause the failure of the foundation.

1.4.2 Precautions

1. To prevent the unequal settlement of subsoil, a right type of foundation, based on the knowledge of soil conditions and all possible loads liable to come on the structure, should be carefully designed and constructed. The intensity of load should always be kept below the safe bearing capacity of the soil. The materials to be used for foundation should be strong and durable.

2. The unequal settlement of masonry can be prevented by using very stiff mortar, raising the masonry uniformly and the wall should not be constructed more than 1.5 m in a day.

3. The sub-soil water during hot weather may dry up and cause shrinkage. This can be avoided by driving piles upto a hard stratum or such sites should be avoided.

4. The lateral pressure on the super-structure can cause failure of foundation. This can be prevented by providing a sufficient base area below the walls and columns.

5. The lateral escape of the supporting material can be prevented by confining to soil be driving Sheet Piles around the foundation.

1.5 LOADS

The loads coming on the foundations are generally divided into :

(i) Live Load
(ii) Dead Load
(iii) Wind Load; and
(iv) Snow Load.

(i) **Live Load.** It is a temporary or moving load. The weight of the inhabitants of a building, the weight of furniture or any stored material is called ***Live Load***. Sometimes the live load is also called super-imposed load. For designing foundations, the live load on the structure also taken into account.

(ii) **Dead Load.** It is the permanent load of the structure, i.e., the weight of the structure itself. The weight of the walls, floors, roofs, weight of fixed machinery and any immovable load, is called *dead load*.

(iii) **Wind Load.** When the wind blows, it causes a lateral thrust or pressure on the vertical as well as the inclined members of the structure. This wind pressure is called *wind load*. The tendency of the wind load is to over-turn the structure. The wind pressure has severe effect on tall buildings but has very little effect on small buildings. Hence the building by-laws specify that if height of a building is less than twice its width, this wind pressure should be neglected, provided that building is stiffened by cross walls, roofs, floors etc.

(iv) **Snow Load.** In places which have a heavy snow-fall, the roofs have to bear the load of the snow in addition to the dead and live loads, therefore, at the time of designing it should also be taken into account. But when the roofs are sloping to an angle of 45° i.e., 1 in 1 or more, no account of the snow load is made. In India while building in hill stations, *snow load* is taken into account.

Table 1.1 *Dead weight of various materials*

Item	*Weight*	*Item*	*Weight*
Excavated Materials		**Building Materials**	
Clay (dry)	1600 kg/m^3	Brick masonry	1600 kg/m^3
Clay (damp, plastic)	1760 kg/m^3	Cement (loose)	1400 kg/m^3
		Chalk	2200 kg/m^3
Earth (dry, loose)	1200 kg/m^3	Glass	2560 kg/m^3
Earth (packed)	1520 kg/m^3	Limestone	2650 kg/m^3
Sand (dry, loose)	1440–1700 kg/m^3	Sandstone	2800 kg/m^3
Sand (dry, packed)	1600–1900 kg/m^3	Steel	7800 kg/m^3
		Timber	650–750 kg/m^3
Structure Items		**Finished Items**	
A.C. sheets	17 kg/m^2	A.C. sheet roof	34 kg/m^2
Brick masonry (ordinary)	1920 kg/m^3	C.G.I. sheet roof	10 kg/m^2
Brick wall (10 cm thick)	295 kg/m^2	Allahabad tiles (Single) roof	83 kg/m^2
Brick wall (20 cm thick)	440 kg/m^2	Allahabad tiles (double) roof	160 kg/m^2
Cement-plaster (2.5 cm thick)	44 kg/m^2	Country tiles roof	70 kg/m^2
Concrete	2306 kg/m^3	Country tiles (double roof)	115 kg/m^2
G.I. sheets (24 gauge)	5 kg/m^2	Manglore tiles with battens	69 kg/m^2
G.I. sheets (16 gauge)	10 kg/m^2		
Rubble masonry	2000 kg/m^3	Timber trusses and purlins	12 kg/m^2
Ashlar masonry	2200 kg/m^3	Doors with frames	39 kg/m^2

Table 1.2 *Minimum live loads on different types of floors*

Types of Floors	*Live Loads*
1. Residential building floors (including dwelling houses)	200 kg/m^2
2. Hospital wards, bed-rooms and private sitting rooms in hostels and dormitories	200 kg/m^2
3. Office floors (excluding entrance halls and light work rooms)	250,400 kg/m^2
4. Floors of banking halls, office entrance halls, reading rooms	300 kg/m^2
5. Shop floors	400 kg/m^2
6. Floors of warehouse, factories (for light weight), dancing halls, waiting halls and public rooms of hotels	500 kg/m^2
7. Floors or warehouses, workshops, factories (for medium weight)	750 kg/m^2
8. Floors of warehouses, workshops, factories (for heavy weight)	1000 kg/m^2

1.6 SOILS AND THEIR BEARING CAPACITY

The soil on which a structure rests may be classified into three categories:

(a) **Hard soils.** These soils are generally rocks in nature, incompressible and can bear fairly good loads. Solid rock, moorum and stony soils are examples.

(b) **Soft soils.** These are alluvial soils and are compressible when loaded. They cannot to take much load. Ordinary clay, loam, and common soils are examples of this.

(c) **Spreading soils.** These soils are compressible when they are confined and prevented from spreading. These soils when loaded spread out laterally. Sand and gravel are examples of this type of soil.

1.6.1 Bearing Capacity of Soils

Bearing power or Bearing capacity of a soil is defined as the maximum load that a soil can bear per unit area (usually tonnes per sq. m) without yielding or causing cracks, displacement or rupture. This is the ultimate capacity of a soil. But as far as designing is concerned, we are less concerned with the ultimate load or the ultimate capacity of soil.

1.6.2 Methods of Determining the Bearing Capacity of Soils

There are many methods of finding out the bearing capacity of soils. A very simple methods of determining the bearing capacity is as follows :

Dig a pit of size 2 m × 2 m and of the required depth. The bottom of the pit is levelled by simply spreading the soil by hand. It should never be compacted. At the centre of this put a steel plate of 60 cm × 60 cm × 5 cm. Drive to pegs equidistant from the steel plate as shown in Fig. 1.1. Over the steel plate erect a wall 40 cm either with bricks or stone or concrete blocks nearly 50 cm above the adjoining ground level. The difference of levels between the top of the pegs and the wall is noted by a dumpy level. Now gently place the loads on the top of the wall by constructing a wooden platform. The load may consist of sand bags, girdess or R.S.J. The loads are increased by a suitable amount usually 0.5 tonne at an of 20 to 30 minutes. Before each increment of load the difference of levels between the pegs and the top of the wall is noted. Note that the difference of level will remain constant till the soil yields. The moment of the difference is increased, the increment of load must be stopped.

The bearing capacity of the soil will be the total load divided by the area of steel plate, that is

$$\text{Bearing capacity} = \frac{\text{Wt. of steel plate + Wt. of wall + Wt. of sand bags etc.}}{\text{Area of steel plate } (60 \times 60 \text{ cm})}$$

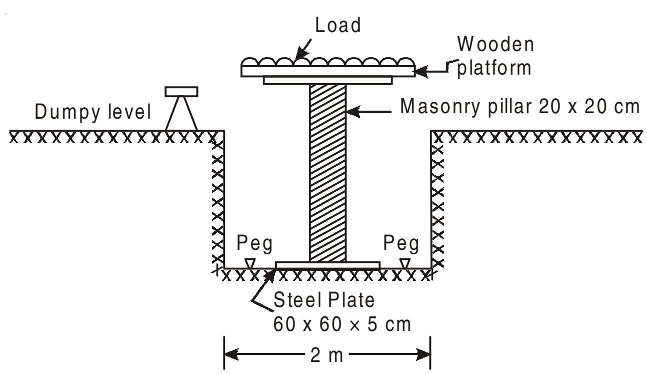


Fig. 1.1. *Method of determining the bearing capacity of soils.*

1.6.3 Safe Bearing Capacity

The safe load to be taken on a soil for the purpose of design is called *Safe Bearing Capacity* of the soil. The Safe Bearing Capacity of a soil may be defined as the bearing capacity of a soil divided by a number usually by constant and called *factors of safety* i.e.,

$$\text{Safe Bearing Capacity} = \frac{\text{Ultimate Bearing Capacity}}{\text{Factors of Safety}}$$

The Factor of safety depends on the type of building and the nature of the soil. Generally a factor of safety of 2 to 4 is taken for different purposes. Thus if the ultimate load of a soil is 6 tonnes/m^2 and its factors of safety is 3 the working or design loads to be given to that soil will be $\frac{6}{3}$ = 2 tonnes/m^2. This is the safe bearing capacity of the soil.

Saff Bearing Capacity of Different Soils

Soft clay	...	2 – 3.75 tonnes/m^2
Black cotton soil	...	5 – 7.5 tonnes/m^2
Alluvial loam	...	7.5 – 16 tonnes/m^2
Alluvial soil	...	5 – 7.5 tonnes/m^2
Moist day	...	11 – 18 tonnes/m^2
Made-up ground	...	5 tonnes/m^2
Ordinary clay	...	22 tonnes/m^2
Clay mixed with sand	...	22 tonnes/m^2
Compact clay (dry)	...	33 – 55 tonnes/m^2
Loose sand	...	22 tonnes/m^2
Compact sand	...	22 – 32 tonnes/m^2
Compact confined sand	...	44 tonnes/m^2
Kankar or sandy gravel	...	22 – 32 tonnes/m^2
Compact gravel	...	44 – 65 tonnes/m^2
Moorum	...	22 – 44 tonnes/m^2
Soft rock	...	25 – 85 tonnes/m^2
Ordinary rock	...	85 – 110 tonnes/m^2
Hard rock	...	Above 250 tonnes/m^2

1.7 METHOD OF IMPROVING THE BEARING CAPACITY OF SOILS

The bearing capacity of a soil mainly depends on the closeness of its particles. The bearing capacity of a soil can be increased by the following methods:

1. By increasing the depth of foundation. The compactness of the soil increases as we go below the ground level. As the bearing capacity directly depends on the compactness of the soil, it will go on increasing as the depth of foundation is increased.

2. By draining of the sub-soil under. Water reduces the cohesive properties and hence reduces the bearing capacity of the soil. By draining off water from the sub-soil the bearing capacity of the soil is certainly increased.

3. By compacting the soil. If the soil is compacted thoroughly, the voids are decreased and bearing capacity is increased.

4. By confining the soil and preventing it form spreading and lateral movement. Spreading soils, if confined by sheet piling will resist more loads, that is, their bearing capacity will increase.

5. By increasing the width of foundation. By increasing the width of foundations, the intensity of load is decreased and on the same soil more loads can be placed. (Virtually speaking the bearing capacity of that particular area of the soil is increased).

6. By hardening the soil by grouting i.e., pumping in the cement grout into the ground. By grouting, the cohesive properties are increased and the soil will be able to take up more loads.

7. By solidifying the ground by chemical processes. In this case also the soil is compacted by mixing certain chemicals such as calcium chloride etc.

1.8 TYPES OF FOUNDATIONS

The following are the different types of foundations, which are generally used for different structures :

1. Spread Footing Foundation
2. Benching or Stepped Foundation
3. Pile Foundation
4. Raft Foundation
5. Well Foundation
6. Caisson's Foundation
7. Cantilever Foundation
8. Combined Footing Foundation
9. Inverted Arch Foundation
10. Grillage Foundation

1.8.1 Spread Footing Foundation

This is the simplest type of foundation and is generally used for ordinary buildings on alluvial soils. This type of foundation can normally be used for three to four-storied buildings on common type of alluvial soils.

The spread footing foundation consists of a concrete base, generally lime concrete and a series of footings below the ground level. The depth and width of foundation depends on the bearing capacity of the soil and the intensity of load. The depth of foundation can be calculated by Rankine's formula which is

$$d = \frac{P}{W}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

where P = safe bearing capacity of soil
W = wt. of soil per cu. metre
ϕ = angle of repose of soil.

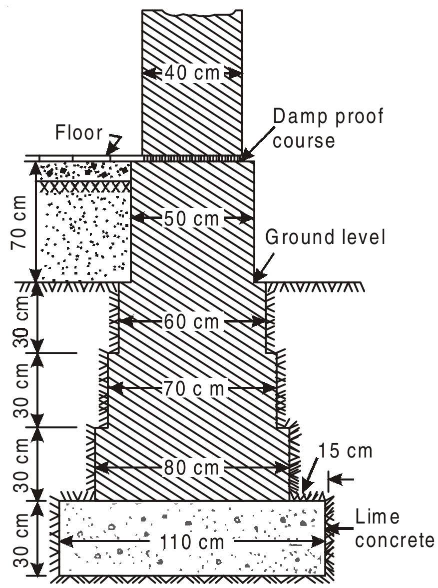


Fig. 1.2 *Spread footing foundation.*

The width of foundation is given by

$$W = \frac{L}{P}$$

where

W = Width of foundation
L = Load of structure per running metre
P = Safe bearing capacity of soil

The width of foundation should in no case be less than $2T + 2J$, where T is the thickness of wall and J is the concrete offset to be provided. If the width of foundation is taken as $2T + 2J$, then the number of footings in this foundation will be equal to number of half bricks in the thickness of wall, excluding the concrete offsets. For example, for the foundation of $1\frac{1}{2}$ bricks thick wall, three offsets excluding concrete offset, will be provided.

1.8.2 Benching on Stepped Foundation

This type of foundation is provided on hilly places or in those situations where the ground is slopy. In this foundation the excavation trenches are made in the form of steps. All the steps should be preferable of equal length and depth. The function of providing steps is to avoid unnecessary cutting and filling. The plinth of the structure should start after the highest point of the ground. Sometimes R.C.C. pile is driven along the lowest base of the footing to avoid any slipping of the structure along with the foundation.

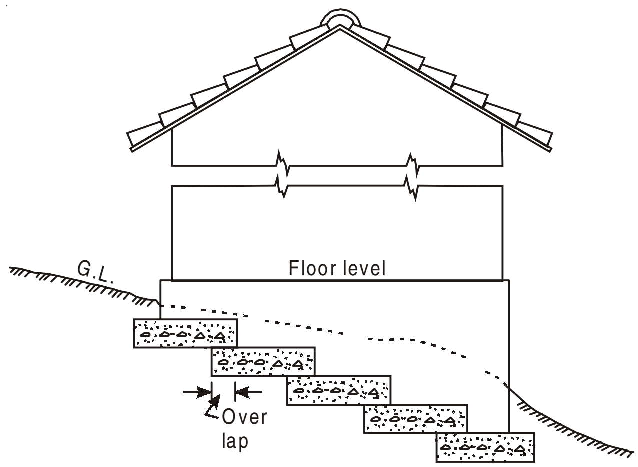


Fig. 1.3 *Benching or stepped foundation.*

1.8.3 Pile Foundation

It is one of the important types of foundation which is used in the following situations:

1. When it is not economical to provide spread foundation and hard soil is at a greater depth.
2. When it is very expensive to provide raft or grillage foundation.
3. When heavy concentrated loads are to be taken up by the foundation.
4. When the top soil is of made up type and of compressible nature.
5. When there are chances construction of irrigation canals in the nearby area.
6. In case of bridges when the scouring is more in the river bed.
7. In marshy places.

Piles are vertical columns driven into the ground on which wooden or concrete platforms are supported. The piles are driven at regular distances. The size and distance apart, of the piles, depends upon the bearing capacity and type of soil and the load of the structure.

1.8.4 Classification of Piles

The piles can be classified according to (i) Material and (ii) Working.

1. **Materials Classification.** The piles are classified as

(a) Wooden piles

(b) Concrete piles

(c) R.C.C. piles

(d) Sheet piles

(a) **Wooden Piles.** These are made from trunks of trees, such as Teak, Sal, Babul, Deodar etc. The wooden or timber piles are generally circular in shape, the diameter varying from 20 cm to 50 cm. The length of the pile is generally 20 times the diameter. The top of the pile is provided with an iron ring or cap and the bottom is sharpened and provided with iron shoe. If the soil is soft, blunt piles may be used, but if the ground contains boulders, meal pants should be used. Timber piles should be driven below the permanent water table, otherwise they decay to fungi and insects. These piles are economical and can be driven rapidly without heavy machinery and much technical supervision.

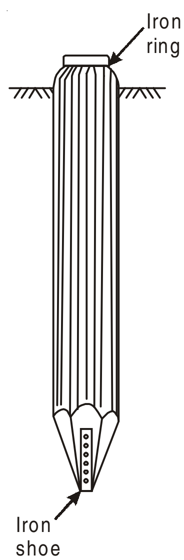


Fig. 1.4 *Wooden piles.*

(b) **Concrete Piles.** Concrete piles are made cast-in-situ. Holes of the specified diameter are made into the ground and filled with cement concrete. Sometimes, the shell driven for making the hole is left inside and the concrete is filled. The advantage of this is that there is the shell to protect the cement concrete of the pile from getting disturbed or eroded by the action of acidic water encountered in the sub-stratum. These piles are used when they are to be driven to hard stratum passing through plastic soils. These are sound in construction as they have not to bear hammer blows. These are cast in exact lengths and there is no wastage like in precast piles. The main drawback of these piles is that they cannot be constructed under water.

(c) **Reinforced Cement Concrete Piles.** R.C.C. piles are generally precast and their feet are bevelled like wooden piles. The R.C.C. piles can be octagonal, square or circular in shape with steel helmets on their top. After the piles are cured and seasoned, they are driven into the ground. These piles are 15 cm to 60 cm in diameter and can be 3 m to 30 m in length. R.C.C. piles should not contain more than 4% steel. These piles can be cast early before starting the foundation work and the execution of the work can be done very quickly. Unlike timber piles these can be used above the ground water table. But these piles are very heavy and cause difficulty in transportation and there are changes of their being damaged in transit.

(a) Concrete piles (b) Concrete pile with steel-shell

Fig. 1.5

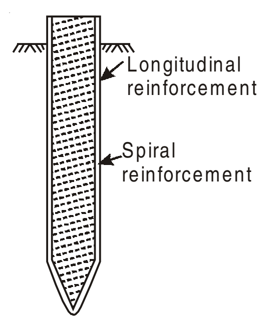


Fig.1.6 *Precast R.C.C with steel-shell.*

(d) **Sheet Piles.** This class of pile is essentially used during the construction of foundation and not as foundation member of structure. Their main function to enclose a certain area of the ground with which the foundation work can be carried and also to confine loose soil and prevent it from spreading. Sheet piles can be wooden, steel, concrete or R.C.C.

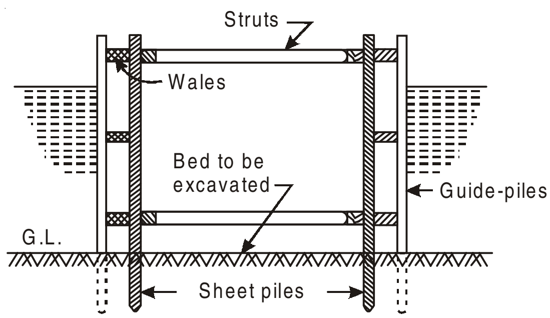


Fig. 1.7 *Sheet piles cofferdam.*

1.8.5 Working Classification

This classification is based on the mode of working of the piles. According to this classification piles are divided into two groups.

(i) Bearing piles, and (ii) Friction piles.

(i) **Bearing Piles.** These piles are used to bear vertical loads on their ends. Bearing piles are used in those places where the depth of hard stratum is not much.

When piles are driven upto the hard stratum, they transfer the load of the structure to the hard stratum below, those piles virtually act as columns.

(ii) **Friction Piles.** When the soil is very loose or soft to a considerable depth, friction piles are used. These piles balance the load of the structure by the friction offered by the surrounding soil on the sides of the piles. They are generally short in length and are not driven to the hard bed. The surface of the friction piles is made rough so as to increase skin friction.

The problem of friction piles is controversial. In some of the soils, the soils become loose due to some reason or the other and reduce the friction, which may result in the failure of the structure.

1.8.6 Raft Foundation

Raft or mat foundation is used in those places where spread footing or pile foundation cannot be used advantageously. This type of foundation is also recommended in such situations where the bearing capacity of the soil is very poor, the load of the structure is distributed over the whole floor area, or where a structure is subjected to constant shocks or jerks.

The raft foundation consists of a reinforced cement concrete slab or R.C.C. T-beam slab placed over the entire area. The T-beam slab may consist of primary and secondary beams as shown in Fig. 1.8.

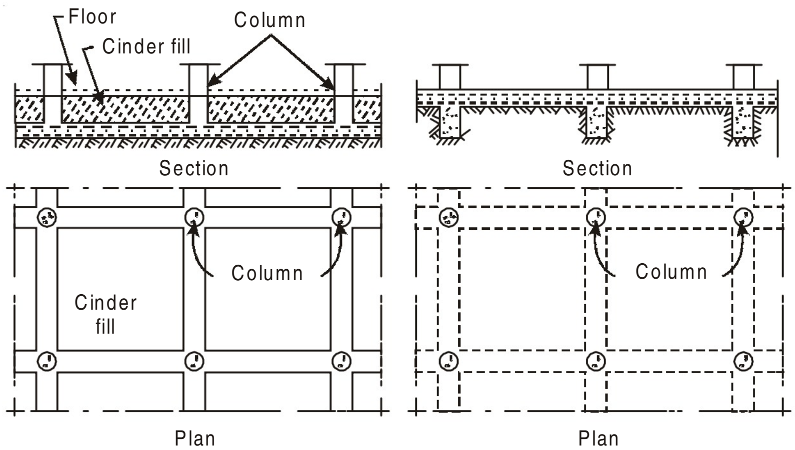


Fig. 1.8 *Raft foundation.*

The T-beam may be inverted also. The inverted T-beam raft foundation is most suited to columned structures, such as in factories or work-shops.

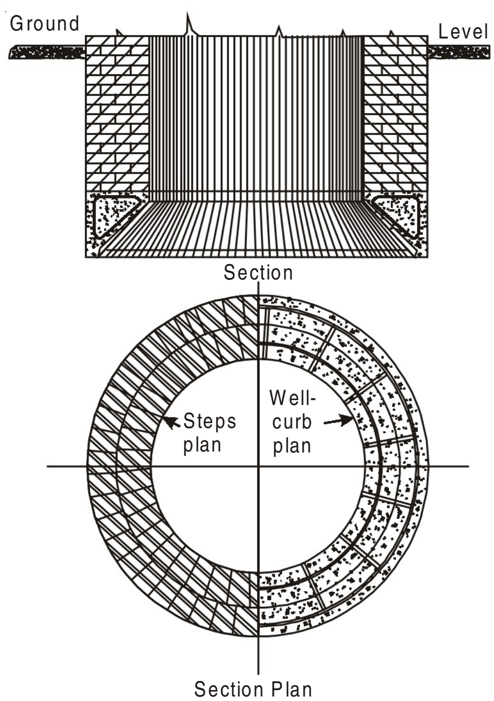


Fig. 1.9 *Well foundation.*

The beams and the slab should be constructed all at a time so as to act as monolithic. The R.C.C. work is laid at the required depth of foundation and then upto the plinth, the inside spaces are filled with dry sand and gravel. The R.C.C. slab and beams can be laid directly over the rammed ground surface or over a bed of lime concrete.

1.8.7 Wall Foundation

Wells are convenient method of securing a trustworthy foundation in deep sandy and soft soils. Well foundation is generally provided for in the construction of bridge piers, ghats etc., where the depth of water is moderate and the foundations are to be carried out in deep sandy soils of soft soils.

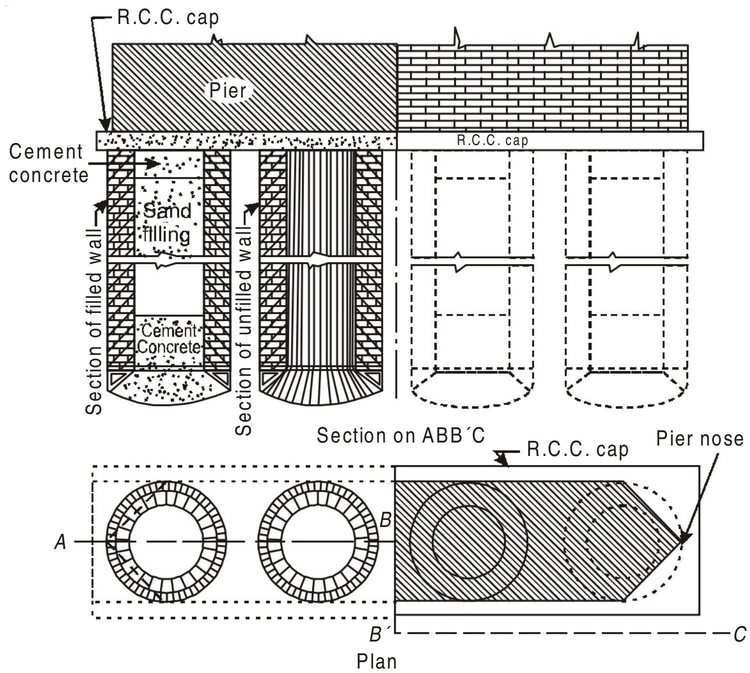


Fig. 1.10 *Use of well foundation for bridge pier.*

For the construction of well foundation in running water as for the construction of a bridge pier, a temporary dam is constructed to exclude the water from the place of construction. This temporary structure is known as cofferdam. The water from the inside of the cofferdam is pumped out. Now a well curb made of steel, concrete or wood with steel cutting edges, is placed over the desired position where the well is to be sunk. A masonry or concrete steining wall is constructed upto a height of 1 m. It is then allowed to dry. The earth from the inside of the well is scooped out either by manual labour or by draggers, and then the well is allowed to sink. Another height of steining is constructed and the material from the inside is dragged out. The well sinks due to its own weight. The process is repeated till the well sinks to the acquired depth or reaches some stratum as the case may be.

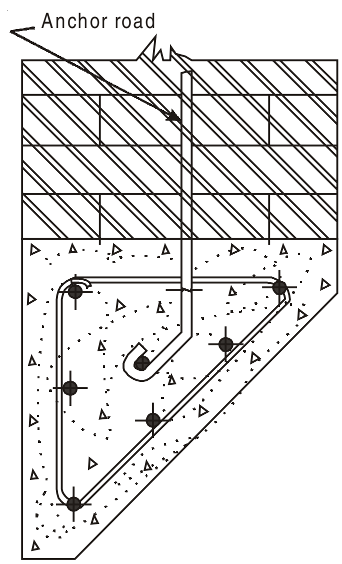


Fig. 1.11 *Details of well curb.*

Before descending the outer surfaces of the steining is plastered smooth so as to minimize the frictional resistances. The sinking is tested by putting the desired loads on the top of the well.

When the sinking in all respects is completed, the lower portion upto a depth of nearly 3 m is plugged with cement concrete, the middle portion with sand and gravel and the top portion with cement concrete.

Now an R.C.C. well cup is constructed over the well. The top of the well cup should be below the bed level of the river. Over the well cup is now constructed the super structure of the bridge pier.

1.8.8 Caisson's Foundation

When the depth of water is considerable and the flow of water is such that cofferdam cannot be constructed easily and economically, then another method of well foundation is used which is called *Caisson Foundation.*

A caisson is a box made of steel, double walled and water-tight, having a well curb with cutting edges attached to its bottom. The drum is carried to the site i.e., the position where it is to be placed. The drum is made to sink with the help of steel rails or sand bags and is kept in position upright by means of steel ropes. The double walled steel caisson is filled with cement concrete, and the water from the inside is pumped out. Now the soil from the inside is scooped out with the help of draggers and the caisson is allowed to sink slowly. The length of the caisson is increased by attaching another length of the caisson, and filled with cement concrete (with some reinforcement if required), soil is dragged out and it is allowed to sink to the required depth or when it reaches the hard stratum. The sinking is tested by putting the designed loads over it.

After the sinking is completed the bottom portion is plugged with cement concrete, middle portion with sand and gravel and again the top portion with cement concrete. The steel caisson above the bed of the river is removed if possible and the remaining is allowed with steining. In this case also R.C.C. well cup constructed over the top of the caisson which the masonry pier is constructed.

1.8.9 Cantilever Foundation

This is a typical type of foundation, which is provided in such places where eccentric footings are to be provided for the external walls or columns due

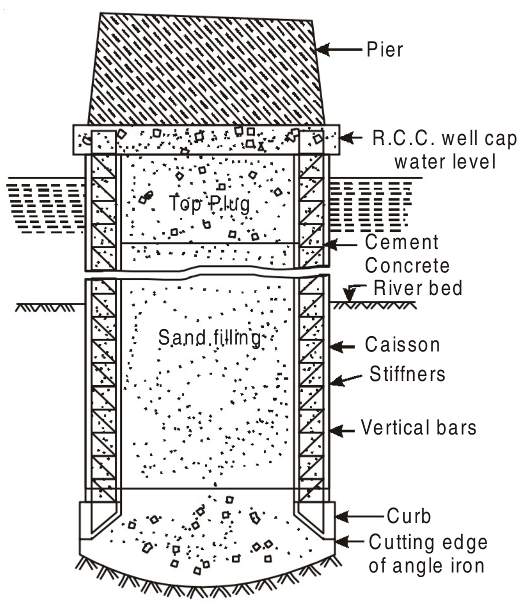


Fig. 1.12 *Caisson's foundation.*

to restrictions of space of some other reasons. In this type of foundation separate footings are provided for the external and internal walls and they are simply connected with each other by a cantilever beam. The tendency of the exterior load to overturn, is balanced by whole or part of the downward pressure acting at the other end of it. See Fig. 1.13.

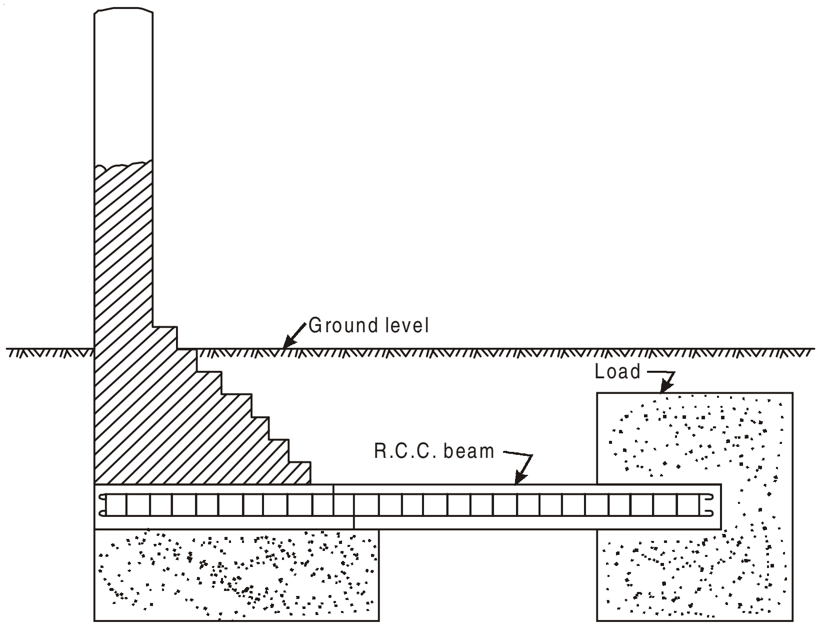


Fig. 1.13 *Cantilever foundation.*

1.8.10 Combined Footing Foundation

When two or more columns are supported by a single base area, the foundations to be provided in such cases are called *combined footing foundations*. The combined footings are also provided to establish the

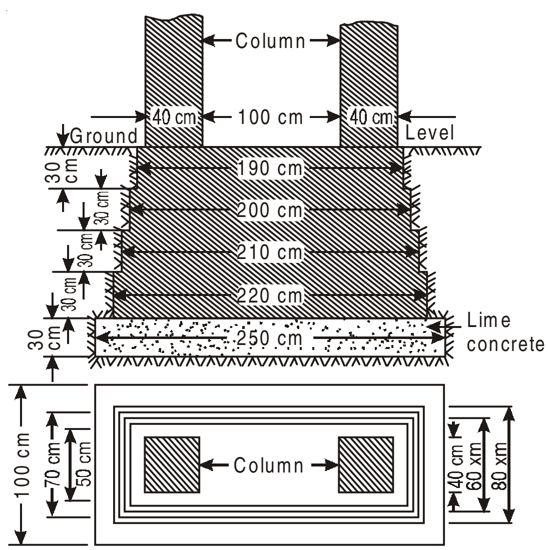


Fig. 1.14 *Combined footing foundation.*

exterior columns along the boundary line, for which symmetrical footings are not possible. The exterior and the interior columns are constructed on the same base in such a way that the base area of the combined footing should be equal to the total load of the two columns, divided by the safe bearing capacity of the soil. The base area should be so shaped as to be symmetrical along the centre line of the columns. See Fig. 1.14.

1.9 INVERTED ARCH FOUNDATION

This is not a common type of foundation. This type of foundation is used in such places were the bearing capacity of the soil is very poor and load of the structure is concentrated over the pillars. The other conditions of the soil are such that deep excavation are also not possible. For this foundation an inverted arch is constructed below the foot of piers etc. Generally segmental arched with a rise of l/5th to 1/10th of the span are used. The span of arches will, of course, depend upon the arrangement of the pillars. The thickness of the arch ring should not be less than 30 cm.

1.10 GRILLAGE FOUNDATION

This is also a very important type of foundation and is suitable for those situations where the load of the structure is pretty heavy and the bearing capacity of the soil is very poor. This foundation is specially suited where deep excavations are not possible. Grillage foundations are usually provided for the construction of stanchions.

It consists of a concrete base over which are placed on or two tiers of I-sections at right angle to each other. The area of the concrete base is calculated by dividing the total load of the structure by the bearing capacity of soil. A trench of the required dimensions is excavated. Over this a cement concrete block generally 30 cm to 45 cm in thickness is spread and properly consolidated. When the concrete is partially dry, I-sections i.e., Rolled Mild

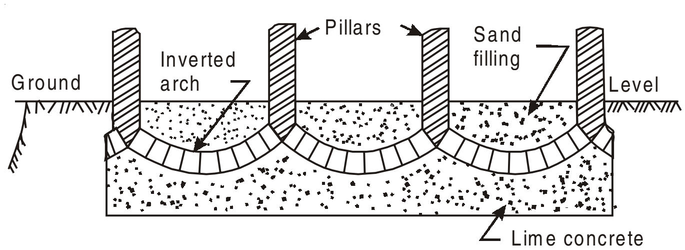


Fig. 1.15 *Inverted arch foundation.*

steel joists are placed at regular distances. (The size and the distance apart of the I-sections depends upon the load of the structure and the bearing capacity of the soil). The lower flanges of the I-sections are connected to the concrete block by rich cement mortar. The I-sections are themselves connected to each other by pipes and bolts so as to form a rigid mass.

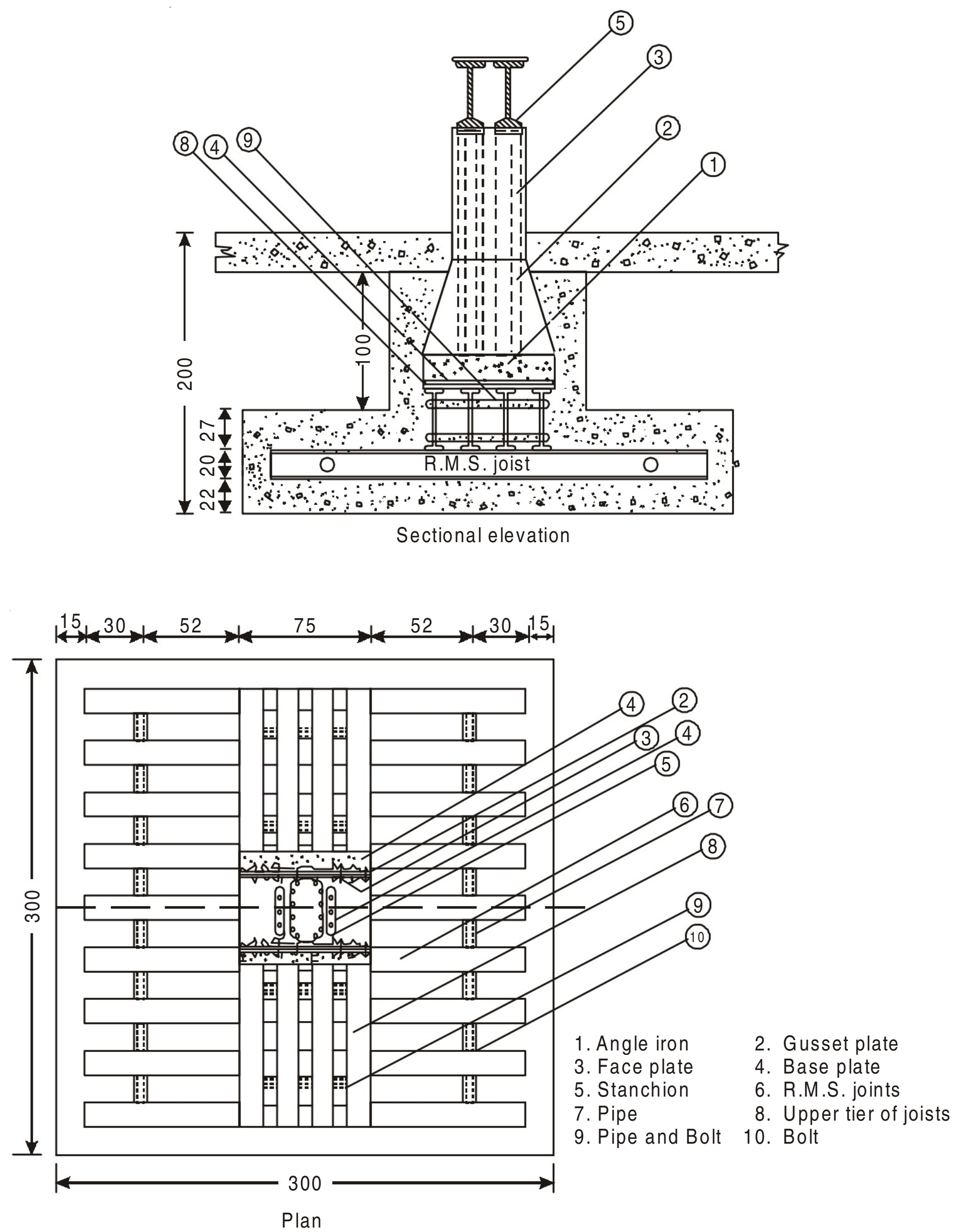
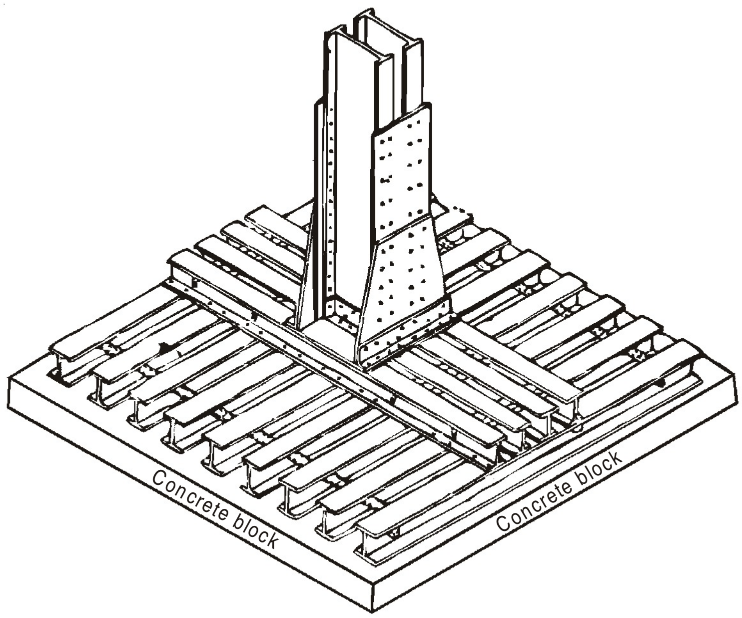
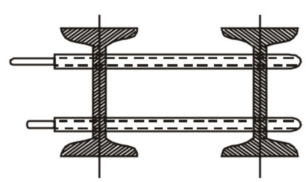


Fig. 1.16 *Steel grillage foundation.*

Another tier of I-sections is placed at right angles to the previous one and connected by means of nuts and bolts. The whole unit is now embedded cement concrete so as to protect the steel from corrosion. Over this the structure is constructed.



Isometric view showing details of connections



Method of fixing distance pieces

Fig. 1.17 *Isometric of a grillage foundation.*

1.11 LAYOUT OF FOUNDATION

After determine the width and depth of foundation, a drawing showing the width of foundations of various walls is prepared. It is known *as foundation plan.* To start the commencement of excavation, the centre line of one of the longest walls is just marked out by stretching a string between two wooden pegs, driven at the ends. Now set out the centre lines of other walls, with reference to this wall. The centre line perpendicular to the reference line, is marked on the ground by 3 : 4 : 5 method. Suppose *AB* is the reference line. A line *BC* is to be marked as perpendicular to *AB*. Now set off a distance of 3 m (or three divisions of any length) on *AB* and take two strings of 4 m and 5 m lengths, (or 4 and 5 divisions of the length taken on *AB*) and set out a triangle with these lengths as sides. The triangle *HBG* will be a right angled triangle and the line *BC* along *BG* will be perpendicular to *AB*.

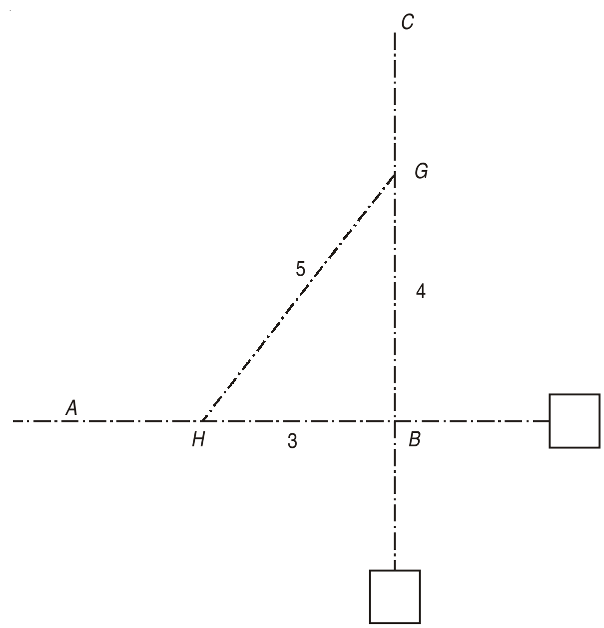


Fig. 1.18 *Setting of perpendicular lines.*

After tracing the center lines of all the walls, masonry pillars or wooden pegs are driven at a distance of nearly 2 m from the centre line. The top of each of these masonry pillars or wooden pegs must be at the same level, irrespective of the nature of the ground. The height of these pillars is recorded with the help of a dumpy level.

The width of the foundation of each wall, is marked on either side of the centre lines and the work of excavation is commenced along the centred lines. With the help of masonry pillars the depth of foundation trenches, is measured. In the case of slopy ground or undulations in the ground, these

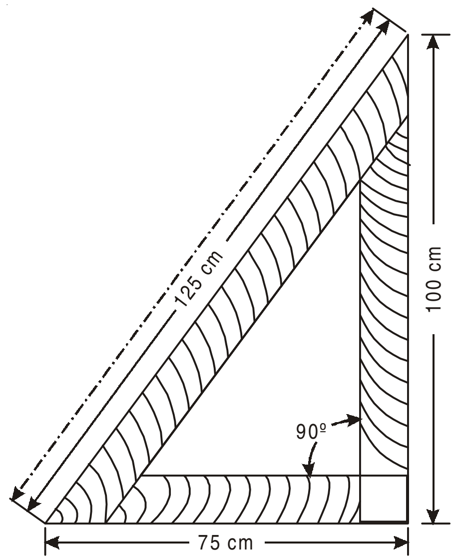


Fig. 1.19 *Mason's square.*

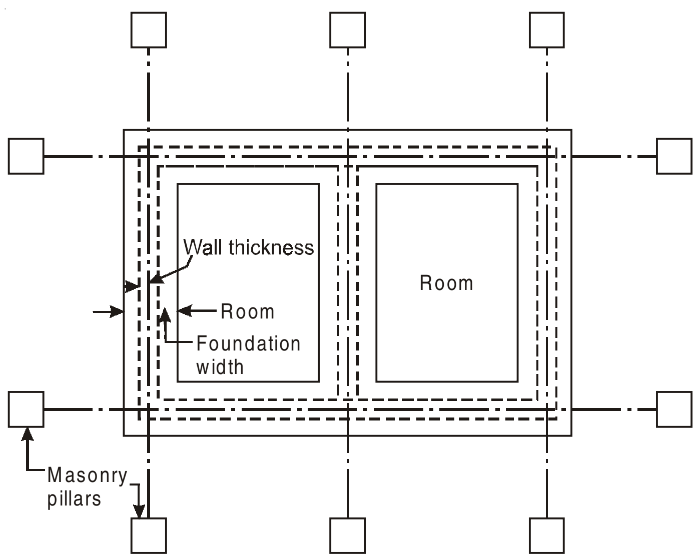


Fig. 1.20 *Foundation plan for layout.*

masonry pillars play an important role, as the *actual* depth of foundation trenches will not be equal but to avoid unequal settlement, the bottom of the trenches of walls having equal thickness or equal depth, must be at the same level.

QUESTIONS

1.1 What do you understand by the term foundation? Discuss the reasons of its failures and suggest remedies for the same.

1.2 What is meant by the bearing capacity of a soil? What is the difference between the bearing capacity and safe bearing of soil? What is factor of safety ?

What is the bearing capacity of the following soils:

Black cotton soil; marum; hard rock; gravel and alluvial soil.

1.3. Name the various types of foundations generally used for various engineering works. Describe in detail the construction of the Grillage Foundation.

1.4 Describe the constructions of a spread footing foundation. Draw a neat sketch showing the details of spread footing foundation for $1\frac{1}{2}$ brick thick wall, having a depth of 1 m below the ground level.

1.5 Name the different types of foundations used in Civil Engineering works. Name the type of foundations you would recommend for the following situations. Describe each in brief:

(i) Bungalow on alluvial soil.

(i) College building on a hill station having slopy ground.

(iii) Stanchion.

(iv) A Bridge pier in deep waters.

1.6 Describe the construction of a well foundation. State the circumstances in which such a type of foundation recommended.

1.7 What are the various types of loads, usually considered for the design of Civil Engineering works ? What are the 'dead loads' of the following materials :

Brick masonry; R.C.C. earth filling; sand; gravel; wood and steel.

1.8 What methods do you suggest for improving the bearing capacity of soils? Describe in brief.

1.9 What are the reasons for the failure of foundations ? What remedies do you suggest for the same ?

1.10 Sketch the type of foundation you would recommend for a building on 'made-up' soil.

[**Hint.** Made up soil means, low lying areas or depressions etc. which are filled up later on with ordinary earth. Such soils, even when they are compacted hard, will yield under the high pressure of the structure. It is, therefore, necessary to take the foundation beds upto the hard stratum. For such situations we recommend, pile foundations. If the soil is properly compacted, holes are driven upto the hard stratum and filled with dry sand. The diameter of the hole will vary from 40 to 60 cm. Over these sand piles, spread footing foundation can be used for ordinary buildings.]

1.11 A building is to be constructed on a sloping ground. Give a neat sketch of the type of foundation you would propose for the walls of the building and give reasons for your choice.

1.12 State under what conditions the following types of foundations are adopted:

1. Well foundation
2. Caisson's foundation
3. Inverted arch foundation
4. Grillage foundation
5. Raft foundation
6. Pile foundation.

Chapter 2

Masonry — Stone and Brick Masonry

2.1 GENERAL

Masonry is the art of the construction in brick or stone. Except in dry masonry some mortar is used to bind the bricks or blocks of stones, with each other. There are in general two types of masonry, viz., Brick masonry and Stone masonry. Brick masonry is that in which bricks are used while in stone masonry, stone blocks are used.

2.2 STONE MASONRY

2.2.1 Comparison of Brick Masonry and Stone Masonry

1. Generally brick masonry is cheaper than stone masonry and can be easily constructed.

2. The minimum thickness of wall in stone masonry can be 35 cm whereas, in brick masonry, walls of 10 cm thickness can be constructed.

3. The brick masonry construction proceeds very quickly, whereas the stone masonry construction proceeds very slowly, as the bricks are handy whereas stones are not.

4. Skilled masons are required for stone masonry construction, whereas unskilled laymen can do the brick masonry work.

5. Brick masonry required less mortar whereas stone masonry requires more mortar which cannot be easily estimated.

6. Stone masonry is stronger and more durable than brick masonry.

7. It is not essential to plaster the stone masonry walls whereas brick walls have to be plastered or painted, when exposed to the open atmosphere.

8. Bricks are of an absorbent nature and no absorbing moisture make the buildings damp, but stones are less absorbent, and hence stone masonry walls or more damp proof.

9. Brick masonry work cannot be allowed to come in contact with urine, sewage etc., without protecting them, whereas this is not the case with stone masonry.

10. Brick masonry is more fire-resistant than stone masonry.

11. Good ornamental work can be cheaply and easily done in plaster in case of brick masonry, but it is not possible in stone masonry.

12. Being uniform and regular in shape, proper bond can be easily obtained in case of bricks as compared with stones. Similarly, obtuse and acute angle joints can be easily provided with brick masonry than stone masonry.

13. Brick absorbs less quantity of heat than stone, therefore in hot climates, during nights, stone walls emit more quantity of heat and make sitting in the room uncomfortable.

2.3 TECHNICAL TERMS IN MASONRY

1. **Back and Backing.** The internal surface of the wall is called *back* and the material used on the back is called *backing*.

2. **Face and Facing.** The outer or exposed face of the wall is called face and the material used on the face is called *facing*.

3. **Hearting and Filling.** The interior portion of wall between the face and back is called *hearting and filling*.

4. **Perpends.** These are imaginary lines containing vertical joints of the masonry.

5. **Voids.** These are spaces left between the blocks of stone in the masonry.

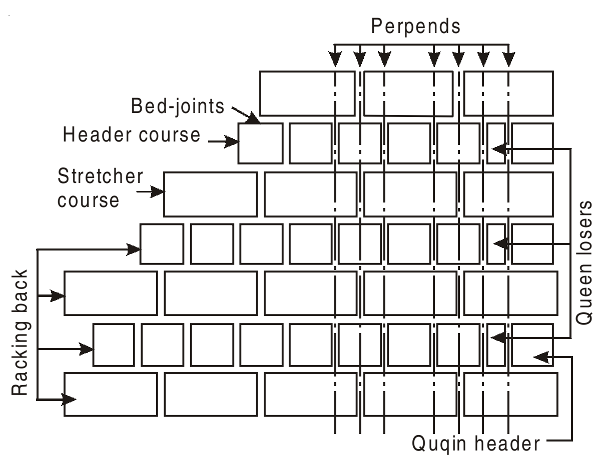


Fig. 2.1 *Elevation of wall.*

6. **Spalls.** These are chips or stone pieces used for backing up or filling the interstices in stone masonry.

7. **String course.** It is a horizontal projecting course of masonry, usually projecting from the face of the wall, intended to throw off rain water. It also gives architectural appearance and adds to the strength of the wall.

8. **Cornice.** It is the projecting ornamental course, usually moulded to add to the appearance of the wall. A cornice is placed in a wall, at the junction of wall and roof.

9. **Coping.** The top of parapet wall is finished with special course to protect it from rain water. This course is called coping.

10. **Drip course.** To facilitate the drainage of water from the coping, a groove is cut on the underside which is called drip course.

11. **Parapet.** It is a low wall built round a terrace in case of buildings with flat roofs. It is intended primarily to act as a fence wall.

12. **Course.** One horizontal layer of bricks or stones is called a course.

13. **Jambs.** These are vertical sides of door and window openings on the back side. These may be either square or splayed and are provided with recesses to receive door and window frames.

14. **Reveals.** These are exposed vertical surfaces which are left on the sides of an opening in front of the door or window frame.

15. **Sill.** This is the horizontal member of stone, concrete or timber provided to support the vertical members of door or window frame.

16. **Stretcher.** When the brick or stone block is laid in such a way that in the elevation its length and thickness is visible, it is said to be laid as *stretcher*.

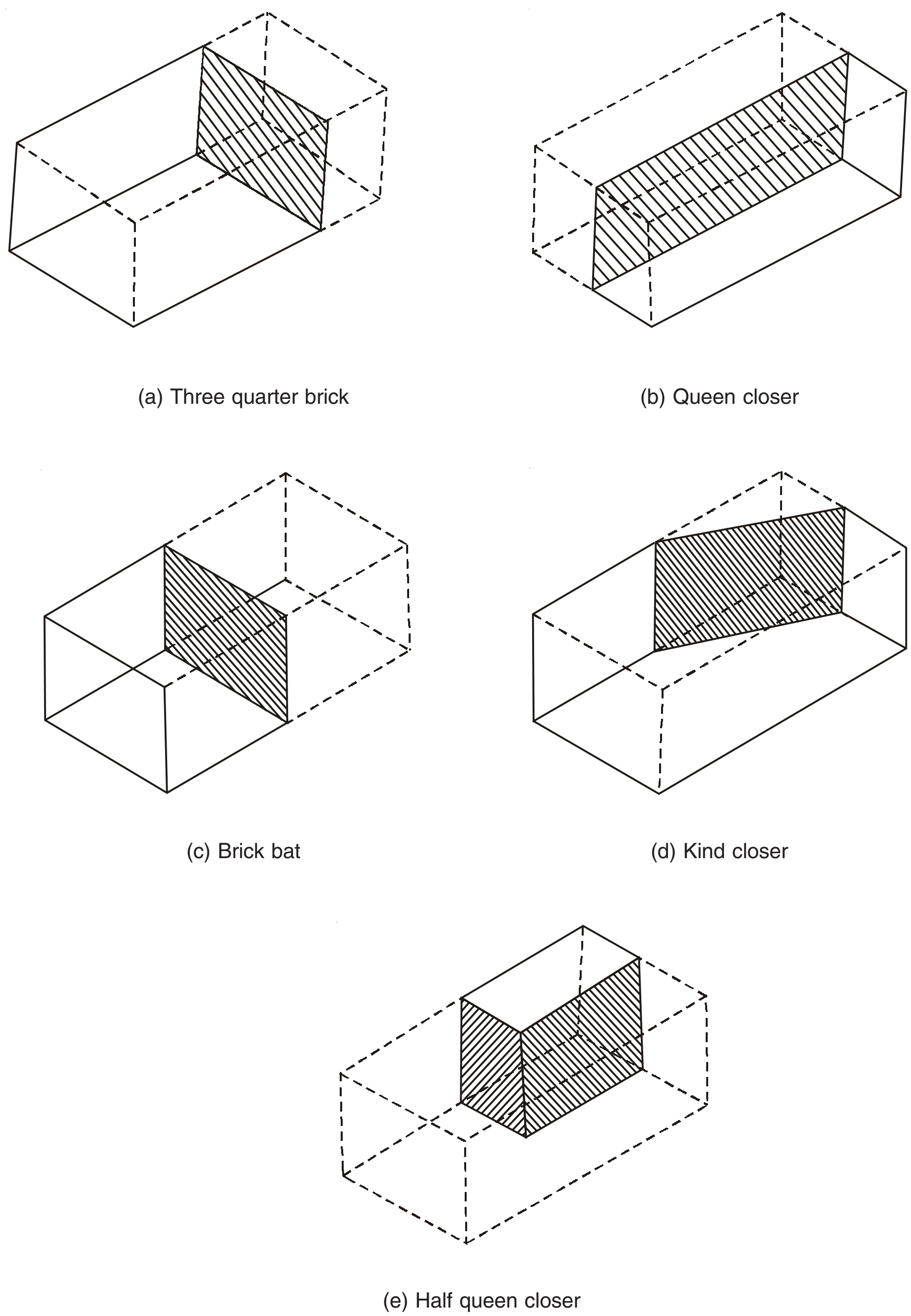
17. **Header.** When the brick or block of stone is laid in such a way that its breadth and thickness is visible, it is said to be laid as *header*.

18. Quoin. The corner stone or brick is called *quoin.* This brick or stone block is used at the corner of two walls meeting right angles.

19. **Queen closer.** It is the name given to the hard brick which is provided just near the quoin to displace perpends to provide the required flap at joints.

20. **Brick bat.** It is a half brick cut along its length.

21. **King closer.** It is a brick cut in such a way that the width of one of its ends is half that of full brick.



(a) Three quarter brick

(b) Queen closer

(c) Brick bat

(d) Kind closer

(e) Half queen closer

Fig. 2.2

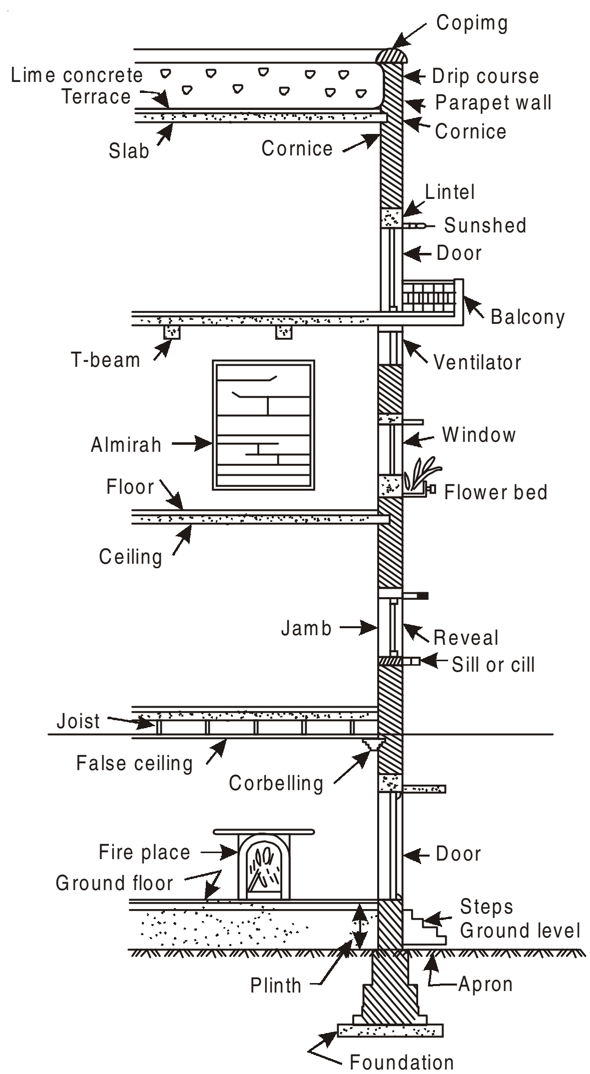


Fig. 2.3 *Section through a masonry wall.*

2.4 GENERAL PRINCIPLES TO BE OBSERVED BY STONE MASONRY

1. Bigger pieces of stone should be used on the bottom layers and smaller pieces at the top layer.

2. The stones should be used on the quarry or natural bed surface or in such a way that the line of pressure is normal to the quarry bed surface.

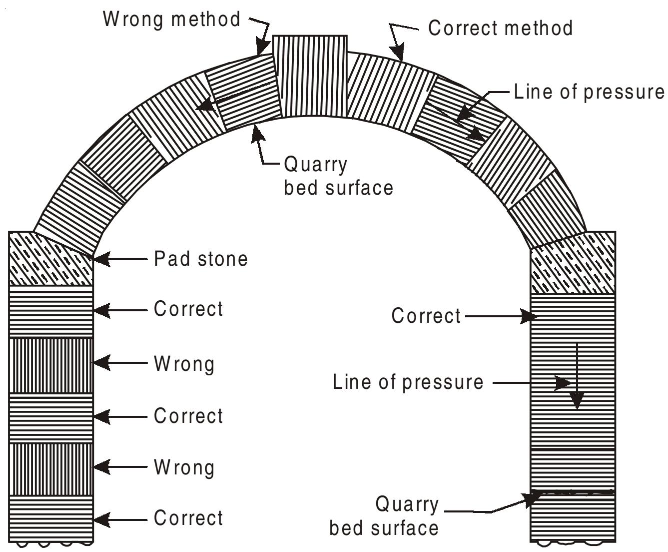


Fig. 2.4 *Method of using stones.*

3. Continuous vertical joints should be avoided.

4. Voids should be minimum.

5. Stone chips should be used to a minimum.

6. The walls should be constructed either to a plumb or to a specified batter.

7. The masonry should be raised uniformly.

8. The masonry should be kept wet for about seven days its construction.

9. The joints in the masonry should be as thin as possible.

10. Through or header stones should be used at regular intervals.

11. Well seasoned, compact grained, tough and uniform texture stones should be used. ,

12. Hollows should not be left in the hearting, and they should be properly packed with chips and mortar.

13. Before using stones they should be thoroughly wetted.

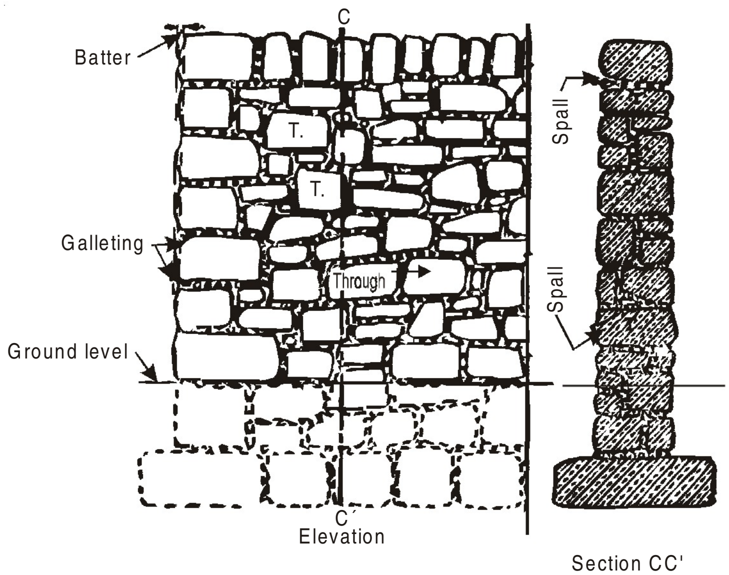


Fig. 2.5 *Header or Through Stone.*

2.5 DRESSING OF STONES

Dressing is the art of cutting the irregular and useless portions of the stones. Stones when they are derived from rocks are highly irregular in shape and size and they cannot be used as they are. Hence they are dressed up, so as to make them useful for any construction work.

Objects of Dressing

(i) Secure proper bedding and bonding

(ii) Secure thin mortar joints

(iii) Secure a neat and pleasing appearance.

Type of Dressing

There are in general two types of dressing :

(i) Quarry Dressing

(ii) Site Dressing

2.5.1 Quarry Dressing

It is a rough dressing and is done at the quarry site itself. The main function of this dressing is (a) to reduce the transportation charges, (b) to mark quarry bed surface, (c) to select the different types of stones for different purposes, and (d) to reduce the cost of dressing.

2.5.2 Site Dressing

This dressing is done on the site where the stones are to be used. Really speaking this is the actual dressing. There are five different types of dressing:

1. Hammer Dressing.
2. Chisel Drafted margin.
3. Tooling and Axing.
4. Fine Tooling or Combing.
5. Rubbed and Polished work.

2.5.2.1 Hammer Dressing

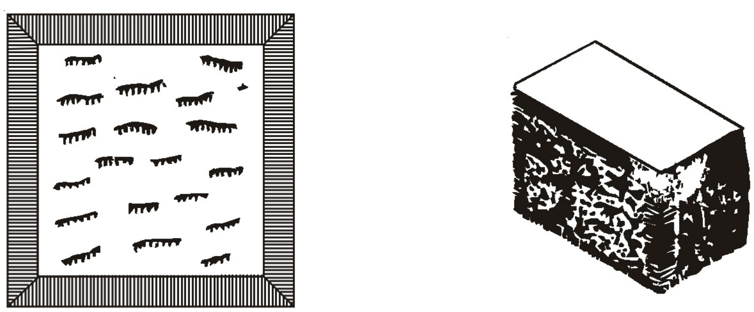
It is a rough type of dressing and the faces of the stone are rough rock-like. The dressing is done by quarry hammers. In this type of dressing the rough or irregular portions are knocked off so as to provide thin joints and improve the appearance.

(a) Hammer dressing (b) Hammer dressing

Fig. 2.6

2.5.2.2 Chisel Drafted Margin

It is a superior type of dressing. After hammer dressing a margin, generally 2 to 4 cm wide, is cut on the edges by means of drafting chisel so as to obtain



(a) Chisel drafted margin (b) Isometric view of chisel drafted margin

Fig. 2.7

reasonably uniform joints and the general surface or the stone is left rough. This type of dressing is generally done for coursed rubble masonry.

2.5.2.3 Tooling and Axing

It is also called *one line dressing*. In this type of dressing, the irregular portions are knocked off and the surface is made roughly flat. Sometimes a

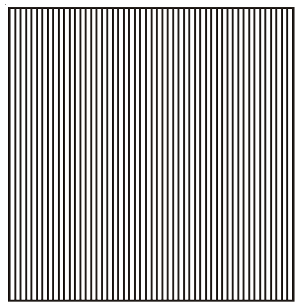


Fig. 2.8 *Tooling and axing.*

margin is formed and the surface is axed. This gives reasonably smooth and thin bed and side joints. This type of dressing is used in superior type of works.

2.5.2.4 Fine Tooling or Combing

It is also called three-line dressing. This type of dressing is done on the hammer dressed surface with the help of saw-like chisel and hammer. By

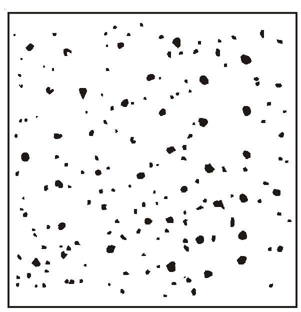


Fig. 2.9 *Fine tooling or combing.*

this dressing all the projecting edges are removed and a smooth surface is obtained. This dressing will give a neat and fine appearance.

2.5.2.5 Rubbed and Polished Work

This is employed when a still smoother surface required. This work consists in rubbing the surface of stone until perfectly smooth and regular. During the first stage of the work pure water and sand is used and then gradually the quantity of sand is reduced, till a good finish is obtained.

2.6 TYPES OF STONE MASONRY

Broadly speaking, stone masonry is divided into two main kinds :

(i) Rubble masonry, (ii) Ashlar masonry.

2.6.1 Rabble Masonry

This is a masonry which is made by either undressed roughly dressed stones. Joints are not uniform, but generally thick and the surface is also very rough. There are four types of rubble masonry.

(a) Random Rubble set dry.
(b) Random Rubble set in mortar.
(c) Squared Rubble coursed.
(d) Squared Rubble uncoursed.

2.6.1.1 Random Rubble Set Dry

It is the poorest type of masonry, and is constructed with roughest stones as they are received from the quarry without any mortar. The stones are picked up from a heap and fitted into the work so as to get a proper interlocking with each other. The voids are filled with stone chips. The larger pieces of stones are used at the bottom and smaller pieces at top. Generally walls built with random rubble set dry are wide at the bottom and thinner at the top. The strength of this masonry does not depend upon the strength of the materials but on the workmanship. This type of masonry is used for compound walls and temporary huts on the quarry sites etc.

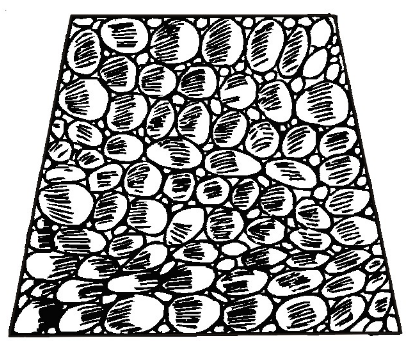


Fig. 2.10 *Random rubble set dry.*

2.6.1.2 Random Rubble Set in Mortar

It is also a cheap type of masonry and is similarly in construction to the random rubble set dry. The only difference between the two is that in this case some mortar is also used for filling up the voids etc. This type of masonry is used for the construction of compound walls, retaining and breast walls, dwarf walls etc. The strength of this masonry also depends upon the strength of mortar and workmanship.

2.6.1.3 Squared Rubble Coursed

This type of masonry is constructed with stones which are dressed either by hammer or chisel. The masonry is constructed in regular courses. All the courses are not necessarily of equal height and it is not essential that

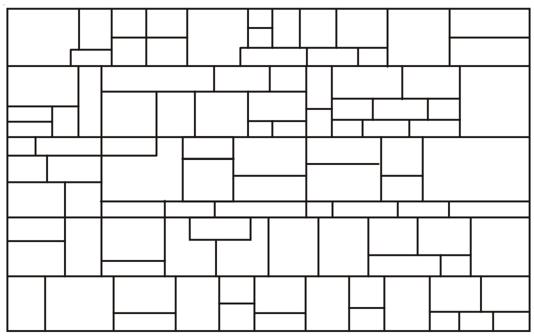


Fig. 2.11 *Squared rubble coursed.*

each course may contain stones of equal size and shape. This is very superior type of masonry. The joints are generally thin and of uniform thickness. This type of masonry is used to construct residential and public buildings, godowns, boundary walls, walls, etc.

2.6.1.4 Squared Rubble Uncoursed

This type of masonry is similar to the coursed masonry but it is not built to courses. The stones are hammer or chisel dressed, squared on edges. The

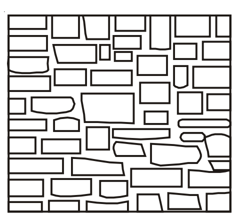


Fig. 2.12 *Squared rubble uncoursed.*

stones are fitted in a haphazard way just to fit in the wall and to interlock each other. Hence this masonry is weaker in strength and inferior to coursed masonry. It is also used for constructing buildings, residential as well as public, boundary walls etc.

2.6.1.5 Ashlar Masonry

The stone masonry in which properly dressed stones are used, is called *Ashlar masonry*. Broadly speaking, there are two types of ashlar masonry.

2.6.2 ASHLAR FACING WITH BRICK BACKING

In this type of ashlar masonry, on the face of the wall Ashlar stones of some kind are used and on the back bricks are used. This type of masonry is used in those places where stones are not readily and cheaply available and

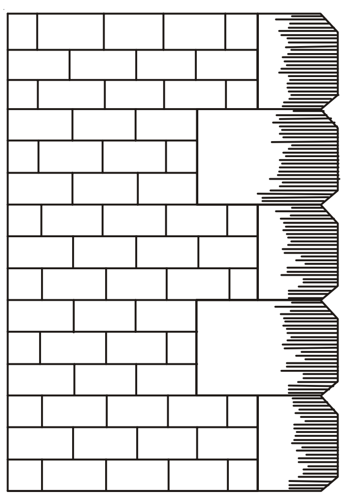


Fig. 2.13 *Ashlar facing with brick backing.*

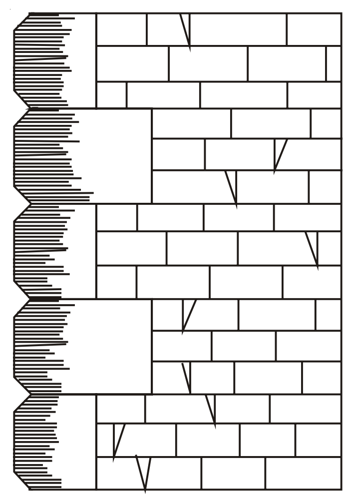


Fig. 2.14 *Ashlar facing with rubble backing.*

good quality of bricks are easily available. This type masonry will have a fine appearance, strength and will be comparatively cheap. If the bricks are properly plastered the strength of this type of masonry will be no less than that of any other stone masonry.

2.6.3 ASHLAR WITH RUBBLE BACKING

In this type of masonry ashlar stones are used on the face of the wall and on the back rubble stones, which are roughly dressed, are used. This type of ashlar masonry is used in those places where good quality stone is easily available.

The above two types of masonries are used mostly for public buildings, high class residential buildings and buildings of monumental character.

Ashlar masonry can also be classified on the basis of dressing given to the face of stones such as plain or fine ashlar, rough tooled ashlar and chamfered ashlar. The surface of the fine ashlar is very smooth, and sometimes polished. The joints are very thin. The rough tooled ashlar will have a comparatively rough and uneven surface but the joints will be very

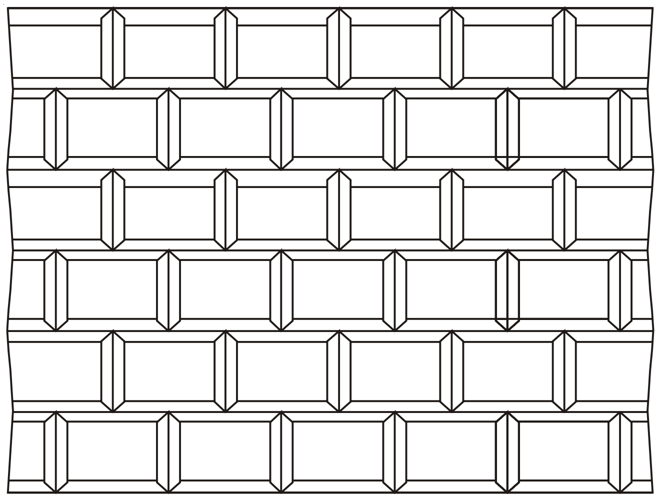


Fig. 2.15 *Chamfered ashlar.*

thin. Rough tooled ashlar also stones have their edges chamfered. In this masonry triangular grooves will be formed at each joint. These triangular grooves will add to the appearance of the masonry.

2.7 JOINTS IN STONE MASONRY

In order to prevent stone blocks to slide over each other and to connect them more rigidly with each other some mechanical type of joints are used in stone masonry. These joints are in some way similar to carpentry joints. The following are some of the important types of joints :

1. **Rebated or Lap joint.** This joint is used in stone roofings, copings etc., to secure a water-tight connection. This joint is made by cutting a

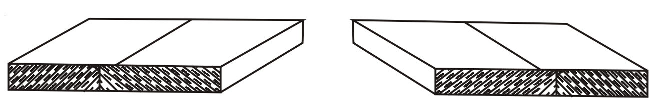


Fig. 2.16 *Rebated joint.*

piece of stone from the thickness and length of the stones to be connected. The two types of rebated joints are shown in Fig. 2.16.

2. **Tongued and Grooved Joint.** This is called *Joggle joint*. This joint consists of a projection in one block, and a corresponding groove in

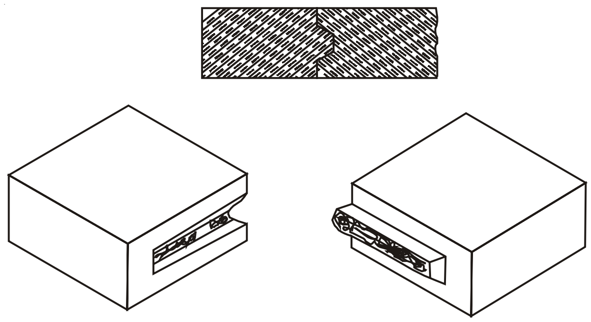


Fig. 2.17 *Tongued and grooved joint.*

the other. This type of joint is mainly used in landings to prevent any movement between the two stones.

3. **Table Joint.** This is a type of joint used for holding stones together by a wide projection left on one stone, fitted into a corresponding sinking

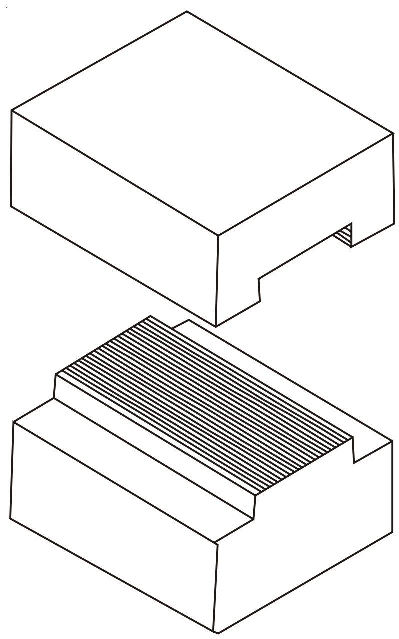


Fig. 2.18 *Tabled joint.*

made in the other stone. This joint is used to prevent lateral displacement of stones in a wall subjected to lateral pressure.

4. **Cramped Joint.** The joints between the stones which are liable to be pulled apart in the direction of their lengths are strengthened by metal or slate cramps. A cramp is a piece of noncorrosive metal such as gun metal or copper. The two ends are bent at right angles and fixed in the blocks as shown in Fig. 2.19.

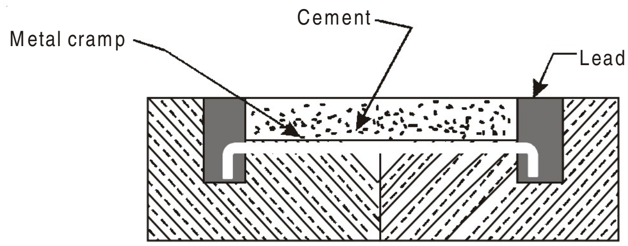


Fig. 2.19 *Metal cramped joint.*

2.8 LIFTING APPLIANCES

Heavy blocks of stones having some carvings on their faces or finely dressed, require some appliances to lift them safely and to keep in position. Ordinary stones are lifted by means of chains or ropes tied to the stone block and passing round a pulley. The ropes or chains tied to the stone are likely to damage the finished edges or faces. This can be prevented by using gunny

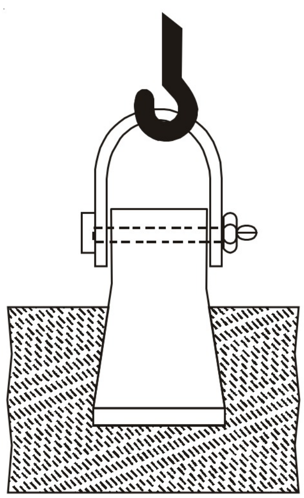


Fig. 2.20 *Three legged Lewis.*

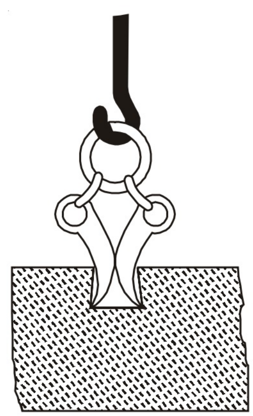


Fig. 2.21 *Chain Lewis.*

bags or wooden planks are packing. Though this method is extensively used, it is a very rough method. The following are the different appliances used for lifting heavy blocks of stones without damaging them :

(i) Three legged Lewis
(ii) Chain Lewis
(iii) Pair of Pins
(iv) Chain Dog
(v) Pair of Nippers

Each of these methods of lifting has been illustrated with self-explanatory figures which will give an idea as to how stones are lifted.

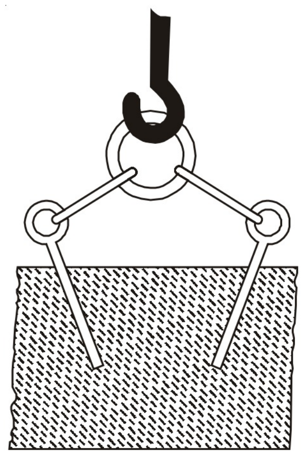


Fig. 2.22 *Pair of Pins.*

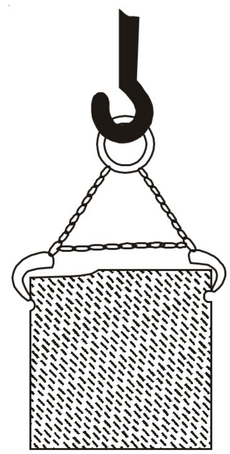


Fig. 2.23 *Chain Dog.*

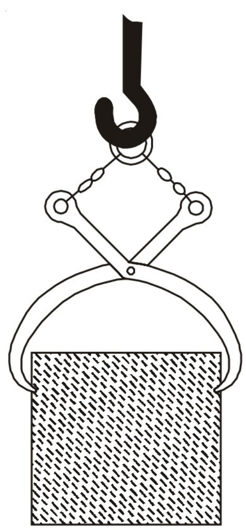


Fig. 2.24 *Pair of Nippers lifting appliances.*

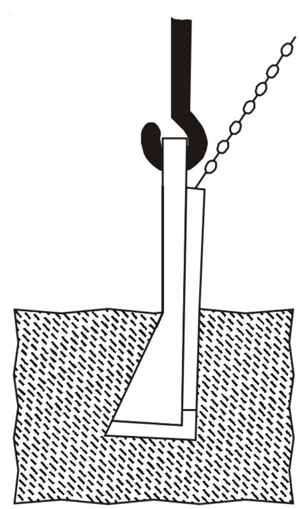


Fig. 2.25 *Lewis for lowering stones under water.*

2.9 BRICK MASONRY

2.9.1 Definition

The art of construction in bricks is called *brick masonry*. Bricks are laid with cement mortar or lime mortar. In ordinary and inferior quality of works, mud mortar is also used. Brick masonry laid with cement mortar is stringer and more durable than that laid with lime mortar. But lime mortar is very commonly used due to its low cost.

2.10 GENERAL PRINCIPLES TO BE OBSERVED IN BRICK MASONRY

While constructing or supervising a brick masonry construction, the following points should be kept in mind:

1. The bricks should be properly soaked in water, before they are used.
2. The bricks should be so laid that their frogs face upwards.
3. Mortar used should be as stiff as possible.
4. The vertical joints of alternate courses should be in one line.
5. The walls should be raised uniformly and verticality of the wall should be tested at every course.
6. All the joints should be of equal thickness and the thickness of each should not exceed 0.5 to 1 cm.
7. In one day not more than 1.5 m of wall in height should be constructed.

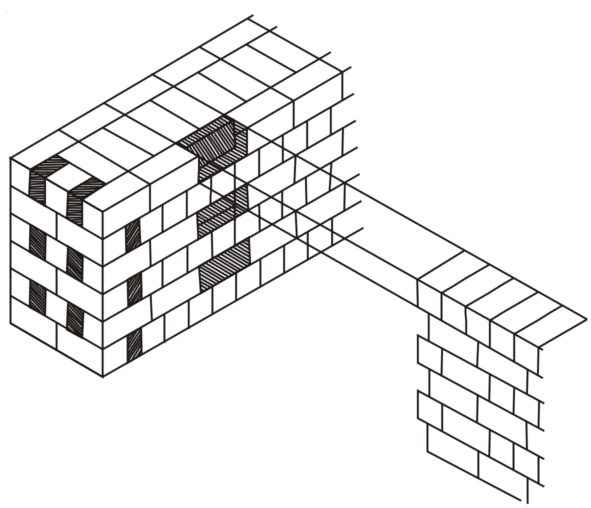


Fig. 2.26 *Toothing.*

8. If the full length of the wall is not approachable, then raking back must be provided as shown in Fig. 2.27.

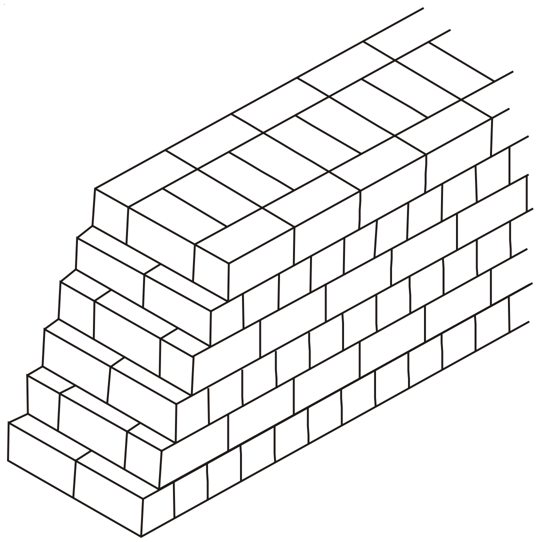
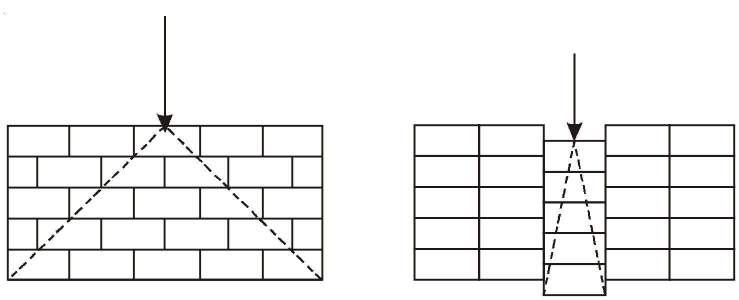


Fig. 2.27 *Raking back or English bond.*

9. The masonry work should be kept wet from 4 to 7 days until the mortar sets and becomes hard.
10. When a main wall is to be connected to a cross wall, recesses, called Toothings should be left in alternate courses to allow the two walls to be bonded with each other, as shown in Fig. 2.26.

2.11 BOND

Bond is defined as the arrangement of bricks or stones in masonry in such a way that the vertical joints in two successive layers should not come over



(a) Bonded

(b) Unbonded

Fig. 2.28 *Bonded and unbonded wall.*

each other. Bond helps in distributing the load of the structure over the foundations and forms a bonded mass of brick work, so as to have a composite mass. To ensure a good bond, the following points should be kept in mind:

1. Minimum number of brick bats should be used.
2. The arrangement of bricks or blocks of stones should be uniform.
3. The lap in the vertical joints should be equal and should not be less than one-fourth of the length of the brick.
4. Strechers should be used only on the face and back of the wall and the interior portion of the wall should be filled with headers only.
5. The vertical joints of alternate courses should be in one line.

2.12 TYPES OF BONDS

The bricks being uniform in size can be arranged a variety of ways. The following are the various types of bonds used in brick masonry :

1. Stretcher
2. Header Bond
3. English Bond
4. Flemish Bond { Single Flemish, Double Flemish }
5. Dutch Bond
6. Garden wall Bond { English Garden, Flemish Garden }
7. Ranking Bond { Herring Bond, Diagonal }
8. Facing Bond

2.12.1 Stretcher Bond

In this type of bond, all the bricks are laid as stretchers, that is lengthwise, as in Fig. 2.29. This bond is used in half brick thick walls.

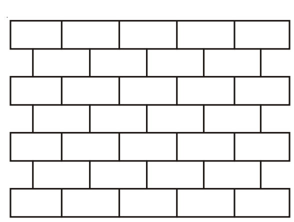


Fig. 2.29 *Stretcher bond.*

2.12.2 Header Bond

In this bond, all the bricks are laid as headers. The elevation of the wall laid in header bond is shown in Fig. 2.30. This bond is used for curved surfaces in brick work such as well lining or well foundation etc.

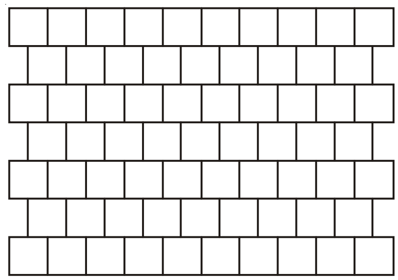


Fig. 2.30 *Header bond.*

2.12.3 English Bond

This is the most common and popular bond and is used in most of the structures. The English bond consists of alternate layers of headers and stretchers. That is to say, one layer will be of stretchers and the other layer of headers. The following are main features of English bond:

1. The alternate courses are of headers and stretchers.
2. Each alternate header is centrally supported over a stretcher.
3. If the thickness of a wall is an uneven or add number of half bricks, there will be best stretchers on the face and headers on the back of wall in every course.

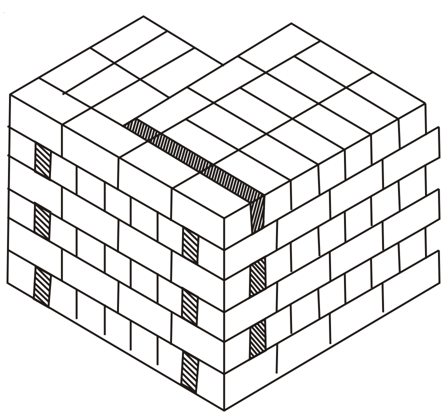


Fig. 2.31. *Isometric view of English bond.*

4. If the thickness of the wall is an even number of half bricks, there will be stretchers on the face and stretchers on the back ; similarly, headers on the face and headers on the back every course of the wall.
5. The walls having a thickness of two bricks or more will have stretchers or headers on the face and back of the wall whereas the interior will be filled with header only.

2.13 ARRANGEMENT OF BRICK IN ENGLISH BOND

1. Two, one brick thick walls meeting at right angles at the corner. (See Fig. 2.32)

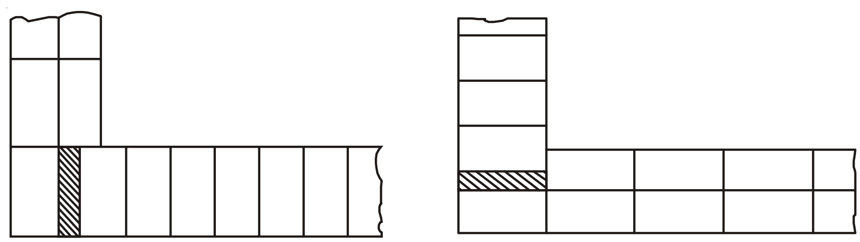


Fig. 2.32. *One brick walls meeting at corner.*

2. Two, one and a half brick walls meeting at right angles at the corner. (See Fig. 2.33)

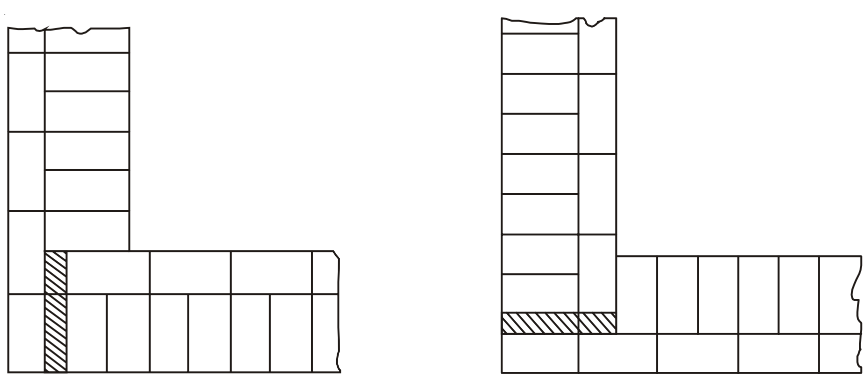


Fig. 2.33. *One and a half brick walls.*

3. Two, two bricks thick walls meeting at right angles at the corner. (See Fig. 2.34)

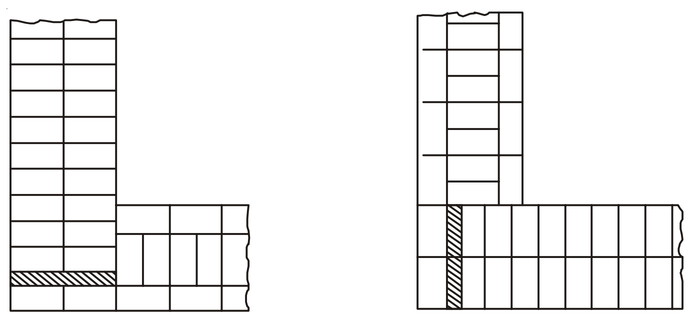


Fig. 2.34 *Two brick walls.*

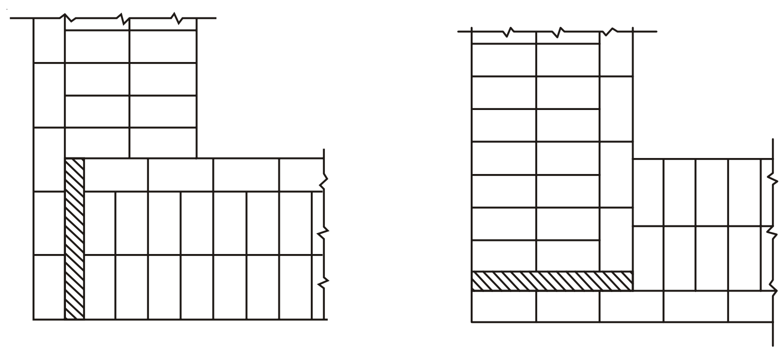


Fig. 2.35 *Brick thick walls.*

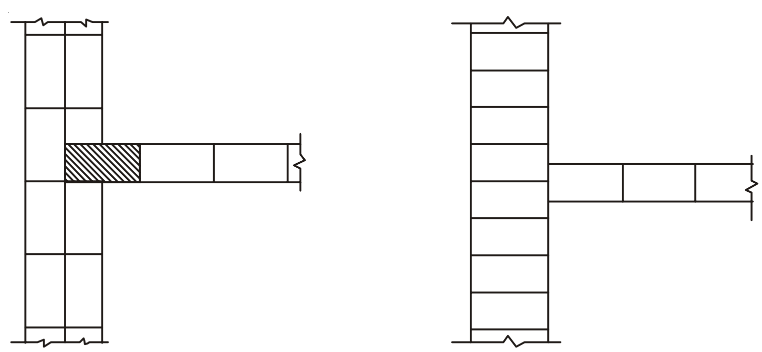


Fig. 2.36 *One brick T-junction.*

4. Two walls, one brick thick and one and a half brick thick, meeting at right angles at the centre (T-junction). (See Fig. 2.37)

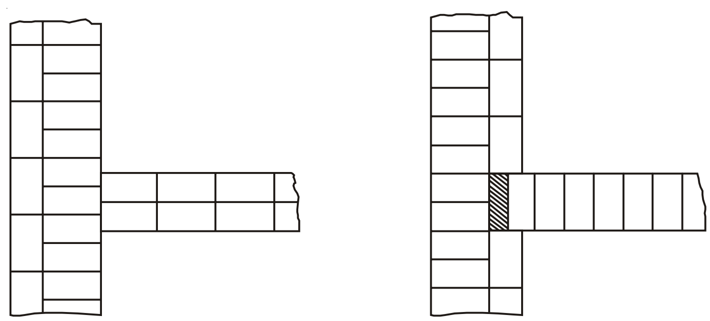


Fig. 2.37 *One and a half brick T-junction.*

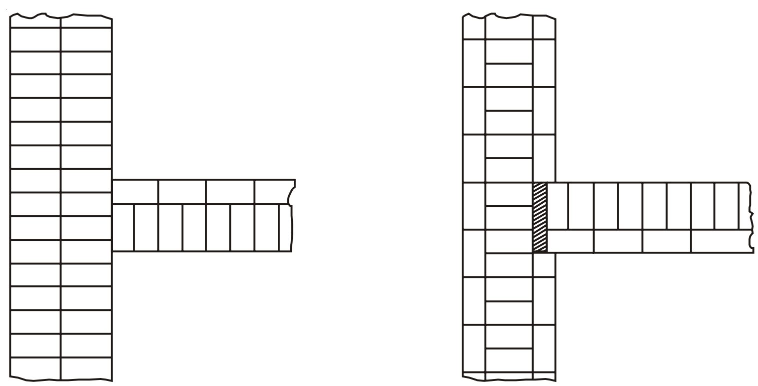


Fig. 2.38 *Two brick and one and a half brick T-junction.*

5. Two, one and a half brick thick walls crossing each other at right angles. (See Fig. 2.39)

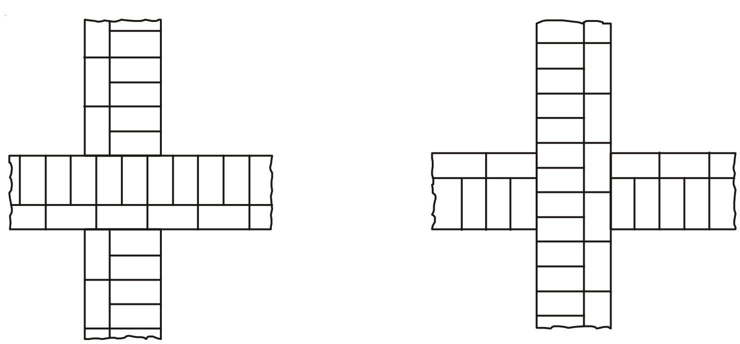


Fig. 2.39 *Wall crossing in English bond.*

2.13.1 Flemish Bond

In this type of bond, each course consists of header and structures alternately arranged. The flemish bond is of two types, viz., Single Flemish and Double

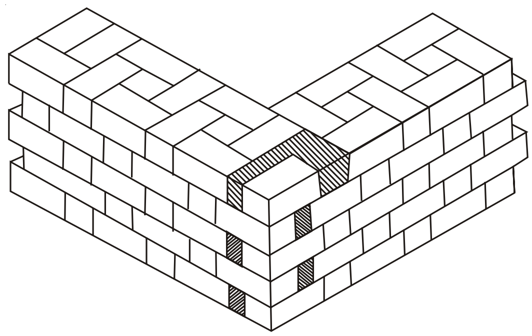


Fig. 2.40 *Isometric view of double flemish bond.*

Flemish. The single flemish bond consists of flemish bond on the face of the wall and English bond on the back of the wall. Whereas the double flemish

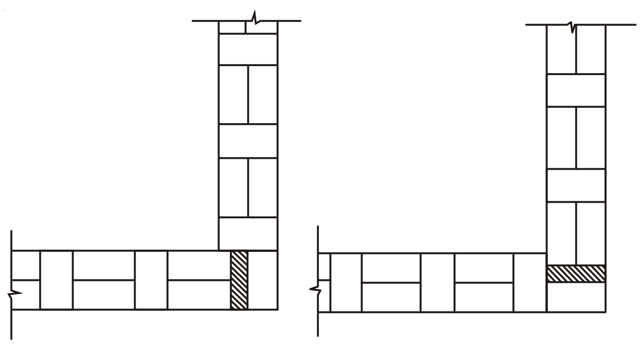


Fig. 2.41 *One brick thick flemish bond corner.*

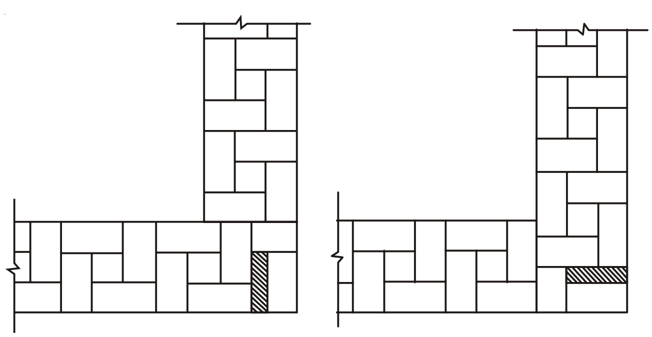


Fig. 2.42 *One and half brick corner in flemish bond.*

bond consists of flemish bond on the face as well as on the back of the wall.

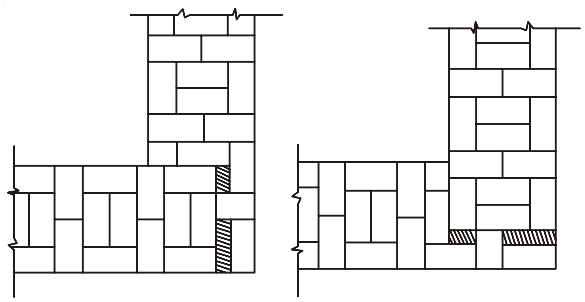


Fig. 2.43 *Two brick comer in flemish bond.*

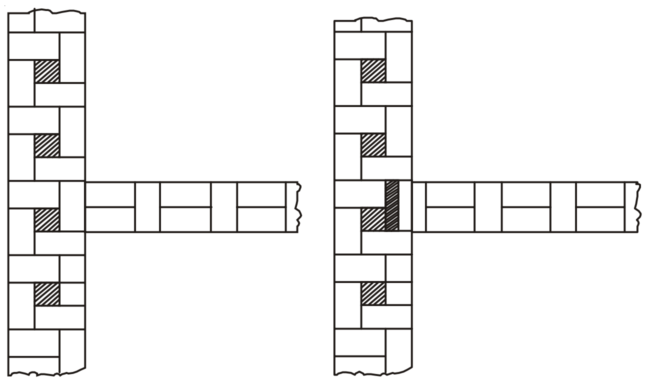


Fig. 2.44 *T-junction in flemish bond.*

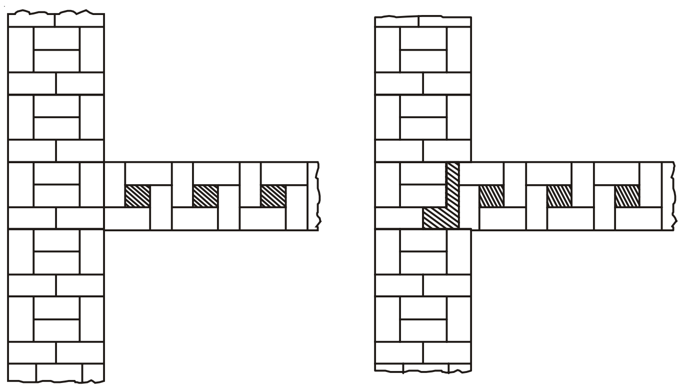


Fig. 2.45 *T-junction in flemish bond.*

Flemish bond admits the use of greater number of brick bats and hence it is economical. But English bond is stronger than flemish bond. It is also claimed that flemish bond is better in appearance than the English bond.

2.13.2 Dutch Bond

It is a modification over the English bond and consists of alternate courses of headers and stretches, except that every stretcher course starts with a

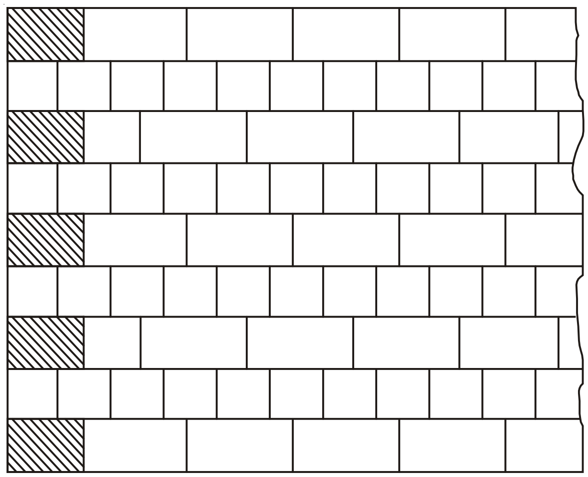
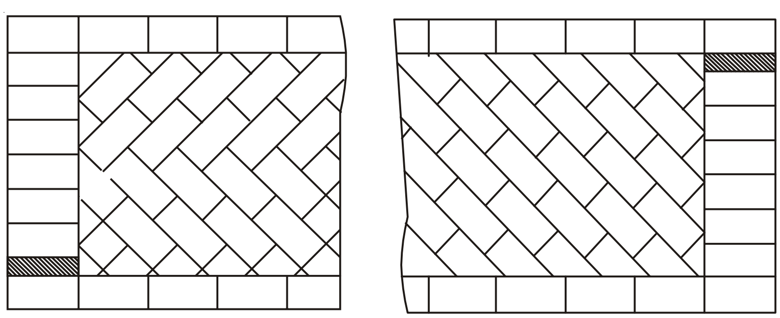


Fig. 2.46 *Dutch bond.*

three-quarter brick and in every alternate stretcher course in header is placed after the three-quarter brick as shown in Fig. 2.46.

2.13.3 Raking Bond

The walls which are more than two-brick thick will become weaker in longitudinal strength, as the headers being used in the interior of the wall



(a) Herring bone bond (b) Diagonal bond

Fig. 2.47 *Raking bond.*

to increase the trasverse strength. This defect is removed by using raking bond (rake means inclination). In this bond the bricks are laid at some inclination to the face of the wall. There are two varieties of raking bond viz., Diagonal bond and Herring bone bond.

2.13.3.1 Diagonal Bond

This type of bond is employed in walls, which are 2 to 4 thick. In this bond, the face bricks are first laid and then the bricks are laid diagonally. The inclination of the bricks should be so adjusted that the bricks may be filled without cutting.

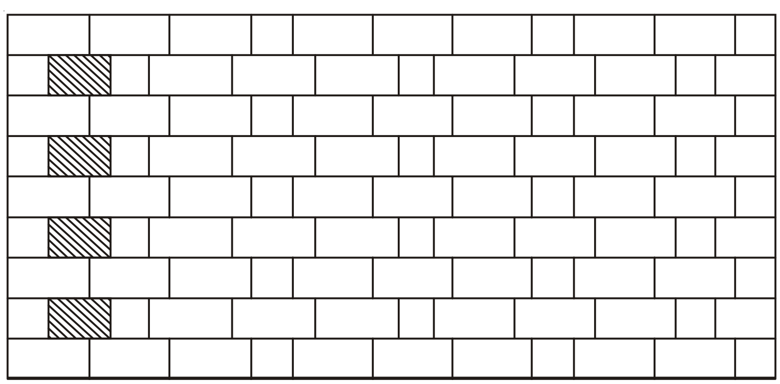
2.13.3.2 Herring Bone Bond

This bond is best suited for walls which are at least 4 bricks thick. In this case, the bricks are laid at an angle of 45° in both directions, commencing from the centre line as shown in Fig. 2.47.

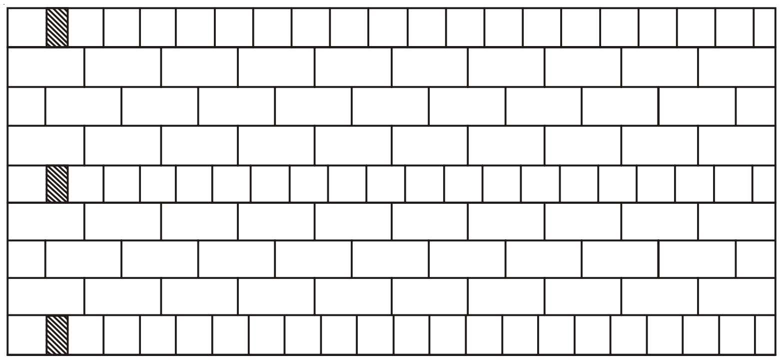
Raking bond pattern of laying bricks is also sometimes used for laying bricks on the floors.

2.13.4 Garden Wall Bond

There are two types of garden wall bond viz., English Garden Bond and Flemish Garden Bond. In the English garden bond, one course of headers is used after every three to four courses of stretchers, whereas in the flemish garden bond in each course one header is used after three or four stretchers.



(a) *Flemish garden bond*



(b) *English garden bond*

Fig. 2.48

2.13.5 Facing Bond

This bond is used when the bricks for the face work are costlier than the other bricks and as such the number of face bricks is economized by using more stretchers. This bond is also used when the thickness of the face and

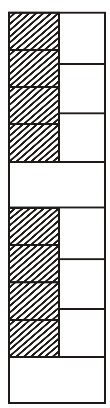


Fig. 2.49. *Facing bond.*

back bricks is different. There are a number of stretcher courses followed by header courses. The thickness of stretcher courses should be multiple of the thickness of thinner bricks. For example, the thickness of face bricks is 5 cm and that of back bricks in 3 cm. Then after three courses of face bricks and five courses of back bricks the height of face and back bricks will become the same. Now at this height header course should be provided.

2.14 RETAINING WALLS AND BREAST WALLS

2.14.1 Retaining Walls

The walls constructed for retaining or supporting earth against their back are called *retaining walls*. Earth cannot remain vertical but would be in a state of equilibrium when it assumes a natural angle which is called *angle of repose*. If it is desired to be retain the earth vertically, that portion of the

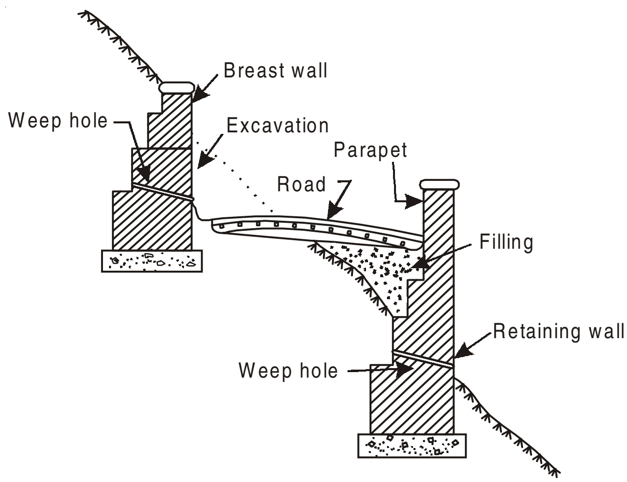


Fig. 2.50 *Retaining wall and breast wall.*

earth will have to be supported by a wall called retaining wall. The back of the wall is in the form of steps and the face of the retaining wall may be either vertical or battered. The width at the base will depend upon the height of earth to be retained as the more the height, the greater will be the pressure at the base and the top can be kept 2 bricks thick or $\frac{1}{2}$ brick thick.

As a thumb rule, the width of the retaining wall can be taken as (0.4 H + 30) cm, where H is the height of the wall in cm.

2.14.2 Breast Walls

A breast wall is constructed to protect the natural sloping ground from the cutting action of natural agents. Breast walls also prevent slides of unreliable soils. The breast walls may be 0.6 m wide at the top. Weep holes should be provided at regular interval among the length of the wall to relieve the walls of saturated earth pressure. The breast walls are so designed that their line of pressure should be normal to the earth pressure or thrust. (See Fig. 2.50)

QUESTIONS

2.1. Define the following terms:

Facing, bed joints, through stones, queen closer, string course, coping, parapet, blocking course.

2.2. What are the comparative advantages and disadvantages of brick and stone masonry? Describe briefly.

2.3. What is meant by dressing of stones ? What are the different methods of dressing stones ? Do you feel any necessity of dressing stones at the quarry site ? If so, why ?

2.4. What precautions do you suggest while supervising a stone masonry construction ?

2.5. Stone blocks are to be carried to a height of 5 metres. Suggest some methods of lifting stone blocks.

Describe any three joints which are commonly used in stone masonry.

2.6. Explain with neat sketches the construction of rubble stone masonry, indicating clearly the position of through stones. What type of mortar would you recommend ?

2.7. Draw the cross section of wall in stone masonry, starting from foundation beds to coping. The section should indicate a two-storied building with a flat roof.

[**Hint.** See Fig. 2.1.]

2.8. Explain where you would recommend the following type of masonry and why :

(i) Fine ashlar masonry ?

(ii) Coursed rubble masonry ?

(iii) Chamfered ashlar masonry ?

[**Hint.** Fine ashlar masonry is used in high class palatial buildings and buildings of monumental character.

Coursed rubble masonry is superior type of masonry and can be used for medium class buildings, residential as well as public, such as bungalow, school, college, hospital, etc., particularly in those places where good quality of stone is easily and cheaply available.

Chamfered ashlar masonry. This type of masonry is mostly used on the exterior walls of places, and other monumental buildings etc. to add to the general appearance of the building.]

2.9. What is a bond ? Name the various types of bonds used in Engineering works.

What is the necessity of providing a bond ?

2.10. What is an English bond ? What are the essential features of an English bond ?

Draw a plan of two consecutive coursed of $1\frac{1}{2}$ brick thick walls meeting at right angles at the corner in English Bond ?

2.11. What are the main advantages and disadvantages of the English bond and the Flemish bond ?

Draw a plan of two consecutive courses of walls $1\frac{1}{2}$ brick thick in Flemish bond, meeting at the right angles at a corner.

2.12. What is a Retaining wall and a Breast wall ? Describe briefly with the help of neat sketch.

2.13. Which type of bond will you suggest for the following situations ? Explain with reasoning :

1. A curve wall.
2. A half-brick thick partition wall.
3. A four-brick thick wall.
4. A wall to be made of bricks of different sizes.

2.14. Suppose you have to supervise the construction of a first class brick masonry wall. What precautions do you expect the brick layer to observe during the process construction ? Illustrate your answer with the help of neat sketches where possible.

2.15. Define the following terms :

1. Header. 2. Queen closer. 3. King closer. 4. Prepend. 5. Bat. Quoin header. 7. Raking face. 8. Toothing. 9. Plinth. 10. Garden bond. 11. Batter. 12. Plumb. 13. Coping. 14. Throating or Drip. Parapet.

2.16. Draw a plan of two consecutive courses of two walls each $1\frac{1}{2}$ brick thick, meetfng at right angles (T-junction) in an English bond.

2.17. What type of mortar would you recommend for the following works? Give reasons for your choice :

1. Temporary site buildings.
2. First class brick work in foundations.
3. Ordinary residential buildings.

[Hint. *Temporary Site buildings.* For such buildings mud mortar prepared from good quality of mud can be safely used. Masonry with mud mortar, if pointed, is reasonably strong.

First class brickwork. Cement mortar 1 : 3 or 1 : 4, that is, mortar consisting of 1 part of cement and 3 to 4 parts of sand.

Ordinary residential building cement 1 : 6 or lime surkhi mortar $1 : 1\frac{1}{2}$ or 1 : 2.]

2.18. What are the general precautions to be taken during the construction of first class brick work.

Describe briefly the procedure to be adopted in construction a long wall of brick work two-brick thick.

[Hint. For the construction of a long wall the following procedure should be adopted.]

1. Each long wall should be divided in such lengths as can be easily approached by two masons working together say 3 or 4 metres.
2. At each section *rank back* should be provided.
3. If the ground is slopy, foundation trenches should be excavated in benches or in form of steps.
4. The plinth of each section should be brought to the same level. In case of long boundary walls, the height of each section of the wall should be the same from the ground level.
5. At certain intervals, the alignment of the wall should be properly checked by stretching a string from one section to the other.

Chapter 3

Dampness and Its Prevention

3.1 GENERAL

One of the most important requirements of a building is that it should remain dry, that is, damp proof. If this condition is not satisfied, it is likely that the building may become unhygienic to the inhabitants and unsafe from the structural point of view, because dampness breeds germs of certain diseases and disintegrates the structure. The following are the effect of dampness:

1. A damp building creates unhealthy conditions for the inhabitants.
2. It disintegrates the structure.
3. Unsightly patches, called efflorescence are formed on the surface of walls.
4. Decay of timber takes place rapidly in the damp climate.

3.2 SOURCES OF DAMPNESS

The various causes which are responsible for causing dampness in buildings are as follows :

1. ***Rising of moisture from the ground.*** The sub soil moisture, present below the ground below the ground level, rises through the foundation beds due to capillary action.

2. ***From the external walls.*** If the faces of walls are subject to heavy showers of rain, or if they are not being protected properly, the water will percolate in and causes dampness.

3. ***Top of walls.*** Parapet and compound walls also become a source of dampness as the rain water descends down the wall and causes dampness.

4. ***Condensation.*** When warm humid air is cooled, condensation takes place. Due to condensation, moisture is deposited on the walls, floors and ceilings and causes dampness.

3.3 PREVENTION OF DAMPNESS

The following are the remedies for making a building damp-proof:

1. By providing a layer of damp-proofing material between the foundation and the plinth, to check the rising of moisture from the sub soil.
2. By plastering the external walls which are subjected to showers of rain by cement mortar, so that rain water may not percolate in.
3. By providing copings on the top of walls and parapets. This will prevent descending of moisture from the top of the walls.
4. The building should be properly *oriented* so that, each room should have sufficient ventilation and may get sufficient sunshine.

(Orientation means, placing or arranging the various apartments of a building in such a way that each room or apartment gets the maximum benefit of natural light, air and sun.)

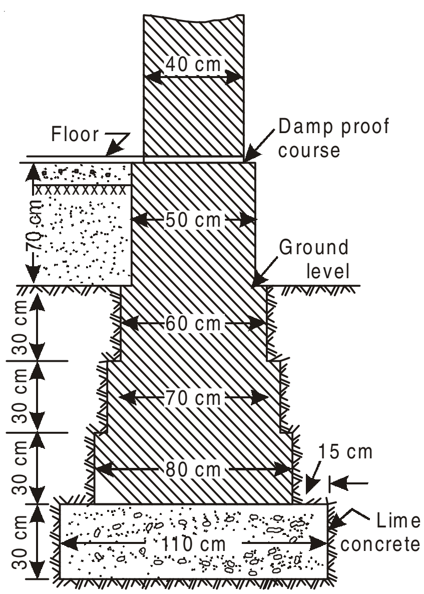


Fig. 3.1 *Horizontal damp-proof course.*

3.4 DAMP-PROOF COURSE

It is a layer of some impervious material provided at various levels of entry dampness in a building. Generally in ordinary residential and public buildings, the damp-proof course (D.P.C.) is provided at the plinth level.

The following points should be kept in mind while providing damp-proof course :

1. The damp-proof course may be horizontal or vertical.
2. The damp-proof course should be in the full thickness of wall.
3. It should be continuous.
4. It should not be exposed to the atmosphere, otherwise it is likely to be damaged.
5. It should be of a good impervious material.

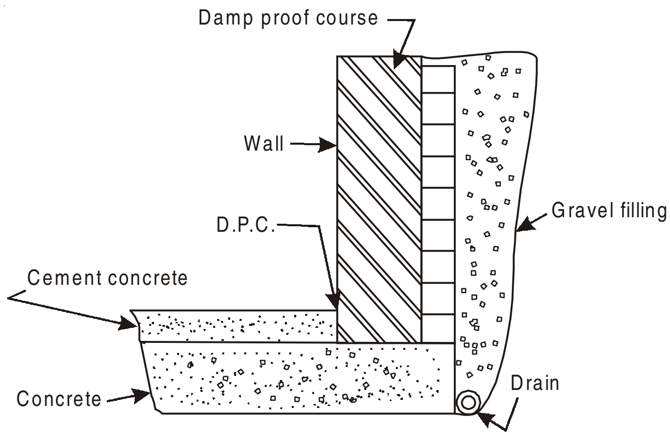


Fig. 3.2 *Vertical damp-proof course.*

3.5 MATERIALS USED FOR DAMP-PROOF COURSE

The following materials are generally used for damp-proofing :

1. ***Bitumen.*** This is a flexible material and is applied on the bedding of mortar or concrete.

2. ***Metal Sheets.*** Sheets of lead, aluminum and copper are also used as a membrane for damp-proofing. Generally lead sheet is used in those places where there are chances of heavy dampness from the sub-soil water.

3. ***Stones.*** Good quality of stone such as slate, granite etc. can be effective damp-proof course.

4. ***Cement concrete.*** A cement concrete layer 1 : 2 : 4 in a thickness of nearby 2 to 3 cm, is generally provided at the plinth level to work as a damp-proof course.

5. ***Cement mortar.*** Concrete mortar in the ratio of 1 : 3 mixed with damp-proofing material in a thickness of 2 to 3 cm can also work as D.P.C.

3.6 CAVITY WALLS

A cavity wall is a double leaf wall having a cavity in between. The outer leaf is generally 10 cm thick and the inner leaf may be 10 cm 20 cm thick with 5–8 cm wide cavity. The two leaves are connected together with the help of bonding bricks or metal tie rods. The cavity is extended right upto the foundation concrete sometimes and then it is filled with cement concrete upto the ground level. The cavity should be upto the roof-level. The bonding bricks or metal ties are placed at a distance of 1 m to 1.2 m horizontally and 60 cm – 80 cm vertically in a staggered fashion.

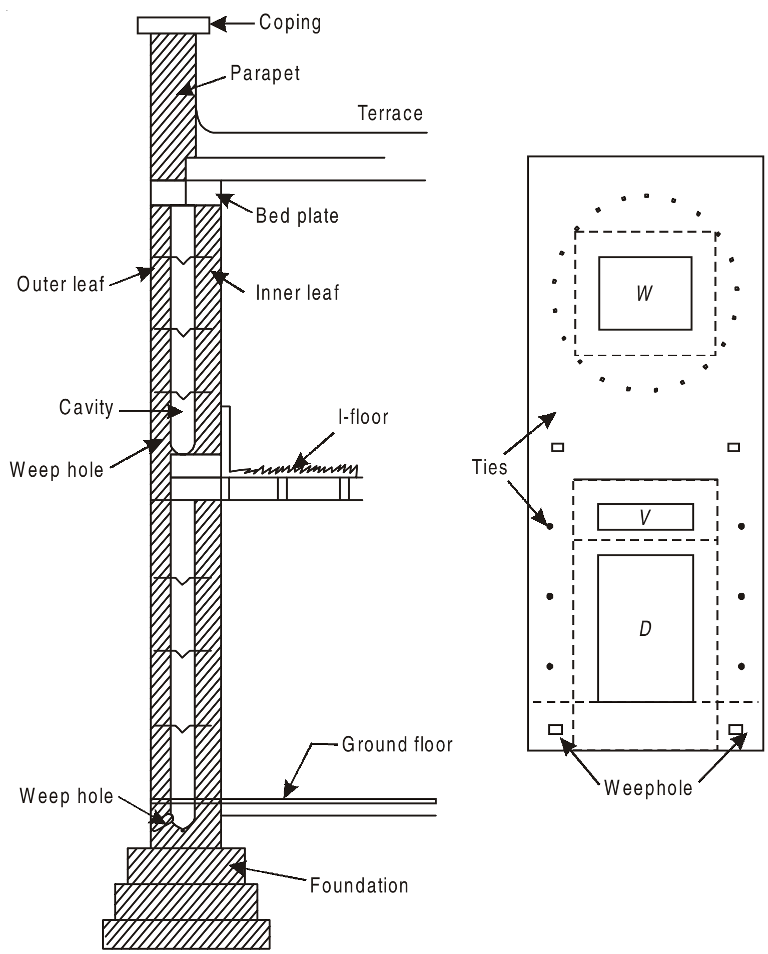


Fig. 3.3. *Cavity wall.*

During the construction, care should be taken to see that mortar is not allowed to drop and lodge upon the ties as water may penetrate through the porous material and cause dampness on the inner leaf. In order to maintain clean cavity a wooden batten of a thickness slightly less than the width of cavity is used. The batten will have two pieces of cards attached to its two end. The batten is supported on ties and is raised with the help of cord as the work proceeds and any intercepted material or brick chipping may be removed. There should be cavity around the opening of doors, windows, ventilators for structural reasons.

Advantages of Cavity Walls

1. For the same thickness of material cavity walls are stronger than the solid walls.
2. Cavity walls are damp-proof, sound heat resistant.
3. Cavity walls are nearly 20% cheap than the solid walls.

Precautions to be taken while Constructing Cavity Walls

1. As far as possible the interior and exterior leaves should be disconnected from each other.
2. Each leaf should have separate D.P.C. layer.
3. Ties should be of rust-proof material.
4. Cavity should be extended from the top of roof to the foundation.
5. The top of the two leaves should be built solid to take up structural loads.
6. Leaf holes should be provided just below the D.P.C.

QUESTIONS

3.1. What is dampness ? What are its causes and what remedies do you suggest for making a building damp-proof ?

3.2. What are the disadvantages of a damp building ? Is it necessary that all the buildings should be perfectly damp-proof ? If so why ?

3.3. What materials are generally used for a damp-proof course ? Describe the method of providing damp-proof course in ordinary buildings and in basements.

3.4. What are the common causes of leakage in flat roofs and what precautions would you take in new buildings to avoid the possibility of leakage?

[**Hint.** The common causes of leakage in flat roofs are :

(i) Faulty construction and bad workmanship of roofs.

(ii) Due to temperature variations cracks are developed through which water leaks.

(iii) Rain water finds an easy access through the parapets and leaks in the roofs.

Remedies

(i) Careful supervision during the construction of roofs.

(ii) Proper ramming of lime concrete and providing expansion and contraction joints, if the roof is very long.

(iii) Providing coping on the top of parapets *(See* also Chapter on Roofs).]

3.5. What is the difference between membrane method and integral method of laying damp-proof course.

Describe the procedure of laying membrane method of damp-proof course.

[**Hint.** If the buildings are to be constructed of stone or cement concrete which are *water repellent* materials, additional layer of damp-proof course is not required. In such cases, the materials to be used where a D.P.C. layer was to be provided, should be of a good quality so that they can work as D.P.C. For example, if a building is to be constructed of stone masonry such as sand stone, the stones to be used at the plinth level should be either good quality sand stone or some other stone such as granite, slate etc. Similarly if cement concrete is to be sued for walls, columns, etc., at the plinth level richer concrete should be used.

The method of damp-proofing is called *Integral method* of damp-proofing and the other method of providing additional layer of some damp-proofing material is called *Membrane method*]

Chapter 4

Doors and Windows

4.1 GENERAL

Doors are openings in the walls for the purpose of communication, light and air. Doors, when they are closed provide privacy and security and admit light, air and entry when they are open. Doors are meant for convenience, but when provided in a haphazard way, they will cause inconvenience and obstruction. They are provided on the floor level.

Windows, on the other hand are provided for the purpose of light and air. The doors or windows to be provided should be just sufficient to satisfy the minimum requirements of particular room.

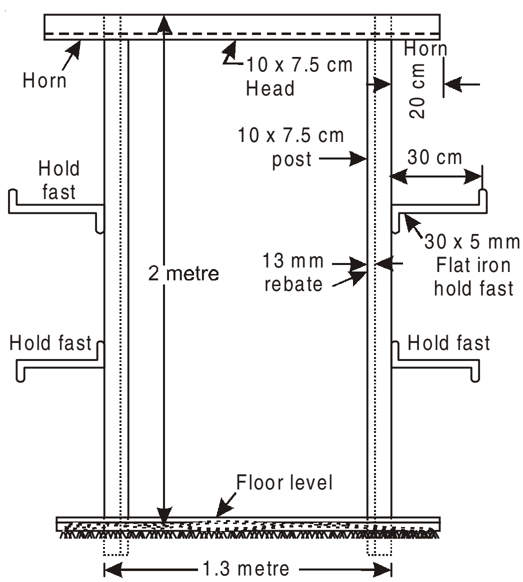


Fig. 4.1 *Door frame (without sill).*

4.2 COMPONENT PARTS OF A DOOR OR WINDOW

Every door or window *generally* consists of a *frame* or *chaukhat* and shutters. The door or window frame consists of two vertical members called posts and two horizontal members called *head* and *sill*. The lower horizontal member, i.e., sill, is sometimes not provided in the case of doors, to facilitate cleaning and washing, and to remove obstruction in the passage. The top and bottom horizontal members of the frame are projected beyond the posts and this projected portion is called horn. The frame is securely fitted into the masonry either by means of *horns* or *hold fasts*. The length of the horn varies from 15 to 20 cm.

The hold fasts are angle iron or flat pieces 22 to 30 cm in length and 2.5 cm × 2.5 cm or 2.5 cm × 0.5 cm respectively in size. The number of hold fasts varies from 2 to 3 on each side of the posts, and are embedded into the masonry so as secure the frame firmly in the masonry.

Generally one or two shutters are provided in a door. A door with one shutter is called *single leaf door* and with two shutters is called double leaf door or *hung folded* door. A groove is cut in the frame to receive the shutter, which is called *rebate*.

4.3 TYPES OF DOORS

The following types of doors are generally used in buildings :

1. Ledged door
2. Ledged and braced door
3. Framed and braced door
4. Panelled door
5. Glazed door
6. Partly panelled and partly glazed door
7. Flush door
8. Louvered door
9. Collapsible door
10. Revolving door
11. Rolling steel door
12. Sliding door.

4.3.1 Ledged Door

It is the simplest type of door mostly used as single leaf, and is provided in stores, kitchens, bathrooms, latrines, etc. in residential buildings (Fig. 4.2). It consists of wooden planks 2 to 3 cm in thickness and 15 to 22 cm in width, secured to each other by horizontal members called *ledges*.

The ledges are generally three in number, having a thickness of 2.5 to 4 cm and are 10 to 15 cm in width. The battens are also secured to each other means of suitable joints and *headless nails.*

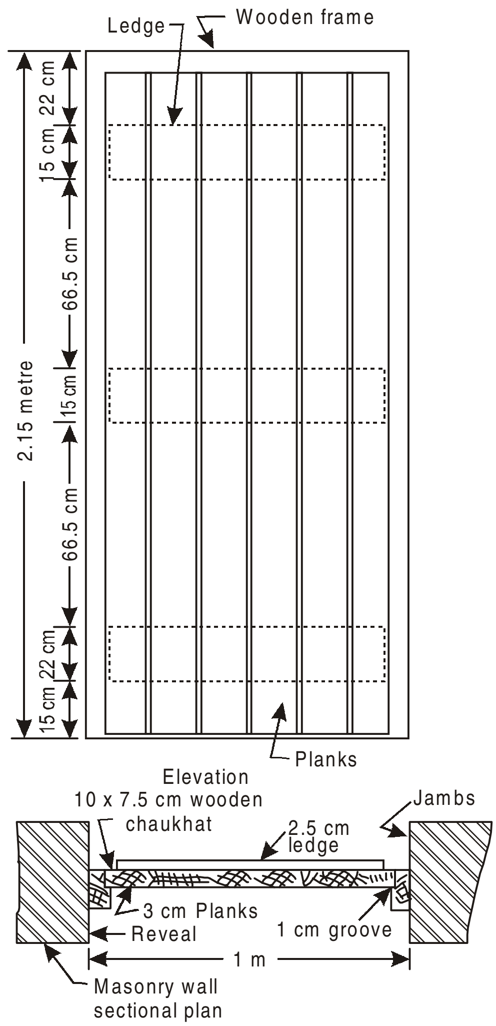


Fig. 4.2 *Ledged door.*

4.3.2 Ledged and Braced Door

The ledged door has a tendency to drop at the outer edge, due to its own weight as shown in Fig. 4.3. To prevent this dropping, diagonal members called braces are provided between the two ledges. Hence the ledged and braced door is more rigid and stronger than the ledged door (Fig. 4.4). The braces are so provided that the upper end of the brace is towards the hanging side. This type of door is also provided in stores, kitchens, bath-rooms, latrines etc. Due to its greater rigidity it can be used for wider openings.

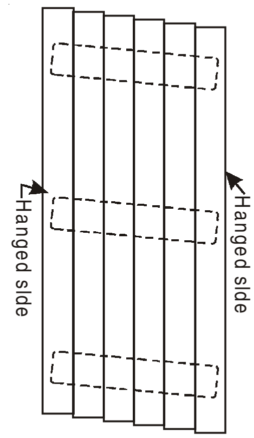


Fig. 4.3 *Sketch showing defect developed in ledged door.*

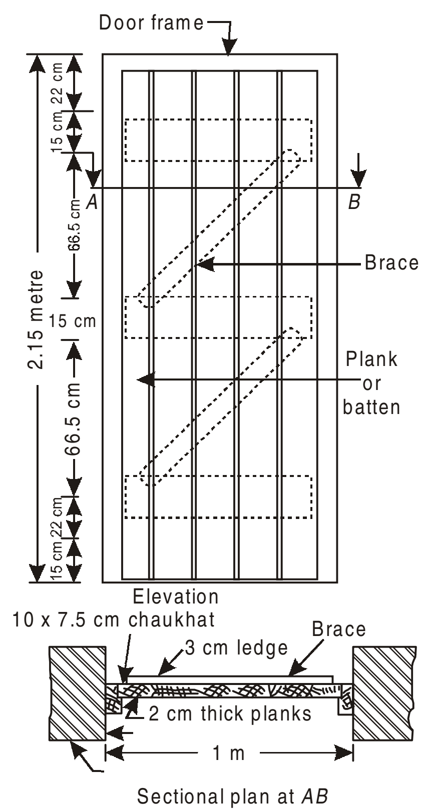


Fig. 4.4 *Ledged and braced door.*

4.3.3 Framed and Braced Door

This type of door is stronger than the above two types of doors. The door consists of a frame in which wooden battens are fitted along with the braces (Fig. 4.5). The frame is made of two vertical members and two horizontal members, one at the top and the other at the bottom, of equal thickness.

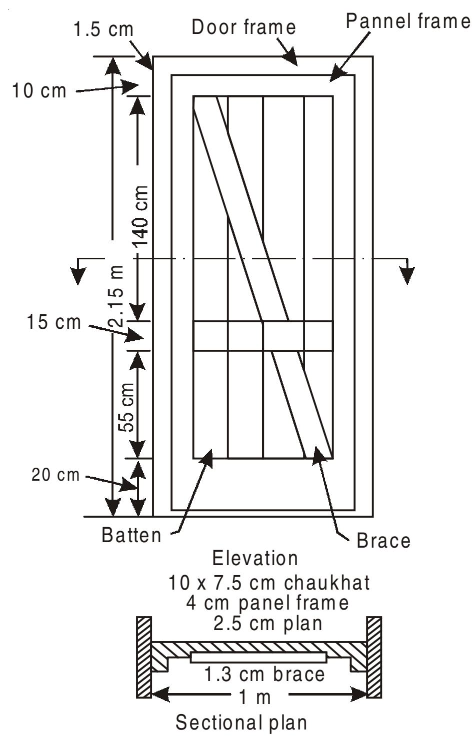


Fig. 4.5 *Framed and braced door.*

Battens are then fitted to the frame. The middle horizontal member and braces, which have thickness equal to the *thickness of the mainframe minus the thickness of the battens,* are fitted to the back of the battens. These doors are now becoming popular these days.

4.3.4 Panelled Door

It is an important type of door and is used in residential as well as in public buildings. It consists of 4 frames made of vertical and horizontal members. The vertical members are called *styles,* and the horizontal members are called *rails*. The top horizontal member is called *top rail,* the bottom member is called *bottom rail* (Fig. 4.6). The rail provided at nearly two-third from the top is called *lock rail*. The rail provided between the lock rail and the top rail is called *frieze rail*. In some cases in between the styles, vertical members are provided to divide a panel vertically and are called *Mullion* or *Muntin*. The open space in the frame is filled with wooden planks called

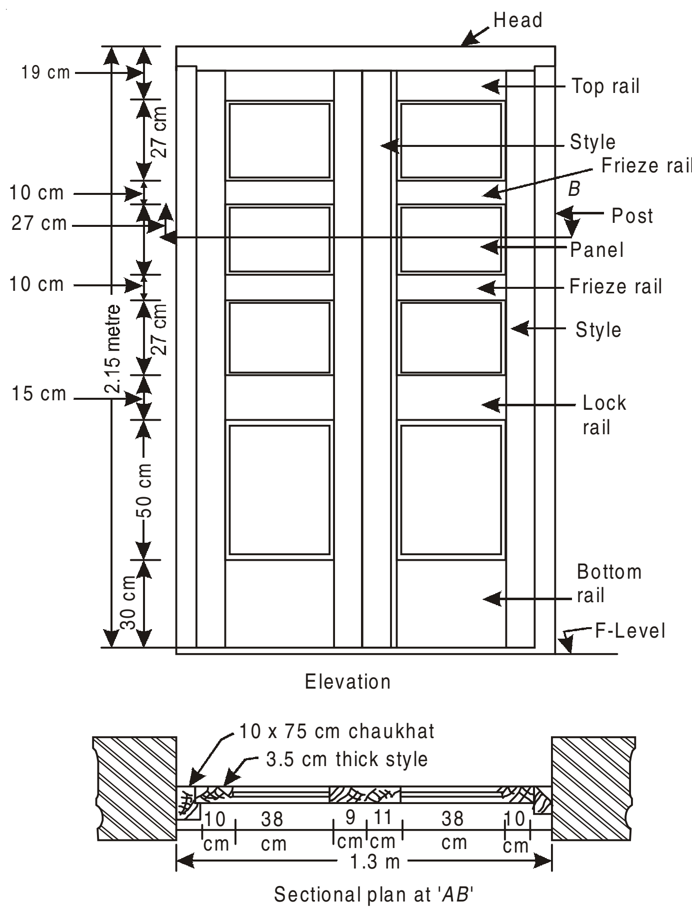


Fig. 4.6 *Panelled door.*

panels. The thickness of the frame varies from 3 to 4 cm and that of the panels 1.5 to 2 cm. The panels are secured in position by grooves made in the inside edges of the framework. The number of panels in one shutter is generally fixed as six for the sake of rigidity and strength.

4.3.5 Glazed door

In order to admit more light, in addition to that coming the windows, glazed doors are used. These doors are mostly used in public buildings and in high class residential buildings. It also consists of a frame similar to that described for the panelled door, in which the panels are sub-divided by

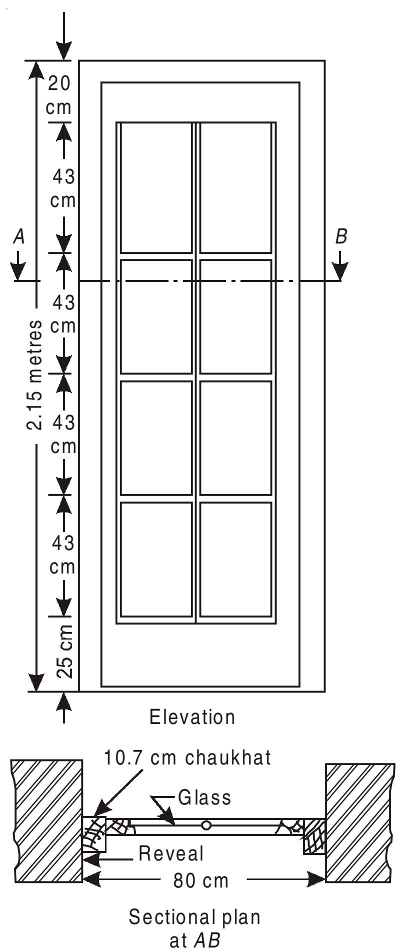


Fig. 4.7 *Glazed door.*

means of *sash bars.* The glass is received into the rebates provided in the sash bars and inside edges of the frame-work and secured by means of nails and putty as shown in Fig. 4.7.

4.3.6 Glazed and Panelled Door

In this type of doors the upper two-third portion is generally glazed and the lower one-third portion is panelled. These doors admit light and keep up privacy, when they are closed. The constructional details of this type of doors are similar to the panelled and glazed doors described above. These doors are used in residential as well as in public buildings.

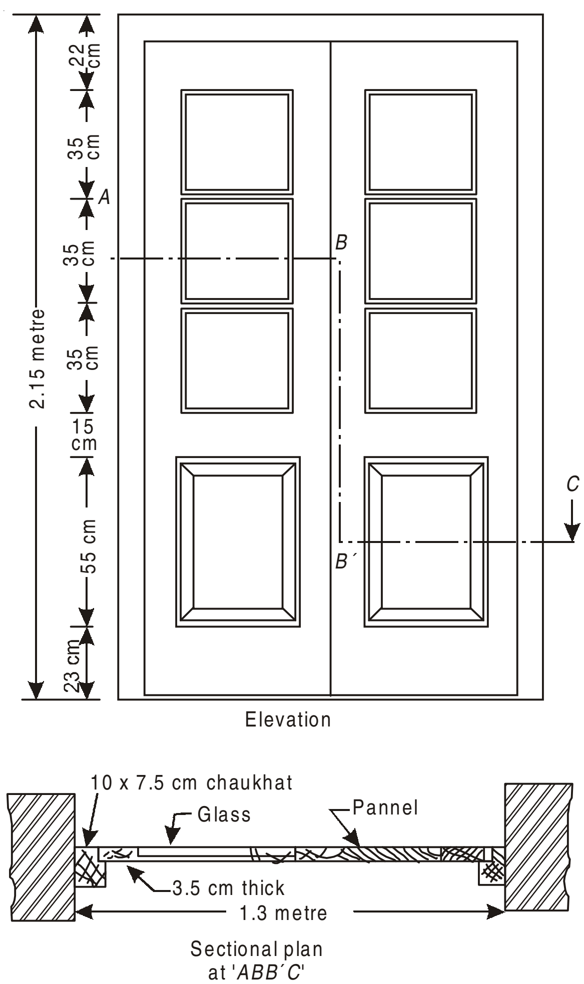


Fig. 4.8 *Glazed and panelled door.*

4.3.7 Flush Door

This door is becoming more and more popular in public and residential buildings, as it is economical, reasonable strong, easy to clean and food ion appearance.

There are two varieties of flush doors viz., *Framed flush door* and *Laminated flush door*.

A Framed flush door (Fig. 4.10) consists of a frame made up of styles, rails, horizontal and vertical ribs, and it is covered with plywood or hard

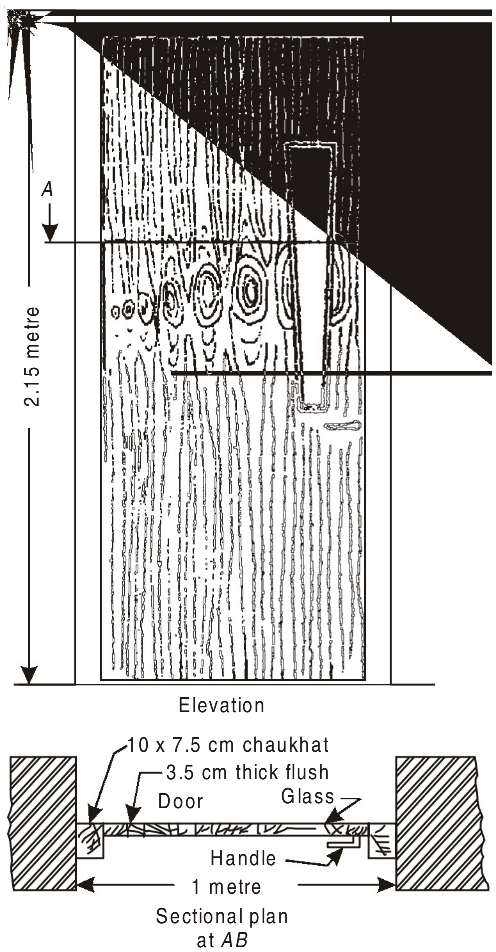


Fig. 4.9 *Flush door.*

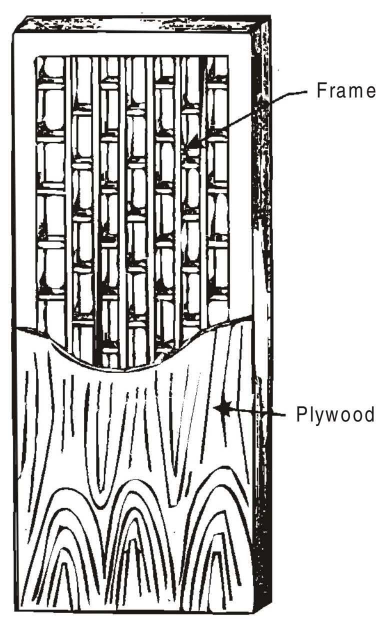


Fig. 4.10 *Framed flush door.*

board. The hollow space, instead of being left empty, is sometimes filled with granulated cork or some other light material.

A *Laminated Flush Door* (Fig. 4.11) consists of a frame made up of styles, and rails. The inside space is filled with wooden pieces called *laminae.* On

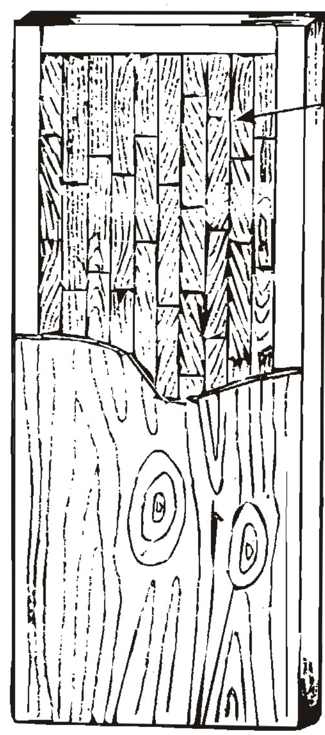


Fig. 4.11 *Laminated flush door.*

either side plywood or hard board is glued and pressed. A laminated flush door is heavy and requires more material for construction. The thickness of a flush door varies from 3 to 5 cm.

4.3.8 Louvered Door

Louvered doors are provided with louvers, mostly in the upper two-third portion is panelled. Louvers are wooden planks fitted in the frame of the shutters at some angle, either permanently fixed in one position or movable. The louvered doors admit light and air even when they are closed and maintain privacy at the same time. They are provided in public sanitary blocks and in residential buildings.

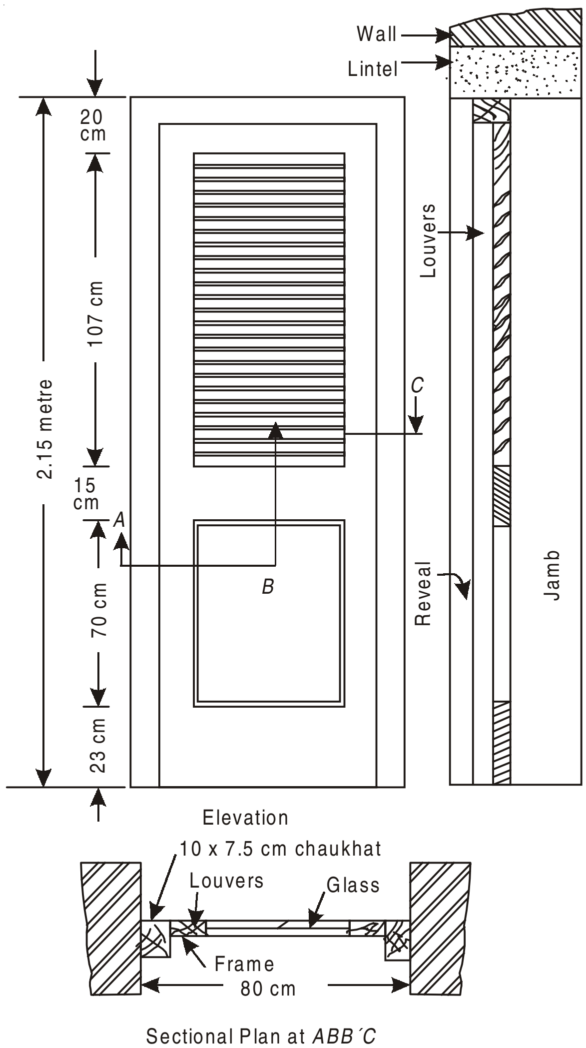


Fig. 4.12 *Louvered door.*

4.3.9 Collapsible Door

This type of doors is generally used in stores, godowns, factories, entrance halls of schools, colleges, cinemas, theatres etc. It consists of flat iron strips to which diagonal flat iron pieces are pinned. On the two ends of the vertical strips, small rollers are fitted to facilitate sliding on T-iron pieces fitted at

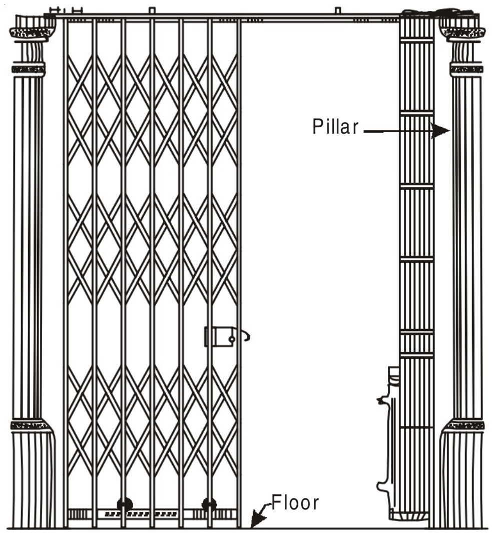


Fig. 4.13 *Collapsible steel door.*

the top and bottom of the door. The vertical and diagonal flat iron pieces are nearly 2 cm wide and are spaced at 10 to 15 cm centre to centre.

4.3.10 Revolving Door

A revolving door consists of a central shaft to which four radiating shutters are fixed as shown in Fig. 4.14. The shutters may be fully glazed, panelled or partly glazed panelled. At the outer edge of the shutters, rubber pieces

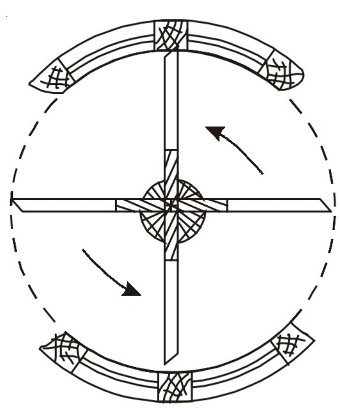


Fig. 4.14 *Plan of a revolving door.*

are fitted to prevent draught of air. Revolving door is used in air-conditioned buildings, where there is heavy rush of foot traffic, in theatres, hotels, offices etc.

4.3.11 Rolling Steel Door

This type of door is becoming more and more popular and is used in workshops, factories, shops, garages etc. Rolling shutters are sufficiently strong, and cause not obstruction on the floor or in the opening. It consists of a frame, a drum and a shutter made of steel plates, having a thickness of

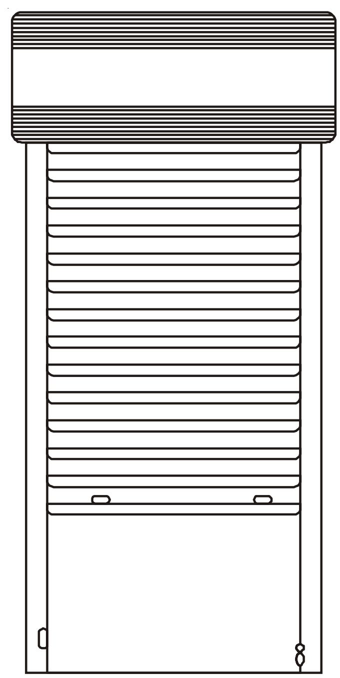


Fig. 4.15 *Rolling steel door.*

nearly 1 mm. A horizontal shaft and a spring are fitted in the drum on which the shutter rolls. For opening the door, the shutter is pushed back and, for closing, the shutter is pulled down.

4.3.12 Sliding Door

In this type of door, the shutter slides on to the sides with the help of *runner and guide.* The shutter may slide either inside the walls for which cavities are left or on to the sides of the walls. A sliding door does not cause any obstruction to movement and is mostly used in godowns, warehouses, entrance halls, etc.

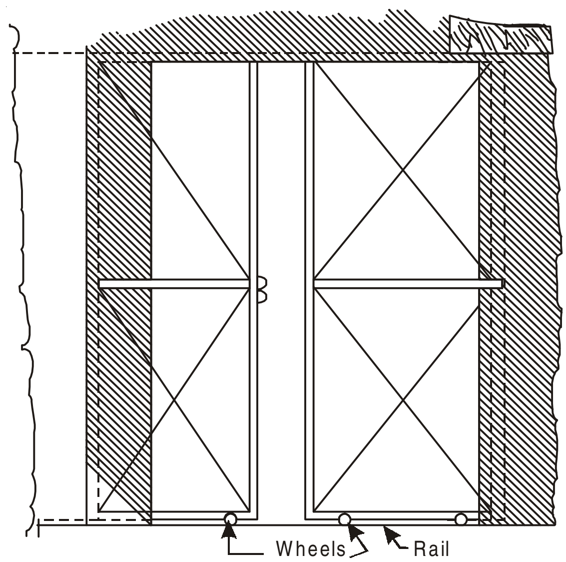


Fig. 4.16 *Steel sliding door.*

4.4 SIZE AND LOCATION OF DOORS

The size of a door depends on the situation and the purpose for which it has been made. The height of a door in no case should be less than 2 m. The width of a door in residential buildings varies from 60 to 120 cm. In kitchens, stores, latrines, etc., the width of a door varies from 60 to 80 cm. The height of a door is generally taken as width plus 1 or 2 m, whichever is more. But as far as possible all the doors in a building should be of equal height.

The location of doors is an important factor and is generally decided by the architects. As has been said earlier, the doors should be just sufficient to satisfy a particular requirement of a room. Doors should not be provided in a haphazard manner, otherwise they will cause obstruction and inconvenience. While providing doors, care should be taken to see that the minimum floor area is occupied with the least obstruction, and maximum privacy is maintained.

4.5 WINDOWS

Windows are openings provided in the walls for the purpose of light air. The windows are generally provided above the floor level in such a way that the top of the windows and doors, is in the same level. The following are the important types of windows generally used:

1. Casement windows

2. Pivoted windows
3. Bay windows
4. Dormer windows.

4.5.1 Casement Windows

These are ordinary windows, the shutters of which open like a door. The shutters are generally glazed or partly glazed. The shutters consist of styles,

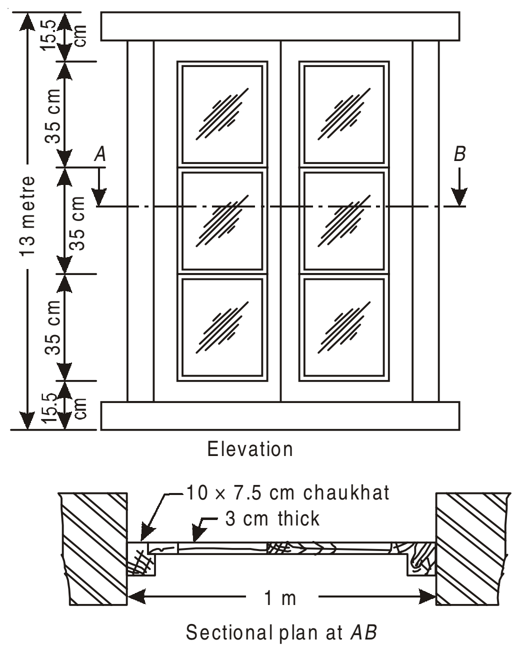


Fig. 4.17. *Casement window.*

rails etc., as in panelled or glazed doors. Glass panes are fitted in the frame with the help of sash bars. Windows are mostly glazed, but partly glazed and partly panelled windows are also used specially in residential buildings for the sake of privacy.

4.5.2 Pivoted Windows

These windows are not hinged, hut pivoted to swing either horizontally or vertically. The frame of the windows will be the same as for doors or casement windows, except that there is no rebate in the window frame or *chauckhat* to receive the shutter. These windows are commonly used in

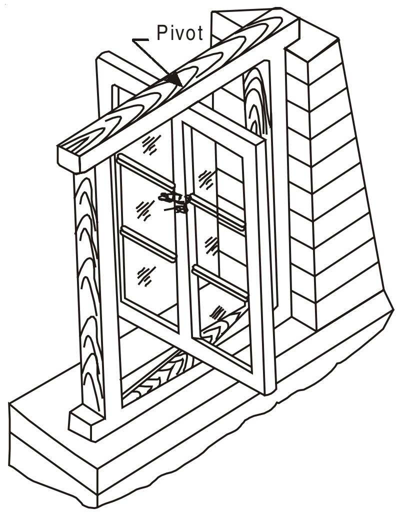


Fig. 4.18 *Pivoted window.*

residential as well as public buildings. The construction of the shutter is the same as explained for panelled and glazed doors.

4.5.3 Bay Windows

These windows project outside the external walls. These windows admit more light and air, and provide more ventilation and improve the appearance

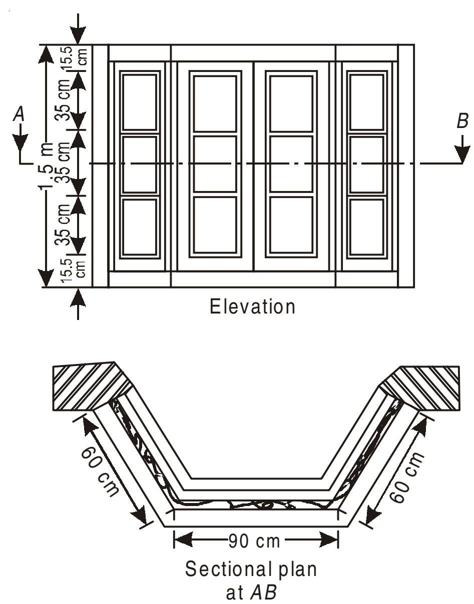


Fig. 4.19 *Bay-window.*

of the buildings. The windows are constructed by projecting a slab beyond the face of the wall. Generally bay windows are constructed in three portions as shown in Fig. 4.19. The frame consists of four parts. One part of the window remains parallel while the other two parts are inclined at some angle. The shutters are generally glazed.

4.5.4 Dormer Windows

These are windows provided in the sloping roof for the purpose of light and air in rooms or portions of a building which are constricted below the roof

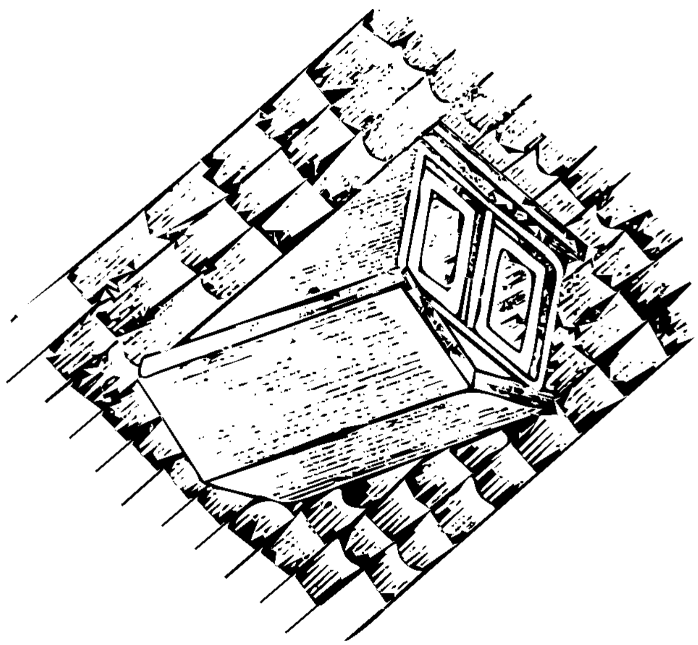


Fig. 4.20 *Dormer window.*

sloped. The main function or Dormer windows is to admit light, and thereby work as ventilators. These are constructed in such a way that the glazed face of the window is vertical. The rafters of the roof are trimmed to provide an opening in the roof. Dormer windows are provided with roof coverings as shown in Fig. 4.20.

4.5.5 Clerestorey Windows

These are ventilators, provided near the top of the main roof for the purpose of light and ventilation. The C.S. windows are generally pivoted in such a

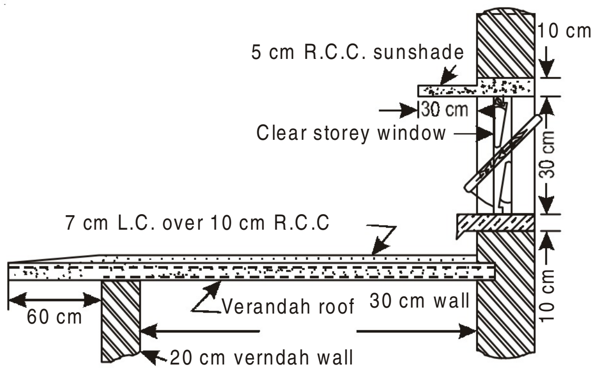


Fig. 4.21 *Clerestorey window.*

way that the upper end of the shutter opens towards the inside and lower end towards the outside. The shutters are glazed.

4.6 LANTERNS

These are openings provided in the flat roofs to admit light. They are generally square or rectangular and are provided with glass panels, fixed

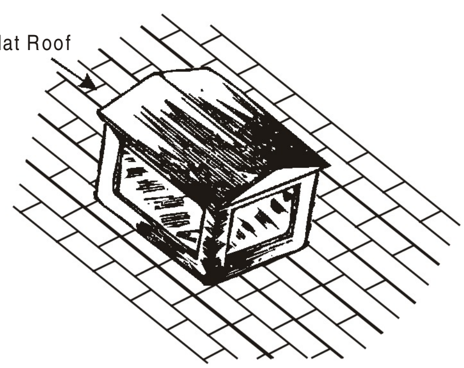


Fig. 4.22 *Lantern light.*

or pivoted. The lanterns project above the normal roof level. On all the vertical faces, glass panes are fixed to admit light. At the top, a roof-flat or inclined, projecting over the vertical faces is provided as shown in Fig. 4.22 to protect them from rain,

4.7 SKY LIGHTS

These are openings provided on the sloping surfaces of pitched roofs. The common rafters are suitably trimmed and the sky light is erected on curve

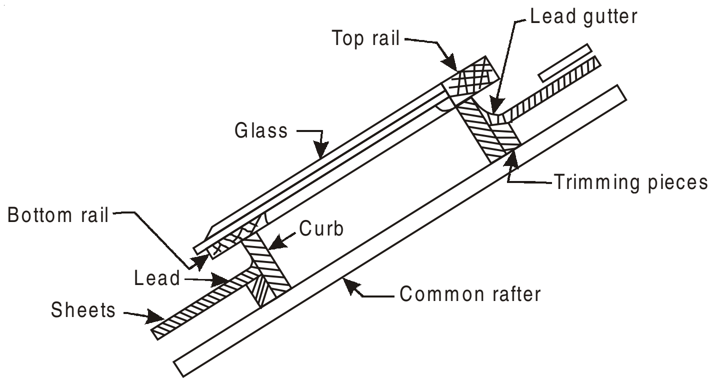


Fig. 4.23 *Sky light.*

frame. A sky light is generally meant for light and is usually provided with fixed glass panels.

4.8 FIXTURES AND FASTENINGS FOR DOORS AND WINDOWS

The following are the fixtures and fastenings which are generally used for doors and windows:

1. Hinges
2. Bolts and Locks, and
3. Handles.

4.8.1 Hinges

The following are the various types of hinges commonly used.

(i) *T-hinge.* It is used for ledged doors, ledged and braced doors and framed and braced doors.

(ii) *Strap hinge.* It is mainly used for heavy doors.

(iii) *Parliamentary hinge.* When it is required to avoid obstruction due to shutters, parliamentary hinges are used. With the help of such hinges, the shutters will lie along the wall.

(iv) *Butt hinge.* This type of hinge is commonly used for doors and windows.

(v) *Rising hinge.* With the help of this type of hinge, it is possible to raise the door shutter nearly 10 mm above the floor level when the door is opened and thereby clearing the carpet on the floor. Such hinges are used in partition walls for automatic closing of the door after opening.

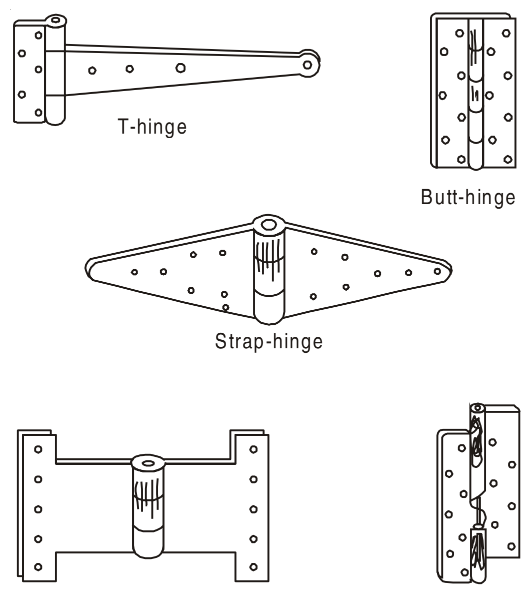


Fig. 4.24 *Hinges.*

4.8.2 Bolts and Locks

The following types of bolts and locks are generally used:

(i) *Barrel bolt and tower bolt.* These are used for fixing to the back feces of doors and windows. They are made of iron, brass, aluminum or bronze.

(ii) *Aldrop bolt.* This type of bolt is generally used on the external faces of doors.

(iii) *Hasp and staple.* These are also used on the external faces of doors.

(iv) *Hook and eye.* This is also known as *thump and latch* and is used to secure doors and windows in position.

(v) *Mortice lock.* This type of locking arrangement is used in doors having a thickness of 4.5 cm. It is fixed in a mortrice formed on the edge of a door.

(vi) *Rim lock.* This type of lock is used for thin doors.

(vii) *Cupboard lock.* This is an inferior type of lock and is used for temporary and inferior works.

4.8.3 Handles

There are various types of handles which are fixed to the door and window shutters to facilitate the opening and closing of the shutters. Some of them are shown in Fig. 4.25.

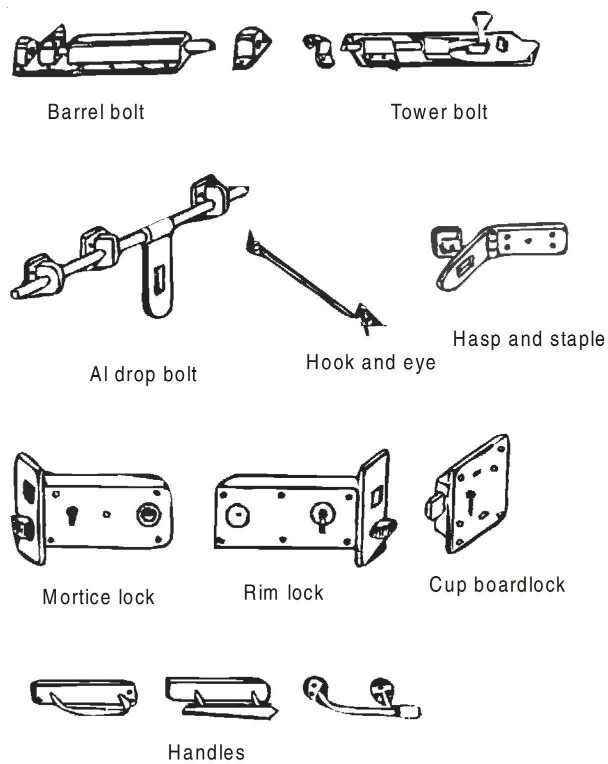


Fig. 4.25. *Bolt, locks and handles.*

QUESTIONS

4.1. What is the purpose of providing doors and windows in a room ? What considerations are necessary while locating the doors in a particular room?

4.2. Give a fully dimensioned sketch of panelled and glazed door having size of 1 m × 2.3 m.

4.3. Explain with sketches the difference between :

(i) ledged and braced door and framed and braced door.

(ii) casement window and pivoted window.

(iii) sky light and lantern.

4.4. Define the following terms :

1. Jamp and reveal.
2. Mullion.
3. Brace.
4. Freeze rail.
5. Style.
6. Sill.
7. Port.
8. Horns.

4.5. Describe in brief the construction of a Flush door. Why is it that this type of door is becoming more and more popular. Give reasons.

4.6. What is the purpose of providing doors and windows in a room ?

Name the various components of a door frame. Draw a neat sketch of a door frame.

4.7. What type of door would you recommend for the following situations and why ?

Hospital ward, bedroom of residential building, a hostel room, an office, workshop gate, main door of shop, drawing room.

How are doors and windows fixed in a wall ? Describe the process of fixing a door frame (or chaukhat) in a wall.

[**Hint.** Doors and windows are secured firmly in a masonry wall with the help of horns and hold fasts. Horns are projections of sill and head beyond the posts and hold fasts are metal strips fixed to the posts. These horns and hold fasts are embedded in the masonry, to secure the frame firmly.

The position of the door or window is marked in the plan and the door frame is placed in position and kept vertical with the help of *Bailies* or Bamboo posts. The verticality of the frame is checked periodically with the help of a plumbob. After the masonry has reached nearly l/3rd height of door, the temporary supports are removed.]

Chapter 5

Arches and Lintels

5.1 DEFINITION

An arch is a mechanical arrangement of wedge-shaped bricks of blocks of stones, mutually supporting each other and being supported at the abutments and piers, for the purpose of spanning an opening. .

5.1.1 Technical Terms

1.*Voussoirs*. The wedge shaped bricks or blocks of stones used in the construction of an arch are called voussoirs.

2. *Key*. It is the uppermost central voussoirs of an arch, which is placed when the arch, from both the ends, has been constructed upto the centre.

3. *Springers*. These are the extreme voussoirs of an arch. The line joining the lower ends of springers is called springing line.

4. *Abutments*. These are extreme supports of arch.

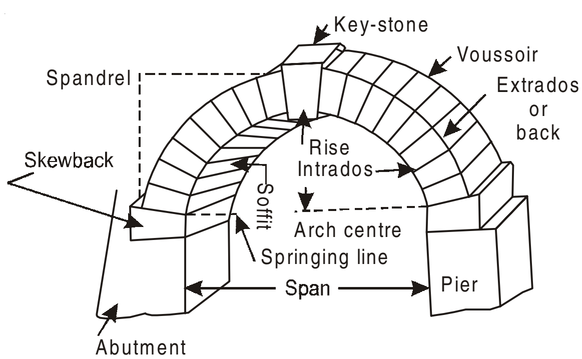


Fig. 5.1 *Parts of an arch*

5. *Piers.* These are intermediate supports of an arcade.

6. *Intrados.* It is the under surface of an arch. It is also called soffit.

7. *Extrados.* It is the upper convex surface of the arch.

8. *Arcade.* The series of arches adjoining each other is called an arcade.

9. *Skew Back.* It is the name given to the inclined supports, prepared to receive the arch.

10. *Crown.* It is the highest point of an arch.

11. *Spandrill.* The irregular triangular portion between the two arches in an arcade is called spandrill.

12. *Haunch.* It is the lower half portion of the arch from the springing to the mid-way of the crown, from either side.

13. *Rise.* It is the vertical distance between the springing line and the highest point in the intrados.

14. *Span.* This is the clear horizontal distance between the two supports.

15. *Impost.* It is the projection at the upper part of an abutment or pier.

5.2 CLASSIFICATION OF ARCHES

Arches can be classified according to

(i) Shape,

(ii) Workmanship, and

(iii) Material.

5.2.1 Shape Classification

The classification is based on the geometrical shape of arches. According to their shape arches are classified into the following forms :

1. Flat
2. Segmental
3. Semi-circular
4. Horse-shoe
5. Stilted
6. Equilateral
7. Lancet
8. Venetian
9. Drop
10. Elliptical
11. Three centered
12. Four-centered or Tudar arch
13. Five-centered
14. Ogee Arch etc

All these arches are shown Fig. 5.2 along with their constructional details. All these arches are used for different situations. As far as strength is concerned, segmental and semi-circular arches are the best.

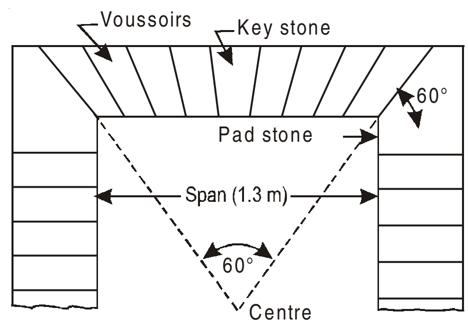


Fig. 5.2. *Flat arch.*

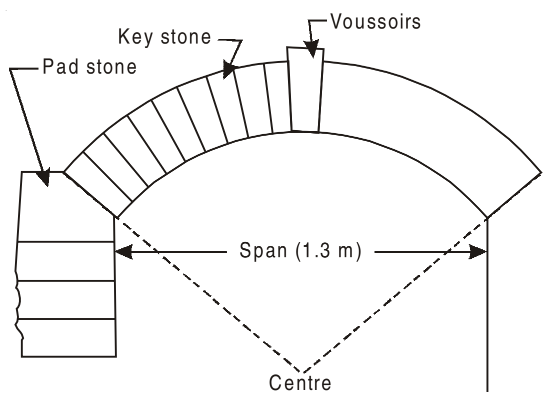


Fig. 5.3. *Segmental arch.*

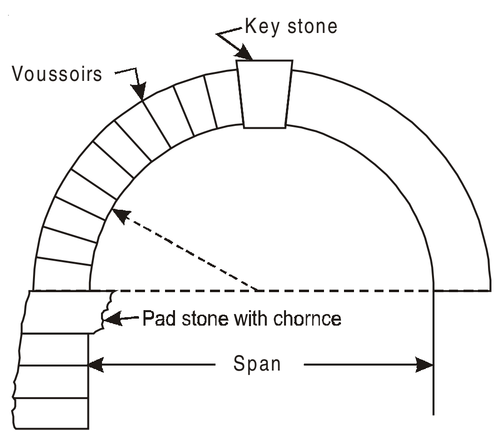


Fig. 5.4. *Semi-circular arch.*

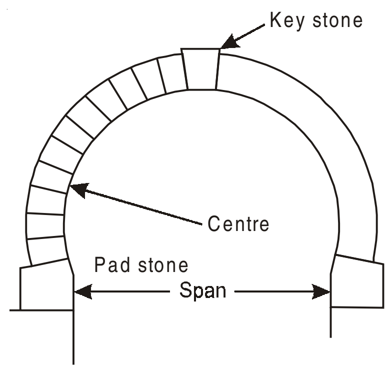


Fig. 5.5. *Stilted arch.*

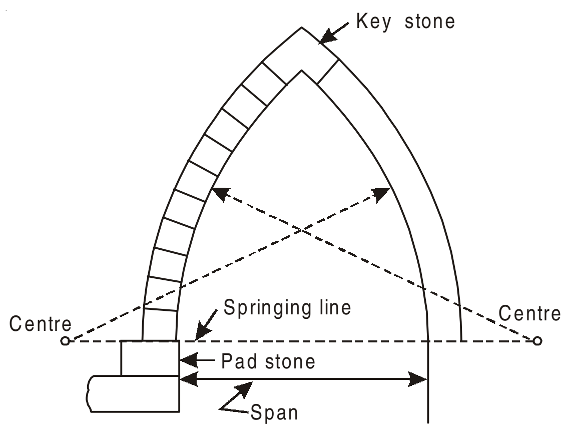


Fig. 5.6. *Lancet arch.*

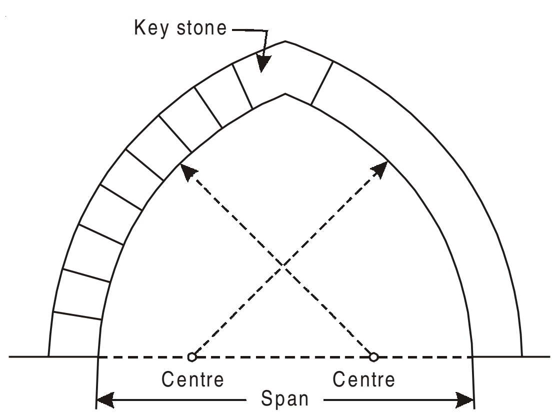


Fig. 5.7. *Equilateral arch.*

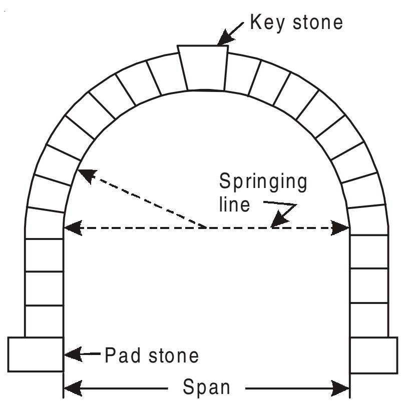


Fig. 5.8 *Horse shoe arch.*

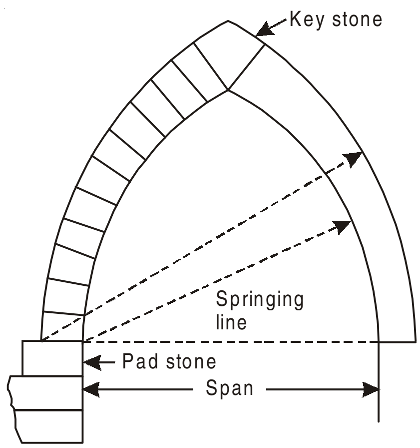


Fig. 5.9 *Venetian arch.*

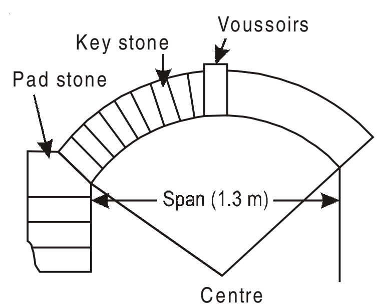


Fig. 5.10 *Drop arch.*

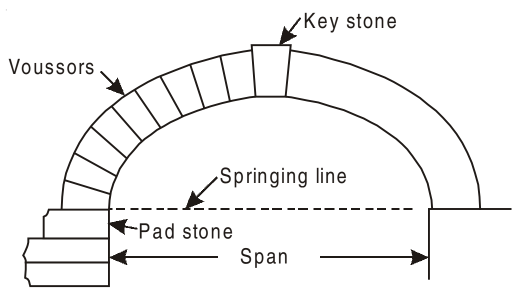


Fig. 5.11 *Elliptical arch.*

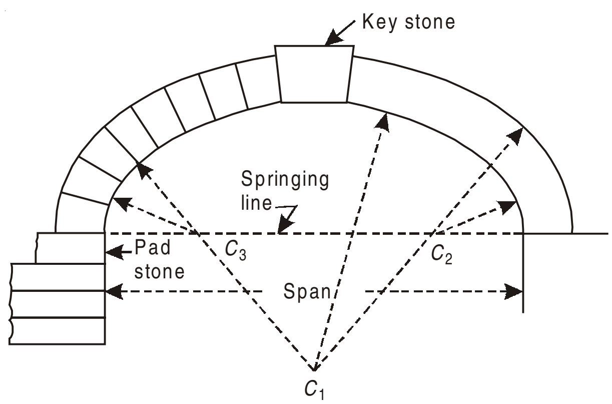


Fig. 5.12 *Three-centered arch.*

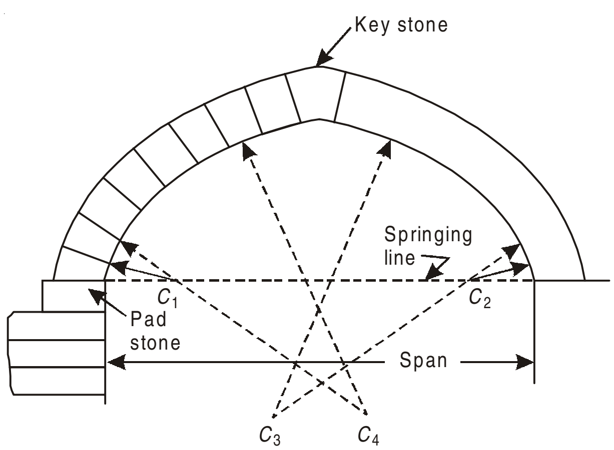


Fig. 5.13 *Four centered arch.*

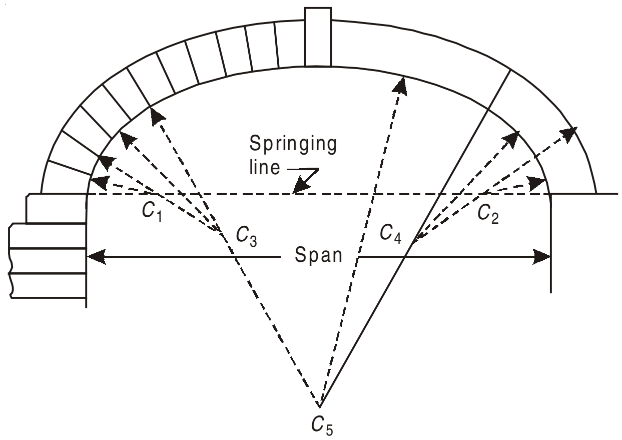


Fig. 5.14 *Five-centered arch.*

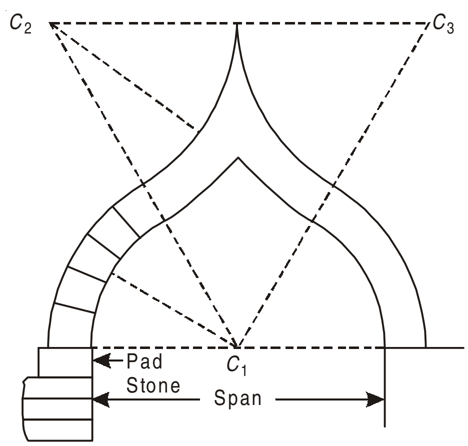


Fig. 5.15 *Ogee arch.*

5.2.2 Workmanship Classification

This classification is based on the workmanship i.e., the way the arch has been constructed. Truly speaking, this classification is based on the method of dressing the voussoirs. According to this classification the arches are divided into two categories, viz.

(a) Rough Arches, and

(b) Gauged or Axed arches.

(a) *Rough arches.* (Fig. 5.16). These arches are constructed from uncut bricks or blocks of stones. As the bricks or stones used in the arch are rectangular in shape the mortar joints will become wider at the top and thinner at the bottom. Rough arches are generally constructed in rings of half bricks. These arches are used in temporary constructions and when it

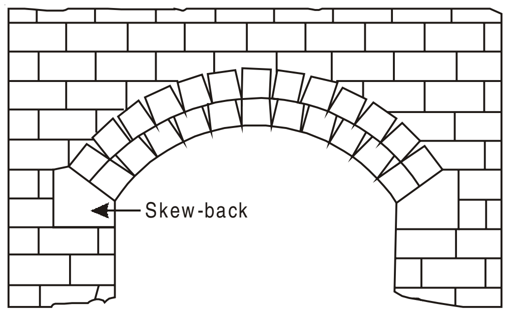


Fig. 5.16. *Rough brick arch.*

is intended to plaster the arch work. These arches are weaker in strength and less durable. The strength of the arches depends upon workmanship as well as on strength of mortar.

(b) *Gauged or Axed Arches.* (Fig. 5.17). This type of arches are constructed from bricks of blocks of stones which are cut finely by means of a wire-saw truly according to the shape of the arch. The mortar joints are as thin as

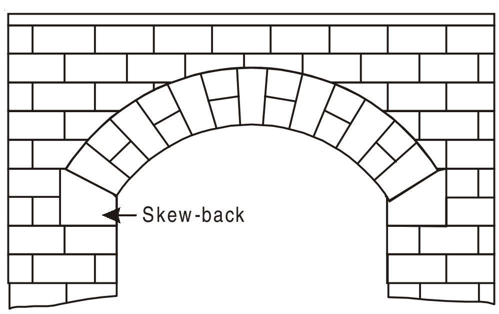


Fig. 5.17. *Gauged or axed brick arch.*

0.75 cm or even less and are of uniform thickness. These arches are used where fine finish of the surface of the arch is required. These arches are stronger than weak rough arches.

5.2.3 Material Classification

According to this classification, arches are classified as under :

1. *Stone arches.* These can be constructed with rubble masonry or ashlar masonry. Rubble masonry arch is comparatively weak and hence is used in inferior quality works. Ashlar masonry arches are constructed with wedged-shaped stone. Sometimes Joggle joints are provided to strengthen the arch.

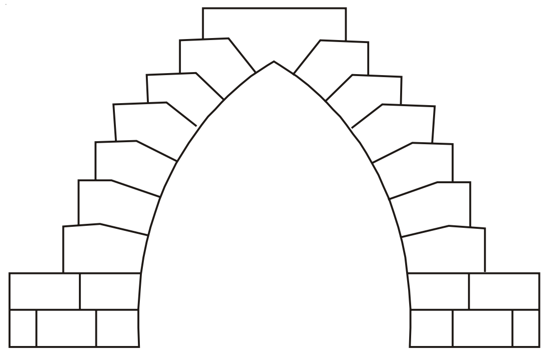


Fig. 5.18. *Stone arch.*

2. *Brick arches.* These arches are mostly used. They can be made, either with ordinary bricks, or purpose made bricks suitable for the construction of an arch. Sometimes soft bricks are also used for the construction of arches. The soft bricks can be easily cut or rubbed to the desired shapes.

3. *Concrete arches.* These can be constructed of pre-cast concrete blocks or monolithic concrete. Monolithic concrete arches are used for larger spans. The concrete arches are mostly used for the construction of bridges, culverts and large span opening. Sometimes steel is also used for reinforcing the arches.

5.3 TYPICAL ARCHES

5.3.1 Jack Arches

It is a special type of arch and is used for the construction of a roof known as Jack Arch Roof. These arches are constructed on the flanges of I-section

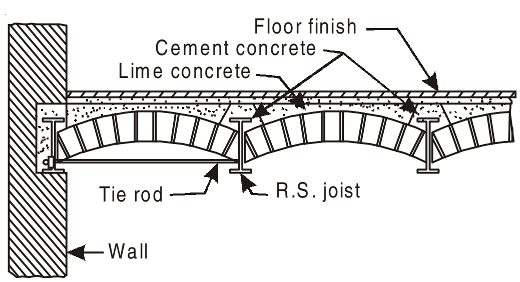


Fig. 5.19. *Brick jack arch.*

which are spaced at 1.25 to 1.75 m centre to centre. The rise of these arches varies from l/10th to l/12th of the span. The thickness of the arch ring is generally half brick. The jack arch can be constructed with bricks or concrete.

5.3.2 Inverted Arches

See Chapter on Foundation.

5.3.3 Relieving Arch

This is also known as *discharging arch.* Relieving arches are constructed over the lintels or flat arches, for the purpose of carrying the super-imposed

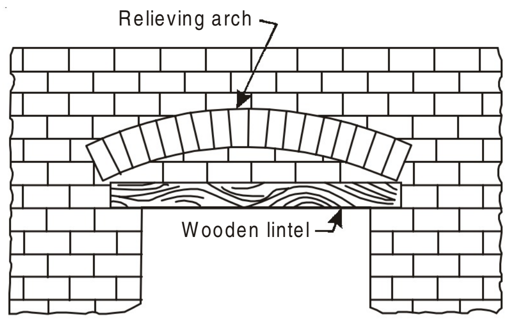


Fig. 5.20 *Relieving arch.*

load of the structure directly coming over the lintel. The relieving arches are constructed along with the masonry and sometimes plastered over. The main advantage of constructing relieving arches is that the size of the lintel can be appreciably reduced and the lintel can be replaced if required.

5.4 CENTERING FOR ARCHES

The construction of an arch ring is commenced at its springing and carried up uniformly towards the center i.e., crown, where a key block is finally

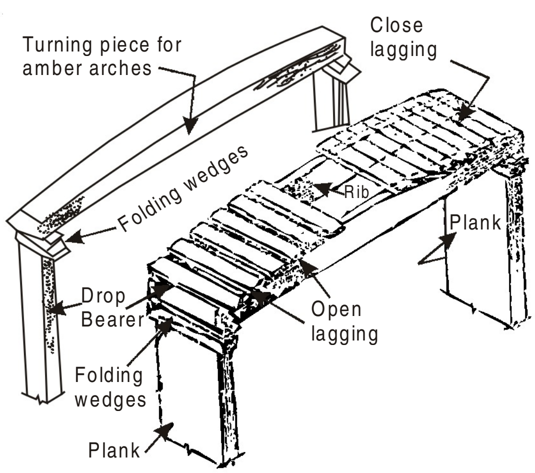


Fig. 5.21 *Centering for a small segmental arch.*

inserted. From this it is evident that the voussoir blocks require some temporary support to keep them in position during the construction of the arch ring. This temporary structure is known as *centering*.

The simplest type of centering use for the construction of an arch ring is Timber Centering. It consists of wooden planks cut to the shape of the arch and are known as Arch Ribs or Turning plates. On the top of the arch ribs,

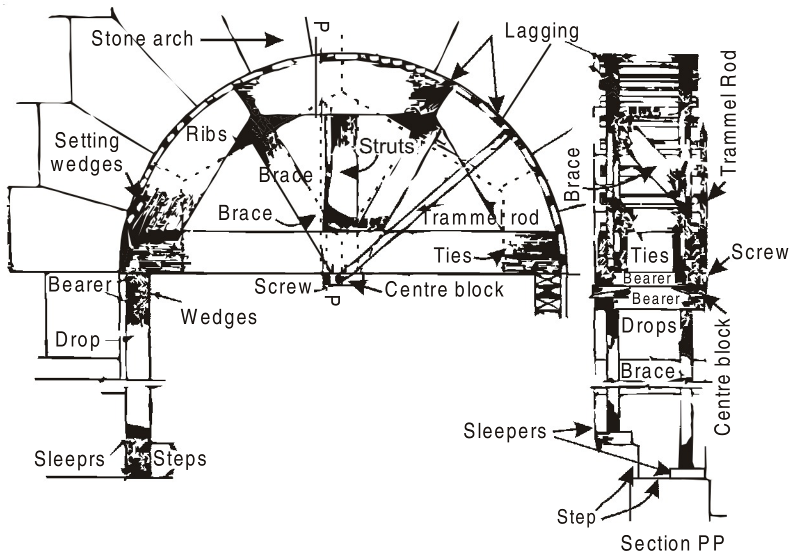


Fig. 5.22. *Centering for a segmental arch.*

narrow wooden strips are nailed which are called *Laggings.* The thickness of the arch ribs varies from 2 to 4 cm and that of the lagging from 1.5 to 2.5 cm. The arch ribs are placed on cross members called bearing plates which in turn rest on a pair of folding wedges. The wedges are placed on vertical posts called *props.* The function of the folding wedges is to adjust the height of the props and to facilitate removal of centering.

For large span openings, centering as shown in Fig. 5.9 are used.

5.5 THICKNESS OF ARCH RING

The thickness of arch rings depends upon the span of the arch material used for construction of arches and the loads. However, thickness of arch ring can be calculated by the following empirical formulae:

1. **Semi circular arches**

(i) $T = \sqrt{0.20 \times \frac{2S}{4}}$ metres

(ii) $T = \sqrt{0.25 \times \frac{2S}{3}}$ metres

where T = thickness of arch ring and S = Span in metres.

2. **Segmental arches**

$$T = \sqrt{0.12 \times \frac{2S}{3}} \text{ metres.}$$

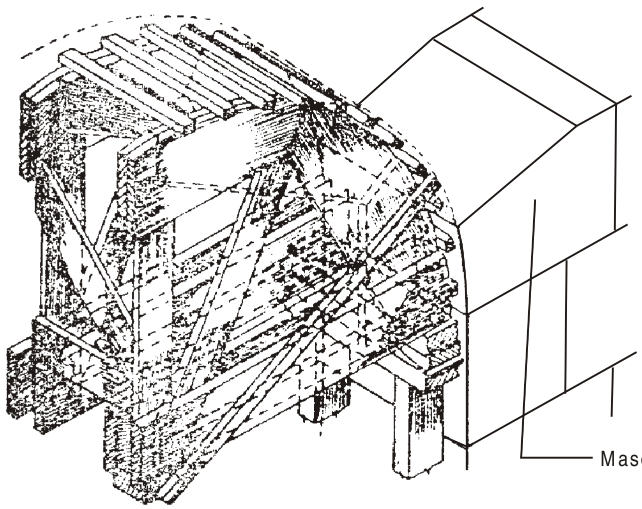


Fig. 5.23. *Isometric View of centering.*

5.6 LINTELS

Opening of doors, windows, verandahs, cup-boards, etc., are bridged by small beams called *Lintels.* The ends of the lintels are embedded into the masonry. Lintels are made of various materials such as wood, steel, brick, stone, reinforced brick and reinforced cement concrete. Nowadays only Reinforced brick and Reinforced cement concrete lintels are mostly used.

The various types of lintels commonly used are :

1. Wooden Lintels
2. Steel Lintels
3. Stones Lintels
4. Reinforced Brick Lintels
5. Reinforced Cement Concrete Lintels

5.6.1 Wooden Lintels

These lintels consist of wooden blocks placed across the openings. The two ends of the lintel are embedded in the masonry. Coal tar should invariably be painted on the ends to be embedded in the wall. This will prevent the material from *dry-rot*. The thickness of the wooden lintels generally varies from 15 to 30 cm. Sometimes *relieving arches* are constructed over the wooden lintels. Wooden lintels can be used for some openings. (See Fig. 5.24)

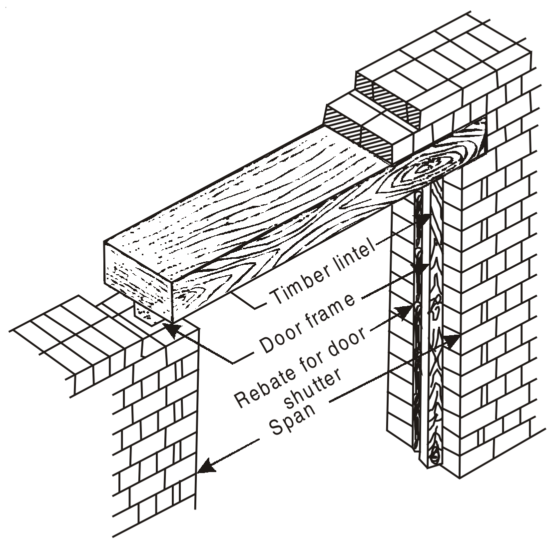


Fig. 5.24 *Wooden lintels.*

5.6.2 Steel Lintels

These lintels consist of steel sections such as I-section, T-section or channel section embedded in brick work or cement concrete. They are also known

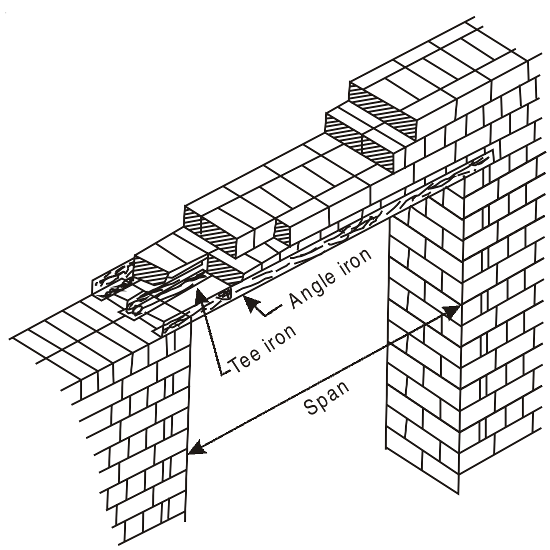


Fig. 5.25 *Steel lintels.*

as Bressumers. The function of embedding steel section in concrete is to protect the steel from corrosion. (See Fig. 5.25)

5.6.3 Stones Lintels

Stone blocks are sometimes used to bridge an opening. Stone, having low tensile resistance, cannot be used for larger spans. Also stone lintels can only be used in those places, where good quality stone is easily and cheaply available.

5.6.4 Reinforced Brick Lintels

These lintels are very common and popular and can be used for large and small openings. An R.B. lintel consists of reinforced steel bars, embedded in brick work, laid in cement mortar.

5.6.5 Reinforced Cement Concrete Lintels

These lintels consist of steel bars embedded in cement concrete. R.C.C. lintels are stronger and more durable than R.B. lintels but are costlier and

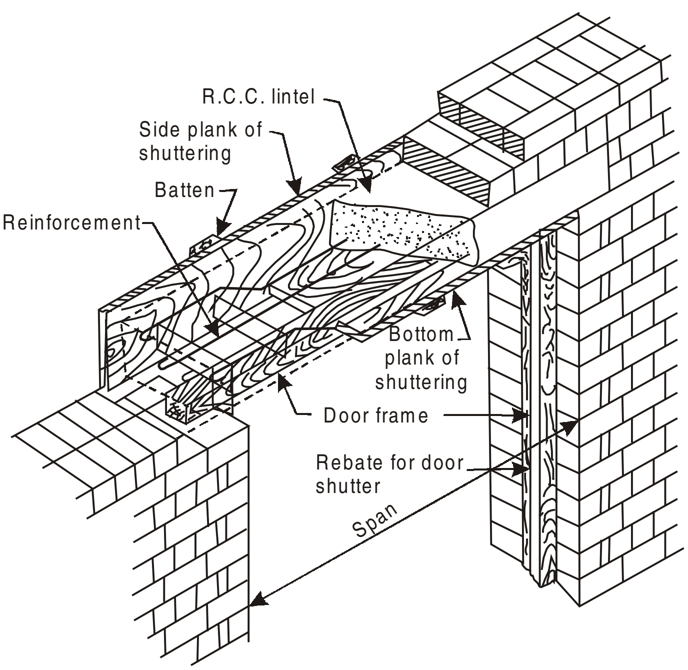


Fig. 5.26 *R.C.C. lintels.*

more difficult in construction. Hence their use is only restricted in public buildings and large span openings.

QUESTIONS

5.1. Define the following terms :

Voussoirs, spandril, skew back, haunch, intrados, rise, crown, key, springers, extrados, arcade.

5.2. What do you understand by the term arch ? Why are arches constructed over the door and window openings.

What is the difference between an arch and a lintel ?

5.3. Describe in brief the classification of arches. Where do you provide an axed arch and rough arch ?

5.4. Write short notes on :

(i) Relieving arch

(ii) Jack arch

(iii) Inverted arch.

5.5. Describe in brief the construction of a segmental arch over a door opening 0.25 m wide. Draw a neat sketch of the centering you will provide.

5.6. Draw neat sketches of the following arches :

(i) Elliptical arch

(ii) Stilted arch

(iii) Ogee arch

(iv) Equilateral arch

(v) Horse shoe arch.

Show in each of these sketches the position of voussoirs.

5.7. What is a lintel ? What is its function ? Why are lintels preferred over arches ? Draw a neat sketch of a R.C.C. lintel over a span of 1.5 m.

5.8. What do you understand by the centering of arches ? Describe the construction of a simple centering used for a segmental arch.

5.9. Write short notes on :

(i) Abutment

(ii) R.B. lintels

(iii) Flat arch

(iv) Wooden lintels

(v) Relieving arch.

5.10. Draw a neat sketch of a rough arch and a gauged or axed arch. Describe in brief the difference between the two types of arches.

Chapter 6

Stairs

6.1 DEFINITIONS

In a building there is several portions to be constructed. The name of the each part is keep its importance. The stairs is the very important in those portions which in explained in brief as following.

1. **Stairs.** Stairs are steps arranged in series for the purpose of an assess from one floor to the other.

2. **Stair-case.** The room or apartment in which stairs are enclosed, is called *stair-case.*

3. **Rise.** It is the vertical distance between the two consecutive steps. The vertical portion of the step is called *riser.*

4. **Tread.** The horizontal portion of the step is called *tread.* The horizontal distance between the two consecutive risers is called *Go, Going* or *Run.*

5. **Nosing.** It is the front edge of the tread which projects beyond the riser.

6. **Flier.** The rectangular steps of uniform shape and size are called *Fliers.*

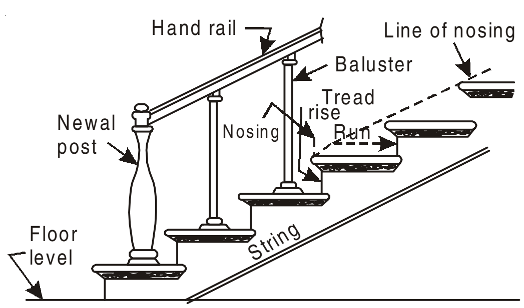


Fig. 6.1 *Elevation of a stair.*

7. **Winders.** The triangular or wedge shaped steps, used for changing the direction are called *winders.*

8. **Flight.** It is a continuous series of steps in one direction, separated by horizontal platforms or winders.

9. **Landing.** It is the horizontal platform provided at the top of a flight. If the landing is of a rectangular shape, having a length equal to twice the width of the stairs, the landing is called *Half Space Landing.* If on the other hand, the stairs run at right angles to each other and are separated by square landing, the landing is called *Quarter Space Landing.*

10. **Line of nosing.** It is the imaginary line joining the ends of nosing of all the steps.

11. **Scotia block.** It is a triangular wooden block used below the nosing to give it additional strength.

12. **Strings or stringers.** These are inclined members which support the steps.

13. **Head room.** It is the vertical distance between the line of nosing and the under surface ceiling of the stair-case or next-flight.

14. **Line of walking.** The tendency of a person going on the stair is to walk along a line which is nearly 45 cm from the center of the hand rail. This imaginary line is called *line of walking.*

15. **Railing.** This is a moulded block of wood or some other material, provided to afford assistance and safeguard to persons while going on the stairs. The height of railing should be nearly 75 cm above the line of nosing.

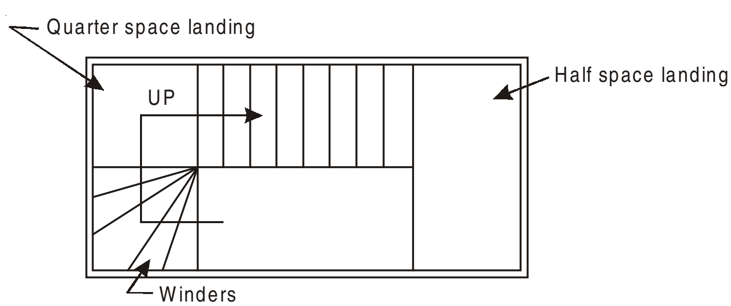


Fig. 6.2 *Plan of a stair.*

16. **Balusters.** These are short vertical members which support the hand-railing.

17. **Balustrade or Banister.** The composite member consisting of a hand rail, balusters, newel posts is called *balustrade.*

18. **Newel posts.** These are principal balusters used at the top and bottom of a flight.

19. **Pitch or slope.** It is the angle which the line of nosing of the stairs makes with the horizontal.

20. **Soffit.** It is the under surface of a stair.

6.2 REQUIREMENT OF A GOOD STAIR

Following are the requirement of a good stair :

1. A stair should be well ventilated.
2. It should have good approaches from all corners of the buildings.
3. Every flight should be separated from the other by spacious and well ventilated landings.
4. Each flight should have not more than 12 steps.
5. As far as possible winders should be avoided. If at all, they are to be provided, they should be provided at the bottom and not at the top.
6. The width of the landing should not be less than the width of the stairs.
7. The width of the stairs in residential buildings should no be less than 75 cm and for public buildings it should not be less than 125 m.
8. The pitch of the stairs should not be more than 25° for making the ascent and descent easy. In order to obtain a satisfactory pitch, the following general rules are used to obtain the satisfactory proportions of rise and tread:
   (i) Rise + Going = 40 to 45 cm
   (ii) Rise × Going = 426 cm
   (iii) 2 Rise + Going = 60 cm
9. There should be an adequate head room, having a minimum height of 22 metres.
10. The hand railing should be of a suitable size and shape that it can easily be gripped in hand. The height of the hand railing should not be less than 75 cm nor more than 10 cm from the line of nosing.

6.3 TYPES OF STAIRS

The following are the different types of stairs generally used in public and residential buildings :

1. Straight flight stairs
2. Dog legged stairs
3. Open newel stairs

4. Quarter turn stairs
5. Bifurcated stairs
6. Geometrical stairs
7. Spiral stairs.

6.3.1 Straight Flight Stairs

It is the simplest type of stairs, and consists of one or in some cases two flights running in one direction only. These stairs are used, when the space available is narrow and long.

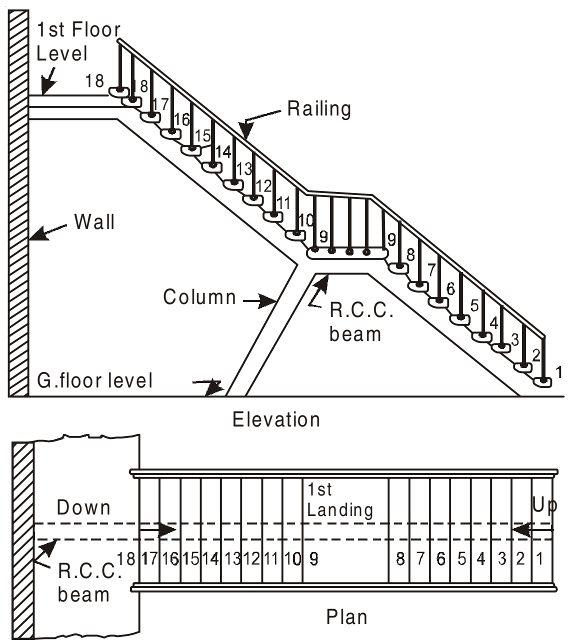


Fig. 6.3 *Straight flight stairs.*

6.3.2 Dog Legged Stairs

It is a very common and popular type of stairs and is used in public as well as residential buildings. It consists of two flights running in opposite directions, separated by a half space landing or a quarter space landing and a set of winders. The dog-legged stair is so called because the bent of the stairs is similar to the dog's leg. When the space available is equal to twice the width of the stairs, dog-legged stair is used.

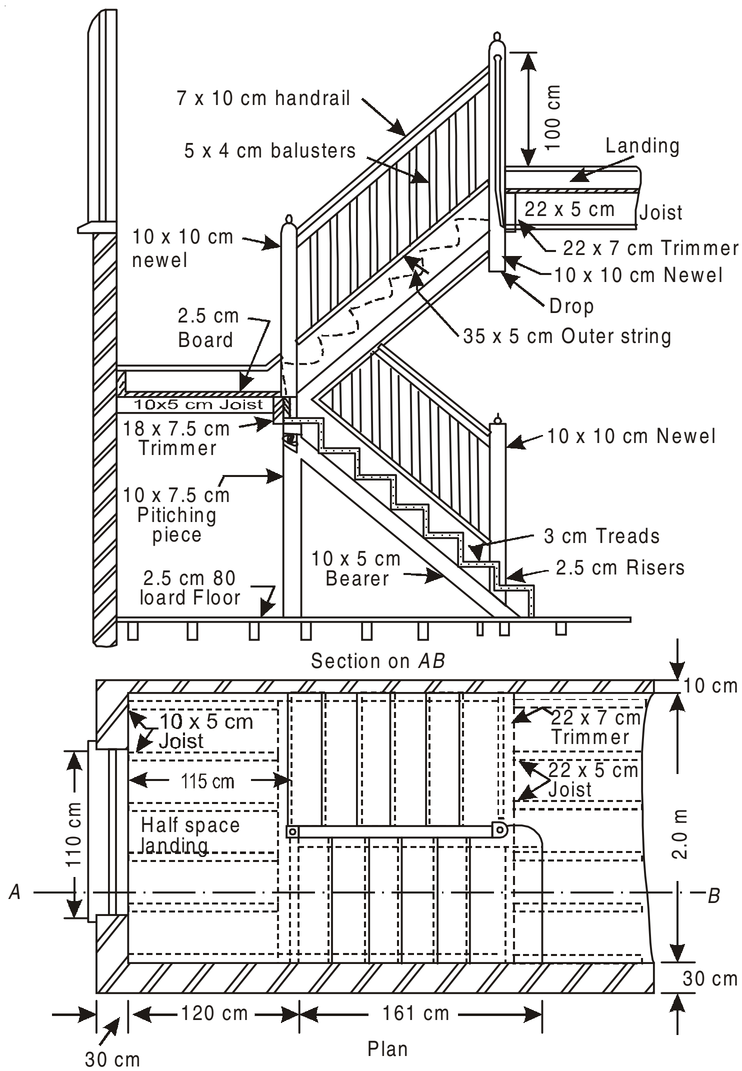


Fig. 6.4 *Dog legged stairs.*

6.3.3 Open Newel Stairs

It is similar to the dog legged stair except that in this case the two flights are separated by and open well. The open newel stairs a convenient type of stair and is generally used in public buildings. The width of the open well depends upon the space available varies from 60 to 120 cm. The two flights are either separated by a half space landing or two quarter space landings with a set of steps as shown in Fig. 6.5. The open well between the two flights can be used for fixing a 'Lift'.

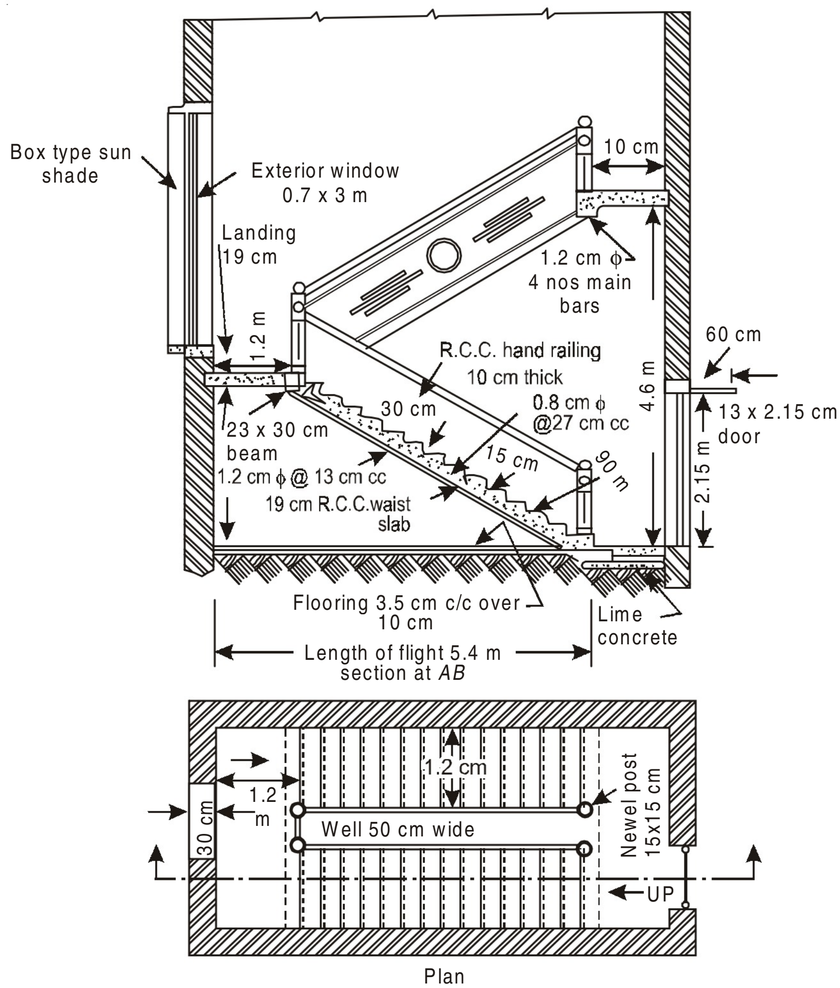


Fig. 6.5 *Open newel stairs.*

6.3.4 Quarter Turn Stairs

In this type of stair, the two flights run at right angles to each other and are separated by a quarter space landing. These stairs are generally provided when wall support is available on one side only, or when in a huge apartment such as an entrance hall, stairs are to be provided.

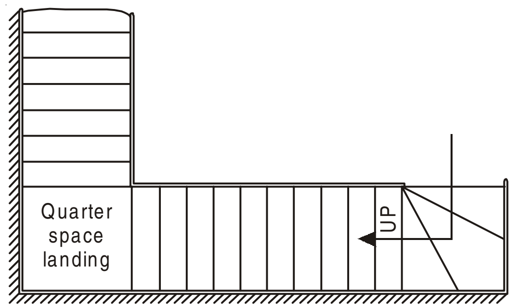
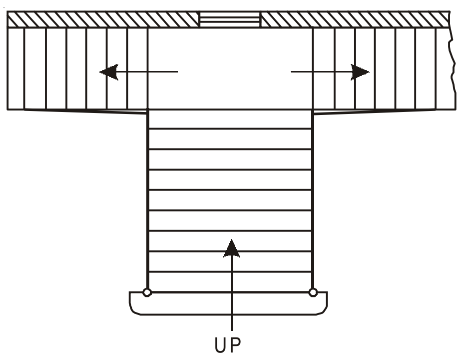


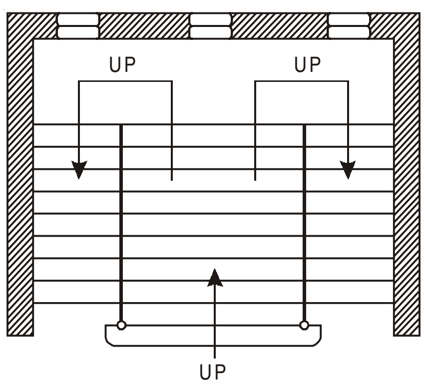
Fig. 6.6 *Quarter turn stairs.*

6.3.5 Bifurcated Stairs

These stairs are commonly used in public buildings. In this type of stairs, the bottom flight is wider and is bifurcated into two narrower flights at the



(a) Bifurcated stairs



(b) Bifurcated stairs

Fig. 6.7

landing. The bifurcated stairs may be of two types, viz. *Quarter turn* and *half turn.* In the quarter turn type, the upper and the lower flights run at right angle whereas in the half turn bifurcated stairs, the sets of flights go in opposite directions as in a quarter turn stair and dog-legged stair respectively.

6.3.6 Geometrical Stairs

The geometrical stairs are generally used in high class residential buildings. The stair is in the form of some curve, having all the steps as winders, radiating from the centre of curvature of the curve. The hand rail of

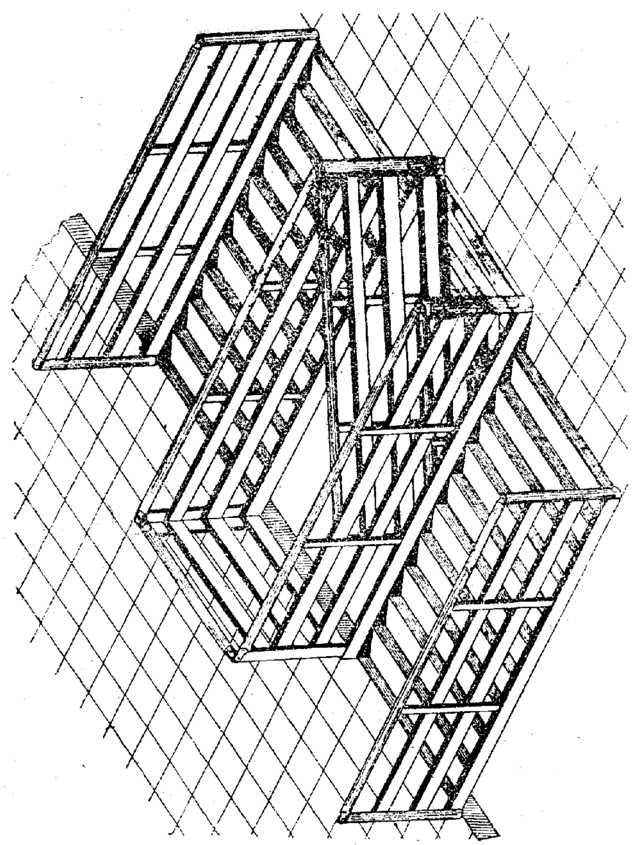


Fig. 6.8 *Isometric view of bifurcated stairs*

geometrical stair, continues without interruption and without any angular turn. Considerable skill is required for the designing and construction of geometrical stair. The minimum width of this stair has been fixed at 1.75 m.

6.3.7 Spiral Stairs

These stairs are generally constructed either of cast iron or R.C.C. The steps, which are all winders, radiate from a central vertical shaft and are attached

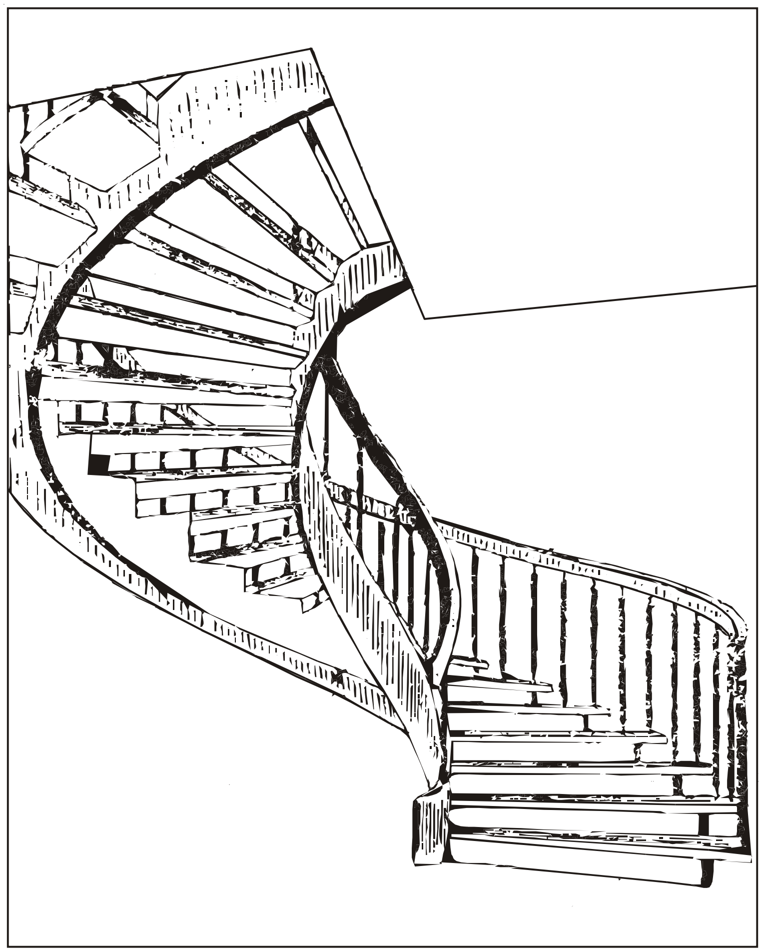


Fig. 6.9 *Isometric of geometric stairs.*

to it. The steps are generally pre-cast and are fitted to the central pillar. These stairs are used on the back-side of a building for emergency use as well as in those places where the space is limited.

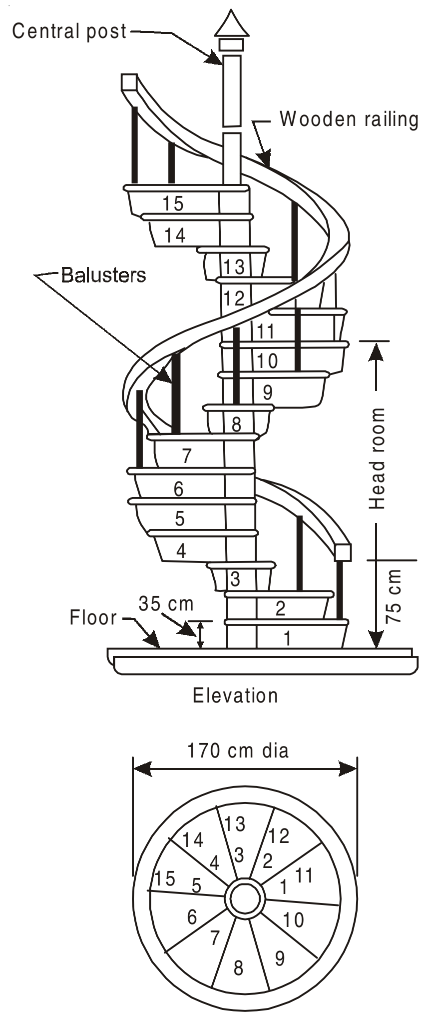


Fig. 6.10 *Spiral stairs.*

QUESTIONS

6.1 What are the requisites of a good stair ? Which of the points, in your view, should attract more attention and why ?

6.2 What are the different kinds of stairs generally used in residential as well as public buildings ? Describe any four giving neat sketches where necessary.

6.3 Draw a plan and elevation of a dog-legged stair and write down the names of various parts.

6.4 Define the following terms :

Tread, run, nosing, stringer, newel post, quarter space landing, hand rail, head room, balustrade, scotia block.

6.5 Design a stair in a room measuring 2.2 × 4.5 m having a ceiling height of 675 m. Draw the plan and a sectional elevation, showing the details of reinforcement.

6.6 How are treads and risers proportioned in the design of a stair ? What is the difference between :

(i) dog-legged stair and open newel stair

(ii) geometrical stair and spiral stair.

6.7 Write short notes on:

(i) Bifurcated stair

(ii) Quarter turn stair

(iii) Straight flight stair

(iv) Geometrical stair.

6.8 What are the main points which are to be kept in mind while designing a stair? Illustrate your answer with the help of sketches where possible.

6.9 What is the function of the following ?

(i) Winders

(ii) Hand rail

(iii) Landing

(iv) Stringers

Your answer must be supported by complete explanation and diagrams.

Chapter 7

Floors

7.1 GENERAL

The floor is defined as the horizontal or nearly horizontal or portion of the building, constructed at different levels, for the purpose of storing of materials and movement of inhabitants. The floors constructed immediately about the ground level, are called *ground* floors. The floors constructed below the ground level are called *basement* floors. The subsequent floors constructed above the ground floor are called *first floor, second floor* and so on. The top finishing given to the floors is called *flooring*. Here we will be discus the construction of ground floors only.

7.2 TYPES OF FLOORINGS

There are various types of floors which are commonly used for residential as well as for public buildings. Each type of floors has got its own advantages. The floorings generally provided are as under:

1. Mud or Muram flooring
2. Brick flooring
3. Flag stone flooring
4. Tiled flooring
5. Cement concrete flooring
6. Mosaic flooring
7. Terrazo flooring
8. Timber flooring.

7.3 REQUISITE OF A GOOD FLOORING

A good floor for a public or residential building should have the following properties:

1. It should be durable.
2. It should be impervious.
3. It should be noiseless and dustless.
4. It should have easy maintenance.
5. It should not be very costly.
6. It should have good appearance.
7. It should have a smooth and easily cleanable surface.

While selecting type of flooring for a particular apartment of a building, keep in view the importance and use of that room, a right type of flooring should be selected that should satisfy the maximum of requirement.

7.4 CONSTRUCTION OF FLOORINGS

7.4.1 Mud or Muram Flooring

Muram is disintegrated rock consisting of sand and clay. In rural districts of India, muram or mud floorings are very common and popular. The flooring is very cheap, can be constructed with local materials available and can be easily maintained. The best quality of this floor is that it equalizes the temperature that is to say, it is comparatively warmer in winter and cooler in summer. Hence it is most suited for those houses where the occupants move bare footed on the floor. But to maintain this floor in good condition, a periodic wash of cow-dung is necessary, which is very objectionable from the sanitary point of view.

Mud flooring. This filled up earth in the plinth is properly rammed and levelled. Upon the prepared bed, a 15 cm thick layer of selected mud is

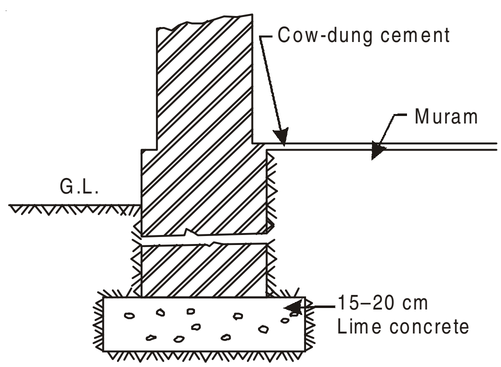


Fig. 7.1 *Muram flooring.*

evenly spread and rammed well, so as to get a consolidated surface. Very little water is used during the process of ramming. Finally, the surface is coated with a thin layer of cow-dung and cement mixed in the ratio of four and one (4 : 1) and the surface is wiped clean, after drying.

Muram flooring. In the case of muram flooring, sufficient quantity of water is used during the process of ramming. After the surface has been rammed, it is then saturated with water and left for drying. After a day, the scum developed over the surface is removed and the surface is again rammed. Finally it is also coated with a thin paste of cow-dung and cement mixed in the ratio of four and one and wiped clean.

These floors are very cheap in construction and maintenance. These are much suitable for Indian conditions and maintain equable temperature in winter and summer both. These are of absorbent nature and require occasional wash of cow-dung.

7.4.2 Brick Flooring

This type of flooring is also very common, and is suitable for stores, court yards, compounds of public buildings such as school, college, hospital, etc. The brick floors do not develop cracks but are not smooth and are dusty. They cannot be allowed bent nature and such floors cannot be used in bath rooms, latrines, kitchens, etc.

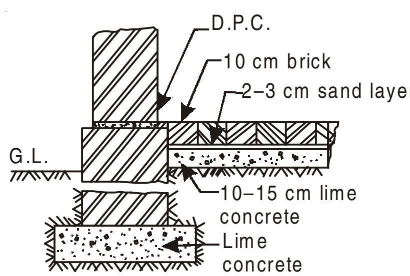


Fig. 7.2 *Brick flooring.*

The area on which the flooring is to be laid is properly rammed and compacted reduce chances of settlement of the floor. If the bearing capacity of the soil is poor, a sub-grade of hand packed rubble of brick bats is spread in a layer of 15 to 22 cm and properly compacted. After the surface has been properly compacted, a layer of 10 to 15 cm of lime concrete is spread and compacted properly. Proper gradient or slope is given to the lime concrete bed. Generally 1 in 30 to 1 in 40 slope is given in the floors, to facilitate washing and cleaning of the floors. Over the prepared bed, bricks are laid in some pattern, either in cement mortar or lime mortar. The joints are then flush pointed. Sometimes over the bed of lime concrete, a 2 to 3 cm thick layer of dry sand is sprinkled and the bricks are laid dry and finally the joints are neatly finished.

7.4.3 Flag Stone Flooring

It is an out-dated floor and was previously used in those places where good quality of stone is easily and cheaply available. However, the flag-stone flooring is suitable for use in warehouse, godowns, railway platforms etc.

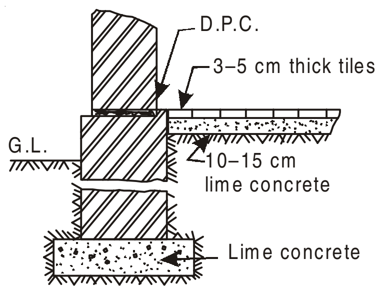


Fig. 7.3 *Flag stone flooring.*

Any laminiscated sand stone of uniform thickness of 2 to 6 cm is called *flag stone*. The stones may be square or rectangular. The sub-grade is prepared by laying a layer of lime concrete over the rammed surface. A suitable gradient generally 1 in 40 given. Over the bed of lime concrete, flag stones are laid on a 2 to 3 cm thick layer of mortar (cement or lime). When the stone slabs are properly set, the mortar from the joints is raked out and the joints are neatly finished.

7.4.4 Tiled Flooring

Tiles are a special clay product. Tiles are also manufactured of cement concrete or crushed pottery, having different colours, shapes and sizes. Sometimes glazed tiles are also used. This type of flooring is not much used nowadays, however the cement concrete tiled flooring is becoming popular.

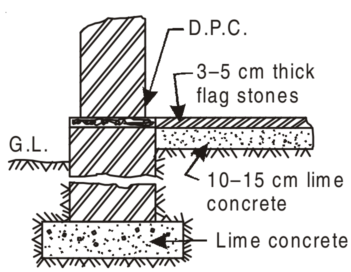


Fig. 7.4 *Tiled flooring.*

The ground is properly rammed, watered and levelled. A layer of 10 to 15 cm thickness of lime concrete is spread and rammed properly. The required slope is maintained during ramming. On this sub-grade a thin layer of cement mortar 1 : 1 is evenly spread and the tiles are laid on this surface in some fashion, with a thin paste of cement on their sides. The tiles are then lightly tamped. The joints in the tiled flooring should be very thin. Sometimes the joints are thin as a paper. After two or three days, the joints are rubbed with corborundum stone.

7.4.5 Cement Concrete Flooring

This type of flooring is commonly used in residential as well as public building. The cement concrete flooring is hard but smooth, non-absorbent, dustless and if construction properly and carefully, it lasts longer. The maintenance and repair of such flooring is practically nil. But on the other hand, if this flooring is constructed carelessly, it will become a perpetual source of headache, as it can never be repaired satisfactorily.

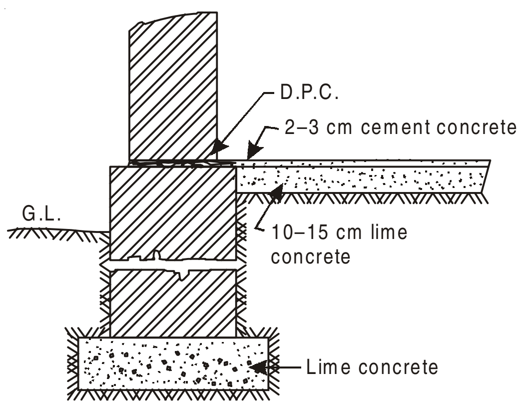


Fig. 7.5 *Cement concrete flooring.*

The surface on which this flooring is to be laid is properly rammed, levelled and watered so as to compact it. The surface so prepared is covered with a 10 to 15 cm thick layer of lime concrete. In case the ground is made of soft or loose soil, a 15 to 22 cm thick layer of hand packed rubble boulders or brick bats is laid and well rammed, before laying the lime concrete. When the concrete bed is set properly, it is thoroughly cleaned and moistened, before laying the cement concrete. The entire surface is then divided into square or rectangular panels not exceeding 2 m in length. Wooden battens of 1 cm to 2 cm thickness and width equal to the thickness of cement concrete layer to be laid, are placed along the sides of squares rectangles. Generally the thickness of the concrete varies from 2 to 4 cm. These wooden battens, so laid will from small panels. Cement concrete in the ratio of 1 : 2 or 1 : $2\frac{1}{2}$: 5 is filled in diagonally opposite and alternate panels. The concrete is evenly laid and rammed with wooden mallets and finally finished with steel trowels, so as to make the surface smooth. Sometimes to get a smooth surface easily, masons sprinkle dry cement over the surface and trowel it, this should never be allowed because the cement layer after drying will be scraped off and the surface will develop cracks. After 24 hours of filling the panels, the wooden battens are removed and the rest of the panels are filled with cement concrete and finished. The surface is then cured for 7 to 10 days.

Instead of wooden battens, aluminium or glass strips are also used and they are allowed to be embedded in the floor. After finishing and curing the surface, the edges of the panels are rubbed so as to have a smooth finish.

7.4.6 Mosaic Flooring

This type of flooring was commonly and popularly used in high class residential as well as public buildings. But nowadays it is not much used.

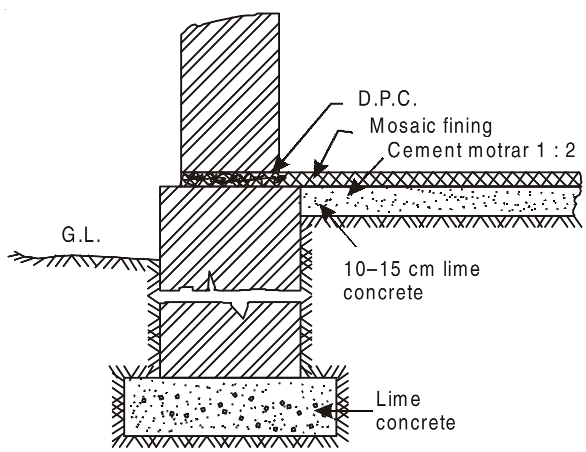


Fig. 7.6 *Mosaic flooring.*

First of all the surface is properly rammed and 10 to 15 cm thick layer of lime concrete is spread as usual. Over the compacted surface of lime concrete, a thin layer of cement mortar 1 : 2 is evenly spread over a small area. Broken pieces of tiles or marble stone chips cut in the desired shape, are laid over the layer of cement mortar, in some pattern and colours, as may be desired. The surface is then gently rolled. Dry cement either ordinary or coloured, is sprinkled over the surface, and the surface is wiped clean. The edges of the tiles or broken pieces of stone, are then rubbed with some hard stone so as to have a clean, levelled and smooth surface.

7.4.7 Terrazo Flooring

This type of flooring is becoming more and more popular and is being used in hospitals, offices, schools, colleges, and in residential buildings. This flooring is very durable, impervious and has got a very good appearance. Actually speaking, Terrazo is a type of finish applied to cement concrete base. There are two methods of its construction. (This is commonly known as Mosaic flooring).

In one method, the cement concrete floor is constructed as usual. The surface is not finished. Over the rough base of cement concrete, 2 to 3 cm thick layer of cement mortar, consisting of one part of ordinary or coloured cement and two parts of clean sharp sand, is spread evenly. Marble chips of 5 to 7 mm size are sprinkled over the surface and are pressed into to mortar, when it is still wet.

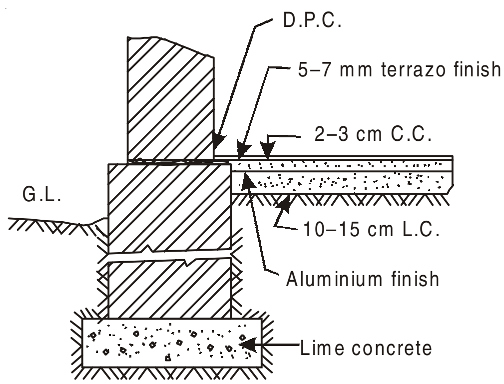


Fig. 7.7 *Terrazo flooring.*

In another method, a 1 cm thick layer of cement mortar 1 : 2 is spread over the surface of cement concrete, when it is still wet. Then a mixture of cement and marble chips in the ratio of $1 : 2\frac{1}{2}$ i.e., one part of cement (ordinary or coloured) and two and a half parts of marble chips, is spread in a thickness of 3 cm and the surface is properly rammed and finished.

When the terrazo finish is sufficiently hard, the surface is ground by a carborundum stone. During the process of grinding sufficient quantity of water is used. The grinding can be done either by hand or by machine. Machine grinding is more effective and economical. Finally, this is washed with a solution of soap water.

7.4.8 Timber Flooring

These floors are rarely used in domestic buildings. In hilly areas where the climate is damp and good quality of timber is easily and cheaply available timber flooring is used. However, the timber flooring is also used in dancing halls, ballrooms, hotels and restaurants etc.

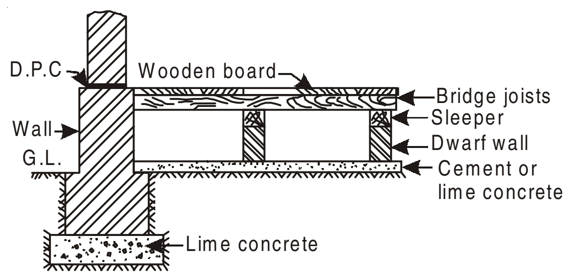


Fig. 7.8 *Timber flooring.*

The entire area of the ground below the floor is covered by cement concrete or lime concrete. This is called site layer. Over the site layer, intermediate dwarf or sleeper walls are constructed at regular distances. On the top of the dwarf walls, floor beams or sleeper plates are placed. The sleeper walls are 10 cm thick and are honeycombed for the circulation of air. Bridging joints, at right angles to the sleeper plates are placed over them. The bridging or floor joints are secured to the sleeper plates by means of nails. Wooden boards of nearly 3 cm to 4 cm thickness are properly nailed to the bridging joints. The hollow space between the side layer and flooring is kept dry and fully ventilated.

7.4.9 Granolithic Floor

This is a wearing surface provided over the cement concrete surface. This floor provides a hard wearing surface for public buildings such as offices, schools, colleges, hospitals, banks etc. Granolithic finish is economically used for those places which are required to resist heavy wear and for which attractive finish or appearance is not required.

Granolithic floor finishing consists of such cement concrete with high grade or heavy duty coarse aggregate such as trap, basalt granite etc. The thickness of granolithic finish may vary form 25 to 35 mm depending upon the service the floor is expected to give. To further improve the quality of finish, the same may be replaced by crushed granite. The proportions of granolithic finish varies from $1 : 1\frac{1}{2} : 3$, 1 : 2 : 3 to 1 : 1 : 2. The granolithic is applied over the prepared base of cement concrete floor monolithically.

7.4.10 P.V.C. Floor

Poly venyl chloride is a plastic product and provides a smooth, soundless wearing surface. It provides a pleasing appearance suitable for high class offices, libraries, residential buildings, etc. This type of floor furnishing is a recent development in the construction of floors. For this type of floor finishing first of cement concrete floor is prepared and when the cement concrete floor is absolutely dry, P.V.C. tiles should never be fixed on damp places.

QUESTIONS

7.1 When are the various types of floors used in public buildings and residential buildings ? Describe in brief the construction of a Muram or Mud flooring.

7.2 A room measuring 3 m × 4 m is to be covered by a cement concrete flooring. Describe in brief the various steps for the construction of this flooring.

7.3 What is the difference between a Mosaic flooring and a Terrazo flooring ? Explain the difference by giving constructional details of these floorings.

7.4 What type of flooring would you recommend for the following situations ? Give reasons for your choice :

Hospital ward, Entrance hall, A high class residential buildings, A school compound, A temporary site building.

[Hint. A temporary site building is that which is constructed at the site, that is, the place where some construction is going on. For example, a bridge is to be constructed at a place which is far away from a nearby town or city. So in such places temporary huts and quarters etc., are constructed for the persons working there. These temporary buildings are pulled out and demolished after the completion of the work. So far as such buildings are concerned, muram flooring is constructed which is plastered with cement mortar instead of cement and cow-dung paste. These floors do not require periodic wash of cow-dung and give quite satisfactory service.]

7.5 Where will you use timber flooring ? Describe its construction.

7.6 How is Terrazo finish given to a cement concrete floor ? What is the function of aluminium and glass strips used in this type of floor ?

7.7 Describe the construction of Tiled flooring and Flag stone flooring. Mention specific points of difference between the two types of flooring.

7.8 What precautions are necessary during the construction of a cement concrete flooring ? Why does this floor become a perpetual source of headache if it is carelessly constructed ?

Chapter 8

Roofs

8.1 GENERAL

A roof is defined as a covering, supported over the walls or pillars to enclose a particular space. Roofs are constructed in the form of a framework to give protection to the building against rain, heat, wind, snow, etc., Roofs also increase the transverse strength of a building. There are, in general, two types of roofs viz., Flat roofs and Slopy roofs.

8.2 MERITS AND DEMRITS OF FLAT AND SLOPY ROOFS

1. Flat roofs are provided in those places where there is less rainfall and no snowfall, whereas slopy roofs are provided in those places where there is heavy rainfall and snowfall.

2. Rooms under the flat roofs are cooler in summer and comparatively warmer in winter.

3. The construction of slopy roofs is easier than that of flat roofs upto a certain span.

4. Slopy roofs can be constructed over very large spans without any intermediate support whereas the flat roofs require intermediate supports and heavy section beams to support it.

5. Slopy roofs are cheaper than flat roofs.

6. The maintenance and repairs of slopy roofs is easier than flat roofs.

7. The top of the flat roof can be used as a terrace whereas the top of slopy roof cannot be used.

8.3 INCLINED OR SLOPY ROOFS

These are very common and are considered as the cheapest alternative for covering a structure. The slopy or pitched roofs are constructed in wood or steel. Nowadays R.C.C, members are fabricated as members of a slopy roof. The following are the various types of slopy roofs, made of wood.

8.3.1 Lean to or Varandah Roof

This is the simplest type of slopy roof, having a slope towards one side only. It consists of inclined members called *rafters.* The upper end of the rafters rest on a horizontal beam called *wall plate,* fixed to the wall with help of *corbels.* The lower end is being supported on horizontal beam, called *post plate,* which is placed over a series of wooden posts or masonry pillars. The lower end of the rafters generally project beyond the pillars, and this projected portion of the roof is called *Eaves.* This type of roof is used for varandahs upto a span of 2.5 metres.

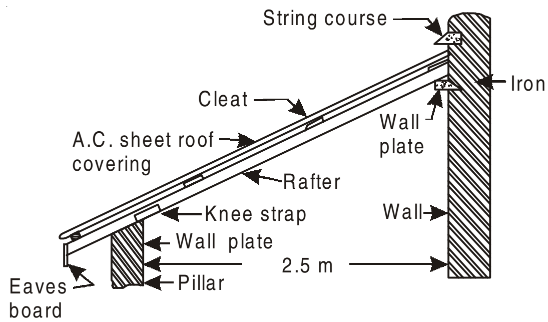


Fig. 8.1 *Lean to roof.*

8.3.2 Couple Roof

It is another type of simple roof, having two way slope. It consists of rafters, the upper ends of which are abutting against each other or connected through

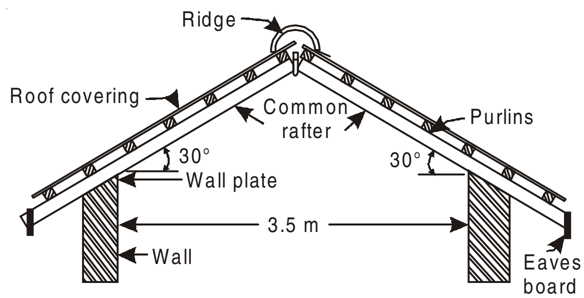


Fig. 8.2 *Couple roof.*

a horizontal member at the top, called *ridge place.* The lower ends of the rafters rest on wall plates as shown in Fig. 8.1. Such a type of roof can be used upto a span of 3.5 m.

8.3.3 Couple Close Roof

As the span increases, the rafters in the couple roof will have a tendency to push back the walls. To prevent this, a horizontal beam called *tie beam,* is

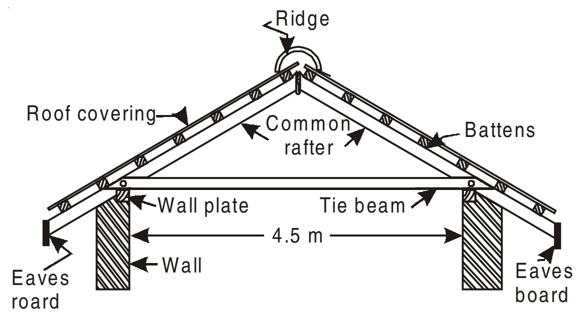


Fig. 8.3 *Couple close roof.*

introduced to connect the lower ends of the rafters. The roof so formed is called *couple close roof,* and can be safely used upto a span of 4.5 m.

8.3.4 Collar Roof

This roof is a modification over the couple close roof. As the length of the rafters increases, due to the increase of span, they will bend or sag in the middle. To prevent this sagging, the horizontal beam, in the couple close

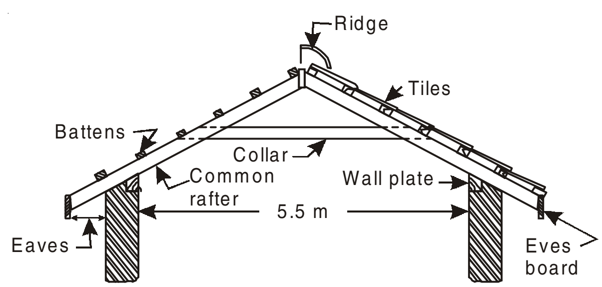


Fig. 8.4 *Collar roof.*

roof is removed and instead another horizontal beam, called *collar beam,* is provided in the centre of the rafters. Such a type of roof is called *collar roof* and can be used upto a span of 5.5 m.

8.3.5 King Post Truss

A truss is defined as a framed braced and triangulated structure. A king post truss is the simplest type of truss. It is actually a modification over the couple close roof. It consists of central member called *King rod* or *King post,* which prevents the sagging of the tie beam. The two inclined members called struts, prevent the sagging or bending of principal rafters. A king posts truss is suitable for spans varying from 5 to 9 m.

Suitable sections for different members are used. The size of a particular member depends upon the loading condition span and the quality of wood. Suitable joints are provided for connecting the different members together. The trusses are connected to each other by *purlins* and *ridge pieces.* A complete detail of the truss is shown in Fig. 8.5.

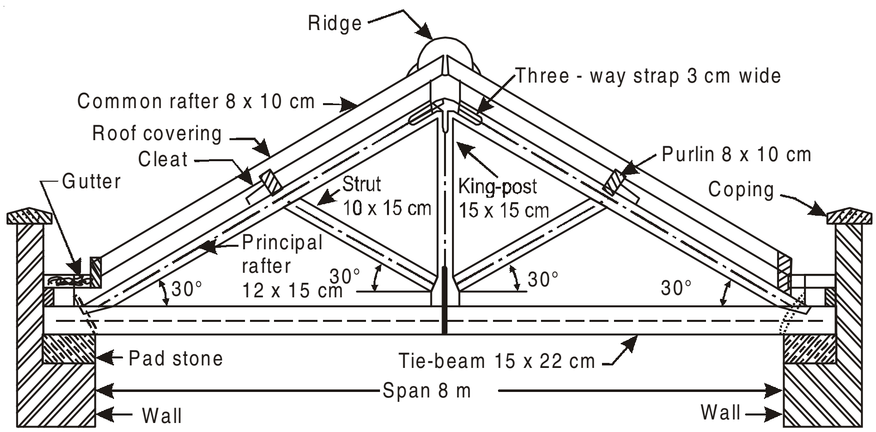


Fig. 8.5 *King post truss.*

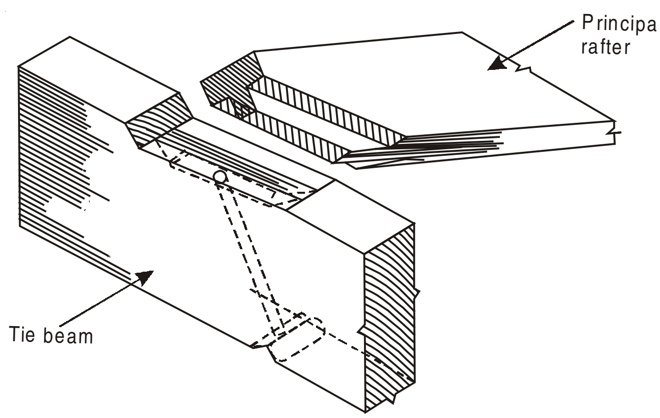


Fig. 8.6 *Junction of the beam and Principal rafter.*

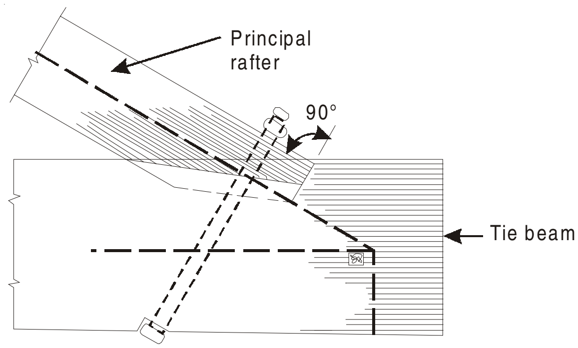


Fig. 8.7 *Junction of Tie beam and Principal rafter.*

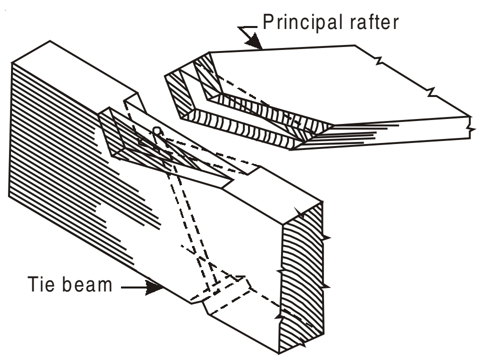


Fig. 8.8 *Isometric view of Tie beam and Principal rafter junction.*

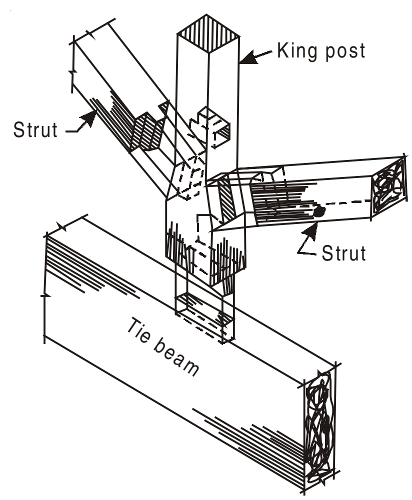


Fig. 8.9 *King post, Tie beam and Strut joint.*

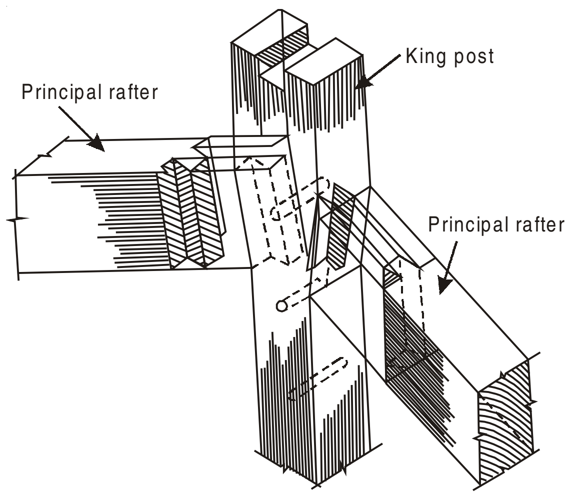


Fig. 8.10 *King post and Principal rafter joint.*

8.3.6 Queen Post Truss

It is another kind of wooden roof truss. It consists of two vertical members called *Queen roads*. These two vertical members help to prevent the sagging of the tie beam. The upper ends of queen posts are kept in position by means of a horizontal member known as *straining beam*. The queen posts have

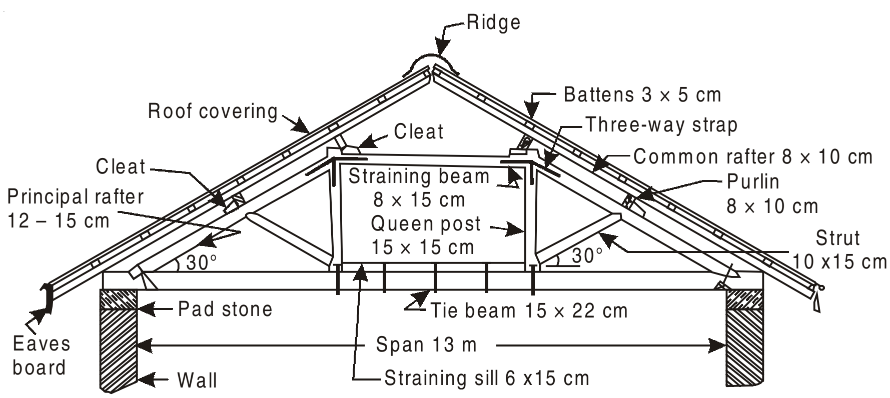


Fig. 8.11 (a) *Queen post truss*

single splay shoulders to receive the struts. The thrust from the struts tends to push the queen posts in wards which is resisted by introducing another horizontal member between the feet of queen post. This horizontal member is called *straining sill*. Figure 8.11 (a) and (b) will give the complete constructional details of this truss.

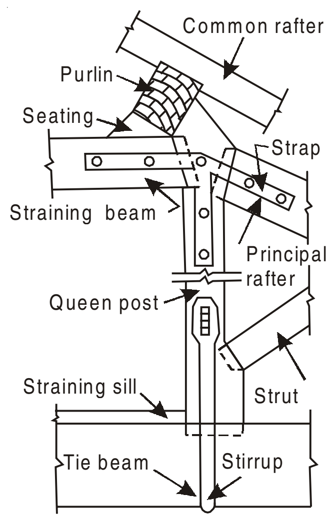


Fig. 8.11 (b) *Details of Queen post truss joints.*

8.4 SOME TECHNICAL TERMS

1. **Pitch.** It is the inclination of roof. The pitch of slope of a roof depends upon the covering material to be used. It is expressed either in degrees or as a ratio of rise to span.

2. **Gable.** The triangular upper part of a wall formed at the end of a pitched roof, is known as *Gable.*

3. **Barge Board.** These are the wooden planks or boards which are fixed at the gabled end of a roof.

4. **Cleats.** These are small wooden blocks which are fixed on the trusses to prevent the sliding of purlins.

5. **Eaves.** It is the bottom end of a slope roof, which are projecting beyond the face of a wall or pillar, to protect them from rains.

6. **Eaves-board.** A thin wooden board or sheet metal piece, fixed to the end of an eaves, is called *Eaves-board.*

7. **Hipped roof.** It is that formation of a roof at the end of which it slopes down from the ridge to the top of the end walls.

8. **Hip rafters.** The rafters used at the hipped end of a roof are called *hip rafters.*

9. **Valley and Valley rafters.** It is the reverse of a hip. It is the line of reentrant or the downward sloping line formed by the junction of the bottoms of two roofs, sloping down from opposite sides. The rafters used at these ends are called *Valley rafters.*

10. **Jack rafters.** These are short common rafters, used at the valley or hipped end.

11. **Dragon rafters.** These are diagonal members, connecting the feet of Jack rafters at the lower portion of the hip rafters.

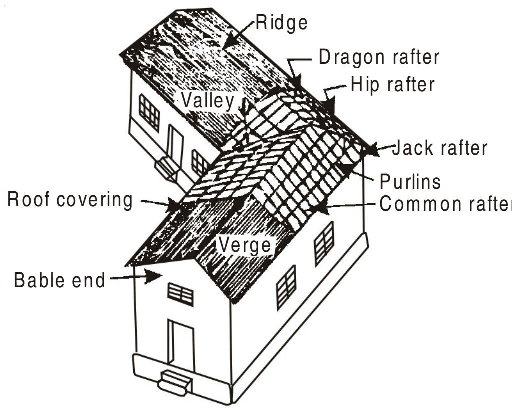


Fig. 8.12 *Component parts of a roof.*

12. **Purlins.** These are horizontal wood members placed on the principal rafters of trusses to connect them together, and a support to the roof converging or common rafters.

13. **Common rafters.** These are intermediate rafters, placed on the purlins to give support to the roof covering.

14. **Ridge piece.** It is a top horizontal member, used to connect the various trusses together.

15. **Template.** A bedding block, made of stone or concrete provided under the ends of trusses, is called *template.*

8.5 ROOF COVERINGS

The following roof covering are generally used in different buildings and in different situations:

1. **Thatch.** This is the simplest type of roof covering. It is light but catches fire very easily. A bed of bamboo matting is prepared to receive the thatch. A slope of 1 : 2 or 45° is given so that the rain water may drained off easily. This type of roof covering is used in villages especially for cow-sheds.

2. **Country tiles.** The country tiles are flat and half round, and are laid in pairs of flat tiles and half round tiles, with proper lapping. The flats are placed on the bamboo matting with the help of mud mortar, with sufficient lapping and over the junction of flat tiles, half round cover tiles are placed. The size of country tiles varies from place to place.

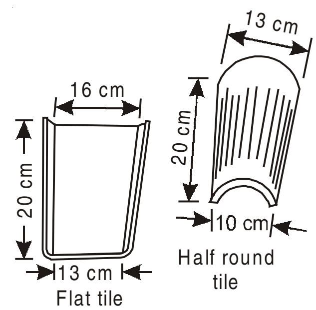


Fig. 8.13 *Country tiles.*

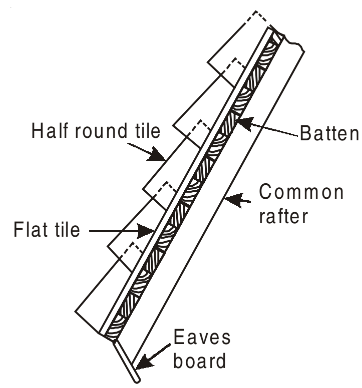


Fig. 8.14 *Fixation of country tiles.*

3. **Allahabad tiles.** The Allahabad tiles are also similar to the country tiles. The flat tiles are laid side by side and joint is then covered by pot tiles overlapping each other. The wider end of the flat tiles is towards the ridge whereas the smaller end of the half round cover tiles is towards the ride

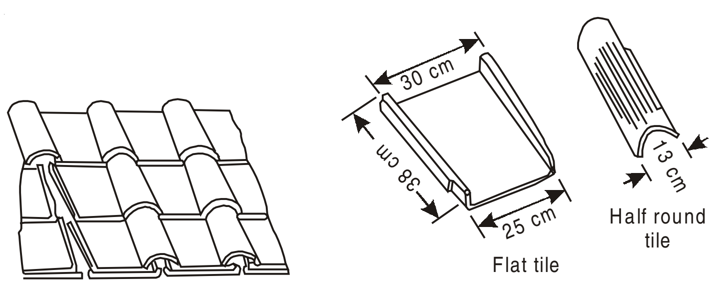
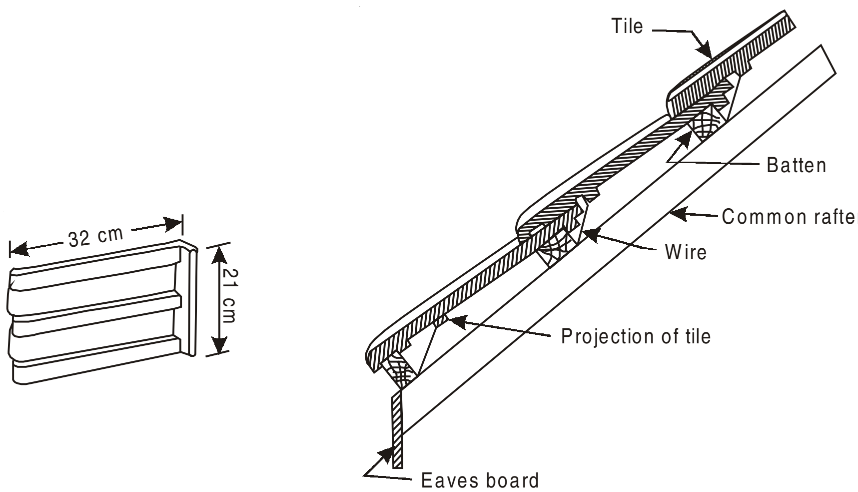


Fig. 8.15 *Allahabad tiles.*

whereas the smaller end of the half round cover tiles is towards the ridge. The method of fixation is the same as that of the country tiles except that instead of mud lime mortar is used, and the tiles are laid on wooden battens, or, small purlins.



(a) Mangalore tiles (b) Fixation of Manglore tiles

Fig. 8.16

4. **Mangalore tiles.** These are flat pattern tiles, with suitable key projections. Each tile covers 32 cm × 21 cm. 16 tiles are generally required for covering 1 sq. metre of space. The tiles are fixed on wooden battens with the help of wire. The method of fixation of the tiles is shown in Fig. 8.16 (b).

5. **Pan tiles.** These are flat tiles with a slight curvature and are laid on the battens which are fixed to the common rafters at a distance of nearly 15 cm centre to centre. The method of fixation is the same as that for *Mangalore tiles*.

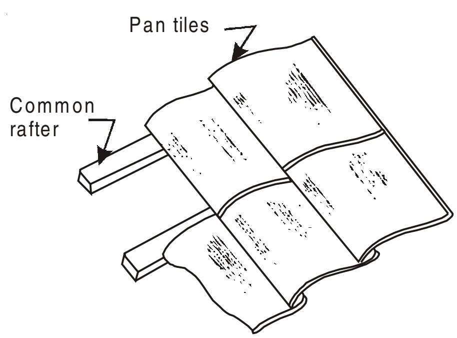


Fig. 8.17 *Arrangement of pan tiles.*

6. **Slate.** In hilly places where good quality of slate stone is easily available, it is used as a roof covering. The tiles are 25 cm × 35 cm are fixed to the battens with the help of wire passed through a hole made in the tiles.

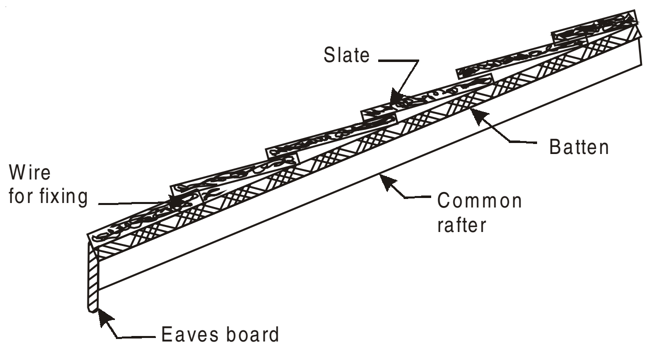


Fig. 8.18 *Fixation of slate*

7. **A.C. sheets.** Asbestos cement is a material obtained by the combination of cement with about 15 per cent of asbestos fibres. The A.C. sheet are corrugated for the purpose of strength and for the easy drainage of rain water. The A.C. sheets are light, impervious, durable and fire-resisting. On account of these properties asbestos sheet are commonly used as a roof covering for factories, workshops, garages, big halls etc. There are three varieties of A.C. sheets.

(i) Everite 'Big-six'

(ii) Everite Standard

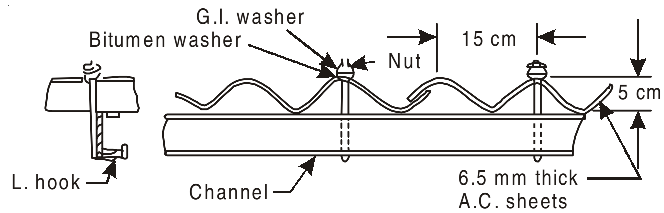
(iii) Turnall Trafford

(i) *Everite Big-six.* These sheets are 1.05 metre wide, 1 to 3 m in length and 65 mm thick. There are $7\frac{1}{2}$ corrugations per sheet at a path of 15 cm and an overall depth of 5 cm.

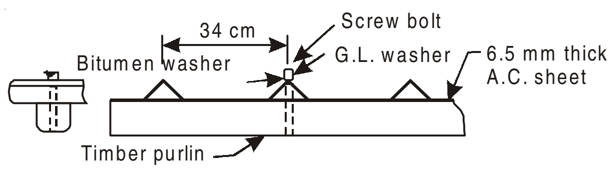
(ii) *Everite Standard.* These sheets are 0.76 m wide, 65 mm thick and 11 to 3 m in length. The overall depth of corrugations is 256 m or 285 cm. There are 10½ corrugations per sheet at a pitch of 54 cm.

(iii) *Turnall Trafford.* These are 112 m wide, 13 to 3 m in length and 65 mm thick. Every sheet has four 5 cm deep corrugations alternating with flat portions. The pitch of corrugation is 34 cm. The sheet provides and excellent covering especially for large span roofs.

Method of Fixing A.C. Sheets. The A.C. sheets are fixed to the purlins (wooden or steel) with the help of hook-bolts in the case of steel purlins and screw bolts in the ease of wooden purlins. Holes are drilled in the sheets at the crown or crest portion. Over the hole Bitumen and G.I. washers are placed and then the bolt is fixed. Bolts or screws are to be fixed at the crown of the corrugation and on no account anywhere else. The diameter of the bolt is generally 0.6 to 1 cm.



(a) Fixation of Big-six A.C. sheets



(b) Fixation of Trafford A.C. sheets.

Fig 8.19

8. **G. I. Sheets.** These sheets are made by pressing wrought-iron sheets between grooved rollers which force and bend them into a series of parallel waves of corrugations. The corrugations increase the strength and stiffness of sheets. The sheets are then carried with a coating of zinc and hence they

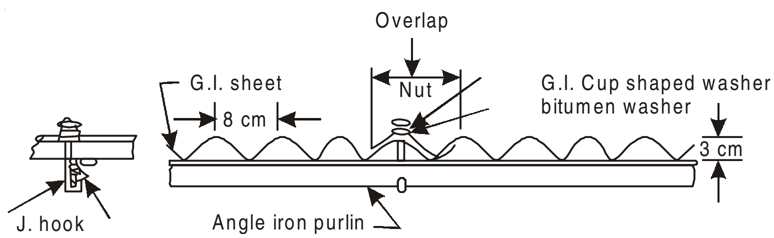


Fig. 8.20 *Fixation of corrupted G.I. sheets.*

are called *Galvanized iron sheets*. The sheets are 60 cm and 75 cm wide, 1.35 m to 3.60 m length and having a thickness of 16 to 24 gauges. The number of gauge indicate the fraction of an inch. Figure 8.20 shows the fixation of G.I. sheets to angle iron purlins. The method of fixation is the same as described for the A.C. sheets.

8.6 SLOPES FOR VARIOUS ROOF COVERINGS

The following sloped or pitches are generally recommended for different roofs :

Type of roof covering	*Slope or pitch*
1. Country tiles	45°
2. Allahabad tiles	45°
3. Manglore tiles	33°
4. States	26°
5. A.C. sheets	25°
6. G.I. sheets	25°

8.7 STEEL TRUSSES

The safe working stress on mild steel is about twenty times that of ordinary structural timber in direct tension, The mild steel is much stronger than timber and is easily available everywhere in various sections and lengths with practically no wastage. The various sections available, can be easily assembled and connected. Mild steel has much longer life than timber if protected against rust and corrosion by painting at regular intervals of 2–3 years. It is mainly for these reasons that mild steel trusses are extensively used for roofs of factory buildings.

The most suitable section for mild steel roof trusses is angle. Angle most effectively resist compression as well as tension stresses. The various members of the steel trusses which consist of single or double angles jointed back to back are connected together either by resisting or welding through gusset plates. Small span trusses are fabricated at the works and transported to the site. Large span trusses are fabricated in parts and assembled at site for the commence of transportation and erection. Trusses are erected by a crane gantry and connected to the building by means of bolts. The trusses which are usually placed at a distance of 2 to 3 m are connected by purlins. If trussed a braced purlins are used the spacing of trusses can be increased to 5 to 6 m. Stone or cement concrete templates or bed plates are under the truss on the walls so as to prevent crushing of wall material. For small trusses upto 10 metre span, both ends of the truss are fixed to the walls with the help of bolts. The large span trusses are fixed at one end and the other end is placed on a chair mounted on steel rollers. This will help in providing expansion and contraction due to temperature variation.

8.7.1 Truss Layout

A steel roof truss should be properly triangulated i.e., all members of the truss should be arranged to form triangles as the triangle is the most rigid structure. A truss in generally is defined as a framed, braced and trianguled structure while designing and fabrication a truss should be taken to see that each member is either an direct tension or compression. As far as possible purlins are placed on the nodes or panel points i.e., the points where the triangles are formed panel points are generally arranged at 2 to 3 m spacing.

8.8 FLAT ROOFS

The commonly used flat roofs are (i) Reinforced cement concrete slab roof, (ii) Reinforced brick slab roof, (iii) Jack-arch roof, (iv) Flag stone roof, and (v) Brick or Tile roof.

8.8.1 R.C.C. Slab Roof

This type of roof is commonly used in public buildings and residential buildings. The main body of the roof consists of an R.C.C. slab. The slab may be a plain R.C.C. slab supported over beams or R.M.S. joists, if the span is more than 3 m or a T-beam slab.

For the construction of the R.C.C slab, a temporary structure, known as *form-work,* is constructed. The form-work may be either constructed with wooden planks, plywood sheets, mild steel sheets or bamboo matting. The top of the form-work, is made perfectly levelled and in level with the under surface of the slab to be constructed. If the form-work has been made with bamboo, the top is covered with a layer of mud and the surface is plastered with lime mortar so as to give a smooth surface. The surface so prepared is now left for drying.

The designed reinforcement consisting of main bars and distribution bars, is placed at the specified positions. The main reinforcement is placed along the span of the room to be covered and the distribution reinforcement is placed crosswise. The design of the R.C.C. slab is beyond the scope of this book. The two types of reinforcement are tied to each other, with the help of wires. The reinforcement is then embedded in cement concrete mixed in the ratio of 1 : 2 : 4 or 1 : 2 ½ : 5. The concrete is properly rammed and it is left for drying for 24 hours. After 24 hours the slab is cured by making small earthen bunds and filling them with water for about 7 to 10 days. (Other methods of curing are described in the next chapter).

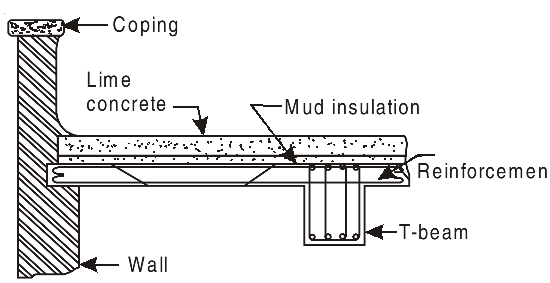


Fig. 8.21 *R.C.C. roof.*

When the slab has become hard, the form-work is carefully removed. While removing form-work care should be taken to see that shock should not develop in the slab.

The top of the slab is clean and is then painted with coal tar or bitumen. Over the plainted surface a 2 to 4 cm thick layer or mud or fine sand is spread. Over the sand or mud bed, lime concrete in a layer 10 to 15 cm thickness is spread. The lime concrete, which is called *lime terracing* is rammed and compacted thoroughly with wooden mallets and the surface is levelled smooth.

In case the top of the roof is to be used as first floor, the insulation layer of mud or sand and the lime concrete terracing is not provided, but instead, over the R.C.C. slab, direct floor finishing is given.

8.8.2 R.B. Slab Roof

The construction of the R.B. slab roof is the same as that of the R.C.C. with the difference that instead of cement concrete, the reinforcing bars are embedded in bricks laid in 1 : 2 or 1 : 3 cement mortar. The distance of the reinforcing bars will depend on the size of the bricks. The two types of reinforcement is not tied to each other.

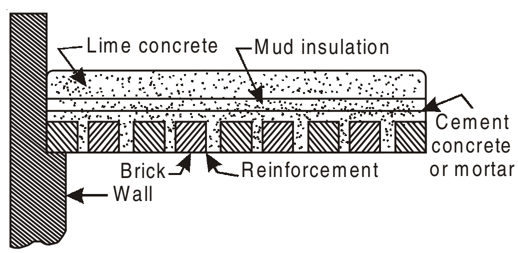


Fig. 8.22 *Reinforced brick roof.*

So for the construction of R.B. slab roof, a form-work is prepared and then R.B. slab is casted as described for R.C.C. slab. Over the R.B. slab, insulation layer consisting of mud or sand lime concrete terracing is laid as usual.

8.8.3 Jack Arch Roof

This type of roof was very common and popular. The jack arch roofs are shock proof, leak-proof and require much less maintenance, if constructed properly. Such type of roofs can be seen in buildings along the railway station and in old public and residential buildings.

The jack-arches are generally constructed with bricks but can also be made with cement concrete. The arches are constructed over the flanges of I-sections spaced at a distance of 125 to 175 m. The rise of the arches varies from 1/10th to l/12th of the span and the thickness of arch ring will be 10 to

15 cm. After the arches have been constructed the portion of the span drill near the joists, is filled with cement concrete and the remaining portion with lime is filled with lime concrete. Insulation layer and lime concrete terracing is done as usual.

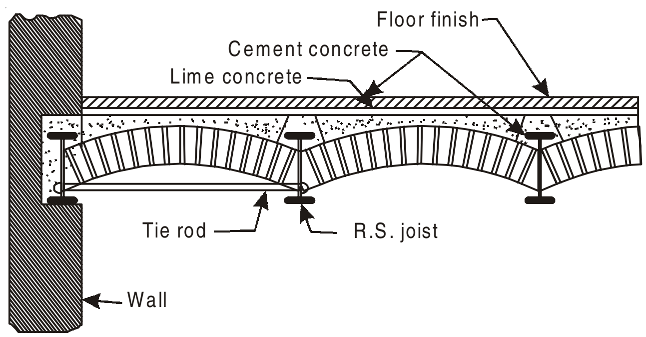


Fig. 8.23 *Jack arch roof.*

To check up the horizontal thrust in the extreme arched tie rods of nearly 1 to 1.5 cm diameter are fixed at a distance of 1.5 to 2 m apart. These tie rods will take up the horizontal thrust and thereby reduce the chances of buckling and cracking of the walls. The fixation of tie-rods is shown in Fig. 8.23.

8.8.4 Flag Stone Terrace Roof

This is an outdated roof. These roofs were commonly used in hilly places where good quality of stone is easily and cheaply available. The flag stone having a thickness of 2.5 to 4 cm are supported over the flanges of T-sections. As far as possible, all the slabs should be of equal size and thickness. The flag stones are fixed to the flanges with help of cement mortar.

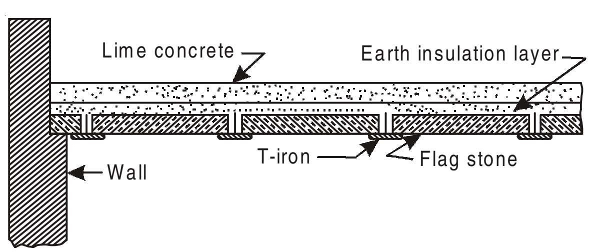


Fig. 8.24 *Flag stone roof.*

After the slabs have been laid, the top is covered having a 2 to 4 cm thick layer of mud and over this lime concrete is laid and properly rammed.

8.8.5 Brick or Tile Terrace Roofs

These roofs are rarely constructed or even seen nowadays. The roof consists of wooden scantlings or nearly 6 cm × 8 cm section, spaced at regular distance depending upon the size of bricks or tiles. The spacings between the bricks

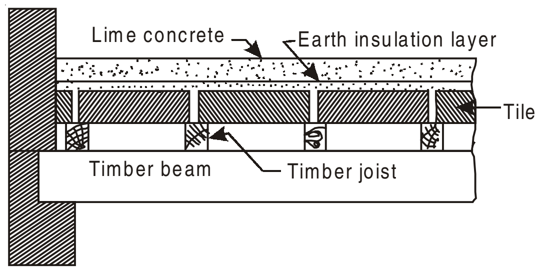


Fig. 8.25 *Brick or tile terrace roof.*

are filled with lime or cement mortar. The top is then covered with mud and lime concrete as for other flat roofs. In cheap quality of works and in places where there is very little rain-fall, the top can also be finished with mud and chopped straw, instead of lime concrete.

QUESTIONS

8.1 What is a roof? What is the function of roofs ? What are the comparative advantages and disadvantages of flat and slopy roofs ?

8.2 Describe in brief the construction of R.C.C. slab roof.

8.3 Describe the comparative merits and demerits of R.C.C. slab roof, R.B. slab roof and a jack arch roof.

8.4 What type of roof would pou recommend for the following situations and why:

(i) A cinema hall

(ii) A building on a hill station

(iii) A workshop

(iv) A school building on plains

(v) Hospital ward.

8.5 Write short notes on :

Couple close roof, Lean of roof, King Post Truss.

8.6 Draw a neat sketch of a slopy roof you would recommend for a village school room which is 4 m wide.

Show clearly the fixation of country tiles. Assume suitable dimensions for the members of the roof.

8.7 What are the comparative advantages and disadvantages of A.C. sheet and G.I. sheet roof coverings ?

Draw a neat and dimensioned sketch showing the fixation of A.C. sheets to angle iron purlins.

8.8 Define the following terms :

Collar roof, eaves, purlins, jack rafters, dragon rafter, valley, hip rafter, ridge piece, bed plate, cleat, principal rafter.

8.9 Draw a neat sketch of a King Post Truss, name the various parts and show the fixation of slates over it.

8.10 Describe the construction of a Queen Post Truss. Upto how much span can this truss be used ? Draw a neat sketch and name the various parts.

8.11 Sketch common types of wooden trusses used for roof construction indicating the span for which they are used.

8.12 Explain the terms Hip, Valley, Ridge and Gable in connection with pitched roof.

Chapter 9

Plastering and Pointing

9.1 GENERAL

Plastering and Pointing are the finishings of a masonry work. They provide a neat appearance and durability to the masonry structures. Pointing is invariably provided on the faces of external walls, whereas plastering can be done either in external walls or internal walls. Pointing is generally done when the material used for masonry work, is sound and good quality and the workmanship, is good.

9.2 PLASTERING

It is the art of covering rough surfaces of wall, with a plastic composition called *Plaster*. Sometimes the word *rendering* is also used for the process of applying plaster. The following are the principal objects of plastering:

1. To hide the irregularities and bad workmanship of construction.
2. To protect the masonry from atmospheric actions.
3. To provide, true, even, smooth and finished surface to the work, to improve its appearance.
4. To cover up unsound and porous materials.
5. To provide a suitable ground for white or colour wash, distemper or some other finish.

Good brick work or stone work, made of well burnt bricks and good mortar or neat stone masonry constructed of durable stones and good mortar, does not require plastering in general, either to preserve or to beautify it.

9.3 TYPE OF PLASTERS

Plaster is a fine paste or mortar, made by working with water a mixture of cement and sand or lime and sand or surkhi (powdered bricks). When cement sand plaster is used, it is called *cement plaster* and if lime, sand or surkhi is used, it is called *lime plaster*. Cement plaster is generally applied for external as well as internal work, but the lime plaster is exclusively recommended for internal work only. The reasons using lime plaster on the internal walls are:

1. To give a smoother surface.
2. To reduce cost of plastering.
3. To provide a suitable ground for special type of finishing such as distempering, painting etc., as the finishing can be more effective on lime plastered surfaces than on cement.
4. To facilitate fixing of picture frames etc. on the walls, it is easier to driver nails in the lime plaster than in the cement plaster.

9.4 CEMENT PLASTER

Cement mortar forms an excellent material for external plaster. The proportion of cement and sand generally is one to four. Cement and sand are mixed in the right proportions and then worked with sufficient quantity of water to have workable paste.

The plaster is applied in one or two coats, depending upon the class of work.

9.5 METHOD OF APPLYING CEMENT PLASTER

Before applying plaster, the joints and the masonry surface should be free from grease, oil, or soot. The mortar from the joints is raked out with some pointed tool to a depth of nearly 1 cm. The surface is then wetted freely with water.

The first coat of plaster is then applied by dashing the mortar against the wall. The first coat, which is called, *rough* or *rendering coat,* is applied to hide the irregularities of masonry and to form a ground for the next coat. The thickness of this coat is nearly 15 cm. The surface of this coat is made rough by scratching it with some pointed instrument, and is left for drying for 3 to 4 days.

When the first coat has become hard, then the surface is wetted and the final or finishing coat in a thickness of nearly 1 cm is applied in a uniform thick layer. The surface is trowelled smooth. For final or finishing coat, generally fine sand is used. Sometimes a little of fat lime is also added in the mortar for the finishing coat, to increase its hydraulic properties so that the surface may weather well.

9.6 LIME PLASTER

Lime plaster is composed of lime and sand or lime and surkhi in various proportions, depending upon the nature of the work and the number of coats to be applied. The following proportions are generally recommended.

	1st coat	2nd coat	3rd coat
(i) Lime plaster if applied in one coat.	1 part of lime and 1½ part of river sand or surkhi.	—	—
(ii) Lime plaster if applied in two coats.	–do–	2 parts of lime and 1 part of sand or surkhi.	—
(iii) Lime plaster if applied in three coats.	–do–	–do–	4 parts of lime and 1 part of fine white sand.

For superior quality of work, some quantity *of jaggery* water should also be mixed. The above proportions of lime plaster, are for interior work only. If the lime plaster is to be used for exterior work, some quantity of cement, depending upon the nature of the work, should also be added, for better qualities.

The method of applying the lime plaster is the same as that of cement plaster.

9.7 POINTING

Pointing is the art of finishing the mortar joints of the walls etc. with either cement or lime mortar; in order to improve the appearance of masonry and to protect the joints from the atmospheric action. The mortar joints are the weakest spots in a masonry and hence they must be protected properly from the disintegrating effects of sun, wind and rains. The pointing is only done on exterior work for the following reasons :

1. Very smooth-surface is not required.
2. Finishing such as distemper, paint etc., is not generally applied on the exterior faces.
3. To exhibit the materials to be used on the face of the wall.

Broadly speaking, the following are the objects of pointing :

1. To exhibit the materials used in the masonry, such as ashlar stone, first class bricks etc.
2. To exhibit neat workmanship.
3. To improve the appearance of work.

9.8 METHOD OF POINTING

Pointing may be done as the work proceeds or after the completion of the work. The former method is stronger and the latter one is neater and cleaner. Before pointing, all the mortar joints should be raked out by a pointed instrument to a depth of nearly 2 cm in order to give an adequate key for the mortar used for pointing. The joints are then wetted and cleaned. After the joints are prepared, the mortar is carefully pressed into the joints and the top of the joint is finished neatly. The pointed surface is kept wet for about three days.

The pointing can be done, either with cement mortar or lime mortar. Lime mortar is generally used for stone masonry. Cement pointing is done with cement mortar made by mixing equal parts of element and fine white sand. For lime pointing equal volume of lime and fine white sand is used.

9.9 TYPES OF POINTING

The following are the different types of pointing generally used :

1. **Flush or flat pointing.** This is the simplest type of pointing and is very widely used in brick masonry. The appearance of this pointing is not very good but it is more durable.

2. **Struck pointing.** It is a good type of pointing and is mostly used in stone masonry. It gives a neat appearance and permits easy discharge of water when the masonry is subjected to rain water. In this pointing the upper end of the mortar joint is pressed inside.

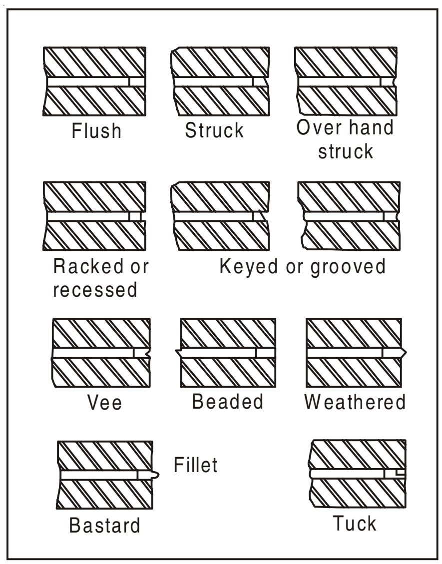


Fig. 9.1 *Varios types of pointing.*

3. **Over hand struck pointing.** This is similar to struck pointing but the lower end of the pointing is also used for stone masonry construction.

4. **Recessed pointing.** This type of pointing is used for very good quality of brick of stone masonry or for false brickwork to be shown on the

plastered surfaces. In this type of pointing the mortar is pressed behind the face of the wall.

5. **Keyed or Grooved pointing.** This type of pointing is generally used for brick walls. First of all the joints are filled up with mortar flush with the wall, then some pointed or blunt edge is pressed into the mortar.

6. **Vee-pointing.** This type of pointing is generally used for good quality stone work. The mortar is first filled with the flush walls and then it is pressed with some pointed or sharp edge.

7. **Beaded pointing.** This type of pointing has a good appearance but is liable to be damaged very easily.

8. **Weather pointing.** In this type of pointing, each joint is finished with a V-shaped raised band of mortar. This type of pointing is mostly used for brick work.

9. **Truck pointing.** This type of pointing done to old work. First of all joint is filled with mortar and then a groove is made which is filled with lime putty.

10. **Baslard of half tuck pointing.** This is similar to tuck pointing but the projection is made with the same mortar instead of lime putty.

QUESTIONS

9.1 What is the function of plastering a wall ? Why is it that the internal walls are generally plastered whereas the external walls are either plastered or pointed ? What type of mortar would you recommend for internal plastering ?

9.2 Name the various type of pointings used brick masonry. Describe in brief the process of pointing a wall.

9.3 Compare the merits and demerits of plastering and pointing a wall. Which in your opinion is better and why ?

9.4 Describe in brief the method of plastering a wall which is 5 m long and 4 m high.

9.5 What is the function of plastering a wall ? How does plastering help in protecting a wall from deteriorating and improving its appearance?

9.6 What is the function of adding lime to cement mortar for plastering external wall ? Write down the proportion for lime and cement mortars used for plastering.

9.7 What type of plastering would you recommend for the following work? Give reasons for your choice :

Ordinary residential building : Cinema Hall; and Petrol pump.

9.8 Describe in detail the process of plastering long walls.

Chapter 10

Concrete — Plain and Reinforced

10.1 GENERAL

Concrete is a composite material, which consists essentially of a binding medium within which are embedded particles or fragments of a relatively inert material or mineral filler. In Portland cement concrete, the binder or matrix, either in the plastic or in the hardened state, is a combination of Portland cement and water. If the binder or matrix is a mixture of lime and water, the concrete will be called *lime concrete.* The filler material called *aggregate,* is generally graded in size from a fine sand (or surkhi in case of lime concrete) to pebbles or fragments of stone (or brick ballast in case of lime concrete) which in some cases may be several centimetres in size. The aggregates which are smaller than 5 mm in size are called *fine aggregates* and the larger ones are called *coarse aggregates.*

The aggregates occupy nearly three quarters of the within the mass. The larger the size of aggregates, the lesser the quantity of water required, with more the strength and durability but lesser the workability.

10.2 INGREDIENT OF CEMENT CONCRETE

10.2.1 Cement

The cement to be used for concrete work, must satisfy the requirements or specifications laid down by Indian Standard Institution.

10.2.2 Fine Aggregate

Fine aggregate should consist of sand, stone screening or some other inert material with similar characteristics, having clean, sharp, hard, strong and durable grains free from dust and other injurious materials. Generally sand is used as a fine aggregate.

10.2.3 Coarse Aggregate

Coarse aggregate should consist of crushed stone, gravel or some, gravel or some other inert material, having similar properties. The aggregates should be clean, hard, durable and free from dust and other injurious materials. Generally crushed sand stone, lime stone, granite, traps, etc., are used as coarse aggregate. The size of coarse aggregate may vary from 2 to 8 cm. For *reinforced cement concrete* work, the size of coarse aggregates varies from 2 to 3 cm.

10.2.4 Water

For all cement concrete works, whether plain or reinforced, the water to be added should be fresh and drinkable. Sea water can also be used where fresh water is not available.

10.3 PROPORTIONING OF INGREDIENTS

Haphazard and careless proportioning of ingredients may even result in the failure of concrete structures. There are many methods of proportioning the various ingredients but the proportioning by weight has given the best results. But in actual practice, proportioning by volume is done, which is not so very accurate. The proportions for various ingredients by volume, generally recommended for different type of work are:

Proportion	*Name of Work*
1 :1½ : 3 and 1:1:2	For thin R.C.C. members such a pre-cast members, water reservoirs, shell roofs etc.
1 : 2 : 4 and 1 : 2½ : 5	R.C.C. works of general nature, cement concrete flooring, foundations etc.
1: 3 : 6 and 1 : 4 : 8	Unimportant work and in some cases mass concrete work.

10.4 MIXING

The dry ingredients are measured separately. The cement and the fine aggregates i.e., sand, are mixed together in a dry state, very thoroughly and intimately. They are then mixed with coarse aggregates. The three ingredients are then mixed vigorously so as to have a uniform mix. Now a *catre* thing is mixed thoroughly. Practically all concrete for large works is mixed in concrete mixture. Hand mixing does not give satisfactory results. In the concrete mixer, all the ingredients are fed from the hopper and the mixing drum rotates. It takes nearly 2 to 3 minutes and mix one batch of concrete.

10.5 WATER-CEMENT RATIO

Water-cement ratio is defined as the ratio of the weight of water and cement in a particular mix. The water cement ratio varies from 0.44 to 0.5. The water cement ratio is an important factor in the design of concrete mix. The strength of a concrete mix directly depends on the water cement ratio. The more the W.C. ratio, the lesser will be the strength but more will be the workability. The cement requires a fixed amount of water for its setting, the extra water present, will cause segregation and make the concrete porous due to which the strength of concrete will be reduced.

10.6 WORKABILITY OF CONCRETE

Workability means the facility and ease of working with a concrete mix. A workable concrete mix will be easy to handle in placing and finishing the work. There are so many factors on which the workability of concrete depends. Gradation, shape of aggregates, proportions, quantity of water and fine aggregates all have their effect on the workability of concrete. Fine sand makes more workable a mixture than coarse sand. If a concrete mix is left for an hour or so it will be found that the concrete has become more workable. But care should be taken to see that the strength of concrete should not be sacrificed for having a more workable mix.

10.7 CURING OF CONCRETE

The chemical process of gradual hardening takes place in the presence of water for a very long time. But the process of hardening takes place rapidly in early days after the concrete has been laid and gradually slows down. It is, therefore, necessary to keep the concrete structures wet, after they have been laid, and to protect them against the weathering action of atmosphere. The process of keeping the concrete surfaces wet, after their construction, is called *curing*. The curing is generally done for 7 days to 10 days. The following methods are generally applied for curing concrete:

1. By sprinkling water directly over the surface.
2. By covering the surface with straw, gunny bags, canvas, etc., and keeping them wet constantly.
3. Horizontal surfaces may be covered with wet sand or mud or by forming ponds and filling them with water to a depth of 2 to 4 cm.
4. Pre-cast concrete units may be kept immersed in water after 24 hours.

10.8 PRECAST CONCRETE

Some of the concrete units are made in the shops and then they are kept in position in the place where they are to be used. Such concrete members are called *pre-cast concrete* members. The pre-cast members are stronger, cheaper and more durable. The concrete members which are casted at the site itself, are called *cast in situ*. The pre-cast members are kept in water for 7 to 10 days, 24 hours after their construction or fabrication. The commonly used pre-cast members are small section R.C.C. beams, lintels, door and window shelves, piles, electric poles etc.

10.9 REINFORCED CEMENT CONCRETE

Concrete is stronger in compression but weaker in tension. To overcome this difficulty, steel bars are embedded into the concrete. The composite mass so obtained is called *Reinforced Concrete*. R.C.C. structures are becoming more and more popular these days. The following are the advantages of R.C.C. structures over other masonry structures :

1. R.C.C. structures are rigid.
2. If carefully designed and constructed, they are life long.
3. They are better fire resisting.
4. They are not affected by the atmosphere.
5. They require practically no maintenance.
6. Concrete can be moulded in any desired shape without any difficulty.
7. R.C.C. structures resist shocks and earthquakes.
8. Sudden failures do not occur in R.C.C. structures.
9. R.C.C. structures are perfectly damp-proof and hygienic
10. The appearance of R.C.C. structures is very good.

Disadvantages of R.C.C. Structures

1. The initial cost of R.C.C. structures is very high.
2. No additions or alterations are possible, after their construction or fabrication.
3. If constructed carelessly or in a haphazard manner, they become a perpetual source of headache as they can never be repaired satisfactorily.

QUESTIONS

10.1 What do you understand by the term concrete ? What are the various components of concrete ? What is R.C.C. ?

10.2 What are the advantages of RC.C. structures over other structures? Explain clearly the reasons of its popularity.

10.3 Write short notes on:

Water cement ratio, proportioning of ingredients, matrix, aggregates.

10.4 What precautions are necessary while proportioning, mixing and laying of concrete ? Describe the properties of various ingredients of concrete.

10.5 What should be the size of aggregates for the following works? R.C.C. structures, mass concrete work, thin R.C.C. members.

Chapter 11

Factory Buildings

11.1 GENERAL

Building is an enclosed space covered by a roof. Buildings are divided into two categories viz., Public buildings and Residential buildings. Public buildings are those which are generally not used for dwelling or living and are meant for the use of the general public. Public buildings may again be sub-divided into commercial buildings, industrial buildings, recreational buildings, educational buildings and so on. Whereas a residential buildings is that which is meant for dwelling. It is meant for a single individual or group of individuals. The residential building may be a hut or a palace.

11.2 SECTION OF SITE FOR A FACTORY BUILDING

Buildings which are primarily meant for the purpose of manufacturing goods are called *factory* or *industrial buildings.* While selecting a site for a factory building the following factors should be considered :

1. It should be very close to the source of raw materials.
2. There should be adequate availability of labour at reasonable rate.
3. It should be accessable to the market.
4. It should get adequate power supply, fuel, water supply etc.
5. It should have adequate drainage facilities.
6. It should have suitable climatic conditions for the manufacture of that particular item.
7. It should have adequate land facilities for future expansion.
8. It should have adequate facilities for docks, sidings for rail or motor transport.

11.3 REQUIREMENTS OF A FACTORY BUILDING

The factory building is the primary tool with which to carry on production into which all the other production tools and mechanism must fit. Like all other tools, the factory building must be adopted to the operation to the performed, if these operations are to be most effectively performed.

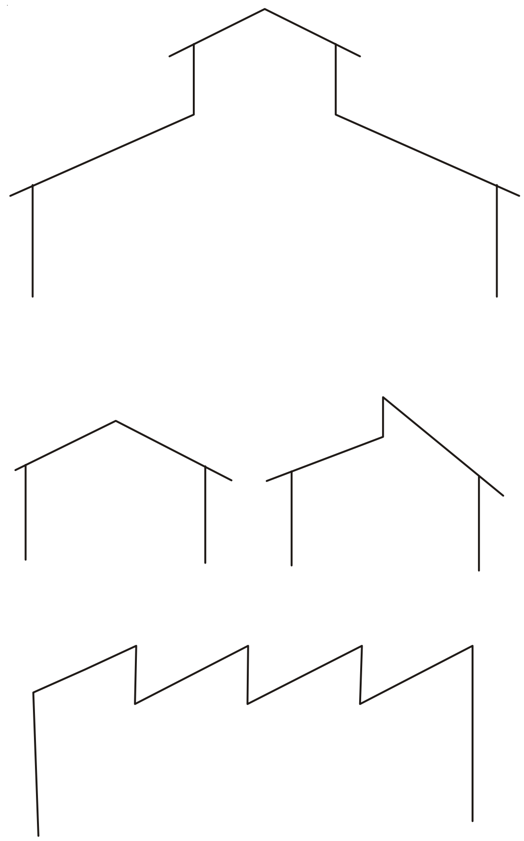


Fig. 11.1 *Factory roofs.*

Most factories require the following components :

1. Factory proper including receipt and storage of raw-materials
2. Finished goods-store
3. Canteen
4. Administrative building
5. Show room
6. Welfare center
7. Research and testing laboratories.

While planning the building for a factory care should be taken to see that every part of the factory should be well ventilated and should admit adequate natural light throughout the day. Future expansion and extension facilities should also be kept in mind.

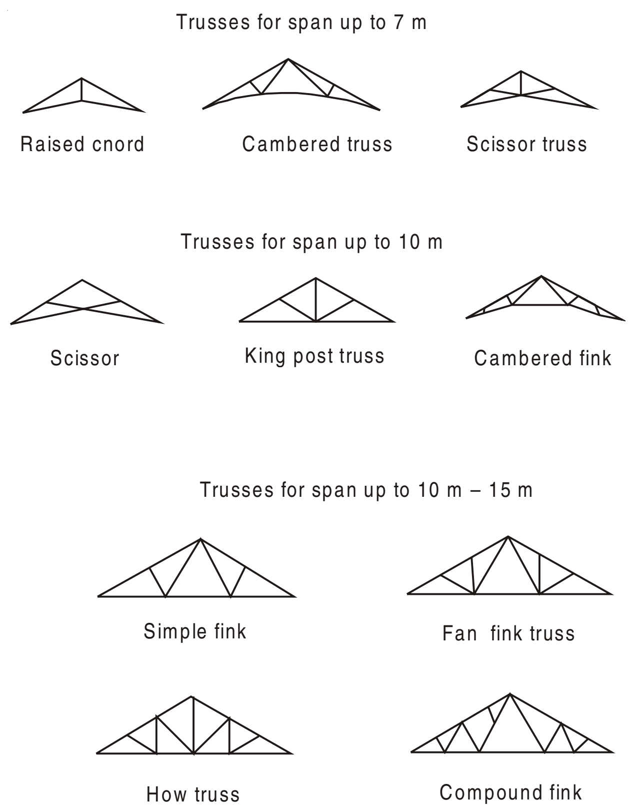


Fig. 11.2 *Roof trusses.*

11.4 FACTORY ROOFS

Very generally sloppy or pitched roofs are provided for factories, godowns, warehouses and such other components of a factory building. The reasons for providing slopy roofs are that slopy roofs can be provided over large spans without intermediate supports which create obstruction in the normal functioning. Slopy roofs provide more natural light, head rooms or clearance required for operations. Guntry cranes can be easily mounted on the trusses. Various forms of factory sheds are shown in Fig. 11.1.

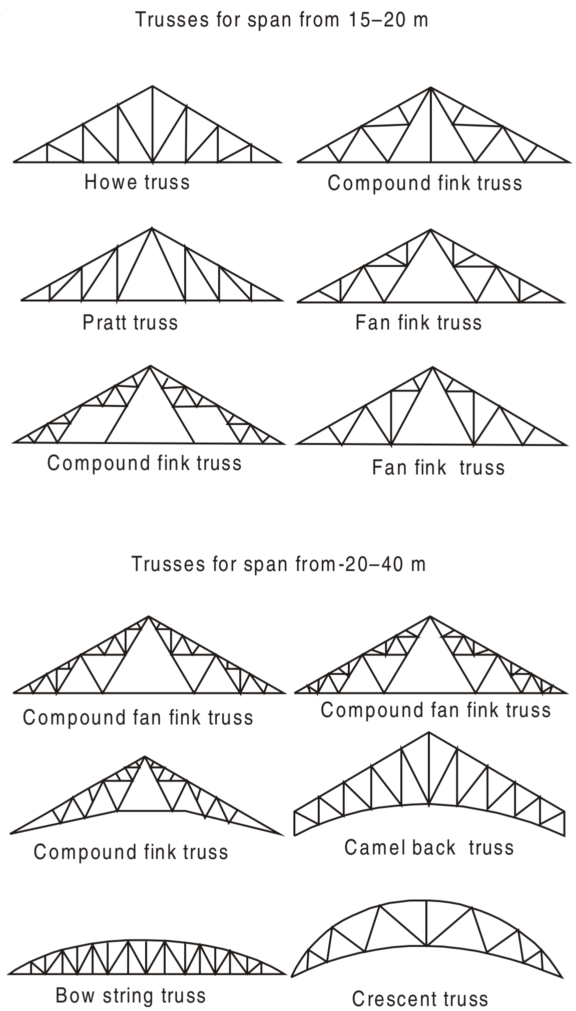


Fig. 11.3 *Detail of joints of roof trusses.*

11.5 FABRICATION OF ROOF TRUSSES

For the construction of factory roofs, steel trusses are used. The various members of the steel trusses are made up of angle and channel sections of mild steel. These members are connected by welding or riveting through steel plates, known as *gusset plates.* The various members of the truss are cut to the exact size with ± 5 mm tolerance. The gusset plates should be cut according to the shape of the joint. Then the various members are jointed together either by welding or riveting through the gusset plates. Trusses on large spans are fabricated in two or three parts and after placing them in position, they are jointed together. The various types of roof trusses used for various spans are shown in Fig. 11.2. Details of some of the joints along with the fixation of A.C. and G.I. sheets are shown in Fig. 11.3.

11.6 MACHINE FOUNDATIONS

For the smooth and efficient working of machines, foundations are provided. However, the following are some of the other objects of machine foundations.

Objects of Machine Foundations

1. It provides stability to the machine.
2. It helps to transmit the load of the machine on to the sub-soil.
3. It prevents the machine from tilting or over-turning.
4. It helps in maintaining the accuracy of the machine.
5. It helps in reducing the wear and tear of the machine components and hence increase the life of the machine.

11.7 METHODS OF CONSTRUCTION MACHINE FOUNDATIONS

There are various methods of constructing machine foundations but the main objective kept in mind is to provide stability to the machine so that it should not tilt or overturn. The following procedures are generally used for machine foundations:

(i) A trench of the required dimension is excavated. The length, breadth and depth of the trench will depend on the size and weight of the machine. Generally the manufactures used to supply the dimensions and specifications of foundation to be provided. But in the absence of any specifications, the length and width of the trench should be nearly 30 cm more than the length and width of the machine and its depth should be half the over-all height of the machine.

After excavating the trench, the bottom of the trench is levelled and properly compacted. Over the levelled bed of the trench a layer of fine sand is laid in a thickness of 3.5 cm. Over the layer of sand, lime concrete in a thickness of 10–15 cm is laid and compacted by hand rammers. Now a masonry platform (or cement, concrete platform in case of heavy machines) is constructed. Foundation bolts are grouted and the machine is fixed on the foundation bolts grouted or embedded in the masonry or concrete platform. Before finally fixing the machine, it should by properly levelled. The height of the platform will depend on the height of the machine. The height of the platform form is so adjusted that working height of the machine is reached. The height of the platform above the ground level had nothing to do with the depth of the foundation.

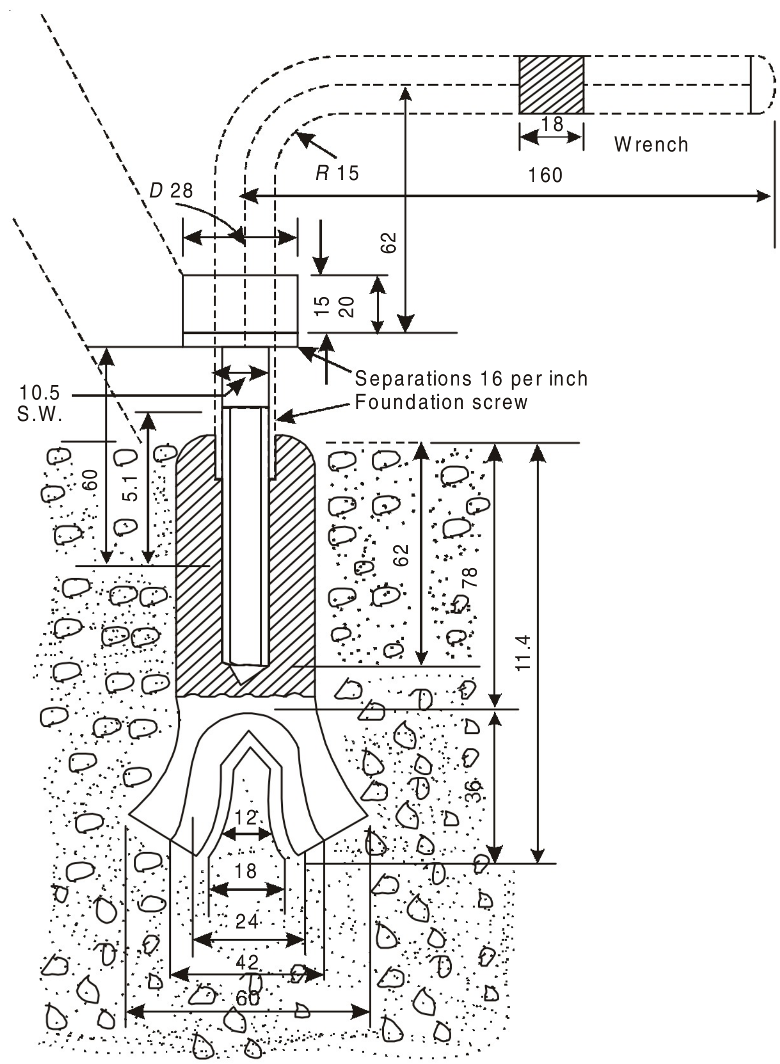


Fig. 11.4 *Foundation nut and screw.*

(b) For heavy and vibrating machine, the trench to be excavated should be trapezoidal in section. The thickness of the sand bed should be increased to 5–8 cm. After constructing the masonry or concrete platform, the trench should be filled with sand only. Sand helps in reducing the effect of vibrations of the machine.

(c) For medium and light machine, *Split bolt* foundation is used. This type of the foundation is used on cement concrete floors. The split bolt consists of a sleeve which splits and spreads when the threaded bolt is inserted into the sleeve. Thus, the bolt is firmly gripped and holds the machine. This is considered to be cheapest and efficient device of securing machine foundation for light weight and medium machines.

11.8 FOUNDATION BOLTS

Foundations bolts are used fixing machines to their foundations platforms. There are various types of foundation bolts, some of them are used only for the specific machine or specific purpose. Holes are left in the foundation platform and the bolts are suspended in the holes. The holes are then filled up with cement mortar consisting of one part of cement and three parts of sand. Sometimes instead of cement mortar, molten lead and sulphur is also used.

11.8.1 Loop or Eye Bolt

This is the simplest type of foundation bolt forged from a steel bar by forming a hook at the bottom and a threaded stem at the top. To provide more

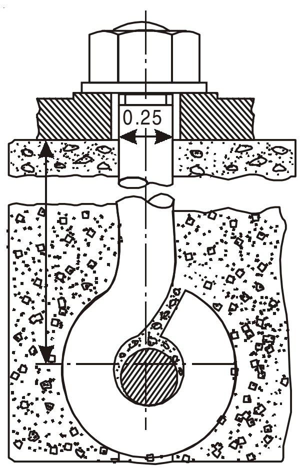


Fig. 11.5 *Loop bolt.*

anchorage a crosspiece is sometimes fixed. This type of foundation bolt is generally used for ordinary machine.

11.8.2 Bolt with a Square Plate

This type of bolt is used to distribute the load of the machine over a large area of the foundation or sub-soil. It consists of an ordinary bolt having a square neck which caries a square plate to distribute the load over a larger area.

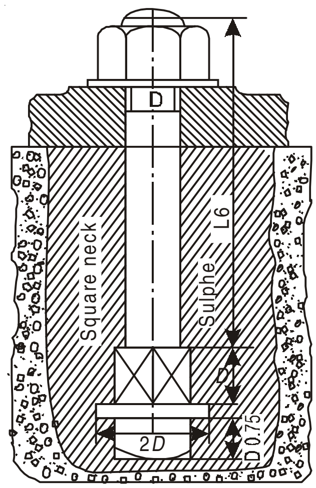


Fig. 11.6 *Bolt with square plate.*

11.8.3 Rag Bolt

This type of bolt provides better anchorage and hence it is used for heavy and vibrating machines. It is a square trapped bolt whose edges are indented

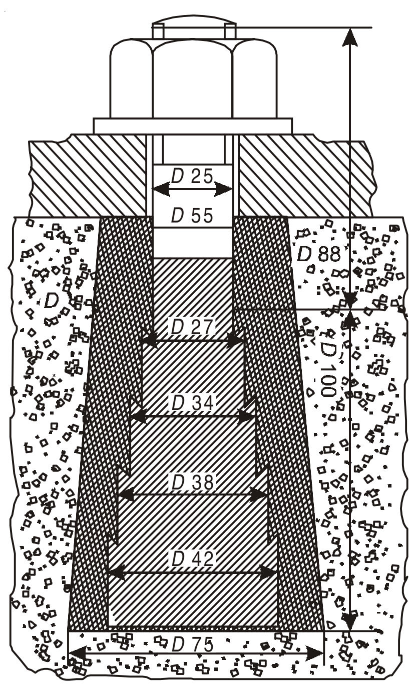


Fig. 11.7 *Rag bolt.*

or gashed so as to provide a rough surface. All those machines with exert vibrations are provided with rag bolt.

11.8.4 Lewis Bolt

The Lewis bolt is used for temporary foundations and for those machines which have a tendency of tilting of the machines are eccentric in nature. One side of the bolt is tappered which slides against a corresponding tappered

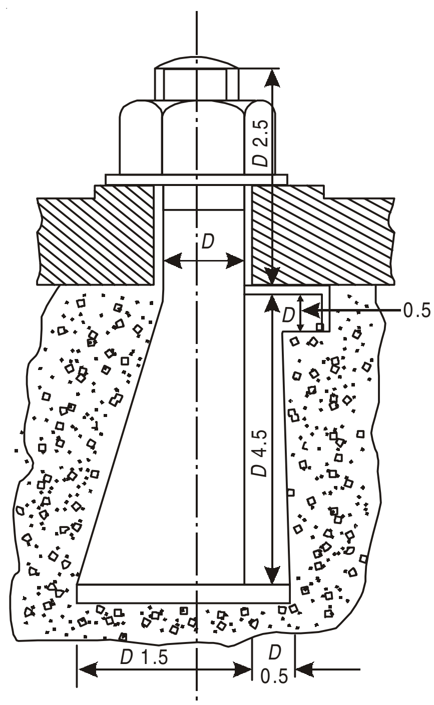


Fig. 11.8 *Lewis bolt.*

side of the foundation. On the other side of the bolt a key is provided which prevents the bolt to come out. But the bolt can be removed by simply removing the key. The bolt is fixed in the tailored made hole in the cement concrete bed or platform.

11.9 METHODS OF REDUCING EFFECTS OF VIBRATIONS OF MACHINE

One of the very important features of a machine foundation is to reduce the effect of vibration of a machine running at higher R.P.M. Vibrations cause more wear and tear of the machine components and inaccuracy of machine. Vibrations also effect the stability of the structure in general. Following are some of the methods at constructing machine foundations for reducing the effect of vibrations:

1. Machine Foundations should invariably constructed away from the main structure. There should be sufficient gap between the walls or columns and the edge of the foundation. This gap should be properly filled with sand and earth. Sand should preferably be filled around the entire foundation structure, because sand is very good shock absorber.

2. The machine should not be eccentrically placed over the foundation. The dead weight or static load of the machine (resultant of if any) should coincide with the C.G. of the contact area or base of the foundation.

3. The weight of the machine foundation should be sufficient to absorb the vibrations of the machine and resist the side thrust exerted on it due to belt pulls or other means. As a thumb rule, to minimize the effect of vibrations of the machine the weight of machine foundation should be 2.5 to 3 times the weight of the machine.

4. The effect of vibrations of a machine can be reduced to a large extend by providing rubber sheets, cork, saw dust, wooden sleepers etc. between the machine and the foundation.

5. Only light machine with less vibrations should be fixed on the upper floors.

11.10 REPAIR AND MAINTENANCE OF FACTORY BUILDING

To keep the buildings fit for living and work, it should be regularly repaired. Repair means the mending or replacing the broken portions. Regular maintenance of buildings, increase the life and living condition in the buildings. Maintenance of buildings can be divided into three groups :

(a) Periodic maintenance

(b) Causal maintenance

(c) Preventive maintenance.

11.11 PERIODIC MAINTENANCE

This maintenance is undertaken periodically i.e., after a regular interval of time. The items of the periodic maintenance consists of white and colour washing, distempering, painting and polishing cement wash etc. The time periodic of these items varies from one year to five years.

11.12 CASUAL MAINTENANCE

This type of maintenance is one which does not have any fixed time period. This type of maintenance is nothing but repairs and replacement of broken components of a building such as repair of broken plaster, repair of floors, roofs and replacement of broken wooden pans, A.C. sheets etc.

11.13 PREVENTIVE MAINTENANCE

This type of maintenance is carried as preventive measure so as to prevent any major breakdown, for example, repair of drains, down water or rain water, pipes, repair of roofs etc. before the rainy season starts. Similarly painting of steel parts before the rains so as to avoid rusting, will also be called *preventive maintenance.*

11.14 WHITE WASHING

This is the most important item of periodic maintenance. White washing is repeated every year. White washing should be done after the rains are over. Lime being antiseptic in nature, kills germs and insects, that is why inner white washing is preferred sometimes in the month of October every year to kill the insects developed during monsoons.

White washing is obtained from pure white lime or shell lime. The lime is soaked in water nearly 24 hours before the work of white washing is started. It should then be stirred so as to form a thin paste. Now more water is added. Roughly 5 litre of water will be required per kg of lime. To this solution, a little of gum and robin blue is added.

Before applying white washing, the surface should be thoroughly cleaned. In case of re-wash on old washed surface, all loose piece and scabs should be scrapped and the surface should be cleaned. After thoroughly cleaning the surface, the surface is white washed. On new surfaces three coats recommended and on old surfaces, one coat is sufficient. In the first coat the brush should be moved up and down and in the second coat right to left. The second coat should be applied when the first coat is dry. The white washing should be started from the ceiling and the top of the walls. Nearly 1 kg of lime is required for 10 sq. metres of the surface area. Rate of white washing per 100 sq. m area is approximately ` 50 to 60.

11.15 COLOUR WASHING

Colour wash is prepared by adding colouring pigment to the white wash solution. 1 to 2 kg of colouring pigment is added to 10 kg of lime. On new surfaces first of all white wash are applied in one or two coats and then colour wash. 1 kg of lime colour pigment costs nearly ` 40. The method of colour wash is the same as that of the white wash.

11.16 DISTEMPERING

It is water paint consisting of powdered chalk, colouring pigment and glue size. Ready made distempers are available in the form of finely divided powder. Distempers are either washable or non-washable. Distempers are applied on dry internal surface. On moist and damp walls, distemper should not be applied. The surface is allowed to dry and properly cleaned of all dust, loose sand etc. A coat of whitening is applied on the dry surface. This coat of whitening will act as a priming coat. Dry distemper is mixed with some water so as to form a paste. It is stirred well and added more water to form a uniform thick solution. Normally, 1 liter of water is mixed per kg of distemper. The distemper is applied on the primined surface with stiff brushed in two coats. Distemper is repeated after three years.

11.17 CEMENT PAINT

It is also a type of water-based paint containing white or coloured cement. No oil or organic matter is used. The cement paint is used on masonry and plastered walls, concrete surfaces etc. The cement paint is applied on the external walls. It is not effected by water and dampness. The paint after drying forms a strong, durable and water-resisting layer which provides strength and durability to the walls.

The surface to be painted is first cleaned, repaired and wetted with water. The paint is applied in two or three coats. Each coat after applying should be wetted properly before the second is applied so that cement should be cured. The commonly used cement paints are Snow-cem, Aqua-cem, Madi-cem, Shalimar-cem etc.

11.18 REPAIR OF PLASTERED SURFACES

The broken or peeled off plastered surfaces are cleaned and brushed. The mortar from the joints is raked out nearly 1 cm deep. The surface is then

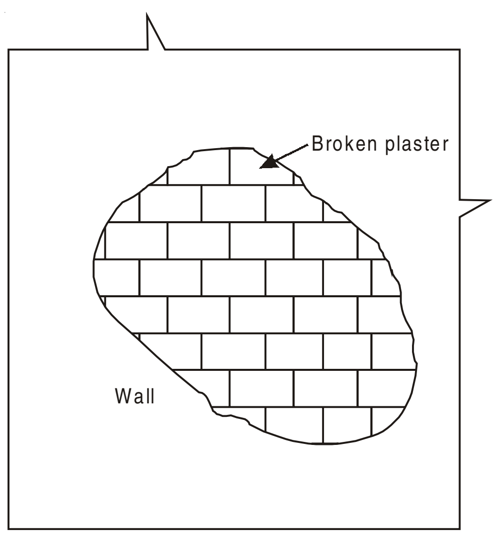


Fig. 11.9

watered. Mortar is dashed against the wall and spreaded evenly over the surface. After plastering the surface, it is cured for 5 to 6 days by directly sprinkling water over the surface.

11.19 REPAIR OF CEMENT CONCRETE FLOORS

Cement concrete floors, if constructed properly does not require any repair or maintenance. But if carelessly constructed it will be spoiled very soon and cannot be repaired satisfactorily. However, a broken cement concrete floor can be repaired in the following manner.

The broken portion of the floor is properly cleaned and soaked with sufficient quantity of water. After soaking the surface, a layer of cement concrete is spread evenly. The surface of the cement concrete should be finished by constantly stirring the concrete only. No dry cement or cement ground should be applied. After nearly twenty four hours, the surface is covered by wet gunny bags, for at least 5–6 days. The gunny bags should always be kept wet.

11.20 HEAT INSULATION OF BUILDINGS

The temperature difference between inside and outside or between the different parts of building results in transfer of heat from hotter to cooler zones. This transfer of heat may take place by any method. The main objective of thermal insulation is to conserve a constant temperature inside the building irrespective of temperature variation outside.

The thermal insulation of factory buildings is one of the most part factor to cut down the cost of maintenance by providing working comfort without investing much on artificial cooling or heating during summer or winter respectively. Thermal insulation of buildings can be achieved by properly designing and planning of buildings in such a fashion so as to maintain fairly constant temperature of the internal environment independently of the varying climatic condition externally. The temperature to be maintained in the inside of buildings depends on the use of buildings, number of persons occupying the floor, other sources of heat such as ovens, kilns, machines etc. In our country hear of buildings, except in some places in the north a hill station is not required. Therefore in most of the buildings, it is necessary to exclude the heat of the outside environment. Following means will help in achieving thermal insulation of factory buildings.

(i) The exterior or external walls should be fully thick.

(ii) Cavity walls construction provide protection from outside heat as the hollow space acts as insulating material.

(iii) Proper orientation, use of projections such as chhajas, sun shades, caves, varandahs etc. also provide protection from direct sun on the walls and hence prevent heat from outside.

(iv) The use of heat insulating materials such as slag wool, rock wool foamed slag aggregates mats, fiber boards on walls, and ceiling etc., also help in insulating the buildings again heat and sound.

(v) Providing false ceilings of fibre glass, fibre boards, thermocol, plaster of paris, convas cloth etc.

11.21 VENTILATION IN FACTORY BUILDINGS

Ventilation is a functional aspect of buildings which when satisfied afford suitable condition of living and working. Ventilation is defined as a process of removing or supplying fresh air by natural or artificial means. Good ventilation is an important factor in providing comfort in buildings. Adequate ventilation or change of air or removal of foul air is also desirable to maintain temperature limits inside a building. Poor ventilation give rise to feeling of discomfort because it causes increase in temperature and humidity. Nausia, headache, sleepiness, lethargy, attentiveness are some of the reasons of poor ventilation.

Following are some of the reasons which necessitate good ventilation in factory building in particular and other buildings in general:

1. To prevent undue concentration of body odour, smoke, fumes etc.
2. To main temperature limit within control.
3. To allow air changes inside a working place.
4. To prevent flammable concentration of gases, vapour, fumes etc.
5. To create healthy living conditions by preventing undue concentration or accumulation of carbon dioxide and moisture.
6. To prevent undue concentration of bacteria.
7. To provide natural light.

A ventilation system in a factory should meet the following requirements to achieve comfortable living and working conditions :

(i) **Rate of supply of fresh air.** The quantity of fresh air to be supplied in a room depends on the use of the room. For factories and workshops 20 to 22 m^3 per person per hour of fresh air is desirable.

(ii) **Air movements or air changes.** Air change or air movement is a must for proper ventilation of the working place. Normally 5 to 6 air changes per hour are desirable for factory or workshop. Properly designed cross ventilation give rise to desirable air changes or air movements.

(iii) **Temperature control.** It is desirable that the incoming air in a work place should be cool in summer and warm in winter. The desirable temperature for comfortable living and working varies between 20°C to 28°C.

(iv) **Humidity.** Properly planned and design also helps in controlling relative humidity in a work place. 30 to 70% relative humidity at 21°C is considered as desirable for comfortable living and working condition. Humidity is the presence of water vapour inside an enclosed space. Air changes or air movements reduce humidity to a optimum level. Too much or too less humidity cause discomfort.

(v) **Purity of air.** Purity of air plays a significant role in the comfort of people effected by a properly planned ventilation system. So while planning ventilation care should be admitted from outside. Ventilation system should not allow air containing dust, fumes, odour, or gases.

(vi) **Sun light.** Natural light has also a pleasing effect on the environment of factory. Natural light also improves the ventilation of the factory. Natural light in the morning in winter and summer as well and day light in winter is very much desirable for natural ventilation.

As per I.S.I. standards the following nouns should be followed for the factory building :

1. Area of permanent and occasional opening should not be less than 1/8th of the floor area.
2. Area of doors must be l/8th of the floor area.
3. For latrines, toilets etc. the window and ventilator area must not be less than 10% of the floor area.

Openings in a building can be permanent of occasional. Permanent openings are made by cement jali or air bricks whereas occasional openings can be windows, ventilators or doors which can be opened or closed as the case may be.

QUESTIONS

11.1 Define the following :

Foundation nut and screw; Loop bolt; Rag bolt; Lewis bolt.

11.2 How will you construct machine foundations ? Give its different methods.

11.3 What are the rules for selecting the site of a factory building?

11.4 What methods do you suggest for the repair and maintenance factory buildings ?

Chapter 12

Temporary Structures

12.1 GENERAL

During the construction of new buildings and repair of old or damaged buildings various types of temporary structures are required. These are called temporary because these are dismantled when their functions are over. Without these temporary structures, it is not possible to completely construct the buildings. Some of temporary structures are very cheap and need no special skill for its construction, but few are very typical and require special skill in its design and construction. The cost of some temporary structure is considerable, as in case of shell roofs, large span masonry arch bridge and multi-storeyed buildings etc., and directly affect the overall cost. If the design and erection of these temporary structures is not done with care, the buildings may collapse during the course of construction and may cause serious accidents. As these structures have a vital role in the construction, so that in this chapter these will be described in such a manner that reader can be familiar with them.

12.2 CLASSIFICATION OF TEMPORARY STRUCTURES

Depending upon their functions, the various types of temporary structures are classified as below :

(a) Scaffolding

(b) Centering and shuttering

(c) Underpining

(d) Shoring

(e) Bracing of trenches.

12.3 SCAFFOLDING

Scaffolding is defined *as a temporary structure in the building construction, for supporting workers, materials and tools etc. during its construction, alteration, demolition, painting and repair etc.* Scaffolding is also connected with the hoisting lowering and distribution of structural materials, tools and other appliances. Without scaffolding it is impossible to construct the buildings. There are different types of scaffoldings, which are used under different circumstances and types of works. The following are the man types of scaffoldings which are employed in the building construction:

(i) Brick layer's scaffolding
(ii) Mason's scaffolding
(iii) Needle scaffolding
(iv) Suspended scaffolding
(v) Ladder scaffolding

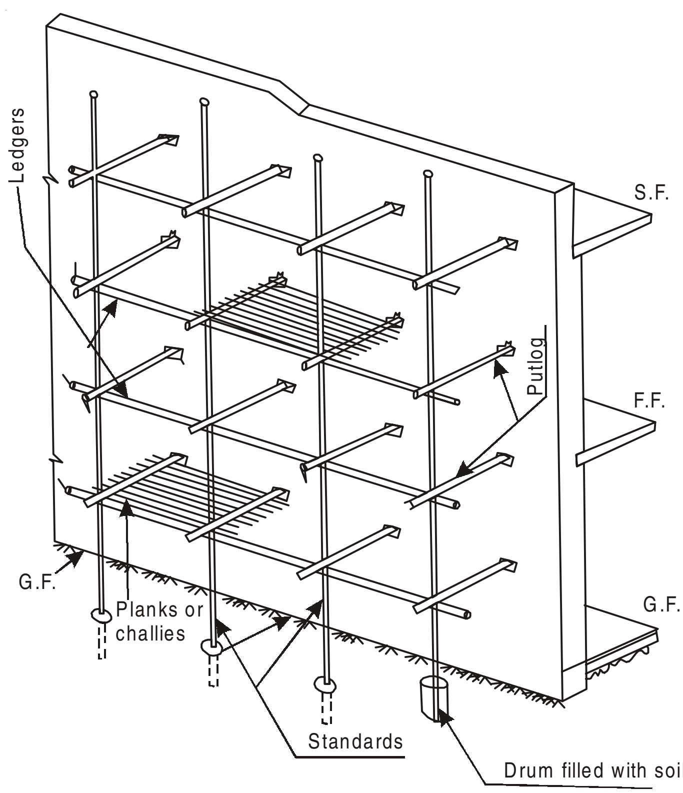


Fig. 12.1 *Brick layer's scaffolding.*

(vi) Tubular scaffolding
(vii) Gantries
(viii) Special scaffoldings.

12.4 BRICK LAYER'S SCAFFOLDING

It is also known as *single-scaffolding* and is most common due to its cheapness and easiness in construction dismantling. In India buildings are constructed with brick masonry, because bricks are cheaply available everywhere and do not require more skilled masons. For the construction of buildings with brick masonry brick layer's scaffolding is used.

Figure 5.1 illustrates the construction of typical type of brick layer's scaffold. It essentially consist of vertical members known as *standards,* which are firmly embedded in ground or in barrels filled with earth or sand. The diameter of these standards is about 10 to 15 cm and are placed 1.0 to 2.0 m away from the buildings in a row with 2.0 to 2.7 m centre to centre spacing. In India for important buildings *Bailies* of good quality are used for standards, for ordinary single or double storey buildings of some places long thick *bamboos* are also employed.

These standards are firmly interconnected means of *ledgers* of thick bamboos horizontally at 1.3 to 1.6 m spacing. The transverse bearers called *putlogs* are then placed with their one end on the ledgers and other end in the holes kept in the wall as shown in Fig. 5.1. In India thick bamboos are employed as putlogs and spaced at 1.0 to 1.3 m apart. The outer end of it is firmly tied to the ledger. For safety purpose sometimes the inner ends which on the inner side of walls are tied together by means of another bamboo so that during traverse movements the scaffolding may not fall or move away from the building from top.

For keeping materials, tools and for the purpose of platforms at different elevation. Timber boards are placed over the putlogs as shown in Fig. 12.1. In India bamboo challies are also used at some places, but these are not preferred. In case of high buildings diagonal members known as *braces* are fixed to the standards and ledgers on the outer side for giving more strength.

12.5 MASON'S SCAFFOLDING

While constructing buildings with bricks, it is easier to leave holes for inserting putlog for brick layer's scaffolding. In case of stone masonry work, it is difficult to make holes for putlogs, secondly as the stone blocks being much heavier than bricks require stronger scaffolding. Required strength and elimination of holes are obtained by providing double frames of standards with ledgers as shown in Fig. 12.2. First row of standards is erected very close to the wall at about 10 to 15 cm from the wall, whereas second row at about 1.3 to 1.7 m away from the wall. Putlogs are fixed over the ledgers. Platforms for storing materials and men are made over the putlogs at suitable heights.

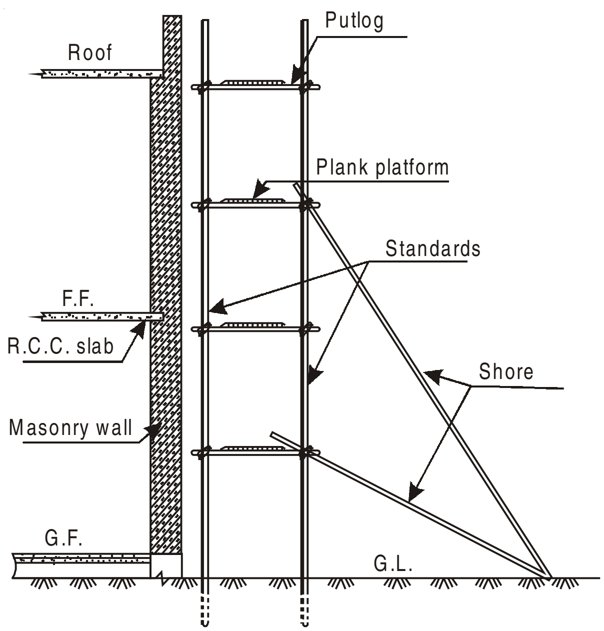


Fig. 12.2 *Manson's scaffolding.*

Diagonal braces are provided in both the rows as in case of brick layer's scaffolding. This scaffolding is completely independent of the wall, therefore to give it more lateral rigidity. Sometimes inclined members called *shores* are fixed as shown in Fig. 12.2.

12.6 NEEDLE SCAFFOLDING

This type of scaffolding is generally adopted for repairing purposes and for adding further stories in the existing buildings, when it is difficult to provide other types of scaffoldings from the ground level, due to shortage of space in lanes or due to heavy cast of scaffolding. As shown in Fig. 12.3, this type of scaffolding essentially consists of series of cantilevers called needle beams, passing through holes in the walls or windows. These cantilever beams support the temporary structure built over it, therefore its design should be done properly.

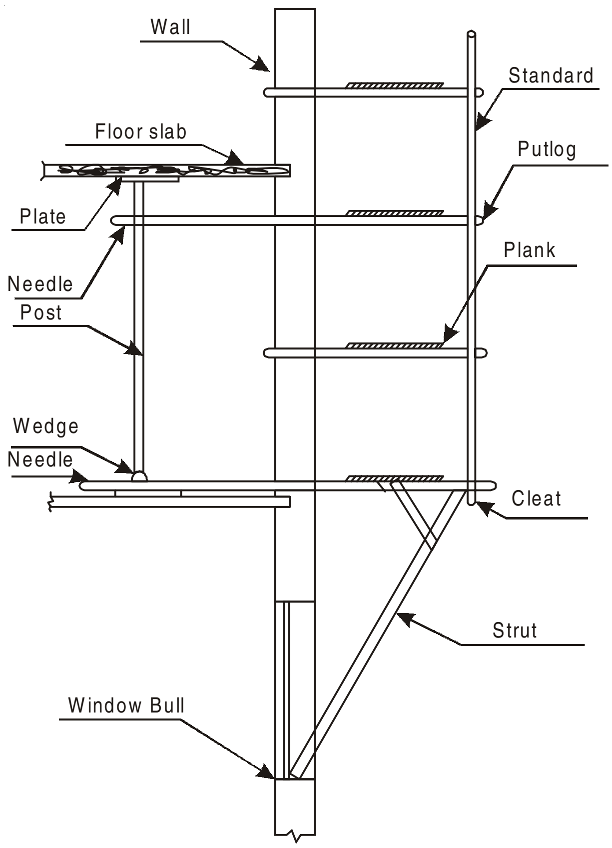


Fig. 12.3 *Needle scaffolding.*

12.7 SUSPENDED SCAFFOLDING

During the repair, cleaning, painting and erection of buildings various types of working platforms are required at various levels, which can easily provided and removed from time to time. Such type of platforms can be easily suspended by ropes or chains from the parapet wall of the buildings or cantilever beams placed at the top of structures. These types of working platforms are called *suspended scaffoldings*.

For large repair or painting work sometimes strong cradle fitted with guard rails and boards is suspended by means of wire ropes attached to the two gibs provided at some distance apart. This type of scaffolding has the advantage of permitting the longitudinal movement of the cradle for a considerable distance without shifting the supporting gibs. The vertical movement in such cases is done by operating the gears arrangement fixed on the gibs.

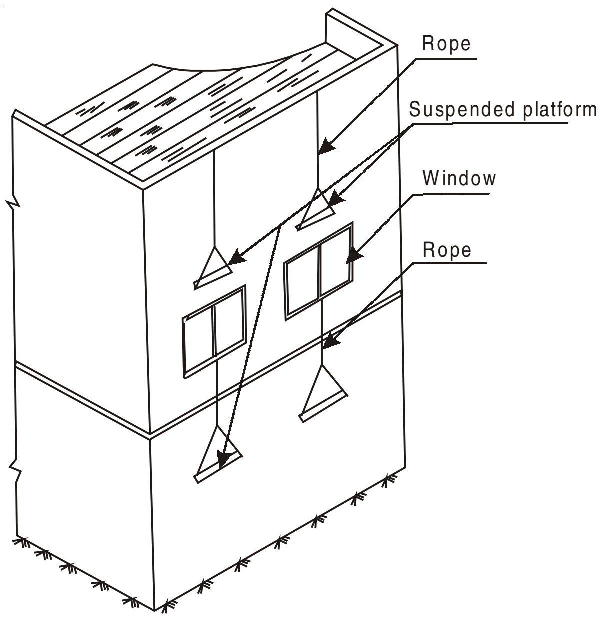


Fig. 12.4 *Suspended scaffolding.*

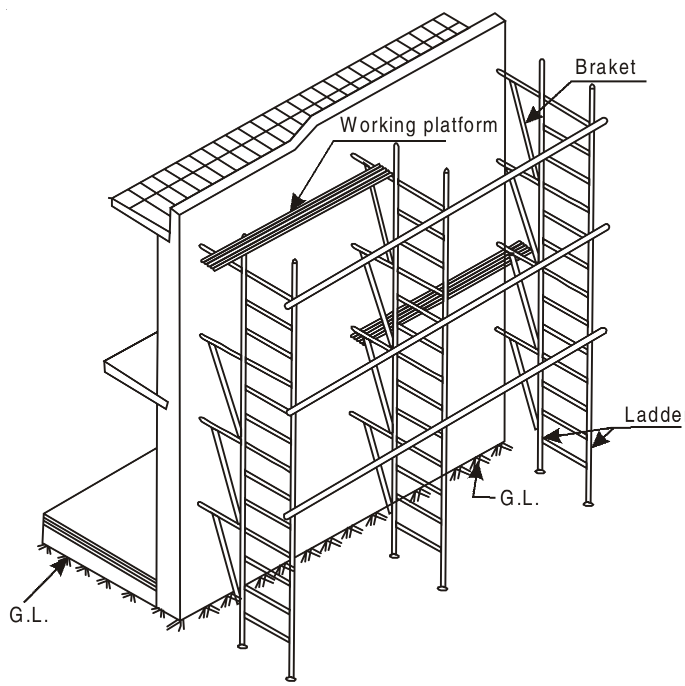


Fig. 12.5 *Ladder scaffolding.*

12.8 LADDER SCAFFOLDING

For painting of small buildings generally ladders are used, because these can be easily moved from one part to another, besides their less cost. But for the painting work of multi-storey buildings ladders are not suitable due to their limited length and difficulty in reaching the wall surface when ladder is supported inclined with wall. At such places ladder scaffoldings are provided as shown in Fig. 12.5, which essentially consists of ladders joined together by means of diagonal braces and horizontal bars which keep it in positions. The horizontal bars are fixed with windows on one side and with ladder on other side and prevent the movement of the ladders.

12.9 TUBULAR SCAFFOLDING

Nowadays steel or tubular scaffoldings are being more popular over bamboos or timber scaffoldings. Greatly improved patented tubular scaffolding consists of about 40 to 60 mm diameter weldless steel tubes which can be easily connected together by means of patent couplers supplied by the manufactures. Tubular scaffolding can be easily erected in position and dismantled quickly and transported from one site to another. These scaffolding do not require holes in the walls as in case of other type of bamboos, ballies and timber scaffoldings.

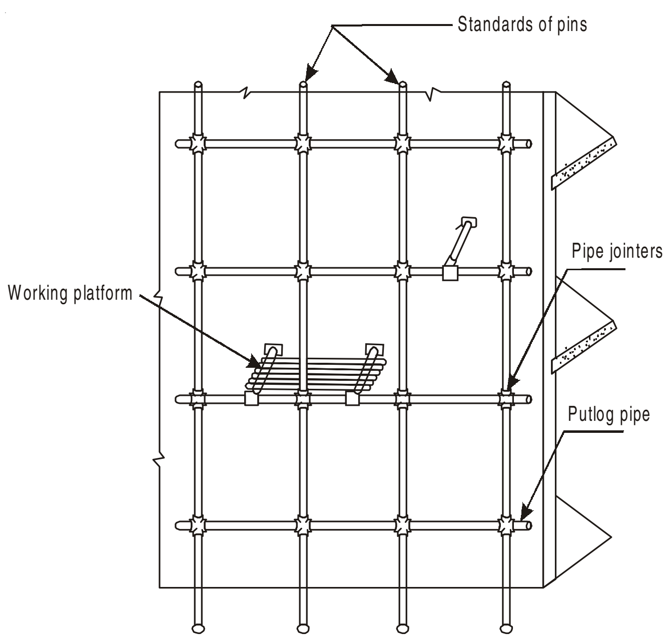


Fig. 12.6 *Tubular scaffolding.*

12.10 GANTRIES

Scaffolding are used where the masons can handle the materials themselves, but stone blocks of bigger size cannot be handled directly by the masons and they require some lifting devices. Gantry is a mechanism with the help of which stone blocks are lifted and laid in position. There are two types of gantries viz. gantry with traveller or crane and platform gantry.

12.10.1 Gantry with Traveller or Crane

This type of gantry consists of wooden *standards* generally square in section erected on either side of the wall longitudinal members called *runners* are fixed at the top of standards, on which rails are fixed. The distance between the standards vary between 2 and 3 m. The traveller consists of trussed beams with lifting tackles, which moves on the rails with the help of rails. The tackle can also move perpendicular to the wall.

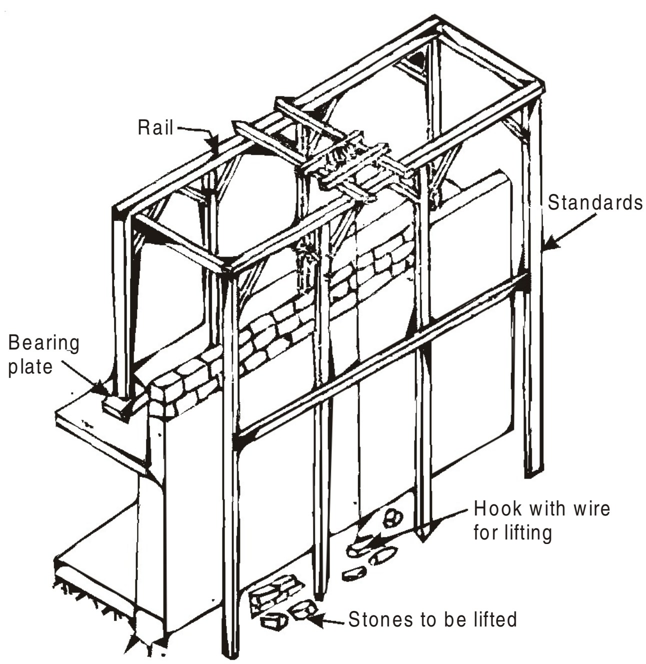


Fig. 12.7 *Gantry with traveller or crane.*

12.10.2 Platform Gantry

A platform gantry is a framed structure finished with a platform for the reception and distribution of materials and for the support of a scaffolding. This type of gantry is used when the space under the scaffolding is to be used free from any obstruction for the movement. Suppose a scaffolding is to be constructed on a footpath, naturally the passage cannot be blocked for a long time. For such situations platform gantry is used. The gantry consists of vertical posts, horizontal ledgers and braces with sufficient headway for the movement of traffic below it.

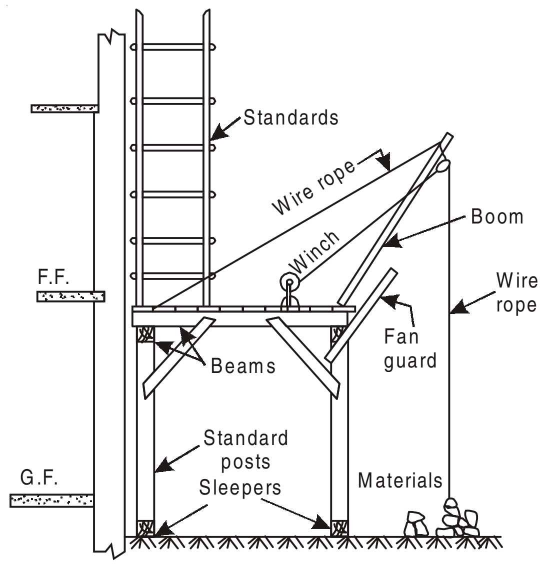


Fig. 12.8. *Platform gantry.*

12.11 CENTRING AND SHUTTERING

Centring is temporary structure used for the construction of arches, whereas shuttering is a temporary structure used for the construction of R.B. or R.C.C. structures such as beam, slab, sun shade, balcony, porch etc.

Centrings. These are shaped wooden frames provided for the temporary support, during construction of arches, vaults and domes. Centring for small arches consists of *turning pieces* only, whereas for bigger span arches, it consists of ribs, built in together the details of centring have been discussed in the chapter on *Arches and Lintels.*

Shutterings. It is also sometimes known as *mould.* It is used for the construction of R.C.C. and R.B. slabs and beams, etc. Normally it is made of timber but steel plates are also used for shuttering. Timber to be used for shuttering should be neither too dry nor too green. In one case there may be excessive swelling and in the other case leaky joints may occur tending to form cavities in the conirete. All shuttering should be properly aligned rigid enough to carry the semi-fluid concrete without distortion and must be adequately supported by struts. They should also be braced laterally especially in open air work. Considerable saving of timber and labour can be effected by planning all details in accordance with a well devised scheme, where due regard is given to erection, taking down and subsequent re-erection elsewhere on the site. Nails should be used to a minimum, wedges and clamps being preferable. Where rails are found indispensable, they should be driven in such a way that their heads projecting slightly so that the nails can be drawn out without injuring the timber.

12.11.1 Shuttering for Columns

Shuttering for columns may be square, circular, hexagonal, octagonal or any other shape. The shuttering or moulds for columns will be open at the top and bottom and should be created in such a way that concrete can be poured easily in a thickness of nearly 20 cm at a time. Moulds closed on all the four sides, should be such that while pouring concrete, segregation of concrete may not occur.

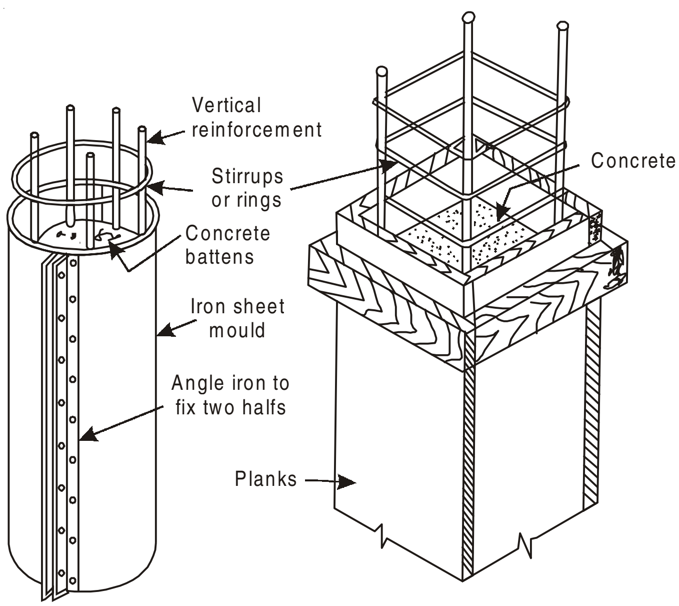


Fig. 12.9 *Shuttering for columns.*

12.11.2 Shuttering of Beams

All moulds for beams should be designed and constructed so that the sides can be removed as soon as the concrete has set sufficiently to support its own weight with object of exposing the surface to the atmosphere. The sides should be clamped at intervals so that they may not be pushed outward by the pressure of the wet concrete. The centre of the shuttering should have a camber of 1 in 200 to 300 and should be properly and rigidly propped in ordered to avoid deflection before the concrete has set.

12.11.3 Shuttering for Slabs

The shuttering for the floor slabs should be formed of boards laid between the beam moulds with closed jointed to prevent the percolation of water from the concrete. Transverse bearers should be provided to prevent sagging and the whole construction adequately supported by struts and props.

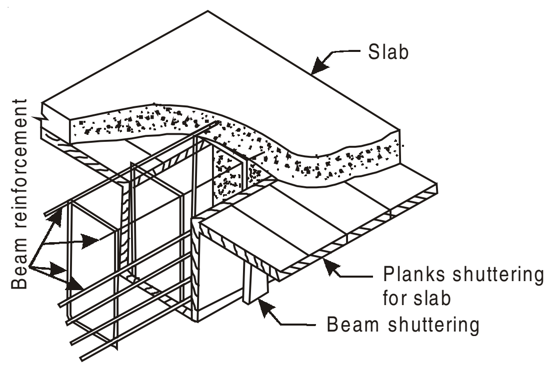


Fig. 12.10 *Shuttering for beam and slab.*

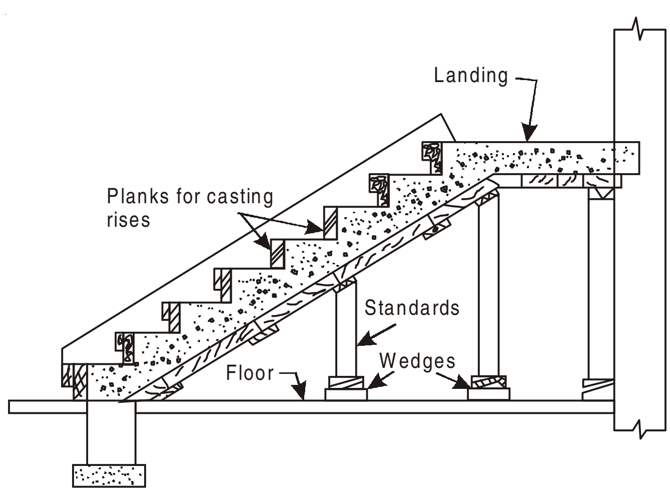


Fig. 12.11 *Shuttering for stair.*

12.12 UNDER-PINING

It is a temporary structure constructed to support a wall whose foundation is to be changed with a new foundation or the existing foundations are to be strengthened. The following situations demand under-pining the foundations:

(i) A building with deep foundations is to be constructed near the existing building.

(ii) Unequal or excessive settlement of the sub-soil, resulting in the serious cracks in the wall.

(iii) The existing foundations are to be deepened so as to increase their strength, durability and bearing power.

There are two methods of under-pining, viz. Pit method and Pile Method.

12.12.1 Pit Method

In this method the entire length of the foundation which is to be replaced is divided into suitable sections of width 1.2 to 1.5 m. Holes are made in these

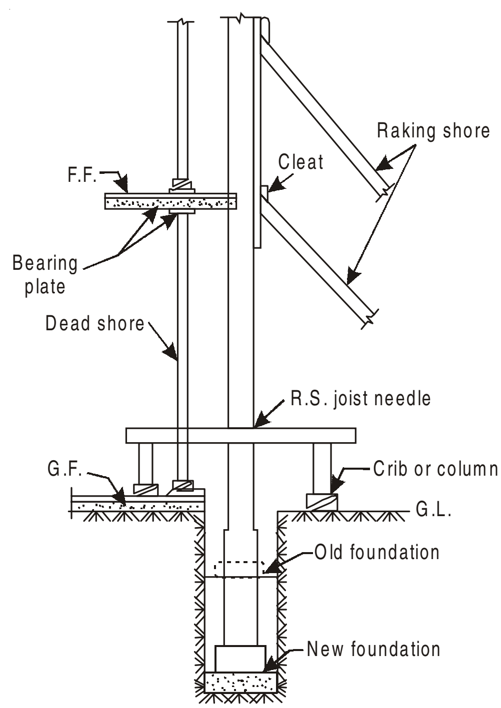


Fig. 12.12 *Pit method of under-pining.*

sections of the walls and through these holes needles with bearing plates are inserted. The needle are supported on jacks. Now the entire wall is supported on these needles. Foundations are now excavated up to the required depth and new foundations are constructed or existing foundations are strengthened. The following precautions are taken.

(i) One section should be taken at a time.

(ii) Alternate sections should be taken in succession.

(iii) Proper timbering should be provided for the trenches.

(iv) The new foundation work should be in concrete work only, if possible.

12.12.2 Pile Method

In this method, piles are driven along both the sides of the existing wall and the needle in the form of pile caps are provided through the existing wall. Thus the existing foundations are relieved of the loads of the walls. The piles are normally of concrete and their distance will vary from 1.5 to 2 m.

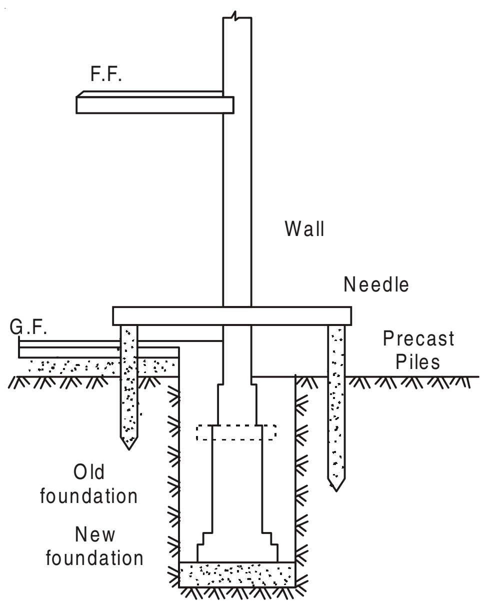


Fig. 12.13 *Pile method of under-pining.*

12.13 SHORING

It is temporary structure used to support tilted or endangered walls. The walls might have been endangered due to unequal settlement of foundations, removal of adjoining structures or making large openings in the walls.

12.13.1 Types of Shoring

There are three types of shoring, depending upon their supporting characteristics:

(i) Raking shore or inclined shores

(ii) Flying or horizontal shores and

(iii) Dead or vertical shores

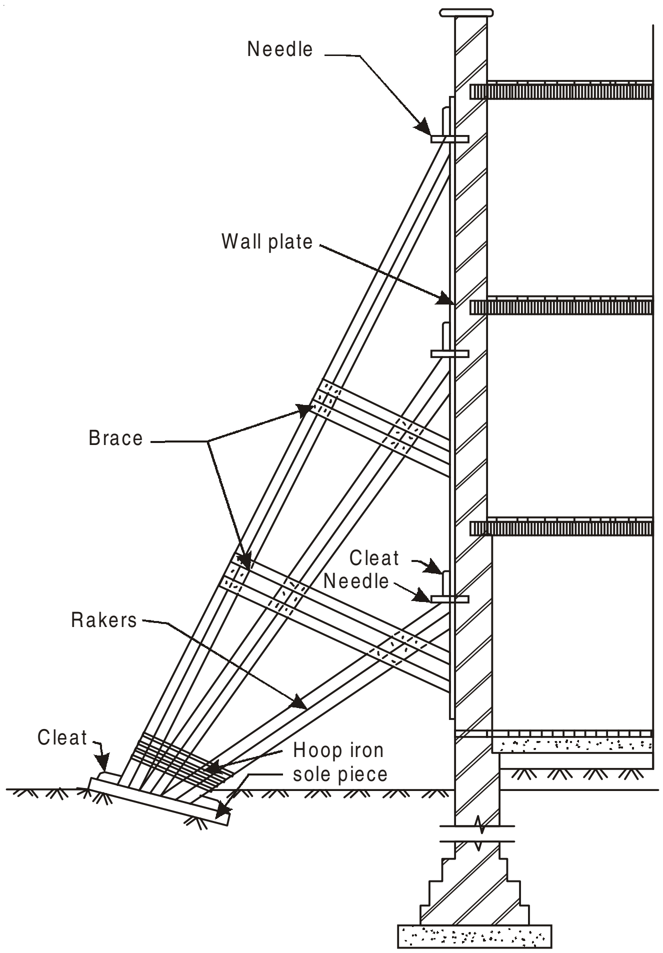


Fig. 12.14 *Raking shores or inclined shores.*

12.13.1.1 Raking Shores

These are inclined supports provided for an external wall which have been endangered. The raking shore consists of inclined members called rakers, the lower ends of which are embedded in the ground and their upper end is abutting against a wall by ball plate. The wall plates are in turn fixed to the wall with the help of needles. The inclination of the rakers is kept between 45° and 60°. The function of the wall plate is to distribute the pressure evenly. The rakers are interconnected by struts or braces or lackings. The feet of rakers are properly stiffened by braces and are connected to the sole plate with the help of iron dogs. For the construction of raking shores, the following precautions should be taken.

1. The maximum inclination of the top raker should not exceed 75° in any case.
2. The rakers should not allow the outward movement of walls and should also prevent the deflection of the roof.
3. The length of the takers should be reduced by providing *riding rakers.*
4. The rakers should not penetrate in the wall.
5. The number of rakers in a row should be equal to the number of floors in the building.

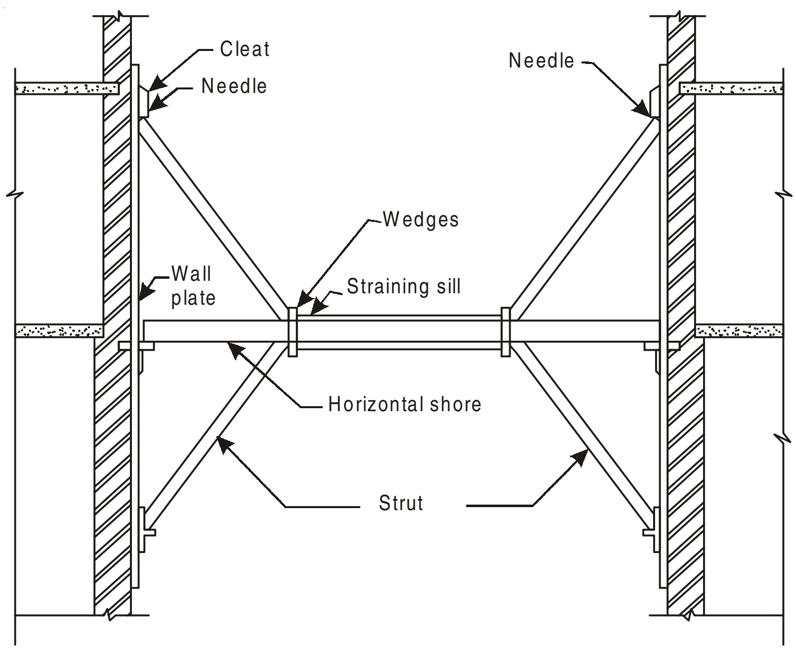


Fig. 12.15 *Flying shores.*

12.13.1.2 Flying Shore

When in a series of building, one of the intermediate buildings is to be pulled down due to some reasons or the other, *flying* or *horizontal* shores are used. In this arrangement, horizontal supports are given to the parallel walls. A flying shore consists of wall plates, needles, cleats, struts, straining pieces and folding wedges. The flying shores are generally not recommended when the distance between the walls is more than 10 m.

The method adopted in the construction of flying shore is more or less the same as of the raking shores. Wall plates are spiked to the walls which are perforated to receive the needle. For a narrow opening or lane nothing more is required than a horizontal beam stiffened by rakers.

When the buildings are of great height and of many floors, several main horizontal members must be used with their raking units or struts formed into a complex system.

12.13.1.3 Dead Shores

It is also known as vertical shore as it provides a vertical support to walls and roofs, when the lower part of the wall is to be removed for the purpose of providing an opening in the wall. The dead-shores consist of horizontal beams,

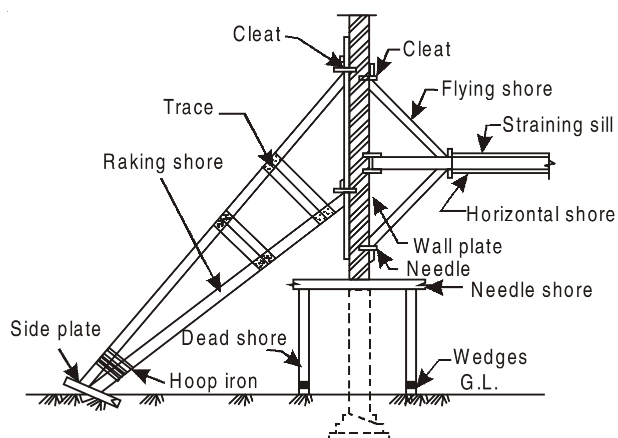


Fig. 12.16 *Dead or vertical shores.*

supported on props. Holes are made in wall at a distance of 1 m to 1.5 m. The horizontal beams pass through the holes and are supported on props called dead shores. The beams also called needles may be of timber of steel must be sufficiently strong to carry the load of the structure over it. The props are tightened with the help of folding wedges. Before dismantling the wall, all the doors and windows must be properly strutted. The floor beams, slabs etc. should be independently propped so that the walls may be relieved of the extra load.

12.14 BREACHING OF TRENCHES

It is also called *timbering*. This has been fully explained and illustrated in the chapter on Foundations.

QUESTIONS

12.1. Name the various types of scaffoldings generally used. Describe and illustrate Mason's scaffold.

12.2. What is the difference between under painting and dead shore. Illustrate your answer with suitable sketches.

12.3. What precaution will you take while pulling down an intermediate building from a series of buildings hammering close walls or common walls? Illustrate your answer with suitable sketches.

12.4. A large opining 3 metre wide is to be prompted in a brick wall, what measures do you propose for the same and how will you proceed with the work ? Recommend also the type of lintel you will provide.

12.5. Write short notes on :

(i) Brick layer's scaffold

(ii) Tubular scaffold

(iii) Gantry.

12.6. Describe in detail the construction of raking shore. Under what circumstances raking shores are recommended.

12.7. State the method of strengthening the existing foundations on their complete removal and replacement.

12.8. Write short notes on different types of shores commonly used. State which type of shore is used where.

12.9. Explain with sketches the term underpining and showing.

12.10. What do you understand by the terms centring and shuttering. Illustrate your answer with suitable sketches.

PART 2

ROAD ENGINEERING

Chapter 13

Introduction

13.1 GENERAL

A road is defined as a structure, constructed to facilitate the movement of man and material from one place to another. The vehicles, cycles, pedestrians etc., are together known as *traffic.* The term *highway,* is given to important roads in a country, a road connecting town with another one, is known as *country road* while a road within a town or city is called *urban road.* In some urban roads, running through congested areas, some portion of the road way is reserved for cycle traffic and is called *cycle track,* while some portion, generally in the centre, reserved for high speed vehicles such as motor cars, trucks, etc., is called *motor way* or *expressway*.

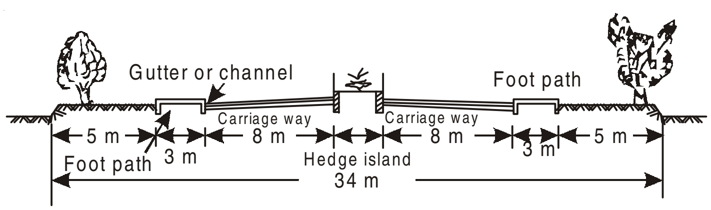


Fig. 13.1. *Cross-section of main city road.*

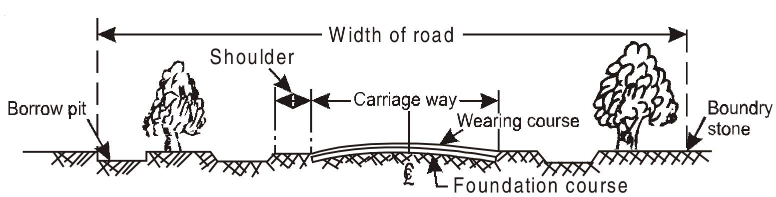


Fig. 13.2. *Cross-section of a country road.*

The carriage way is defined as the portion of the road, used by vehicular traffic. Each side of the carriage way is protected by 1.25 to 3 m wide *shoulders* or *foot paths.* Foot paths are provided in case of urban roads and are 15 to 20 cm above the road level. The shoulders provide lateral stability to the carriage way.

13.2 ADVANTAGES OF ROADS

Roads are arteries of a country. *Roads* are pre-requisite to speed and speed is essential for progress. It is difficult to enumerate the advantages of roads. Without roads, nothing is possible in a country.

The following are the main advantages of roads hence their importance for a country:

1. Roads facilitate communication on land. That is to say roads make it easy for the traffic to go from one place to another.
2. Roads help in the economic and general development of a country.
3. Roads help in the growth of trade and other economic activities in and outside the villages and towns.
4. Roads help in keeping cultural and educational contact among people.
5. Roads are essential for the defence of a country.
6. Better law and order can be maintained, especially in rural areas.
7. Roads serve as a feeder for railway, airways, waterway etc.

13.3 CLASSIFICATION OF ROADS

In India, the roads are classified as under :

1. National Highways
2. State Highways
3. District Roads { Minor District Roads / Major District Roads }
4. Village Roads.

13.3.1 National Highways

These are important roads of a country connecting important towns and capital cities of different states, and important cities to ports. Roads connecting the neighbouring countries are also called *National Highways.* The construction and maintenance of these roads is being done by Central Government departments such as Central Public Department (C.P W.D.), M.E.S, etc.

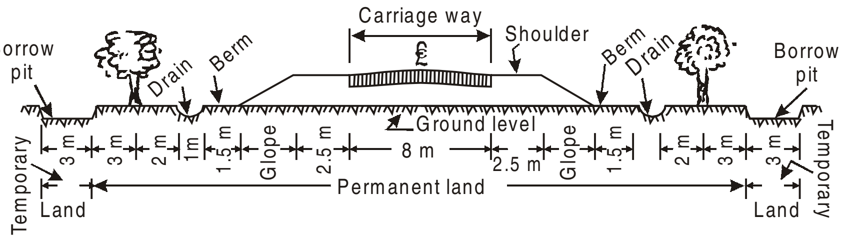


Fig. 13.3 *Cross-section of a national highway.*

13.3.2 State Highways

These roads connect important cities and district headquarters of a particular state. They also connect cities of a state with National Highways. The construction and maintenance responsibilities of these roads is the responsibility of the State Government departments such as P.W.D.

13.3.3 District Roads

These are roads which run within a particular district. They are of two types :

(a) *Minor district roads.* These roads run within a particular town or connect a town with a village.

(b) *Major district roads.* These roads connect the areas of production and markets either with state highway or railway. These roads also connect the important places or towns with the district headquarters, within a particular district.

The district roads are being constructed and maintained by district board authorities. Minor district roads are being maintained by municipal boards and corporations. The State Government also provides some grants for the maintenance of district roads.

13.3.4 Village Roads

These roads connect a village to a village or village to a railway station or a district road. The local district board authorities are responsible for their construction and maintenance.

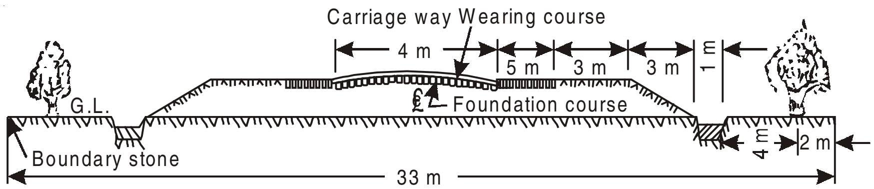


Fig. 13.4 *Village road.*

QUESTIONS

13.1. Describe clearly the importance of roads in a country.

13.2. How are roads classified in India ? Describe in brief.

13.3. Write an essay on the importance of village roads in India. What suggestions for improvement do you have in mind ?

14.4. Draw a neat sketch for the following roads : National highway, road in an urban area, a country road.

Chapter 14

Roads Standards

14.1 REQUIREMENTS OF A GOOD ROAD

The following are the requirements of a good road :

1. It should have a good carriage-way.
2. It should remain dry.
3. It should have smooth gradients, large and smooth curves.
4. It should have a good wearing surface.
5. It should be cheap in construction, cheap and easy in maintenance.
6. It should have an impervious surface.

14.2 ROAD STRUCTURE

Like other engineering structures, a road has also a foundation and super-structure. The top of the ground on which the foundation of the road rests, is called *sub-grade.* The top of sun-grade should be at least 0.6 m above the highest flood level (H.F.L.) of the area. The foundation of the road is also called Base or Soling. The super-structure of the road is called *Road surfacing,*

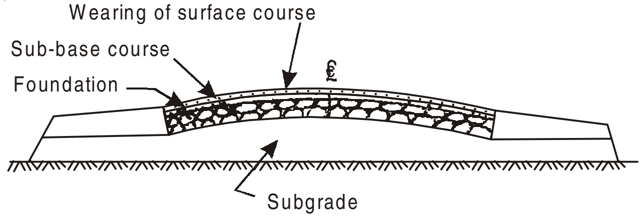


Fig. 14.1. *Structure of a road.*

wearing layer or *wearing course.* In those places, where the bearing capacity of soil is poor and the intensity of traffic is high there may be an additional layer between the sub-grade and the soling and this layer is called *sub-base*.

The soling or base is the most important part of a road. The strength and durability of a road depends on the soling. The base or soling consists of a layer of hard murum, hand packed big size stones i.e., rubble, brick or brick-bats. Lean cement concrete slab is also sometimes used as a soling. The type and thickness of soling depends on many factors, including bearing capacity of traffic etc. The thickness of the soling will vary from 8 to 15 cm. The thickness of the sub-base, if provided will, also vary from 8 to 12 cm.

The life of a road will depend primarily on a stable and dry sub-grade, when the sub-grade fails, the base and the surfacing cannot perform their function satisfactorily. For this very reason, it is essential to give considerable though to the preparation and selection of sub grade.

The surfacing consists of earth, kankar gravel, lime stone, bitumen concrete or blocks or stone. The thickness of a surfacing is decided, by keeping in view the material of surfacing, natural and quantity of expected on the road. The main function of road surfacing is to provide a smooth and stable running surface suitable for the type of traffic anticipated for that road. The surfacing should be durable, stable, non-slippery and economical in construction and subsequent maintenance.

14.3 ROAD ALIGNMENT

The course or route along which the centre-line of a road is located in the plan, is called *road alignment*. Before starting the actual construction, the centre line of the road is first marked on the plans and then on the site. The following points should be kept in mind while aligning a particular road:

1. The road length between two points should be the shortest.
2. The straight alignment is deviated when it is desired to give the benefits of a road to an intermediate town, railway station, a market place, or some important highway.
3. The road alignment should cross another road, railway line, a stream, etc., preferably at right angles.
4. The alignment should cross a river or a stream at such points where the width is minimum and where good and durable foundations are possible (for a bridge).
5. Minimum number of crossings, bridges and culverts, should be in the alignment.
6. As far as possible, alignment should not pass through thick forests, built up areas and cultivated land.

7. There should be minimum of cutting and embankment. Practically speaking, the amount of cutting and filling should be equal.
8. The alignment should ensure easy gradients and smooth curves.

14.4 ROAD CAMBER

Road camber may be defined as the gradient or slope of a line joining the top-most point on the road surface (or crown) to its edges. It is also sometimes called as *cross slope* or *cross fall* of a road.

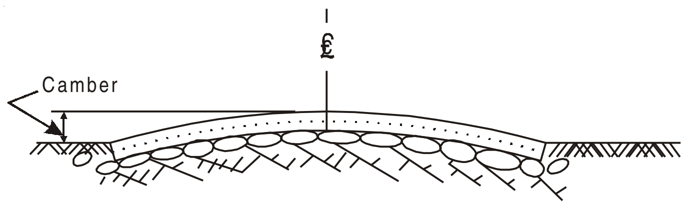


Fig. 14.2 *Road camber.*

The main object of providing a camber is to drain off rain water from the surface of the road to the side drains. The provision of camber on the road surface depends upon the following two factors viz., Rainfall in the area and the permeability of road surface, that is, the materials used for the surface layer. If the rainfall is distributed or spread over the whole year, a steeper camber will be provided; for the same surfacing material, then when the rainfall is only for a few months in a year. Similarly if the surfacing material is of an impervious nature, there will be flatter camber. The following cambers for different types of road surfacings are generally recommended.

1.	Earth roads	1 in 20
2.	Gravel, kankar or water bound mecadam roads	1 in 24 to 1 in 30
3.	Black top or bituminous roads	1 in 30 to 1 in 40
4.	Bituminous concrete, premixed carpet roads	1 in 48 to 1 in 60
5.	Cement concrete roads	1 in 70 to 1 in 80

14.5 ROAD GRADIENT

The ground surface is never dead flat, hence the road to be provided will also have rises and falls along its length. The rate of this rise and fall is called *road gradient* or grade and is usually expressed as a ratio of vertical rise or fell and the horizontal distance covered by the road. Thus, if a road rises or falls 1 metre in 200 metres length then the gradient of the road will be in 200. The gradient of road is regulated by the nature of the ground, nature of the traffic and the surfacing material used. The gradient also helps in draining off water in the side drains to some nearby *nallah* stream or river.

Steeper gradients are very inconvenient to the traffic especially the draught animals pulling the slow moving traffic like carts tongas, etc. It should, therefore, be noted that the gradient should be as gentle as possible. The gradient which should never be exceeded in any part of the road, is called *limiting gradient,* or maximum allowable gradient. Its value in plains is 1 in 20 and hilly roads is 1 in 15. It is, however, desirable to give the gradient upto a certain desirable upper limit but bellow the limiting gradient. Such a desirable upper limit of the gradient is called ruling gradient, and its value is fixed as 1 in 30 in plains and 1 in 20 in hills. It has also been found that for the efficient drainage of water from the road surface, a certain minimum gradient must be provided. Such a gradient is called *minimum gradient* and its value has been fixed as 1 in 200.

In some cases, in certain short strips of land, a gradient which may be either lower than the minimum gradient, or more than the limiting gradient, is to be provided due to some reasons or the fixed value for such gradient.

14.6 SUPER-ELEVATION

When a fast moving vehicle, such as a motor car, traverses a horizontal curve, a centrifugal force acts on the vehicle and disturbs the lateral stability

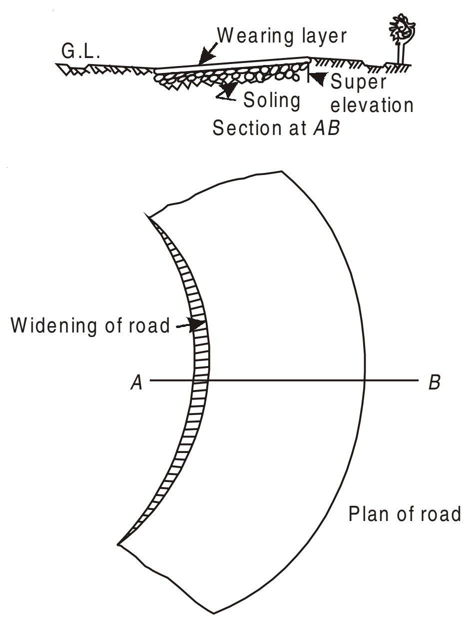


Fig. 14.3 *Super elevation.*

of the vehicle. This force is experienced by wheels and acting at right angles to the direction of motion of the wheels. If this force is greater than the frictional resistance between the wheels and the surfacing, the wheels will have a side slip. At such points, if the speed is not reduced, the outer wheels of the vehicle will be raised up from the surface and the vehicle may topple down. To counter-balance this effect, the outer edge of the carriage way is raised from the inner edge, on curves, and at all such points the chamber is removed. This raising of the outer edge of the carriage way, is called *super elevation*.

The amount of supper elevation depends on the radius of the curve, speed of the vehicle and the surfacing material.

14.7 WIDENING OF ROAD

When a vehicle negotiates a horizontal curve, the steering wheels turn sideways and occupy more space i.e., more width of the carriage way than

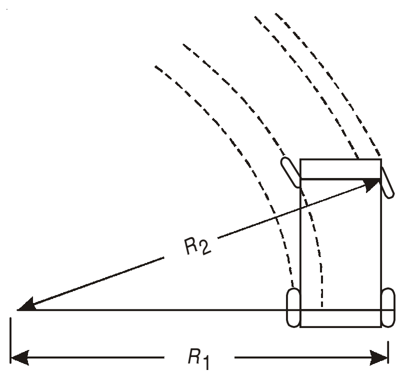


Fig. 14.4 *Showing position of steering wheels on curves.*

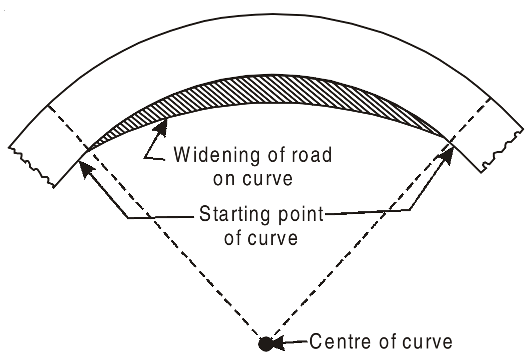


Fig. 14.5 *Widening on curves.*

on straight portions of the road. Hence the carriage way is increased on the entire portion of the curve on its inside. The widening is effected gradually, with a maximum in the central portion, when the radius of the curve is more than 460 m, this widening is not required.

14.8 SIGHT DISTANCE

Sight distance or visibility is defined as the distance measured along the centre line of a road, over which a driver of a fast moving vehicle can see the opposite object on the road surface and the provision of this distance is necessary to avoid any accident. It may also be defined as the ability to see over such a distance on the road that the driver and the pedestrians are given sufficient time to react to an emergency and thus avoid accidents.

When two fast moving vehicles negotiate a horizontal or vertical curve at the same time, but from opposite direction, a good sight or visibility of the vehicle coming from opposite direction is essential to avoid any accident.

The minimum sight distance to be provided should not be less than $d = 2\left(\frac{V^2}{2g\mu} + r\right)$ metres, where V = average velocity of the vehicle and coefficient of friction between the wheels and the surface, which is generally taken as 0.4 to 0.5.

14.8.1 Non-passing Sight Distance

It is defined as the lowest distance at which a driver of a vehicle whose eyes are supposed to be at a height of 1.3 m above the road level can see the top of the object 10 cm high from the road surface.

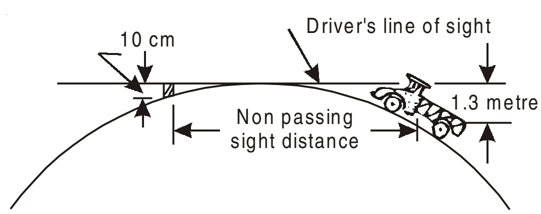


Fig. 14.6 *Non-passing sight distance.*

14.8.2 Passing Sight Distance

It is defined as the longest distance at which a driver whose line of sight is supposed to be 1.3 m above the road surface, can see the top of an object 1.3 m above the road way.

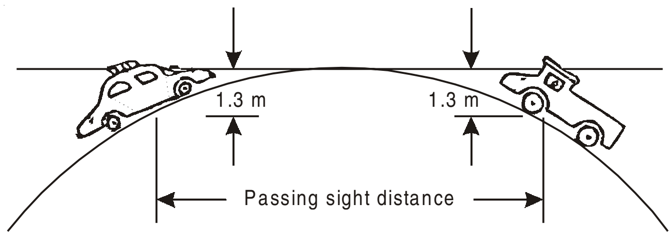


Fig. 14.7 *Passing sight distance.*

14.8.3 Overtaking Sight Distance

In a two-way carriage lane, the two-lanes are reserved for opposite direction vehicles. When a fast moving vehicle wishes to overtake another vehicle, the distance required to do so, is known as *overtaking sight distance*. This distance is measured from the first position of the vehicle to the next position to be occupied by the overtaking vehicle, as shown in Fig. 14.8.

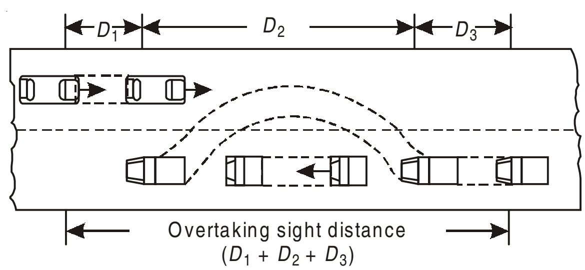


Fig. 14.8 *Overtaking sight distance.*

QUESTIONS

14.1. What do you understand by the *alignment of a road* ? What construction do you suggest while aligning a road ?

14.2. Write short notes on :

Camber, Super elevation, Gradient, Carriageway, Foot path.

14.3. What is ruling gradient and an exceptional gradient ? What is the value of a ruling gradient in plains and in hills ?

14.4. Draw a neat sketch showing the structure of road and describe the various component parts of a road.

14.5. Define the following terms :

Sight distance, supper elevation, camber, alignment, gradient, widening of road, horizontal curve, vertical curve, carriageway, borrow pits, crown.

14.6. What is the function of providing a chamber ? On what factors does the camber of a road depend ? How much camber is recommended for different types of roads ?

14.7. What is soling ? What are its functions in a road construction ? What materials are generally used for soling ?

When is sub-base provided ?

Chapter 15
Construction and Maintenance of Different Types of Roads

15.1 EARTH ROADS

The earth roads are the cheapest roads. They become muddy in rainy season and dusty in dry weather. These roads are also called fair weather roads and are mostly used in Indian villages. There are two types of earth roads:

(i) Which are constructed from the local materials available at the site.

(ii) Stabilized earth roads.

(i) In the construction of this type of roads the earth available along the alignment or road, is given proper camber and gradient. The pits and depressions etc. are filled with mud taken from borrow pits or some other elevated portions, nearby of along the alignment of the road. The surface is then compacted by hand rammers or light rollers. Such type of roads are highly unsatisfactory and are not durable.

(ii) This is a better road and is being used in most of the villages. The principle of construction of this type of road is that the earth for the purpose of road making should contain clay land sand or fine and coarse grains in the ratio of 1 and 2. Clay particles provide cohesion and bind the sand particles together, while the sand particles provide stability and reduce shrinkage and cracking of the soil. So, is the soil along the alignment is clayey, sand is brought from some nearby place and mixed with clay in the proper proportions. On the other hand, if the soil is sandy, clay is mixed with it so that the proportion of sand and clay is one and two.

In each case, the original surface is ploughed to some depth and mixed with clay or sand as the case may be. The soil is mixed thoroughly and compacted by light rollers. During the process of rolling, water is sprinkled so that the compaction of the surface is done at Optimum Moisture Content (O.M.C.). Sometimes another layer of land clay mixture is spread over the surface so prepared in a thickness of 10 to 15 cm and again rolled. During rolling, proper chamber and gradient is maintained.

The road should have shoulders and side drains on each side. Efficient drainage is essential for better service of this road. Therefore, side drains should be properly constructed on both sides of the road. This type of road will give better service.

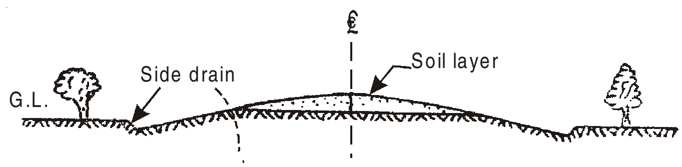


Fig. 15.1 *Earth road.*

Maintenance. The maintenance of earth roads is an important factor. After some time ruts and pot holes will be formed, due to wear and tear. These are periodically filled with earth and compacted by hand rammers. Side drains should also be repaired as the efficiency and durability of the earth roads depend on a good drainage system especially in rainy season.

15.2 ROAD STABILIZATION

It is the process of treating a soil in such a manner so as to improve or alter its physical properties so that it may become more stable and durable. The soil so stabilized will form a good wearing layer of an earth road and the road so constructed will be called *stabilized earth road.*

There are five different methods, based on different principles for the stabilizing of soil :

(i) Mechanical stabilization
(ii) Chemical stabilization
(iii) Cement stabilization
(iv) Lime stabilization
(v) Bituminous stabilization

15.2.1 Mechanical Stabilization

This method is based on the principle that if a soil contains coarse and fine particles in the ratio of two and one or if a particular soil contains sand and clay particles in the ratio of two and one, and if this soil is compacted by sprinkling water, it will have good wearing qualities.

So in this method of soil stabilization, earth is ploughed to a depth 15 to 20 cm and tested. The deficit quantity of clay or sand is mixed so that the portion is one and two then rolled to compaction at optimum moisture content (O.M.C.).

15.2.2 Chemical Stabilization

The method is based on the feet that the earth requires some amount of water to be retained in it permanently for its stability. Hence to achieve this end some hygroscopic materials (those substances which absorb moisture form the atmosphere) such as sodium chloride, calcium chloride etc., are mixed with the soil thoroughly and the soda is compacted at O.M.C. The amount of hygroscopic materials to be added will depend on the soil and atmospheric conditions.

15.2.3 Cement Stabilization

Cement is a binding material, it is mixed with the soil and compacted by adding sufficient quantity of water. The soil will then be stabilized. So in this method of soil stabilization, the earth is ploughed to a depth of nearly 10 to 15 cm and cement 8 to 12% by weight is mixed with the soil, with sufficient quantity of water. The soil is now compacted, by *sheep rollers*. After the surface has been compacted, it is cured for about a week.

15.2.4 Lime Stabilization

This process stabilization is similar to cement stabilization with the difference that instead of cement hydrated lime is used. The quantity of lime helps in preventing cracking and shrinkage of soil. After compaction curing is not necessary.

15.2.5 Bituminous Stabilization

Bitumen is a viscous material and when applied over the surface will hold the particles of clay together. So in this method of soil stabilization, the soil is thoroughly compacted. After compaction, the surface is painted by bituminous oil at the rate of 5 litres per square of space.

15.3 GRAVEL ROAD

It is a cheap type of road and is mostly used in Indian villages. Gravel can be obtained from the river beds or by crushing the stone. The surface layer of gravel consists of 6 to 36 mm size gravel mixed with sand and clay which works as a binder. The function of the binder is to bind the particles of gravel and fill up voids.

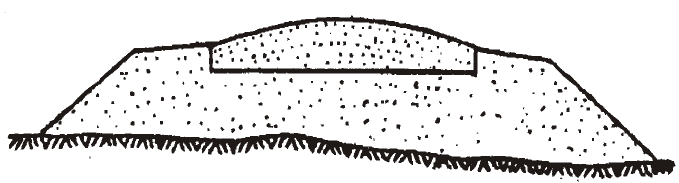


Fig. 15.2 *Trench type gravel road.*

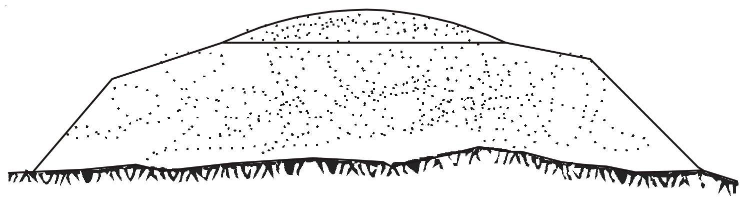


Fig. 15.3 *Feather type gravel road.*

The sub-grade is prepared and properly compacted. Proper gradient and chamber is given to the sub-grade surface. The mixture of gravel, sand and clay is spread in a thickness varying from 15 to 30 cm depending upon the intensity of traffic. This is then rolled by light roller. During the process of rolling, proper gradient and camber is maintained. The gravel is generally laid in two layers. During rolling, some quantity of water is sprinkled on the surface.

15.4 WATER BOUND MACADAM ROAD

The W.B.M. road is an important road and is very much suitable for iron wheeled traffic such as bullock-cart, but it is very much unsuitable for fast moving traffic as motor car. It was first constructed by a Scotch Engineer.

It consists of a soling of boulders, hand packed rubble, brick bats or bricks either laid flat or on edge. The soling is properly rolled by 8.10 tonne roller, to proper grade and camber. The soling or foundation layer should be at least 30 cm wider than the wearing layer. After the soling has been compacted thoroughly, a layer of nearly 10 to 12 cm thick of road metals (i.e. broken stones) is spread evenly and to be rolled to nearly 8 cm thickness. During the process of rolling, proper grade and camber should be maintained. Rolling should begin from the edges and gradually shifted towards the centre. Water is lightly sprinkled during rolling and the surface is rolled till the pieces of stone metal interlock each other and the surface becomes hard and smooth.

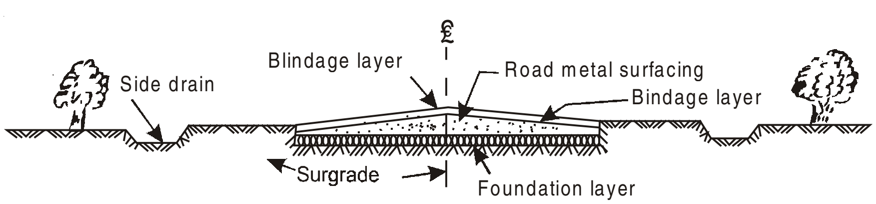


Fig. 15.4 *Water-bound macadam road.*

After this nearly 1 or 0.5 cm thick layer of muram, bajri, or kankar is spread and the surface is again rolled. This layer is called *blindage layer*. The function of this layer is to fill up the voids ; copious quantity of water is used during the rolling of blindage layer. After a day's long rolling, the surface is left for drying. Next day, the surface is again rolled and covered with 2/3 cm thick layer of coarse sand, which is called *blindage layer*. Therefore, the surface is kept wet for about 7 days and then opened for traffic.

Under the fast moving traffic, the W.B.M. road is worn out very easily. Due to the fast movement of wheels the blindage is sucked up and the road is disintegrated. The pot holes and the depressions are repaired by first cleaning the surface with brushed, wetting it and filling it with stone metals. The surface is rammed by hand rammers. Water is sprinkled and the surface is finally covered by a layer of mud, muram or sand. If the pot holes and depressions occur over a more than 2/3 portion, the whole of the surface is scrapped off and remetalled.

15.5 KANKAR MACADAM ROAD

Kankar is granular lime stone, containing nearly 30% of clay. Kankar is also sometimes used as a road metal. The road made of kankar is known as *Kankar Road* or kankar macadam road. The construction of this road is similar to W.B.M. road. Only instead of road metal, kankar is used. It is rolled with light rollers as under the heavy rollers, the kankar is likely to be crushed.

The kankar road is mainly used in villages and is only suitable for light traffic of bullock carts, etc. It becomes muddy in rainy season and dusty in dry weather. Under the heavy iron wheeled traffic the road metals are crushed and the road disintegrates.

15.6 SURFACE PAINTED OR BLACK TOP ROAD

Surface painting, surface dressing or surface treatment is a kind of Bituminous surface treatment in which a film or coal tar or bitumen is applied on the prepared top of a road foundation and on this film, is spread a thin layer of stone chippings having nearly 2 cm thickness and its purpose is to seal the foundation layer. The foundation may be W.B.M. surfacing, stabilized gravel layer or a stabilized soil. Surface dressing is given to W.B.M. surfacings either on existing one or newly constructed. If a W.B.M. road is to be given surface treatment, the blindage and blindage layers should not be provided.

In case of an existing W.B.M. road, the surface is brought to the required gradient and camber by necessary repairs etc. This is called *re-conditioning*.

It is then cleared with the help of wire brushes and then surface dressing is applied.

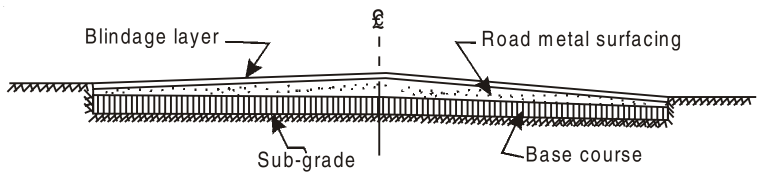


Fig. 15.5 *Surface painted road.*

The tar or bitumen is either applied hot or cold. In the process, the tar or bitumen is heated to a temperature of 120°C and is applied over the prepared surface in an uniform thin layer. Stone chippings are then evenly spread over the surface. The grit is first hand packed and then rolled by light rollers. The coal tar is used at the rate of 20 kg per sq. metre of the road surface and the stone chipping at the rate of 15 m^3 per sq. metre of the surface.

In the cold process, rapid setting emulsions are spread at the same rate and over it grit is spread at the rate of 1 m^3 per 100 sq. metre of the road surface. The emulsion contains water. So after spreading the water evaporates and emulsion becomes thick and holds the chippings together firmly. The cold process is used in hot countries, especially when the road construction is to be done in hot weather.

The above type of surface dressing to water Bound Macadam surface is called *single coat surface dressing*. It is suitable for mixed traffic consisting of motor cars, trucks etc. and bullock carts, of light intensity. This type of road is better than ordinary W.B.M. road as it cannot be easily integrated under the fast moving traffic.

The maintenance of this road is very simple. The pot holes are cleaned with a wire brush. Coal tar is applied and grit is hand packed and then compacted by hand rammers.

15.7 RENEWAL COST SURFACE DRESSING

Due to constant wear and tear, the surface is worn out under the mixed traffic. If pot holes and ruts appear on more than two-third or road surface in a particular portion of the road, a renewal coat is necessary. The surface is cleaned and the worn out portion scrapped if necessary. After cleaning the surface, bitumen is applied in a uniformly thin layer. When the bitumen has become tacky, stone chippings are broadcast at the rate of 15 to 100 m^3. The size of chippings should not be more than 1 mm. The bitumen to be applied should be 1.5 kg m^3 of the road surface. The surface is then properly rolled. During the process of rolling, proper camber and gradient should be maintained.

15.8 BITUMEN MACADAM ROAD

This type of road is suitable for heavy bullock-carts as well as for fast moving traffic. In this type of road construction the macadam i.e., road metal, is bound together with the help of tar or bitumen.

The foundation is prepared as usual. Over the foundation bed, road metal in a thickness of 8 to 10 cm is laid and rolled dry to compaction. Hot coal tar or bitumen poured from the top with the help of a spout or a spraying machine and over it stone chips or grit is broadcast uniformly and the surface is rolled to compaction.

This treatment can be given to the existing W.B.M. surface also. The surface is reconditioned by necessary repairs. After cleaning the surface, coal tar or bitumen is poured from the top and over it a layer of gut, bajri or stone chips is spread and the surface is rolled properly, maintaining proper gradient and camber. The amount of coal tar to be used varies form 5 to 8 kg/m of the road surface.

QUESTIONS

15.1. Describe the construction of an Earth road. What modification do you suggest for making the earth road more durable and giving better service ?

15.2. What is a Water Bound Macadam road ? How is it constructed ? Describe the advantages of a W.B.M. road over that of an Earth Road.

15.3. Describe the construction of a Black Top or surface painted road. If the surface treatment is to be given to an old W.B.M. surface, what precautions are necessary, before the treatment is given ?

15.4. What is road stabilization ? What are its advantages ? What are the different methods of road stabilization ?

15.5. Describe the construction of a kankar macadam road. Where is this type of road used ? How does this type of road differ from a W.B.M. road ?

Chapter 16

Hill Roads

16.1 GENERAL

Hill roads are also called *ghat roads* in India. Hill roads present more difficulty in their design, construction and maintenance. These roads are very dangerous and sometimes fatal accidents occur on such roads. Hence very special care is taken in their design and construction.

16.2 TYPES OF HILL ROADS

Hill roads may be classified as

(i) Bridle paths

(ii) Village paths or tracks and

(iii) Motor roads.

16.2.1 Bridle Paths

These are meant for pedestrians and other pack transports such as horses, ponies etc. They are 2 to 2.5 metre wide, having a ruling gradient of 1 in 10. The maximum permissible gradient is 1 in $7\frac{1}{2}$. This bridle paths serve as feeder for motor roads or main communication system. The surfacing of bridle paths may be W.B.M. kankar, earth or natural surface brought to the required camber and gradient. Side drains should also be provided for such paths to keep the surface in good running condition.

16.2.2 Village Paths

These are *katcha* or un-metalled paths, connecting interior villages and other working places with each other or with the bridle paths. The width of village path varies from 1 metre to 1.5 metres. The natural surface is levelled by filling the depressions or cutting the elevated portions, for the construction of village paths.

16.2.3 Motor Roads

These are actually the roads which may be called *Hill roads.* In the following lines, we shall be discussing the principles of design and construction of these types of roads.

16.3 ALIGNMENT OF HILL ROADS

The success and utility of a hill or ghat road depends on the proper and careful alignment. During the alignment of such roads, care should be taken to see that the road is as short as possible, but should have easy gradients, smooth curves and good foundations. In the alignment of the road, a number of sharp curves such as *hair pin* bends, *corner* bends, zig-zag bends etc. will have to be provided. At such points special care should be taken during alignment. As far as possible, the minimum radius of the curve should be metres and desirable radius 30 metres.

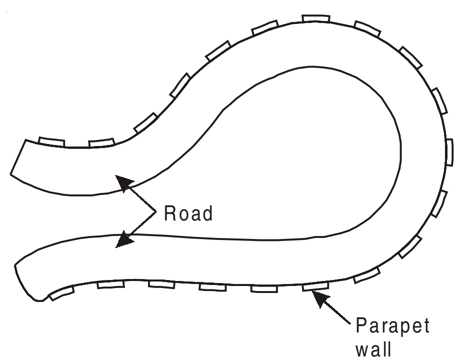


Fig. 16.1 *Corner bend.*

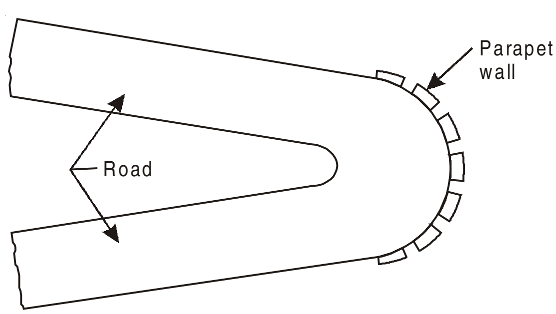


Fig. 16.2 *Hair pin bend.*

The main aim of the alignment should be to establish the easiest, shortest, and most economical line communication between the obligatory points in consideration of the physical features of the country and the traffic need of the area served. The principle which the engineer should keep in mind is *m* align the road in such a way that the vehicles can travel with case and in safety and the expenditure of motive power and wear and tear of the vehicles should be reduced to the minimum. The cost of construction and subsequent maintenance of the road should also be as low as possible.

16.4 HILL ROAD FORMATIONS

The top of the soil, on which the road is constructed, is called *formation.* The formation of a hill road may be :

(i) Wholly in cutting.

(ii) Partly in cutting and partly in embankment, or

(iii) Wholly in embankment.

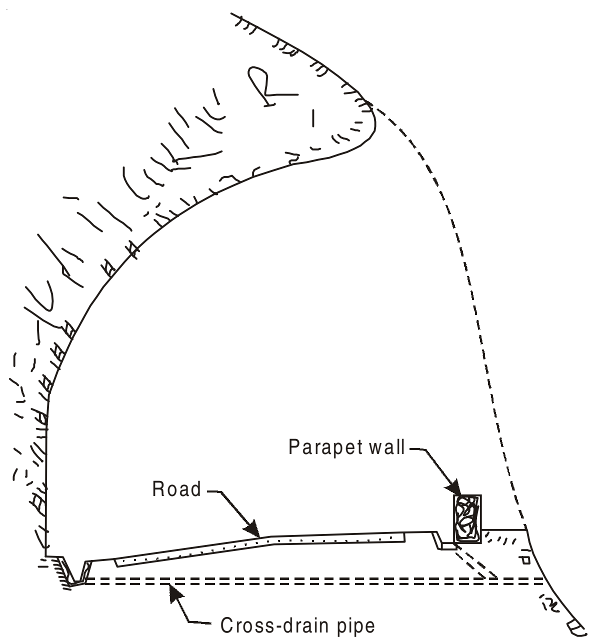


Fig. 16.3 *Road in half tunnelling.*

(i) The road in cutting means, when the road to be aligned in such places where the hill side slope is very steep. Road in cutting may be either in half tunnelling or full tunnelling as shown in Fig. 16.3. Road in full tunnelling is generally avoided. In general, road in cutting is avoided as far as possible.

(ii) Hill roads are generally constructed partly in cutting and partly in embankment. The ideal road section may be *two-thirds* in cutting and *one-third* in embankment.

In this case, the road formation is partly on the natural cut surface and partly on the filled up portion.

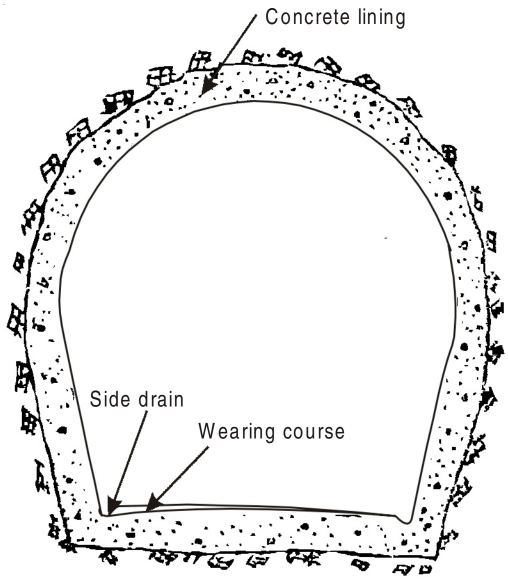


Fig. 16.4 *Road in full tunnelling.*

(iii) Sometimes the entire road will have to be taken in embankment. This happens when a depression comes in the alignment. In this case, too,

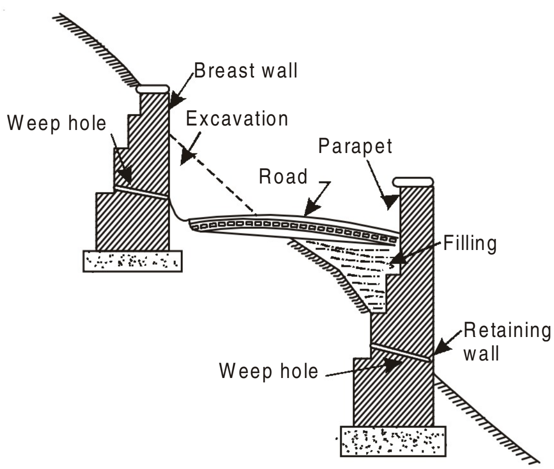


Fig. 16.5 *Road partial cutting and partial banking.*

retaining walls, one on each side of the road, will have to be construction. This type of construction is very costly and hence avoided as far as possible.

16.5 RETAINING AND BREAST WALLS

These have been described in the subsequent pages.

QUESTIONS

16.1. Write short notes on :

(a) Bridle path
(b) Retaining and Breast walls
(c) Hair pin bends
(d) Corner bends.

16.2. What are the essential points to be kept in the mind while aligning a hill road?

16.3. Draw the cross-sections of hill roads in the following cases :

(i) Full tunnelling
(ii) Partial half tunnelling
(iii) Full embankment
(iv) Partly cutting and partly embankment.

PART 3

W A T E R S U P P L Y E N G I N E E R I N G

Chapter 17

Sources of Water

17.1 GENERAL

Water is available on earth in abundance. The primary source of water is *rain and snow*. When rain and snow fall on the ground, a part of their water flows in the form of rivers, streams, lakes etc., a portion of water percolates into the ground while the remaining portion evaporates. The rivers, streams, lakes, ponds, reservoirs, etc. are called *surface water sources,* whereas wells, springs, etc., are known as *groundwater or sub-surface water* sources. Water to be used for industrial or domestic purposes can be had either from the surface water sources or sub-surface water sources depending upon the availability conditions and economy. The different sources of water are described briefly in the following paragraphs.

17.2 SURFACE SOURCES

17.2.1 Streams

When rain water flows over the mountains, streams are formed. During rainy season their discharge becomes much more as compared to summer and winter. The quality of water of streams is normally good but sometimes mineral impurities, sand and clay are mixed in it and make it *contaminated.* These suspended impurities can be easily removed in settling tanks. From mountains streams flow into the valleys and are the main source of water supply.

17.2.2 Lakes

At some places in hills natural basins are found with impervious beds, to which water flows from various streams and springs. The water is collected and lakes are formed. The quantity of water in lakes depends on its catchment area. The quality of water is good because all the suspended matter settles on the bed and clear water is available at the top, which can be used without any treatment. Lakes are the main source of water in hilly regions such as Nainital.

17.2.3 Rivers

Large number of streams when combined together in hilly regions form a river, the discharge of which goes on increasing as it moves forward due to the increase in its catchment area. Rivers contain the maximum quantity of water, therefore most big cities are developed along the banks of rivers. This source of water is available only to those cities which are situated near them. In summer the quality of river water is better than in monsoons, because in the rainy season water from catchment area flows towards river and carries silt, sand, clay etc., with it, which makes the water *turbid.* At some places where sewage is disposed of in rivers, it causes pollution upto a certain distance. Both due to self purification (natural purification) the water becomes clean. But even then river water should be used after purification. Perennial rivers which flow throughout the year do not need reservoirs, but others which dry up partly or wholly require reservoirs to meet the water demand during dry weather.

17.3 IMPOUNDED RESERVOIRS

It is mostly found that there is a great variation in the quantity of river water during monsoons and dry weather. In some rivers the flow of water

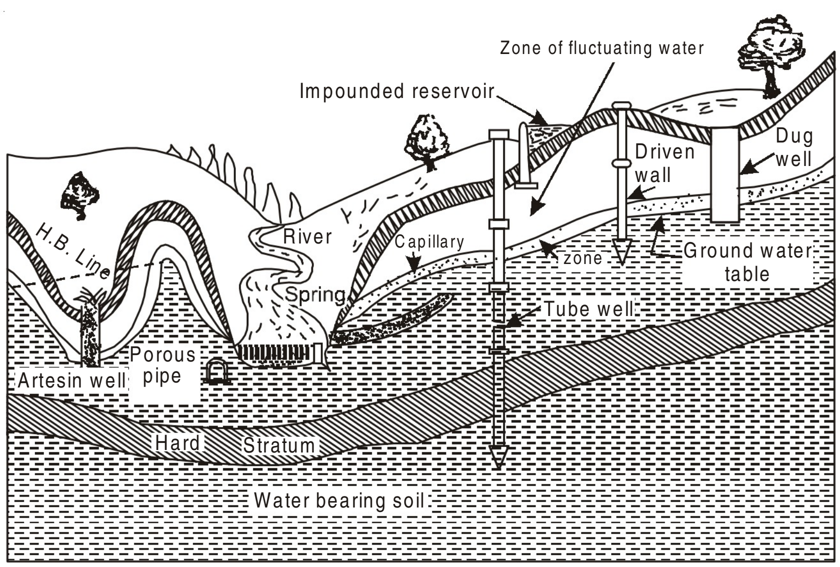


Fig. 17.1 *Different sources of water.*

remains sufficient to meet the demand, but in some rivers the flow becomes very small and cannot meet the requirements of hot weather. In such cases it becomes essential to store water for dry weather demand, which can be done by constructing a bund, a weir or a dam at such places where minimum area of land is submerged in the water and the reservoir basin remains cup-shaped having maximum possible depth of water.

17.4 STORED-RAIN WATER

At some places, where neither surface water nor ground water is easily available, the rain water can be stored in water-tight tanks at ground level with the help of channels. These channels allow the rain water to flow into the tank. But the quantity of water stored in this way is limited and can never be utilized for water supply schemes on large scale.

17.5 PONDS

These are depression in plains like lakes of mountains, in which water is collected during rainy season. Sometimes ponds are formed when much excavation is done for the manufacture of bricks, katcha houses in villages or embankment for roads and railways. Usually the water of ponds is used for washing clothes, animals, bathing and drinking. In most backward villages people also take bath in these dirty ponds. Generally all the used foul water flows towards the ponds and therefore water of pounds should not be used for drinking purposes even after purification.

17.6 GROUND SOURCES

17.6.1 Springs

In hilly regions at some places sub-soil water table gets exposed on the slope and springs are formed. These are generally of two types : (a) Surface springs, (b) Deep seated springs. The main difference between them is the deep-seated springs are formed when pervious stratum between two impervious stratum is exposed, while there is no impervious stratum above the water table in case of surface springs. The water of surface springs is not so pour as compared to that of deep seated springs. The quantity of water is more in deep seated springs than surface springs. Generally mineral impurities such as salt, sulphur and iron are dissolved in it and change its taste. In some hilly villages these are the only sources of water.

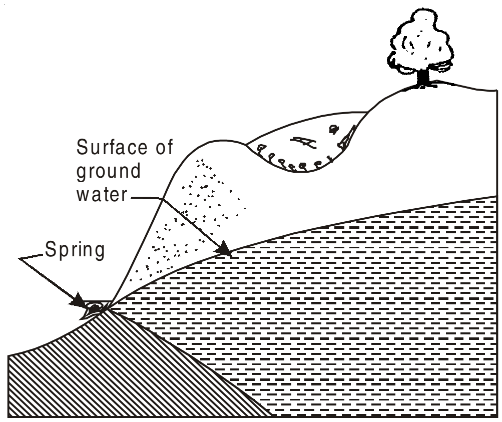


Fig. 17.2 *Surface spring.*

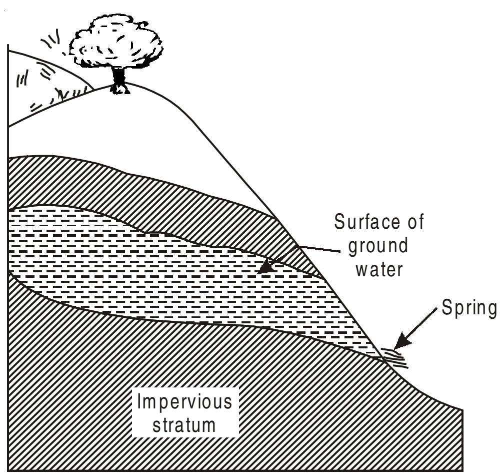


Fig. 17.3 *Deep-seated spring.*

17.7 WELLS

Wells can be classified into the following categories :

1. Shallow wells
2. Deep wells
3. Tube-wells
4. Artesian wells
5. Infiltration wells

17.7.1 Shallow Wells

These are also called Dug wells or Gravity wells. These are the ordinary type of wells of 3 to 6 metres diameter and upto 30 metres or more below the ground depending upon the sub-soil water-level. These are most popular in rural areas for drinking and irrigation purposes. People irrigate their field with the water of these wells if canal irrigation is not available. They are very cheap in construction and maintenance. In some rural area where irrigation facilities are available, dug-wells are constructed for getting drinking water. These wells should be kept covered on the top and occasionally $KMnO_4$ should be added to its water to remove bacteria. Figure 17.4 shows the essential parts of Dug-well.

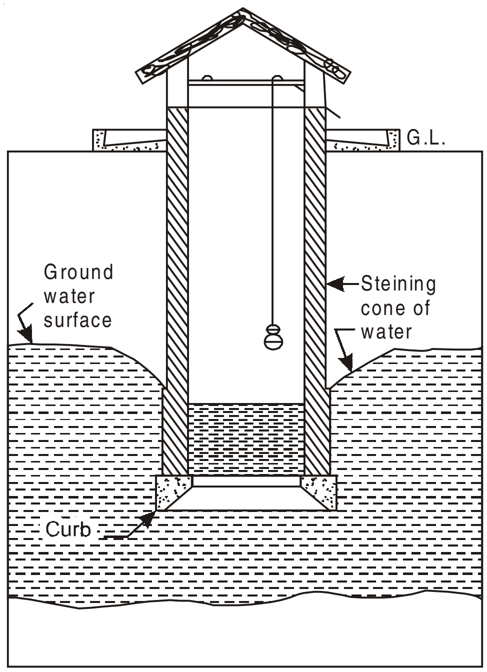


Fig. 17.4 *Dug-well.*

17.7.2 Deep Wells

These wells are similar to shallow-wells, but the depth is more. These wells receive water from several acquifers or water strata. Generally these wells pass below hard stratum and receive water from lower water-bearing soil.

17.7.3 Tube-wells

There are two types of tube-wells:

1. Shadow tube-wells 2. Deep tube-wells

1. **Shadow tube-wells.** These are tube-wells constructed into the first water bearing stratum and draw only unconfined ground water. These are constructed with two pipes of steel. One is of bigger diameter than the other and the smaller one passes through it. The water is drawn through the

smaller pipe which is connected to the pump. The bigger pipe is first driven and then the smaller pipe is inserted. The bigger pipe is then withdrawn. The diameter of the smaller pipe varies from 10 to 20 cm and that of the bigger pipe varies from 20 to 30 cm.

2. **Deep tube-wells.** It is nothing but a pipe passing into the ground through pervious and impervious strata of the earth. It essentially consists of blind pipes (pipes without perforations) and strainer pipes (pipes with perforations). Water enters into the pipe through filter pipes, which receive water from several acquifers. Blind and strainer pipes are placed against impervious and pervious stratum respectively. These wells may go upto 300 metres depth.

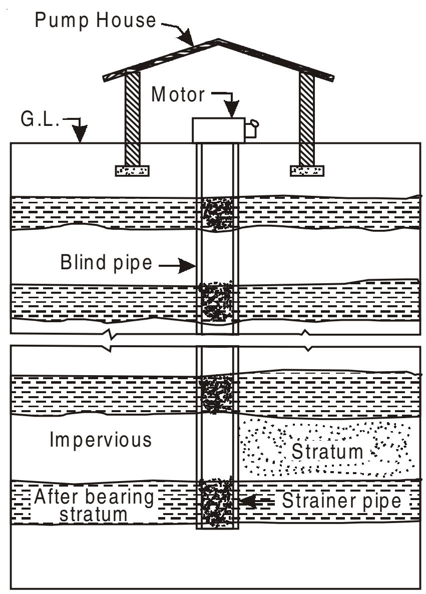


Fig. 17.5. *Tube-well.*

17.7.4 Artesian Wells

The water from these wells flows out naturally and comes out as a function to a height of 2.5 metres above the ground level. No pumping is required to raise the water from the well. In some well water flows continuously throughout the year and can be stored in tanks for water-supply purpose, which varies between 4,500 to 1,14,000 litres. Artesian wells are formed when in a valley, the water table is much below the water table of the adjoining areas as shown in the Fig. 17.5. They are rarely found and are not a dependable source of water. These are found in valley portions, where confined stratum acquifers on both sides are inclined towards the valley and sub-soil water level of the valley much below the water table of the adjoining land, wells due to which the pressure becomes greater in the valley forcing the water to come out from the wells.

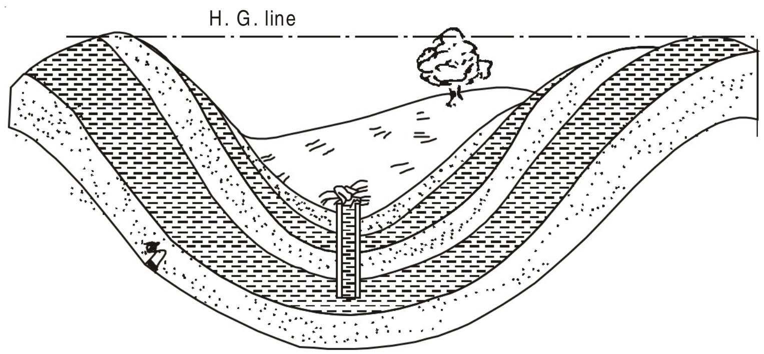


Fig. 17.6 *Artesian well.*

17.7.5 Infiltration Wells

These are shallow wells excavated along the banks of rivers. River water percolates into these wells through sand beds, therefore, the water collected in these wells is clearer than the water of the river. The water collected in these wells is carried under gravity to Jack-wells and then pumped to the town.

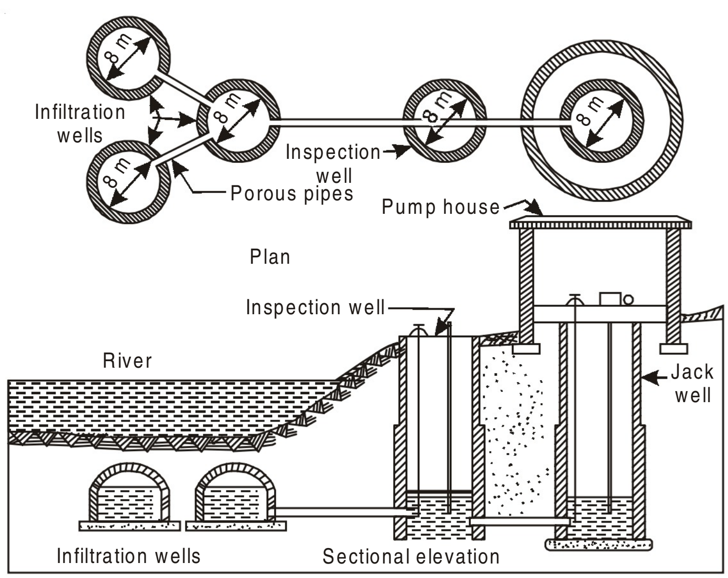


Fig. 17.7 *Infiltration well.*

Figure 17.7 shows a plain and sectional elevation of three infiltration wells, which are joined by porous pipes. Water from these wells go into inspection well, where it is inspected before going in Jack-well, from where it is pumped for further treatment and distribution.

17.8 POROUS PIPE GALLERIES

Mostly the beds of the rivers are sandy and therefore much water percolated down in it. As this water comes through sand which acts as a filter, it is free from the suspended load, organic and inorganic impurities. The quality of this water is better than Draw-wells and is not contaminated by natural agencies. To get this water porous pipes or pipes with open joints are laid under the bed of the river in the sandy soil as shown in Fig. 17.8. The water enters in these pipes through open joints and after flowing, it is collected in a sump from where it can be pumped and sent to the water-works for further treatment, if required for distribution.

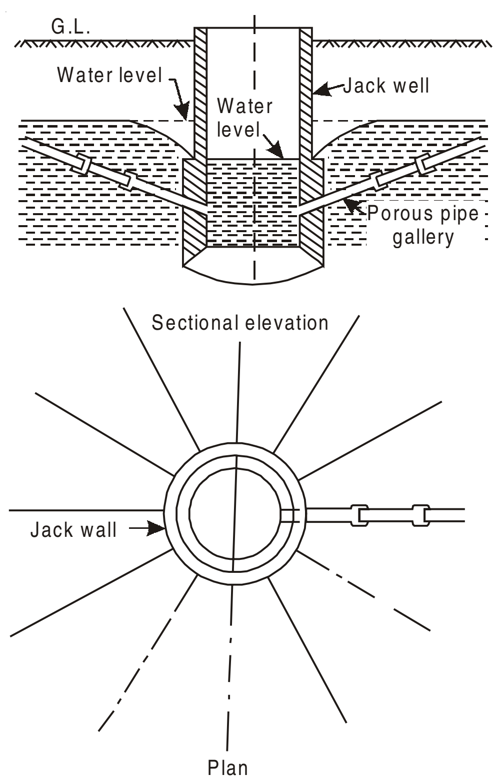


Fig. 17.8 *Porous pipe gallery.*

17.9 INFILTRATION GALLERIES

These galleries are useful where ground water exists in large volumes just below the ground level. The galleries are made of concrete or 20 cm thick brick masonry under the slope of a river or nala with 5 × 10 cm weep-holes as shown in Fig. 17.9. The sub-soil water enters through the weep-holes and after flowing in the galleries it is collected in the sump-well from where it is pumped. Sometimes instead of weep-holes open joint pipes are connected to the galleries.

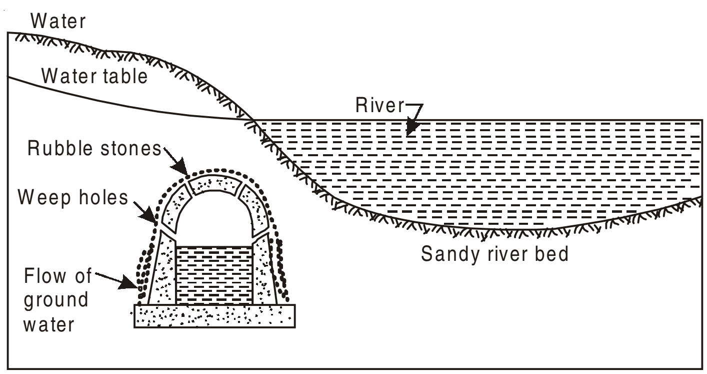


Fig. 17.9 *Infiltration gallery.*

QUESTIONS

17.1. Name the different types of sources of water-supply. Describe any one with the help of a neat sketch.

17.2. What are the various sources of water used for water supply schemes?

17.3. With the help of a neat sketch, describe a tube well.

(a) Infiltration gallery

(b) Impounding reservoir

(c) Infiltration wells.

17.5. What are the various sources of water-supply for a small hill town ?

17.6. Distinguish between a Shallow, Deep and Artesian well.

17.7. The natural source of supply of water for a village is from a perennial river. Outline the procedure that you would adopt to obtain purified water for drinking purposes.

17.8. Give a sketch of a sanitary dug well for rural areas.

Chapter 18

Purification and Treatment of Water

18.1 GENERAL

The water from any of the sources described in the previous chapter may contain suspended impurities, colloidal impurities and bacteria. The water to be used for domestic or industrial purposes must be free from all these impurities. The treatment and purification of water consists of the following operations:

1. Sedimentation
2. Filtration
3. Disinfection.

Sedimentation helps in removing suspended impurities, filtration in removing colloidal impurities whereas disinfection removes bacteria and other harmful germs of diseases.

18.2 SEDIMENTATION

It is the process of removing suspended matters from the water by keeping it quiescent in tanks, so that suspended solids may settle down at the bottom due to the force of gravity. Plain sedimentation is a preliminary process to further treatment, because, it decreases the load on the subsequent process; the cost of cleaning the chemical coagulation basin is lowered; less chemicals are required for further treatment and no chemicals are lost with the sludge in this process. In olden days it was done by 'Draw and Fill' method, in which the water was first filled in tank, then allowed to remain quiescent so that suspended impurities may settle down and then it was taken out. But nowadays 'continuous flow type tanks are used, in which flows through the basin continuously in a horizontal direction at a uniform rate of flow.

There are two types of sedimentation processes:

(a) Plain sedimentation.

(b) Sedimentation with coagulation.

18.3 DIFFERENCE BETWEEN 'DRAW AND FILL' AND 'CONTINUOUS FLOW' TYPE SEDIMENTATION TANKS

18.3.1 Draw and Fill Type

In 'draw and fill' system the tanks are filled with water which remains at rest till sufficient sedimentation has taken place; then without causing any disturbance, the water is taken out. This system has the following disadvantages:

(i) This water level in the tank falls down as the water is drawn out, which causes a loss of head equivalent to at least 1/4 th the depth of water, which affects the design and location of subsequent purification work.

(ii) Initial cost is more, as at least three or four tanks are required, when one is being filled the other is emptying and water remains at rest in the third.

(iii) Filling, emptying and clearing has to be done regularly from day to day which requires expert supervision and more labour, therefore it is costly in maintenance.

(iv) Every time one-fourth of the depth of water at the bottom cannot be drawn due to the deposited sediments, which is a waste.

18.3.2 Continuous Flow Type Tanks

In the continuous flow system the water flows slowly and continuously through the tank, therefore no time is lost in filling and emptying the basin, which always remains full except when it has to be emptied for cleaning and repair works. The quantity of suspended matter removed depends mainly on the detention-period. As far as possible each element should remain in the tank for the same period and must prevent the passage of part of the liquid through the tank too quickly. For this purpose baffle wells are generally provided.

18.4 DIFFERENT TYPES OF TANKS

There are three types of continuous flow tanks; they are described as below.

18.4.1 Rectangular Tanks

Figure 18.1 shows the essential parts of a rectangular tank. It consists of a rectangular tank with channel type inlet and outlet extending on the whole width of the tank in the chamber. There are baffle-walls in the tank which gradually reduce the velocity of the incoming water. These tanks may be intermittent or continuous in operation.

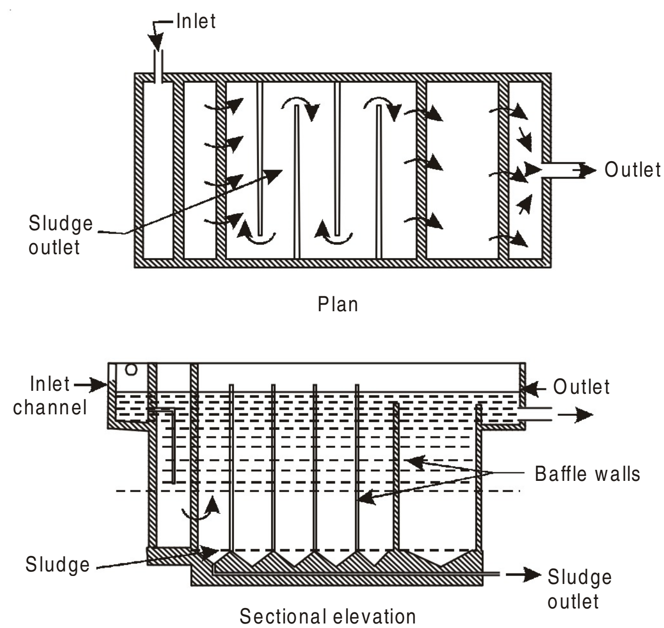


Fig. 18.1 *Rectangular tank.*

18.4.2 Circular Tanks

These may be intermittent or continuous in operation. But generally these are not used in plain sedimentation. The direction of flow can be arranged radial or circumferential.

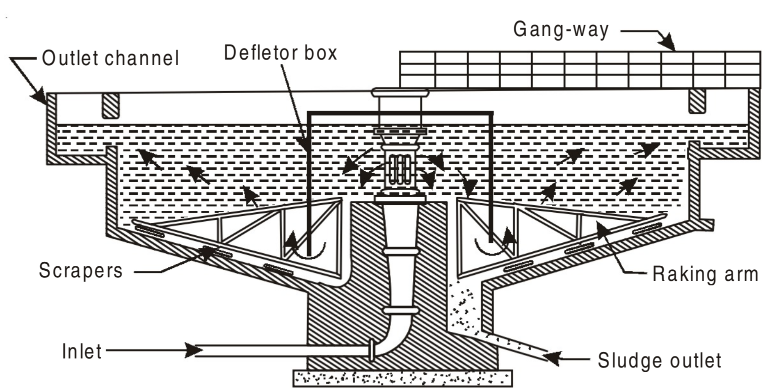


Fig. 18.2 *Radial flow circular tank.*

18.4.3 Radial Flow Circular Tanks

The water enters in this tank at the centre through inlet pipe, then it flows downward in the deflector box and then allowed to flow upward as shown in Fig. 18.2. The outlet in these tanks is a peripheral channel around the circumference. The suspended inpurities like silt, clay, etc. settle downward and are removed by sludge-outlet. The sludge is removed by scrappers (also known as raking arms) rotating at a maximum velocity of 4.5 metres per hour.

18.4.4 Circumferential Flow Circular Tank

Figure 18.3 shows the outlines of a circumferential flow circular tank. Water enters in the tank through two or three vertical slits and after flowing along the circumference it is drawn over a small weir type outlet. The length of outlet weir should be about l/8th circumference.

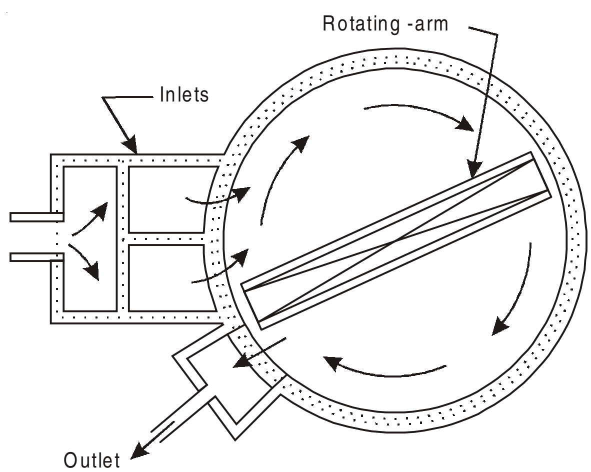


Fig. 18.3. *Circumferential flow a tank.*

18.4.5 Hopper Bottom Tank

In these tanks water flows vertically as shown in Fig. 18.4. Water enters from the top into the deflector box and after flowing downward it reverses its direction. All the suspended impurities which are heavier cannot flow with the water, settle down in the bottom, from where they can be taken out by sludge outlet pipe under hydrostatic pressure. The water is drawn out by a row of 4 to 6 perforated decantling channels. The sludge is removed from the sludge outlet pipe.

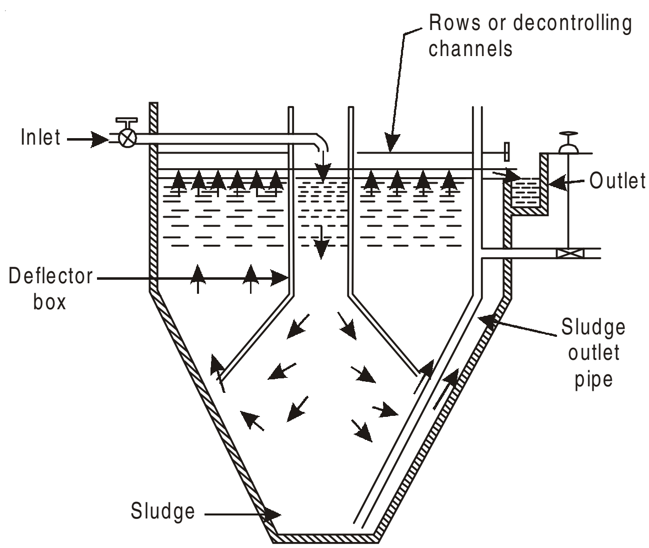


Fig. 18.4 *Hopper bottom tank.*

18.5 SEDIMENTATION WITH COAGULATION

It has been found that the addition of certain chemicals to water, an insoluble, gelatinous, flocculent precipitate is formed which in its formation descends through the water, absorbs and entangles suspended and colloidal matter and caused sedimentation. These chemicals remove very fine and colloidal suspended matter completely more rapidly than by plain sedimentation. The addition of coagulant also removes colour, odour and improves its taste.

The coagulants in sufficient strength are mixed with water, to produce the required precipitates and this water is allowed to flow in sedimentation basins, where floc and all suspended particles settle down and are removed by sludge outlet.

18.6 COAGULANTS

Among the commonly used coagulants are aluminium sulphate (Alum), ferrous sulphate together with calcium hydroxide and ferric chlorides.

18.6.1 Alum

This coagulant is used when the water contains some alkalinity, usually in the form of calcium carbonate. The reaction of alum and natural alkalinity is as follows:

$$Al_2(SO_4)_3\,18H_2O + 3Ca\,(HCO_3)_2 \longrightarrow Al_2(OH)_6 + 3CaSO_4 + 6CO_2 + 18H_2O$$

Aluminium hydroxide $[Al_2(OH)_6]$ is the insoluble precipitate (*floc*) which entangles other particles.

18.6.2 Ferrous Sulphate

It is cheaper than alum and also produces heavier floc which sinks more rapidly, but it requires lime with it for the formation of floc. The use of ferrous sulphate is limited to those waters in which alkalinity will not interfere, with colour removal. The chemical reactions are as follows :

$$FeSO_4 7H_2O + Ca(OH)_2 \longrightarrow Fe(OH)_2 + CaSO_4 + 7H_2O$$

$Fe(OH)_2$ is the floc which is further oxidised by dissolved oxygen of water and very good floc $Fe(OH)_3$ is formed $[4Fe(OH)_2 + 2H_2O + O_2 \longrightarrow 4Fe(OH)_3]$

The ferric hydroxide is a precipitate which forms a desirable floc and attracts suspended impurities.

18.6.3 Ferric Chloride

When ferric chloride is added to water the following reaction takes place:

$$FeCl_3 + 3H_2O \longrightarrow Fe(OH)_3 + 3H{+}3Cl$$

The ferric hydroxide is a precipitate which forms a desirable floc acid attracts suspended impurities.

18.7 FEEDDING DEVICES

Coagulants can be added in powdered form or in the form of a solution.

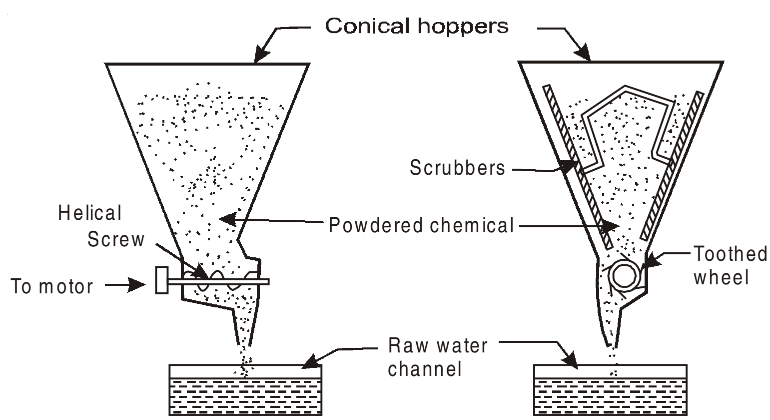


Fig. 18.5 *Helical screw and toothed wheel dry-feed devices.*

18.7.1 Dry-feed Devices

All chemicals cannot be added by dry-feed apparatus because of caking, clogging and deliquescence. For dry-feed it is essential that chemical should be of uniform size, constant composition, and remain connected under different conditions of temperature and pressure. Dry-feed services are designed on volumetric or gravimetric displacement of dry chemicals. Revolving helical screw or the toothed wheel at the bottom of the conical hopper allows only the required quantity of coagulant to be drawn off continuously.

18.7.2 Solution Feed Devices

In this method before feeding the coagulants, its solution is prepared. Preparation of solution is done by spraying worm water over the chemical

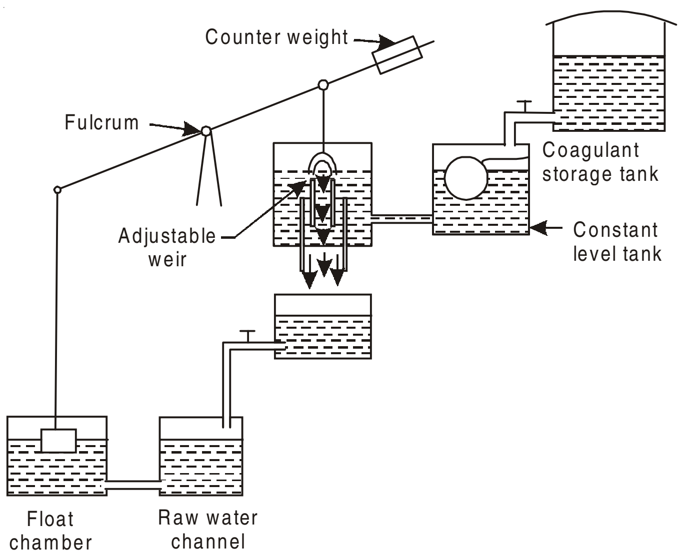


Fig. 18.6 *Adjustable weir type solution feed device.*

which is kept in a basket or perforated box, and this water containing the chemical is stored in solution-tanks from where it is mixed in water. In another method solution pot is used, into which chemicals are placed and through which water flows as shown in Fig. 18.5. Adjustable weir type solution feed device is shown in Fig. 18.6, in which the quantity of coagulant solution is controlled by an adjustable weir which is of coagulant solution is controlled by an adjustable weir which is operated by float fixed to a level. When the quantity of raw water increases, the float is lifted up and the weir goes down, thus allowing more solution to go in raw water. If the quantity of raw water falls down, the weir is lifted up and only the required quantity of solution can reach the raw water-channel.

18.8 MIXING DEVICES

After dosing the chemical, its mixing in water is required, which can be done by any one of the following methods :

(a) Baffle Type Mixing Basin

(b) Flash-Mixer

18.8.1 Baffle Type Mixing Basin

These may serve both as mixing and coagulation basins, depending on the flow of water. Water may flow around the baffle-walls horizontally, back

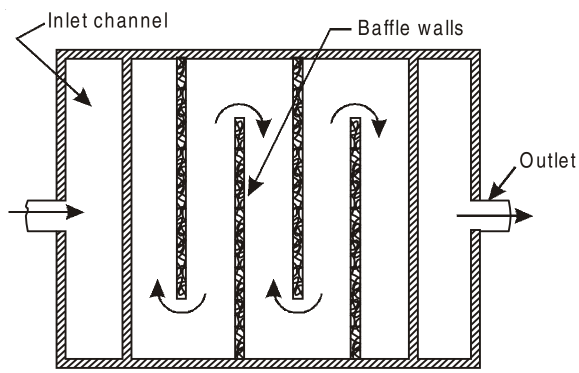


Fig. 18.7 *Plane of a baffle mixing basin.*

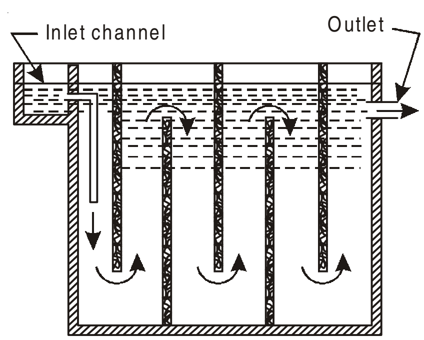


Fig. 18.8 *Sectional elevation of a baffle mixing basin.*

and forth, past around-the-end baffles or up and down. Their use is becoming less due to so many disadvantages as less flexibility of control, greater loss of head, greater expense of construction due to baffle walls. Figures 18.7 and 18.8 show these basins. Water with coagulants enters from the inlet is mixed thoroughly with coagulants while passing around baffle walls and comes from the outlet.

18.8.2 Flash-Mixer

Figure 18.9 shows a flash-mixer. The chemical is added through the chemical feed pipe. The deflector wall deflects the water towards the fan blades which

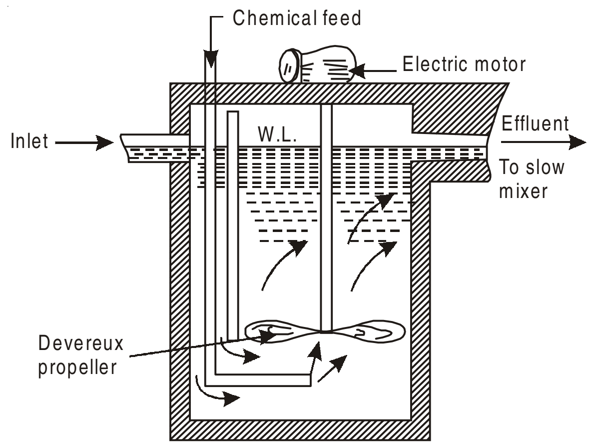


Fig. 18.9 *Flash mixer.*

mixes it thoroughly and water goes out from outlet for further treatment in filtration process.

18.8.3 Mechanical Flocculators

Figure 18.10 shows the essentials of a mechanical-flocculator. These are new replacing other forms of flocculators

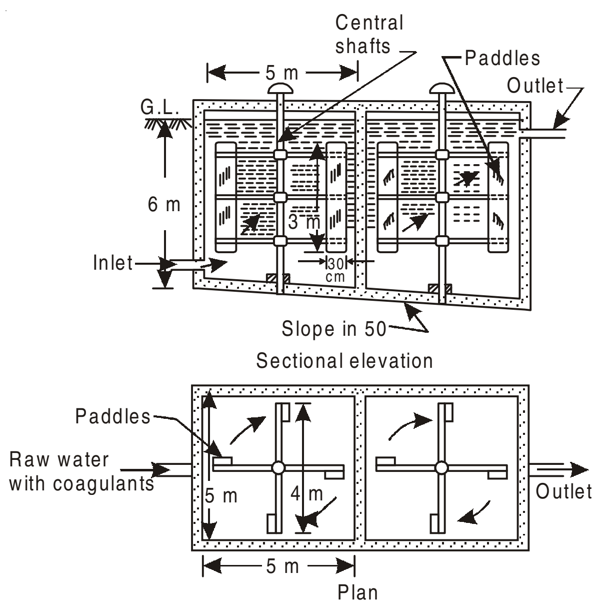


Fig. 18.10 *Mechanical flocculator.*

because they provide a number of gentle contacts between the flocculating particles which are essential for the successful formation of flocculator. There are a number of compartments, in which paddles are rotated by motors, which mix the coagulant with water. The water from one compartment goes to other compartment where the same process is repeated. Thus the water which comes out from mechanical flocculators is uniformly mixed with the coagulant.

18.9 ADVANTAGES OF MECHANICAL FLOCCULATOR

1. 10–40% less quantity of chemical is required as compared with other basin
2. Better floc formation
3. Less cost of plant
4. Flexibility in operation
5. Low head loss, and
6. Less filter washing.

18.10 DISADVANTAGES OF MECHANICAL FLOCCULATOR

1. Low velocity near paddle shaft
2. Dead space in corners
3. Equipment maintenance is needed
4. Bad short circuiting.

18.11 FILTRATION

Raw water contains a large number of suspended and dissolved impurities of organic and inorganic nature. Sedimentation removes suspended matters and bacteria to a certain extent, therefore it becomes necessary to remove the remaining impurities, colour and bacteria from the water through a thick sand layer, suspended and colloidal matter, bacteria, colour and odour of water are removed. The process of passing water through a thick layer of sand is known as filtration. In some cases where water contains more bacteria, it is better to chlorinate the water before it goes under filtration process.

18.12 TYPES OF FILTERS

There are three types of filters, which are commonly used in water-works. They are described as following.

18.12.1 Slow Sand Filter

A slow-sand-filter is an under-drained water light basin containing a sand about 1 to 2.3 metre depth, which is submerged under 1 to 2 metre depth of water in the basin, arranged to permit the percolation of water through sand.

Figure 18.11 shows a section of a typical slow-sand filter. The filtering media of this filter consists of graded sand and gravel with 0.9 metre depth of fine sand for top-layer and largest size gravel 2.5 cm size to 3.5 cm size about 15 cm layer being laid at bottom. Water after sedimentation process enters in slow-sand filter, where it is filtered by passing through the filtering media. The filtered water comes out from the outlet pipe and then it is collected in service reservoir from where it is distributed.

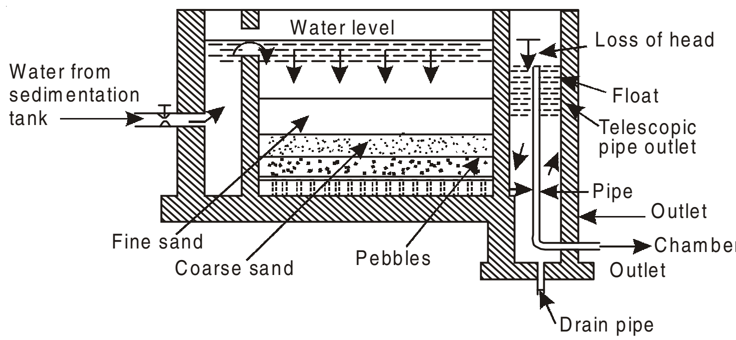


Fig. 18.11 *Slow sand filter.*

The rate of filtration of slow sand-filter is usually of the range of 0.2246 × 10 to 0.3380 × 10^6 litres/km/day. In this filter when a certain amount of dirt is accumulated on the sand bed, 2.5 cm depth of sand is scrapped off from the top. This sand is washed, dried, screened and subsequently used.

18.12.2 Rapid Sand Filters

These are also known as mechanical filters. The rate of filtration in these filters is usually 20 × 10^{16} litres/km^2/day.

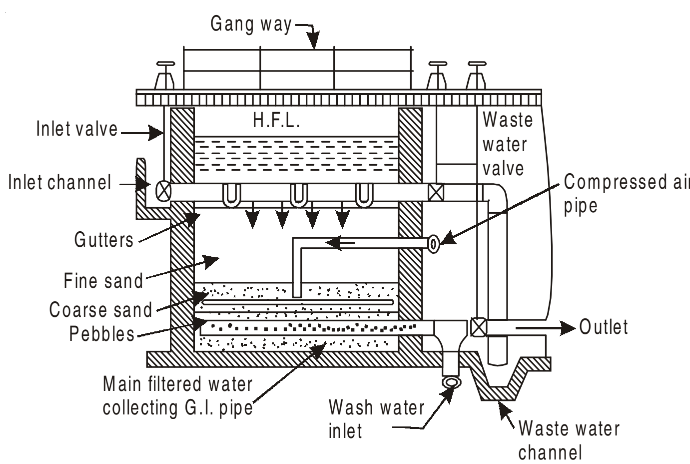


Fig. 18.12 *Rapid sand filter.*

Figure 18.12 shows the sectional elevation of rapid-sand-filter. The water comes from coagulation tank and filtered water is collected by a 25 cm diameter G.I. pipe, having 5 cm diameter holes 20 cm apart on the lower side of the pipe. The purpose of making these perforations at the bottom is that if any fine sand goes down with the filtered water, it should settle in the lower and only filtered water should enter the collecting laterals.

18.12.3 Operation of Filter

Water enters the filter unit through inlet pipe and uniformly distributed on the whole sand bed. This water starts filtering due to force of gravity through the sand bed and is collected in the clear water tank under the drainage system. The outlet is fitted with filter rate controller. In the beginning the loss of head is very small, but after 12 to 24 hours this loss of head increases due to which rate filtration decreases too much. This indicates that the filter bed requires cleaning.

Generally rapid-filters are clogged and their periodic cleaning is necessary after 24 to 27 hours. This is done by back washing. Some quantity of filtered water from the clear water reservoir is stored in the wash water tank for the back washing filter. Clear water is applied under pressure to the strainer system. The upward flow of water agitates the sand and carries away the matter which has clogged the pores of sand. Back wash water after cleaning the sand bed is collected through gutter provided at the surface of filter, which allows it to go in the drain. A successful plant should not use more than 3–4% of its filtered water in washing. Wash water pressure should not exceed 10 metres.

Nowadays compressed air is used to agitate the sand before back washing. It is applied at the rate of 0.61 to 915 m^3/mid/m^3 of filtering surface for a period of 5 minutes. It is distributed by a pipe as shown in Fig. 18.13.

18.12.4 Pressure Filter

It is a type of rapid sand filter placed within a closed, water-tight tank. These filters are used on small supplies in which water is received under pressure, which can be used to force the water through the filter. Mostly pressure filters are used for industrial plants and for small water supply schemes. They are not economical for large scale domestic or industrial supplies. A pressure filter is one in which the filtered bed is contained in a cylindrical steel shell, which may be kept vertical or horizontal. The vertical filters range in size from 0.3 metre to 2.75 metres in diameter, height being 2 to 2.5 metres. The horizontal units are generally 0.8 to 3 metres in diameter and length upto 9 meters. The rate of filtration is 5875 to 4700/litres/hour/m^2

area of the filter bed. Figure 18.13 and 18.14 show vertical and horizontal pressure filters.Unfiltered water mixed with alum solution enters through the top of the shell and strikes against the baffle which causes it to be

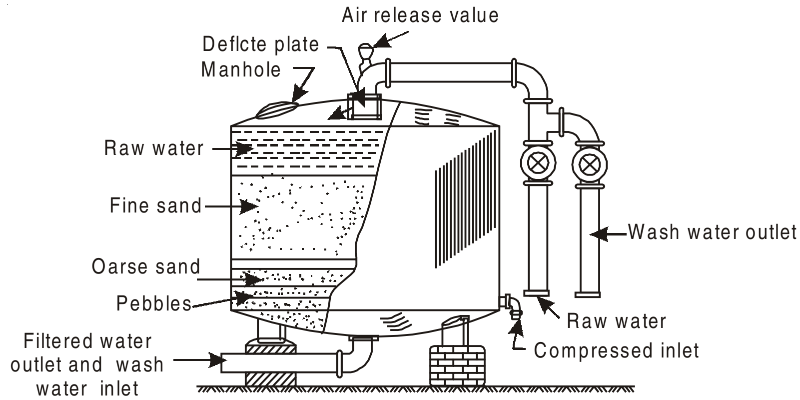


Fig. 18.13 *Vertical pressure filter.*

uniformly distributed over the top of the sand bed. It passes downward through the sand and gravel bed about 1 to 1.8 metres thick and finally to the filtered water outlet. Cleanining of the bed is done by back washing similar to rapid sand filter. Air pressure is maintained on the surface of the water increase the rate of filtration.

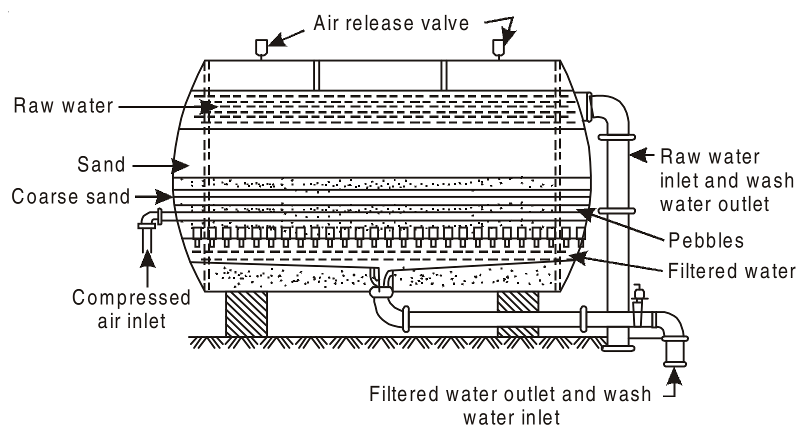


Fig. 18.14 *Horizontal pressure filter.*

18.13 COMPARISON OF SLOW SAND FILTER AND RAPID SAND OF FILTERS

18.13.1 Slow Sand Filter

1. It is less likely to go wrong.
2. It does not require skilled labour.
3. There is less loss of head.
4. It removes bacteria more efficiently.
5. Its mainteance cost is less.
6. It requires a large area and more quantity of sand.
7. It requires cleaning every 1 to 3 months.
8. It requires 0.2% to 0.6% filtered water for its sand washing.

18.13.2 Rapid Sand Filter

1. A smaller area of land is required.
2. Effluent is clearer and sparkling.
3. A smaller amount of sand is required.
4. Cleaning can be done in less time by back washing.
5. It can be adjusted according to the variation of water quantity.
6. If the cost of land is taken into account it is cheaper than slow-sand filter.
7. The treatment of water with chemical is necessary before sending in filter.
8. It requires skilled supervision.
9. It requires mostly coarse sand.
10. It cannot remove bacteria efficiently.

18.14 DISINFECTION

The water after passing through sedimentation, coagulation and filtration, is not completely purified. It still contains a small percentage of pathogenic bacteria, which if not removed or destroyed may cause water-borne diseases. For the removal of these bacteria number is known as *disinfection.* Bacteria in water may be killed by chlorination, adding ozone, passing ultra-violet-rays, boiling, adding lime, adding iodine and so on. Some of the methods commonly used are described below.

18.15 METHODS OF DISINFECTION

The following are the common methods employed for the disinfection water.

(a) **Disinfection by chlorine.** Chlorine can be sued directly as a gas or by dissolving it first into a small quantity of water and then applying it as a strong solution. Liquid chlorine is most effective when applied to filtered water at such a point when adequate mixing is done. The liquid chlorine is fed in water by an apparatus known as chlorinator. Different varieties of chlorinators are available in the market which feed chlorine at any desired rate irrespective of the change in pressure. For filtered water 0.3 to 0.5 p.p.m. of chlorine is sufficient. The water should be used 20 minutes after the addition of chlorine. The quantity of free chlorine should not be more than 0.1 to 0.2 p.p.m.

(b) **Adding bleaching powder.** Bleaching powder can be used for disinfection of water for small water works. This powder contains about 30% available chlorine which disinfects the water. Bleaching powder can be used directly as a powder or by making its solution in water and then applying it.

(c) **Disinfection by ozone.** Ozone (O_3) is an unstable isotope of oxygen which when broken down from O_3 to O_3, releases an atom of nascent oxygen, which is very effective and kills all the bacteria. Disinfection by ozone is costlier than chlorine but it removes odours, tastes and colour without leaving any residue of any type in the water.

(d) **Disinfection by ultraviolet-rays.** This method requires a ultraviolet-ray machine consisting of mercury vapour lamp enclosed in a quartz globe. The water flows in a thin clear film very close to the ultraviolet-rays, which kills all the bacteria. This method is widely used for the disinfection of swimming pool water, because it does not require any chemicals to be mixed in the water. It is very costly method and cannot be used for water-works.

(e) **Disinfection of Iodine.** It has been observed that if tincture comprising 7 parts iodine, 3 parts potassium iodine and 90 parts alcohol are mixed with 7 liters of water it gives very good disinfection of water. Generally this is not used.

(f) **Disinfection by excess lime.** It has been seen that one part of quicklime (containing 75% CaO) can disinfect 5,000 parts of water in 10 to 24 hours. But the effect of lime should be neutralized before using water.

(g) **Disinfection by copper sulphate.** Copper sulphate also disinfects water upto a certain extent, if a dose of 10 to 12 p.p.m. is added in water. When chlorine is not available, copper sulphate can be used for the disinfection water.

18.16 AERATION

Mostly water contains dissolved gases, which causes unpleasant odours; these gases can be expelled by passing air in the water which helps in the reduction of organic matters.

Water can be aerated by the following methods :

(a) Exposing the water to atmosphere in reservoirs and aqueducts.

(b) Flowing over weirs, steps, through etc.

(c) Flowing through trickling devices as coke beds.

(d) Spraying it in the air.
(e) Passing air in it or diffusing.
(f) Mixing air in water under pressure.
(g) Aspirating air through the water.

QUESTIONS

18.1. What do you understand by sedimentation ? Explain any one of the methods used for carrying out sedimentation.

18.2. Explain with the help of a neat sketch the working of any one of the sedimentation tanks which are most commonly used.

18.3. What are the advantages and disadvantages of the 'Draw and Fill, and 'Continuous Flow Type' sedimentation tanks ?

18.4. Describe the working of Hopper-bottom settling tank with the help of a neat sketch.

18.5. Write short notes on coagulations.

18.6. Write a short note on coagulants commonly used for the purification of water.

18.7. What do you mean by flocculation ? Describe a mechanical flocculator with the help of a neat sketch.

18.8. How are the coagulants added in water ? Describe with the help of sketches the working of any one of the feeding devices.

18.9. Write short notes on the mixing of coagulant in water.

18.10. Why is it necessary to add a coagulant in water ? Mention two important coagulants which are commonly used.

18.11. What is the principle of filtration ?

18.12. What is the function of a filter ?

18.13. Describe briefly the methods of cleaning sand which is normally adopted in case of rapid sand filters.

18.14. What are the advantages and disadvantages of slow sand and rapid sand filters ?

18.15. With the help of a neat sketch, explain the working of a rapid sand filters.

18.16. Explain the principal difference in the working of rapid and slow sand filters.

18.17. Write a short note on the pressure filter.

18.18. What do you understand by the term disinfection of water ? Why is it necessary ?

18.19. Describe the various methods employed for the disinfection of water.

18.20. What do you understand by Aeration ? What are the different methods of Aeration ?

18.21. The natural source of supply of water for a village is from a perennial river. Outline the procedure that you would adopt to obtain purified water for drinking purposes.

18.22. What do you understand by sterilization of public water-supply and how is it cheaply and effectively done ?

18.23. (a) What do you understand by filtration of public water-supply, and why it is necessary ?

(b) Explain in short the various processes in use in filtration of public water-supply ?

18.24. Describe the following processes as applied to water treatment:

1. Sedimentation
2. Filtration
3. Sterilisation.

Chapter 19

Pipe and Joints

19.1 GENERAL

Pipes are required to carry the water from the source of supply to the consumers. It can be taken in open channels like a canal, but is not possible in towns in cities, because it has to follow the hydraulic gradient line which cannot be available. Among the disadvantages of an open channel may be included : (1) there is loss of water by evaporation, (2) it can be easily contaminated, (3) it is costly to maintain, (4) water cannot rise to upper storeys and higher level, hence not available at required place, (5) any breach may cause interruption in water supply.

Due to a number of difficulties of conveying water in open channels as described above, the water is conveyed only in closed pipes made of different materials according to requirement of pressure and quality of water.

19.2 MATERIALS OF PIPES

Pipes are constructed of different materials. They are described below :

1. **Cast iron pipes.** These are manufactured from the best gray pig-iron and coated with anti-corrosive paint. The life of these pipes is about 50 years, and therefore, these are commonly used for mains, sub-mains and branches with head caulked and spigot joints. The other advantage of these pipes is of easy service connection to buildings. Generally these are upto 85 cm diameter, but sometimes those upto 1.3 metres diameter are also used. These pipes can easily laid on curves by giving a slight turn at joints.

2. **Masonry and concrete pipes.** These were used in early times for conveying water from storage reservoir or a lake. If water is to be conveyed at high pressure, these pipes cannot be used.

3. **Reinforced concrete pipes.** The life of these pipes is much more. The joints in these pipes can be made sufficiently strong. Sometimes steel

pipes with inner and outer lining of cement concrete are used. These pipes are very heavy, and hence very costly in conveyance and laying.

4. **Asbestos cement pipes.** These are also known as Hume pipes. These are manufactured by centrifugal process using reinforcement of steel tubes, roads of expanded metal with asbestos fibres. These are lighter in weight and the joints can be made very satisfactorily by rubber-rings and a collar joint.

5. **Steel pipes.** These can withstand very high pressures and can be made of big diameters. The life of these pipes is about 50 years, which can be increased by anticorrosive paint of lining of cement concrete. These are very light in comparison with other pipes.

6. **G.I. pipes.** These pipes are very convenient for house connections, because branches, bends, reducing sizes, fixing taps and cocks can be easily done in these pipes.

7. **Lead pipes.** These pipes may cause lead poisoning and are, therefore, not used in India. These can be given bends and can withstand high pressures, and are used in sanitary-fittings. If hot water passes through these pipes they sag. These pipes are used in alum dosing and chlorinators.

8. **Copper pipes.** These pipes are not liable to corrosion if water contains some traces of acids, nor do they sag in hot water supply and can be easily bent.

9. **Spun iron pipes.** These pipes are manufactured by centrifugal casting, therefore, termed as spun iron pipes. Mostly these have a thinner section than cast iron pipes.

10. **Wooden pipes.** These pipes are made of good timber and are light and durable and can be dismantled at one place and erected at another. They can withstand high pressure and can be made up to 6 metres diameter. The only disadvantage in this pipe is that if water-supply is intermittent, it causes rottening of the timber.

19.3 PIPE JOINTS

For the facilities in handling transporting and placing in position, pipes are manufactured in small lengths. These small lengths of pipes are then jointed to make one continuous length of pipe line. The design of these joints mainly depends on the material of pipe, internal water pressure of pipe and the condition of support. The different types of joints which are commonly used are as follows:

19.3.1 Spigot and Socket Joint

Cast iron pipes are made a bit enlarged to form socket on one end, and normal or spigot on the other end. The spigot end of one pipe is placed into the socket or bell end of the other pipe and yarn of hemp, asbestos or rubber rings are packed for maintaining a regular annular space and for preventing

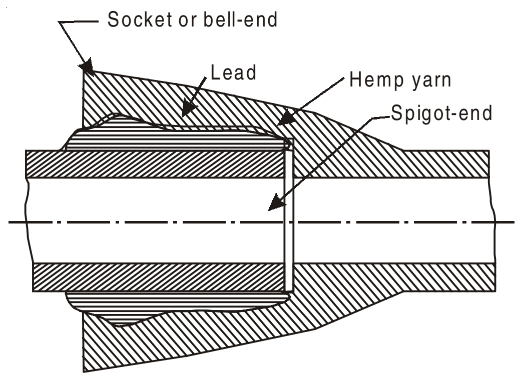


Fig. 19.1 *Spigot and socket joint.*

jointing materials from falling inside the pipes. After this lead is poured in the annular space between the socket and spigot by means of a funnel arrangement. When lead is hardened, it is caulked by caulking tools (Fig. 19.1)

19.3.2 Expansion Joint

At such places where pipes expand or contract due to changes in temperature, this type of joint is required for preventing breakage of pipe line. The socket end is flanged with C.I. follower ring, which can slide freely on spigot end.

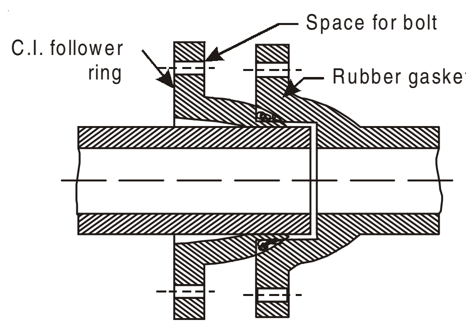


Fig. 19.2 *Expansion joint.*

The annular space between socket and spigot is filled by an elastic gasket as shown in Fig. 19.2. Even when the pipe expands, the socket moves forward and when it contracts, it moves backward in the space left between C.I. follower ring and the flange of socket. Thus in every position the joint remains water tight.

19.3.3 Ball and Socket Joint

These are also known as flexible or universal joints and are used at such places where settlement is likely to occur after the laying of pipe line. The ends of pipe are specially cast as shown in Fig. 19.3. A gasket or rubber is

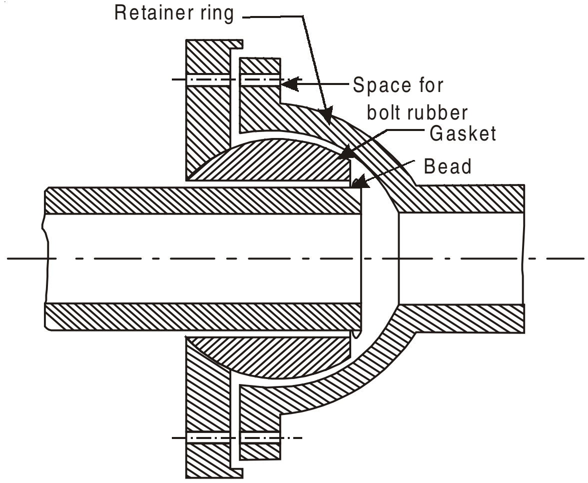


Fig. 19.3 *Universal-joint.*

filled and over it a gland ring, having the same spherical shape as that of the inner surface of socket is placed and then the retaining ring is fixed with bolts to the flange of socket as shown in Fig. 19.3.

19.3.4 Flanged Joint

In this the pipe has flanges on both its ends, cast with the pipe or screwed if cast separately. Two ends which are to be joined are brought in perfect level

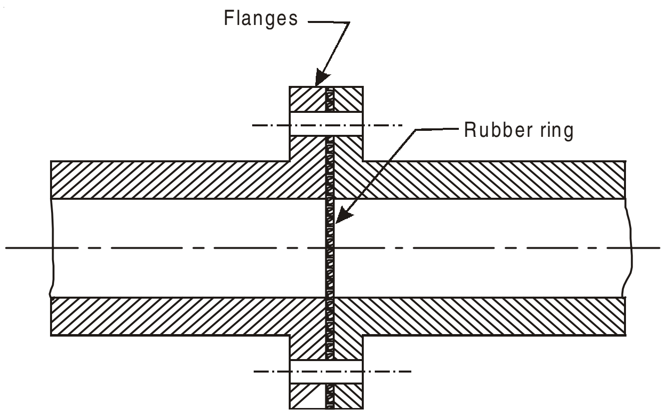


Fig. 19.4 *Flanged-joint.*

and after placing one hard rubber washer between them flanges are bolted together as shown in Fig. 19.4.

19.3.5 Collar-joint

Mostly this type of joint is provided to R.C.C. or Hume pipes. Two pipes are brought in one level in contact and a jute-rope soaked in cement is kept in

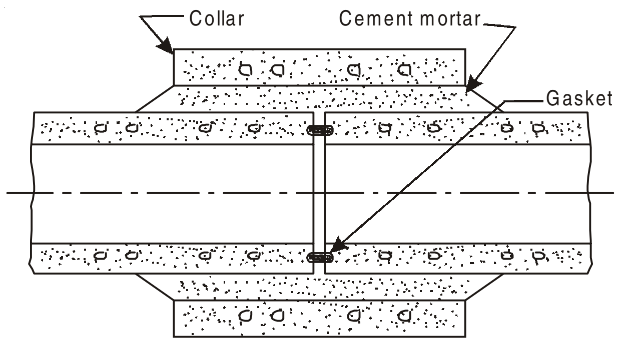


Fig. 19.5 *Collar-joint.*

the grove and collar with 1 : 2 cement mortar or concrete as shown in Fig. 19.5.

19.3.6 Screwed-joint

This joint is mostly used for connecting small diameter wrought iron and G.I. pipes. The ends of pipes have threads on outside, while coupling has

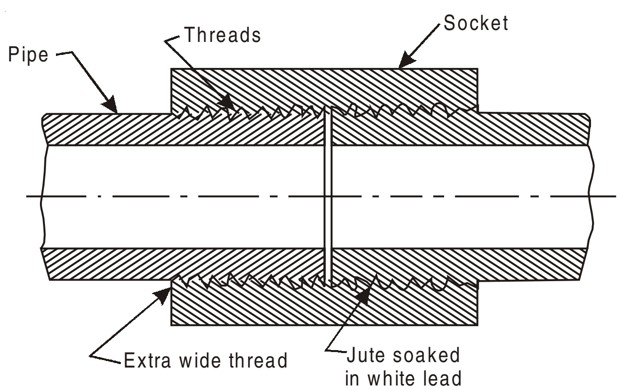


Fig. 19.6 *Screwed-joint.*

threads on the inner side. For making water-tight joint zinc paint or hempyarn is placed in the threads of the pipe before screwing it.

QUESTIONS

19.1. Write short notes on the following types of pipes used for water-supply:

(a) Lead pipes

(b) R.C.C. pipes

(c) C.I. pipes.

19.2. Describe different types of pipes used in water works.

19.3. Describe with help of neat sketches the following pipe joints :

(a) Spigot and socket joint

(b) Flanged joint

(c) Expansion joint.

19.4. Describe the different types of pipe joints which are commonly used.

19.5. What are 'Hume' pipes ? What are their advantages and disadvantages over the steel and cast iron pipes ?

19.6. Draw neat sketches of joints in a Hume and R.C.C. pipes and explain the method of their construction.

19.7. (a) What type of pipes are generally used for water mains ? What are their advantages ?

(b) Mention the defects of an intermittent supply system.

Chapter 20

Valves and Fittings

20.1 GENERAL

For controlling the flow of water, checking increase in pressure, preventing flow in opposite direction and releasing of air which has entered in the pipe line, a number of devices are required which are known as *valves.* In houses, different types of fittings such as tap, bends, tees, sockets, etc. air required for the distribution of water and from a network of pipes insides the house.

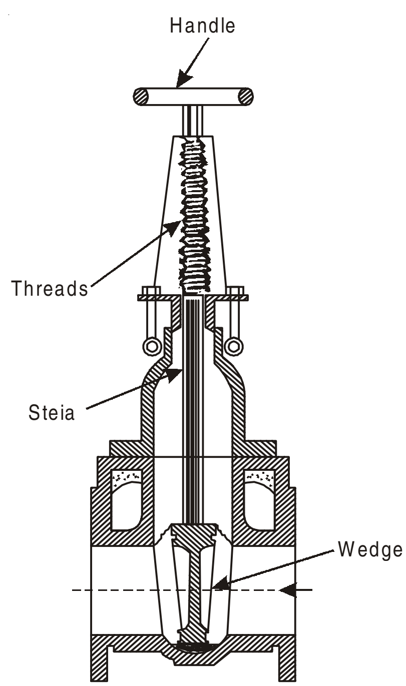


Fig. 20.1. *Sluice valve.*

20.2 VALVES

The following are some of the valves which are commonly used in pipe lines.

20.2.1 Sluice Valves

It controls the flow of water through pipes. In large size mains bringing water from the source to a town, they are fixed at 3 to 5 kilometres intervals to divide the pipe line into different sections. Thus during repairs, only one section can be cut off at a time by closing the sluice valves at both ends. Figure 20.1 clearly shows the most common type of sluice-valve which is also called the *Gate valve.* This valve is made of cast iron with brass, bronze or stainless steel mountings and its ends are screwed, flanged or spigot and socketed on the pipe. It consists of a wedge-shaped circular disc fitted closely in a recess against the opening in the valve. This is connected to a nut or wheel above by means of threaded spindle passing through a gland and stuffixing-box arrangement. When the wheel is rotated the spindle rises up, raising the disc along with it. The opening in the valve thus gets uncovered and the water from one section of the pipe line passes into another. The valve will be closed by rotating the wheel in the opposite direction.

20.2.2 Pressure Relief Valve

This relieves high pressure in pipe lines. Figure 20.2 illustrates this valve which consists of a disc controlled by a spring which can be adjusted for any

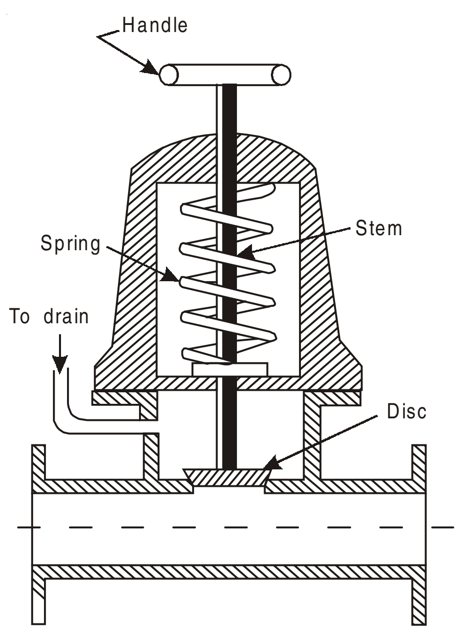


Fig. 20.2 *Pressure relief valve.*

pressure. When the pressure in the pipe line exceeds the desired pressure, the disc is forced off from its seat and excessive pressure is relieved through cross-pipe, after this, the disc comes down automatically due to the force of the spring.

20.2.3 Proppet Valve

This is also known as *Air-valve.* This device consists of a cast iron chamber bolted to the pipe over the opening in the crown. A weighted float and lever in it are so adjusted that when the chamber is filled with water under pressure

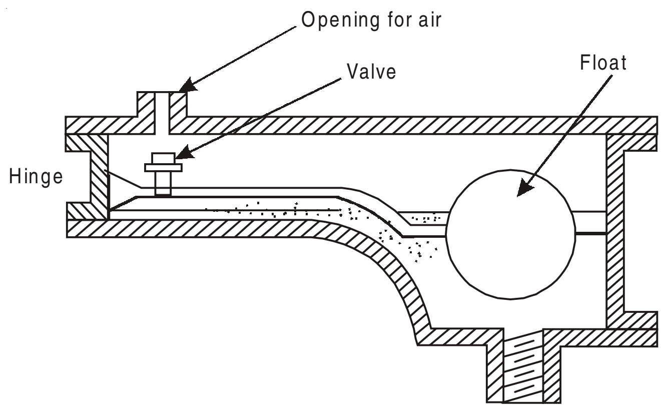


Fig. 20.3 *Poppet-valve.*

from the pipe line below, the float and the lever remain raised up and the valve is closed. But when air goes on accumulating at the top and builds up some pressure, the water level gets depressed and the float sinks down with the level, thus it opens the valve. The air escapes out and the water-level in the chamber again rises, the float is lifted up and the valve gets closed (See Fig. 20.3).

20.2.4 Floating Ball-Valve

The poppet valves are automatic in action and are very useful in removing the small amounts of accumulated air in the pipes lines. But they cannot admit in or take out large volumes of air, while draining or filling back with water the big mains, therefore at such places. Floating-ball valves are used.These are generally connected through small sluice valves to the main, thus the connected sluice valves are required to be operated first before these valves can come into action and hence their function is not an automatic one.

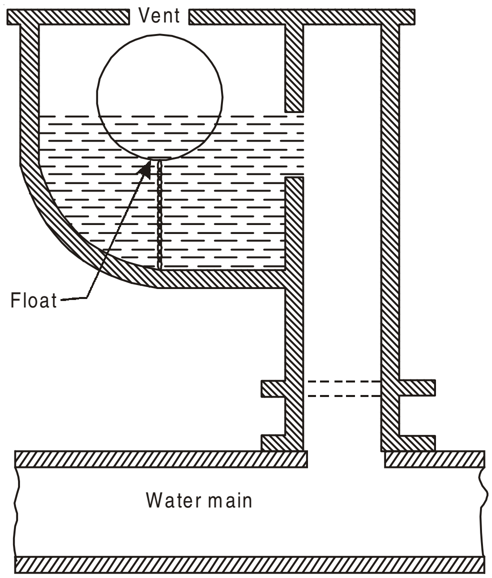


Fig. 20.4 *Floating ball-valve.*

20.2.5 Reflux Check Valve

This valve is an automatic device which allows water to flow only one direction and prevent it from flowing back. It consists of a metallic disc hinged from the crown which fits tightly against the annual valve seat.

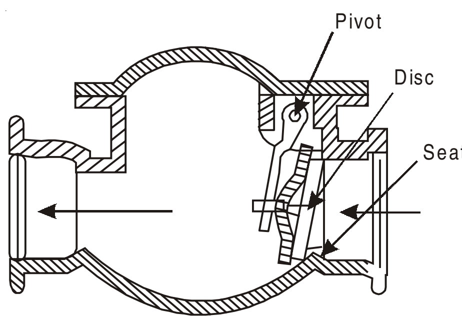


Fig. 20.5 *Reflux-valve.*

The water flows in the direction marked by the arrow in Fig. 20.5. The disc rotates round the hinge and remains in a horizontal plane. The water, therefore, passes off without any obstruction. Now if the flow reverses, the disc automatically falls down by rotating round the hinge and remains tightly pressed against the valve-seat by the pressure of the water itself, thus it does not allow the water to flow in the reserved direction.

QUESTIONS

20.1. With the help of a neat sketch describe the function of a Scour valve.

20.2. Name the different types of valves used in a water-supply system. Describe the working of any one with the help of neat sketches.

20.3. Write short notes on:

(a) Sluice valve, and

(b) Reflux valve.

20.4. Why are Air-valves provided in pipe lines ? What is their function? With the help of a neat sketch describe the working of an Air-valve.

20.5. Under what circumstances are Reflux-valves provided ? Describe how it works.

20.6. Describe the function of 'Pressure Relief Valve'. What are these provided?

20.7. Write short notes on:

(a) Air relief valve

(b) Safety valve

(c) Check valve

(d) Sluice valve.

20.8. Name the types of valves commonly used water-supply scheme. Sketch any two of them and briefly explain their function.

Chapter 21

Distribution of Water

21.1 GENERAL

When the treatment of water is completed, it becomes essential to distribute it to individual houses and by stand-posts, at different places in the city or town, so that it may reach every consumer immediately after treatment with the same degree or purity. This is done by a net-work of pipes of different methods, which require pipe-lines of various sizes, valves, metres, hydrants, service connections, pumps and distribution reservoirs.

21.2 DISTRIBUTION SYSTEMS

For efficient distribution, it is required that water should reach every consumer with the required rate of flow. Therefore some pressure in pipe line water is necessary, which should force the water to reach at every place. Generally there are three systems for maintaining the pressure.

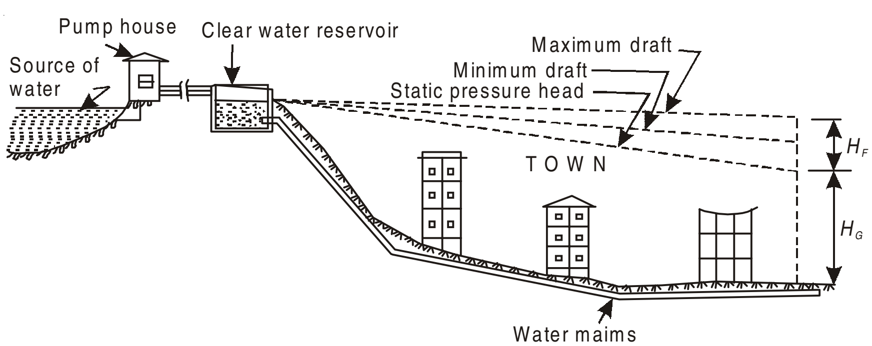


Fig. 21.1 *Gravity system.*

21.2.1 Gravity System

If some ground sufficiently high above the distribution area is available near the city this can be best utilized for the distribution-system in maintaining pressure in water pipes. In such purification works service-reservoir is placed on the high ground and the water flows in the water-mains only gravitational force. No pumping is required in this system and it is the most reliable system for the distribution of water.

21.2.2 Pumping System

In some towns where high ground is not available, the required pressure in the water-mains is maintained directly by pumping the water in mains.

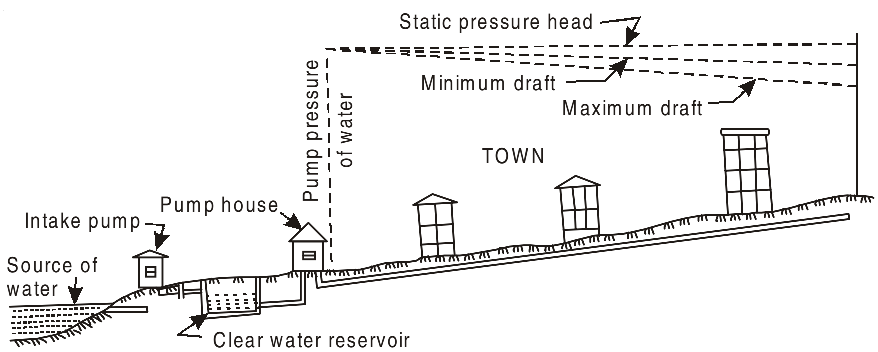


Fig. 21.2 *Pumping system.*

Since the pumps have to work at different rates in a day, the maintenance cost increases and also the life of pumping machinery is reduced.

21.2.3 Combined Gravity and Pumping System

In some towns where gravity-system is not possible, the required pressure in water mains is obtained by pumping the water to an elevated reservoir of

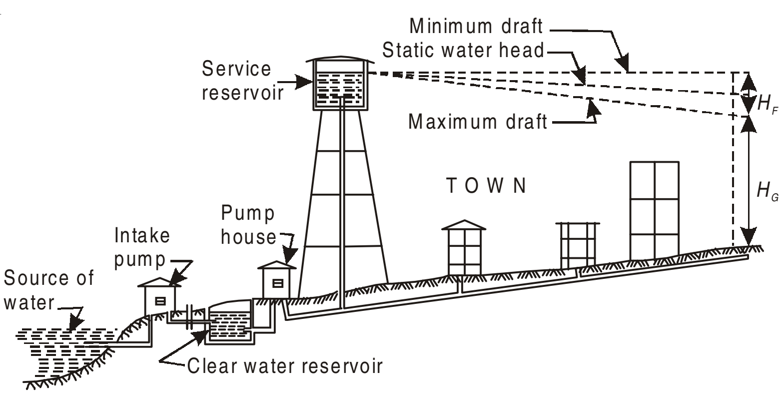


Fig. 21.3. *Combined pumping and gravity system.*

sufficient height, from where it is distributed to the city by the force of gravity. In this method water is first pumped in the service-reservoir and then distributed by the gravitational force, therefore, it is called as *combined gravity and pumping system.*

21.3 METHOD OF DISTRIBUTION

Commonly there are four methods, which are employed in the distribution of water. These are described below.

21.3.1 Dead-end or Tree-system

The layout of this type of system is shown in Fig. 21.4, and it is suitable only for irregular developed towns. It consists of a main line to which numbers of sub-mains are connected. Branches are connected to these sub-mains from

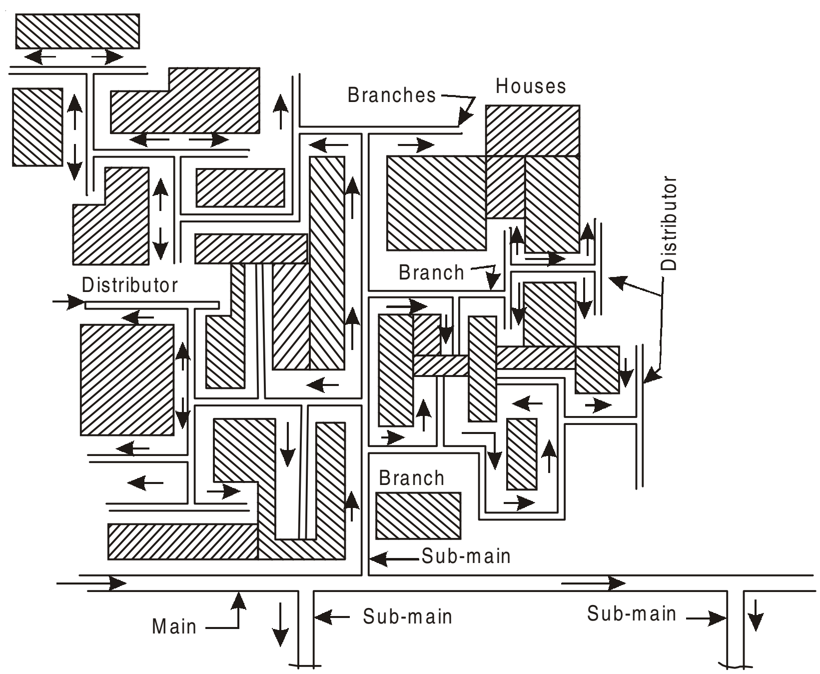


Fig. 21.4 *Dead-end or Tree-system.*

which service connections are made. In this way the whole system looks like a tree, hence called *Tree-system.* The main disadvantages of this system is the formation of dead-ends and if the pipe breaks down or is closed for repairs, the whole area beyond this point goes without water. The only advantage is that pipe diameters are easy to calculate and less number of valves are required.

21.3.2 Grid-iron or Reticulation System

This system is most convenient for towns having a rectangular layout of roads. All the dead-ends are inter-connected with each other and the water

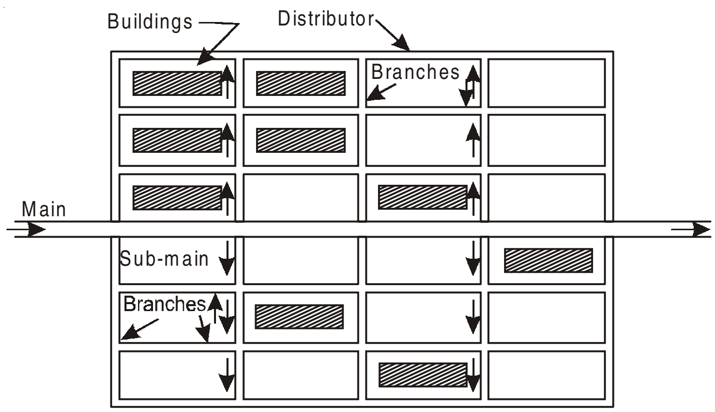


Fig. 21.5 *Grid-iron system.*

is allowed to circulate continuously through the whole system removing all the disadvantages of dead-end system. The disadvantages are that design of pipe lines becomes difficult and more valves and fittings are required if any desired section is required to be cut off.

21.3.3 Circular or Ring System

How the pipe lines are laid in this system is shown in Fig. 21.6. The water supply mains are laid around the whole city and water reaches at every

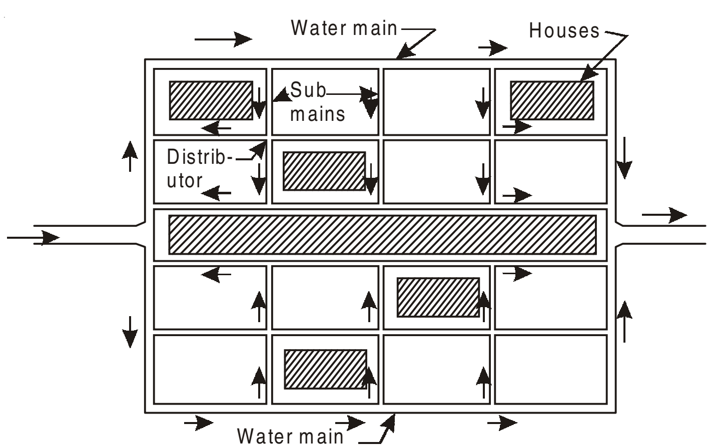


Fig. 21.6 *Circular or ring system.*

point from both sides with minimum loss of hand and time. In the down of any pipe line, the water reaches that point from the other direction by another pipe line, thus no difficulty need be faced by the consumers.

21.3.5 Radial System

In this system reservoirs are placed in the centre of each zone and water lines run radially from it, as shown in Fig. 21.7. This gives very quick and satisfactory water-supply and calculation of pipe diameters is very easy.

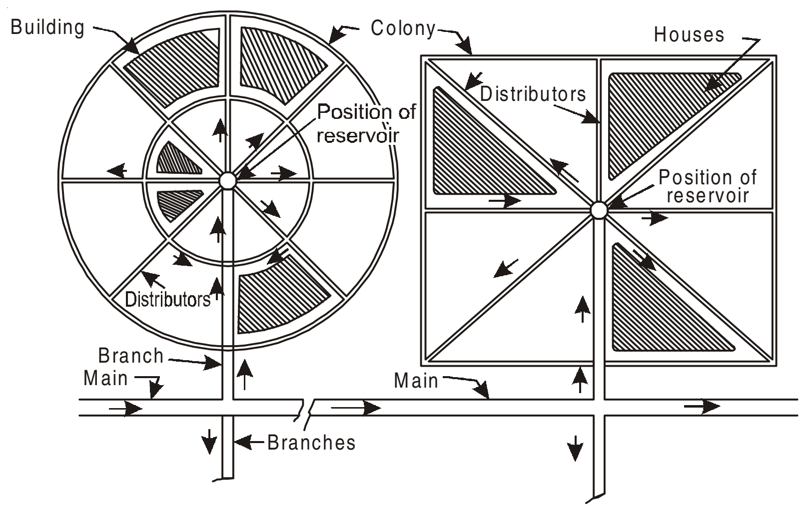


Fig. 21.7. *Radial system.*

21.4 METHODS OF SUPPLYING WATER

There are two main systems, by which water is supplied to the consumers. These are described below.

(a) Continuous system

(b) International system

21.4.1 Continuous System

In this system water is supplied to the consumers for all the twenty-four hours. This is the best system, which can only be possible if there is possible there is adequate water for supply. In this system ample water is always available for fire-fighting and due to continuous circulation water always remains fresh.

21.4.2 International System

If plenty of water is not available, the supply of water is divided into zones and one zone is supplied with water for fixed hours in a day, therefore, it is called the *intermittent system*. Some of the disadvantages of this system are as follows:

(i) The consumers have to store water for the non-supply hours, which is likely to get contaminated.

(ii) If fire breaks out in non-supply hours, no water is available. This may cause immense before the supply be turned on.

(iii) It has been observed that consumers leave their taps open every time, which causes a great wastage of water.

(iv) Partial vacuum is created in the pipe line during the non-supply period, which causes soil particles to enter in pipes through joints and this may lead to the contamination of water.

(v) Bigger diameter pipes are required to supply the water for the whole day in a very short period.

QUESTIONS

21.1. What are the various systems of distribution of water ?

21.2. Differentiate between 'Intermittent' and 'Continuous' systems of supplying water. In what circumstances would you recommend the use of latter?

21.3. Sketch the various types of layout used in the distribution systems of city water-supply.

21.4. Differentiate between the radial and circular methods of water-distribution.

21.5. Briefly explain the general methods of distribution of water employed in municipal water supply schemes.

21.6. Explain how water is distributed from storage to consumers in a public wafer-supply. Illustrate your answer with a flow diagram.

21.7. Distinguish between gravity system and pumped system.

PART 4

SANITARY ENGINEERING

Chapter 22

Systems of Sanitation

22.1 DEFINITIONS OF SOME COMMON TERMS, WHICH ARE MOSTLY USED IN SEWERAGE

22.1.1 Sewerage

It is a branch of engineering which deals with the collection and carrying of sewage through underground sewers by water-carriage system, away from the towns and to dispose it of in such a way that it may not cause any danger to the health of people.

22.1.2 Sewer

It is the general term indicating an underground conduit in which sewage flows.

22.1.3 Sewage

It includes all kinds of liquid wastes which are daily produced in a community i.e., liquid wastes from kitchens and bath rooms, urine, night soil and industrial wastes from manufacturing processes.

22.1.4 Refuse

It includes all kinds of dry wastes of the community i.e., street and house sweeping, garbage and sweepings from houses.

22.1.5 Garbage

It includes all types of semi-solid and solid waste food products such as vegetables, peelings of fruits, waste meat, etc.

22.1.6 Rubbish

It means all sundry solid wastes such as paper, broken furniture, pottery, waste building materials etc.

22.1.7 Ashes

These are the residues which remain after the combustion of coal, coke, timber in the hearths furnaces of houses and industries.

22.2 SYSTEMS OF SANITATION

There are two common systems for the collection and disposal of sewage:

(a) Conservancy system.

(b) Water-carriage system.

22.2.1 Conservancy System

In olden times it was used in every city and town and even now in smaller and backward cities this system in used. In this system all types of refuse, sewage, garbage, etc. are collected and disposed of separately. The human excreta is collected from the individual houses in buckets mostly twice a day and is taken out in covered carts from the city and buried in trenches. But at some places improved types of privies are used like pit privy, bore-hole privy, dug-well privy, concrete vault privy, removable receptacle privy and chemical toilet. In a good privy, (a) there should be no adour and unsightly conditions, (b) files should not reach it, (c) it should be economical to construct, and (d) it should not contaminate surface or ground water.

In the conservancy system refuse is collected in dust bins and taken out by covered tractor-trailors or lorries at least once a day from the town and disposed of. Non-combustible garbage is used for filling the low-lying areas and making it useful for constructing buildings, ground etc. Sullage and storm water is taken out by the drains provided along the sides of roads, upto natural streams or rivers where these are disposed of.

22.2.2 Water Carriage System

With the development of cities an urgent need was felt to replace the conservancy system with a more improved type of system in which human labour should not be used for the collection and conveyance of sewage from the city. After many experiments it was found that water is the only cheapest substance, which can be used for the above purpose. In this system specially designed water closets are used, in which human excreta is removed by flushing it with water. Sullage and human excreta are carried in underground sewers upto the point of disposal. Industrial waste and storm-sewage is also allowed to enter in these sewers and flow upto natural courses of water, where all these are disposed of after necessary treatment.

22.3 ADVANTAGES OF CONSERVANCY SYSTEM

(i) Strom water can pass in open drains, hence economical.

(ii) The quantity of sewage which will reach at the treatment plant before disposal will be low.

(iii) If the level at the out fall rises, it will not be costly to pump the sewage for disposal.

(iv) As the storm water goes in open drains, the sewer sections will be small and will run full for the major portion of the year and there will be no silting and deposit in the sewer-lines.

22.4 DISADVANTAGES OF CONSERVANCY SYSTEM

(i) It is possible that storm water may go in sewers, therefore, it is to be watched.

(ii) More space is required for laying two sewers in crowded lanes.

(iii) More space is required for burying the human excreta.

(iv) Decomposition of sewage cause insanitary conditions which are harmful to the health of people.

(v) Houses cannot be designed as one compact unit, because latrines are to be provided away from the living rooms due to foul smell.

(vi) Liquid refuse may get into ground soil and affect the subsoil water.

(vii) This system completely depends on the mercy of the sweeper every time. If sweepers go on strike, there is danger of spreading many diseases in the city due to decomposition of foul matters.

22.5 ADVANTAGES OF WATER-CARRIAGE SYSTEM

(i) As all the sewage goes in closed sewers under the ground, there is no nuisance from offensive matters.

(ii) Rain water dilutes the sewage.

(iii) As only one sewer is laid, it occupies less space in crowded lanes.

(iv) Volume of sewage being large, even at less gradients self-cleaning velocity can be obtained.

(v) Buildings can be designed compact as one unit.

(vi) The land required for disposal after treatment is smaller than that required for burying in conservancy system.

(vii) No additional water is required and usual water-supply is sufficient.

(viii)It is not dependent on manual labour at all times except when the sewers get choked.

22.6 DISADVANTAGES OF WATER-CARRIAGE SYSTEM

1. In monsoon times a large volume of sewage is to be treated, while in the other period of the year a very small volume with low velocity of discharge is treated.

2. Sometimes it becomes difficult to obtain self-cleaning velcocity.
3. A bigger outlet is required.
4. In monsoon times the disposal plant becomes overloaded.

22.7 MODERN DRAINAGE SYSTEMS

Mostly three types of drainage systems are employed in sewerage.

22.7.1 Combined Systems

When only one big diameter sewer is used for the collection and conveyance of both storm and sewage, it is called *combined system*.

22.7.2 Separate System

When sewage and storm water are taken in different sewers, this is known as *separate system*.

22.7.3 Partially Separate System

In rainy season if a portion of storm water is allowed to enter into the sewers carrying sewage and the remaining quantity of storm water is taken in separate sewers or drains, it is called *partially separate system*.

22.8 MERITS AND DEMERITS OF DRAINAGE SYSTEMS

The combined system is most suited to those cities where rain fall is very small, because there will not be much difference in the discharge of dry weather and monsoon, therefore self-cleaning velocity will be available in every season in sewer lines. On the other hand if it is used in cities having heavy rainfall, the self-cleaning velocity will not be available for the most part of the year and suspended matters will be deposited on the sides of sewer and will cause an obstruction to the flow.

The initial cost for laying one single pipe is cheaper in the combined system, as compared with the separate system, but the cost of treating the sewage will be much more in case of the combined system. In case of flood the cost of pumping will be very excessive in the combined system. Therefore as far as possible the separate system should be employed, because in the long run it will be cheap in maintenance and best from every point of view.

QUESTIONS

22.1. What do you understand by the term 'sewer' and 'sewage'? Explain the implication of the Double system of sewage.

[**Hint.** Double system means separate system in which two sewers or double sewers are laid.]

22.2. Described the Separate and Combined systems of sewers.

22.3. Describe the advantages of Water Carriage system.

22.4. Explain what do you mean by 'Conservancy system'.

22.5. What are the advantages of water-carriage system over the conservancy system of sanitation ?

22.6. Explain the main function of the Water-carriage system.

22.7. Compare the Combined, Partially Combined and Separate Systems of sanitation.

22.8. Differentiate between sewage, sullage and storm water.

22.9. What do you understand by 'Domestic' and 'Industrial' sewage ?

22.10. What do you understand by the terms Separate and Combined Systems of sewerage ?

22.11. Define (i) Sewer (ii) Sullage (iii) Drain.

22.12. Discuss the merits and demerits of a Combined System and a Separate Drainage System of sullage of storm water.

22.13. Discuss briefly what you mean by sanitation. How could it be achieved? Distinguish between :

1. Sullage and Sewage.
2. Sewer and Drain.

Chapter 23

Drains and Sewers

23.1 OPEN DRAIN

Open drains are used for conveying water from kitchens, bath rooms, washing places and rain water from court-yards, roads, roofs, open grounds, etc., except foul discharges from water-closets. If rain water is not taken out of the city, it will stagnate and endanger the safety of structures, health of the public, interrupt traffic movements, and decrease the beauty of the city. If discharges from the kitchens, bath-rooms and washing places are not discharged in natural drains or taken outside the town, these will accumulate around the houses and cause insanitary conditions and harm to the public in so may ways. For taking out the unfoul discharges from different places of the town including rain water, mostly open drains are used.

An open drain should be of such cross-section and laid on such a slope that self-cleaning velocity should be developed even for very low discharge. With maximum discharge, it should have sufficient freeboard at top and be cheap in construction and maintenance. It should have easy curves with smooth inner surfaces and smooth finish at every joint, so that frictional losses may be minimum.

23.2 OPEN DRAINS

The following are the sections of open drains, which are commonly employed at different places.

23.2.1 Semi-circular

This type of drain is mostly used for taking small discharges from buildings. Half stone-ware pipe can be used for its construction, therefore it is stable, cheap and easy in laying. If the discharge in this section decreases, the self-cleaning velocity will not develop and suspended particles will settle down in the bottom and cause an obstruction to the flow of water. Figure 23.1 shows a semi-circular drain which is mostly used.

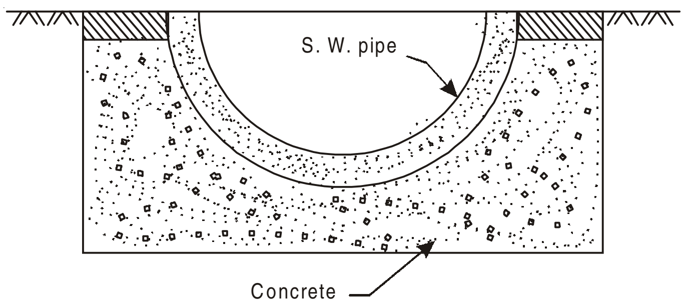


Fig. 23.1 *Semi-circular section.*

23.2.2 U-section

This is semi-circular type of drain with high sides. It is used at such places where discharge is more and cannot be taken by a semi-circular drain. Half

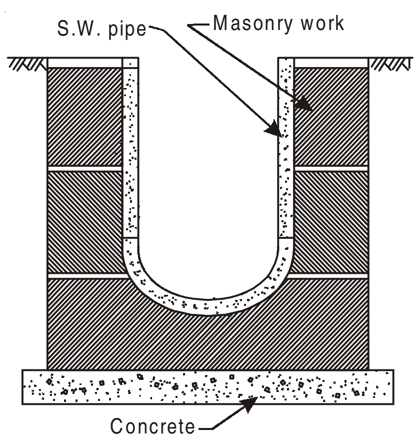


Fig. 23.2 *U-section.*

stone-ware pipe is laid in the bottom and over it masonry work is done as shown in Fig 23.2. It has some disadvantages as that of the semi-circular type.

23.2.3 Rectangular Section

This type of section is used for large discharges because for low discharge self-cleaning velocity will not develop and suspended particles will settle down. For the construction of this section plain cement concrete is laid at the bottom and both sides constructed with stone or brick masonry and plastered inside. Figure 23.3 shows a rectangular drain.

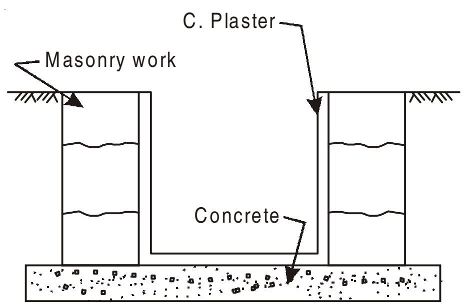


Fig. 23.3 *Rectangular section.*

23.2.4 V-section

This section gives self-cleaning velocity even for very small discharges because greater depth is available. In the bottom stone-ware pipe or concrete block is laid and the sides are constructed with brick work or flag stones and

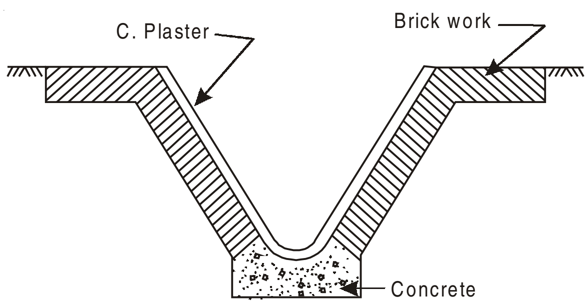


Fig. 23.4 *V-section.*

plastered inside. It is easy to clean this type of section. These may have 120°, 140° or 60° at the centre of lining glazed pipe of concrete blocks. Figure 23.4 shows one of the common types of V-sections.

23.3 SEWER

For conveying foul discharges form water-closets of public and domestic buildings, chemical mixed water from industries, closed conduits are required, which can carry these foul materials without creating any nuisance. These closed conduits are known as sewers and are laid under ground. Connections from public, domestic and industrial buildings are made to these sewers which carry foul material outside the city. As sewers carry acidic discharges these should be made of such a material which can resist corrosion and abrasion of it. In combined and partial combined systems sewers have to carry storm and less foul discharge also. Therefore it should be designed according to the system of conveyance of sewage and sullage.

Sewers should have such cross sections that in dry-weather flow, sufficient depth of water should remain in it for self-cleaning velocity. No deposits should settle down in it under any circumstances. These should be laid in the city such as in slope that in case of flood water the outlet should be clear and should not come out from the manholes and cause in sanitary conditions. These should be made of impervious material and with smooth insides that there should be no obstruction in the flow of sewage in it.

23.4 SEWERS

The common sections of sewer pipes are described in subsequent sections as described below.

23.4.1 Old Rectangular

These were used in ancient times and are not used nowadays. It was constructed by laying concrete in the bottom and constructing stone masonry on sides and covering it at top by slate stones.

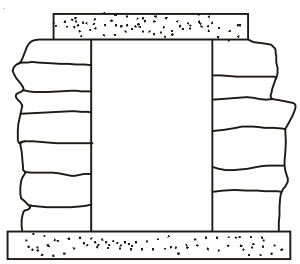


Fig. 23.5 *Old rectangular.*

23.4.2 New Rectangular

This type of section is constructed of R.C.C. These may be precast or cast-in-situ.

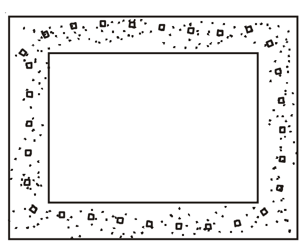


Fig. 23.6 *New rectangular.*

23.4.3 Old Semi-circular

This was used in olden days. Two layers of bricks were laid in semi-circular shape as shown in Fig. 23.7 and it was covered with flag stones at the top. These were constructed at the site.

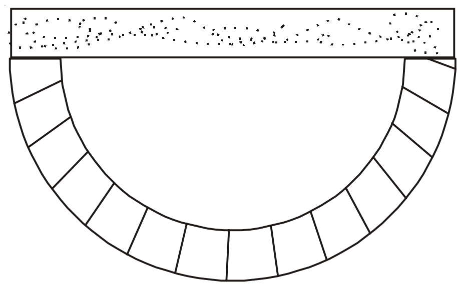


Fig. 23.7 *Old semi-circular.*

23.4.4 Circular Brick-sewer

This type of sewer section is used under culverts and at such places where very big diameter is required for a short length. After construction these are

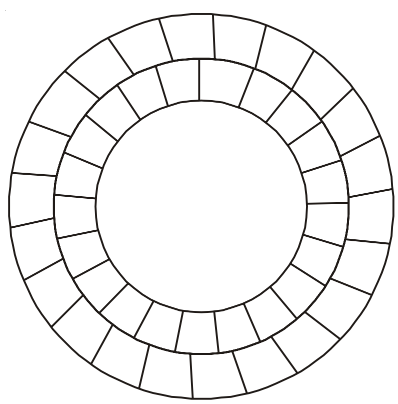


Fig. 23.8 *Circular brick sewer.*

plastered from inside. The maintenance and construction cost is much more in these sewers due to much wear and difficult centring, therefore these are not commonly used.

23.4.5 Egg-shaped Sewer

The depth of these sewers is one and half times its width. In olden form it was used with more radius at the bottom as shown in Fig. 23.9 while in new shape radius have been reduced at the bottom. These types of sewer sections are more commonly used because in dry weather flow, self-cleaning velocity can be obtained due to greater depth of water as compared with other

Fig. 23.9 *Egg-shaped sewer.*

sections. These are mostly constructed by concrete and brick arch with a special invert at the bottom or of R.C.C.

23.4.6 Semi-elliptical

This is useful for sewers carrying large discharge throughout the year, because they provide wider base. These are constructed of R.C.C.

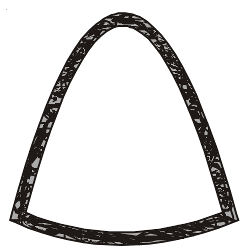


Fig. 23.10 *Semi-elliptical sewer.*

23.4.7 Inverted Egg-sewer

This is also used for sewers carrying heavy discharge and constructed of R.C.C.

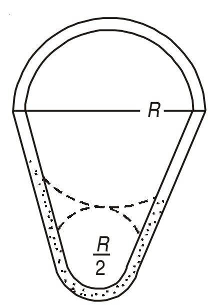


Fig. 23.11 *Inverted egg-sewer.*

23.4.8 Horse-shoe Type

This is constructed of R.C.C. and is used in the case of high discharges. This has semi-circular area on the top with sides inclined or vertical. The invert may be flat, circular or parabolic in section. Its bottom is constructed with slight curve. Its height is less than the width.

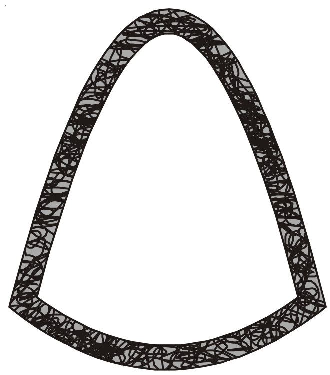


Fig. 23.12 *Horse-shoe type.*

23.4.9 Basket-handle Type

Its shape resembles a basket handle, therefore, it is called as *Basket-handle type.* This is also constructed of R.C.C. and used for larger discharges.

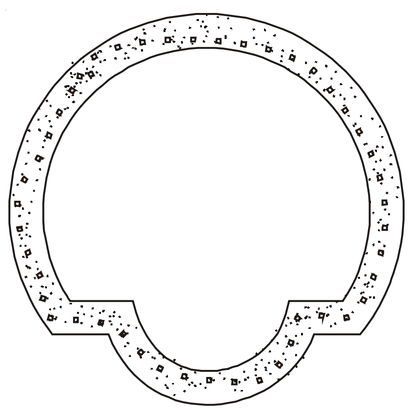


Fig. 23.13 *Basket-handle type.*

23.4.10 Circular Pipe

These are precast asbestos cement concrete pipes reinforced with steel. These are mostly employed nowadays. Laying of these pipes is very easy. Sometimes steel pipes with lining of cement concrete on inside and outside are also used. Cast iron pipes are also used on a large scale for lesser diameter on branch sewers.

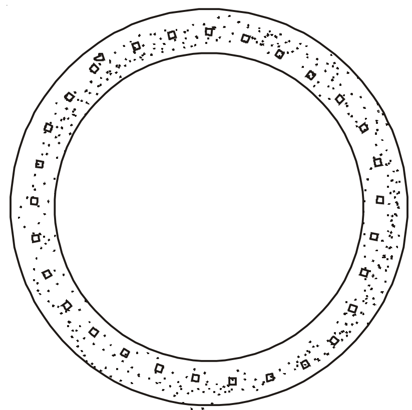


Fig. 23.14 *Circular pipe.*

QUESTIONS

23.1. What is the difference between 'Drain' and 'Sewer' ?

23.2. Draw neat sketches of the common type of drain used in town areas.

23.3. Differentiate between surface and underground systems of drainage.

23.4. Write short notes on surface drains.

23.5. Why is it necessary to provide underground sewers in towns and cities. What are the advantages of sewers over open surface drains ?

23.6. What do you understand by the term 'Dry weather flow' ?

23.7. What are the different types of materials commonly used for the construction of sewers?

23.8. Sketch different types of materials commonly used in city areas.

23.9. Where are the following types of sewers used

(a) Cast-Iron pipe

(b) Hume pipe

(c) R.C.C. pipe.

23.10. Write short notes on various sections of sewers, giving reasons for their specific use at different places.

23.11. Sketch different types of surface drains commonly used in town areas.

23.12. Differentiate between surface and underground systems of drainage.

Chapter 24

Sewer Appurtenances

24.1 GENERAL

Sewer appurtenance means sewer accessories or belongings, fitted along with a sewer line to facilitate the flow of sewerage properly in a sewer line.

If only sewers are laid, the sewage cannot flow in sewers for a long time. If the sewage system is not maintained properly, silt, ashes, greasy matters, etc., will stop the working of this system. For the operation and maintenance of sewage system some devices are essential, which should be inaccessible

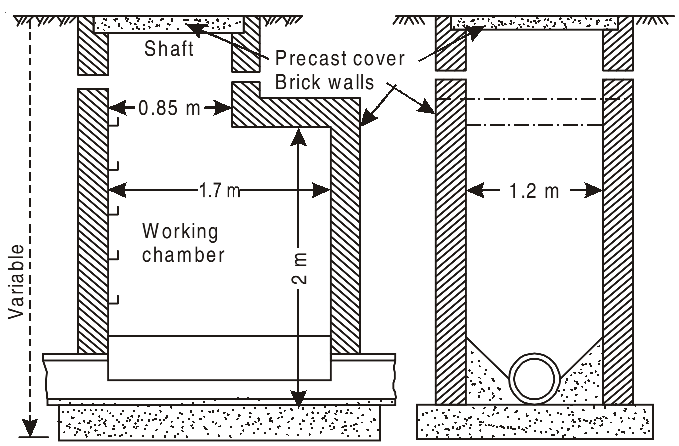


Fig. 24.1 *Manhole.*

to the general public. Some important devices commonly used in the working and maintenance of sewers are described briefly in this chapter, so as to give some idea to the students, regarding these accessories or appurtenances, as they are sometimes called.

24.2 MANHOLES

For cleaning the sewers and their periodic checking, manholes are constructed at intervals of 60–100 metres. Manholes are also constructed at every junction, bend or change of gradient. For small sewers manholes are constructed directly above them with sewer opening at the top. For large sewers manholes may be concentric or eccentric of the sewers.

The manhole consists of a *working chamber of size* 1.7 × 1.2 × 2 metres and the upper portion called the *access shaft* having minimum lateral dimensions as 0.85 × 0.7 metre. The manhole covers are generally made of C.I. or R.C.C. slab. The walls of manholes are constructed with 30 cm thick brick masonry or R.C.C. with smooth cement plaster on their inside. For reaching the working chamber a series of steps or a ladder is provided.

24.3 DROP-MANHOLE

When two sewers running at different levels are to be connected, the branch or street sewer, which is assumed to be running at a higher level than in the main sewer and if this difference of levels is more than 1 metre, *drop manhole* are provided. The branch line is taken with the same slope and is given a

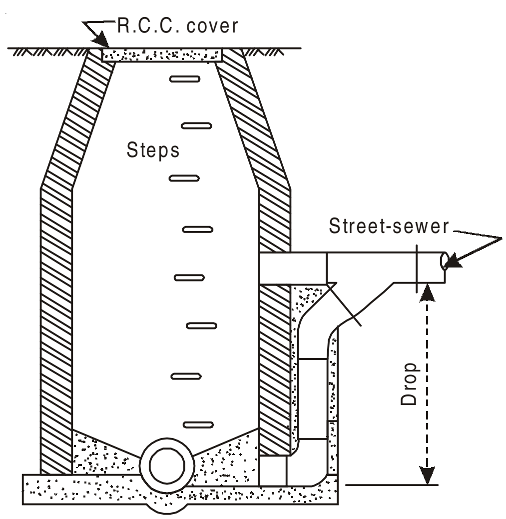


Fig. 24.2 *Drop manhole.*

vertical drop at the manhole. The sewage is allowed to drop at the side of the manhole through a vertical or inclined pipe and the sewer line is connected to the manhole so that it can be cleaned and rodded when necessary. It is better to take sewage through a pipe curve shape in plan because it will prevent splashing of sewage in the manhole.

24.4 LAMP HOLES

In narrow lanes, where space is insufficient for the construction of a manhole, a vertical shaft of about 23 cm in diameter is connected to the sewer by a T-bend. This is covered by a C.I. or R.C.C. cover at the top. These lamp-holes are provided at places of slight curve. While inspecting, a lamp is lowered in it, and is seen from the manholes on either side to find out whether the sewer is clean or not. (Fig. 24.3.)

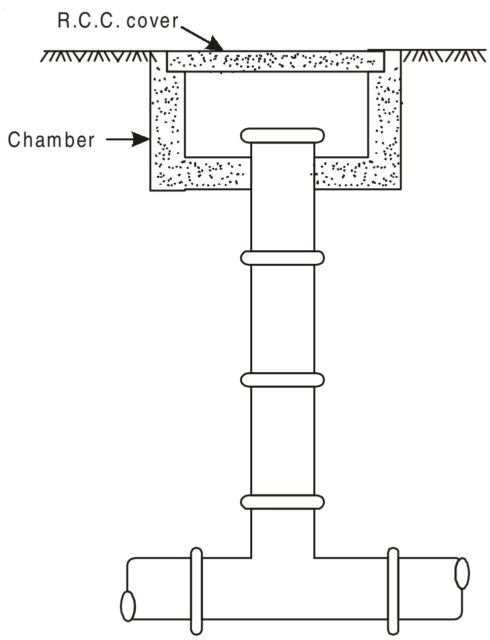


Fig. 24.3 *Lamp-hole.*

24.5 VENTILATION OF SEWERS

Various gases are produced in sewer pipes due to *purification* of sewage. These gases are very foul in nature and cause harm to human health. Gases are highly explosive and in high concentration, may cause explosion. These interference with the flow of sewage and if pressure becomes high, they may blow-off the manhole covers causing accidents. Therefore manhole covers are provided with fresh air inlets. Due to the above difficulties ventilation is provided in the sewer lines at every 80 to 100 metres which will prevent the above nuisance and will provide fresh air to workers working in manholes.

For efficient ventilation, there should be inlets and outlets for fresh air and foul gases respectively. Generally the manholes in the inhabited parts are made air-tight and the ventilation shafts act as inlet or outlet depending on the relative position of the temperatures inside and outside the sewer, the rise and fall of the water level the sewer and force and direction of wind at that time. The ventilating shafts may be of R.C.C. or cast iron, 15 to 23 cm in diameter with a cowl on the top. The spacing between ventilating shafts should be about 170 metres and height should be more than the tallest building in its neighbourhood. Figure 24.4 shows a ventilating-shaft which is generally connected to the manholes.

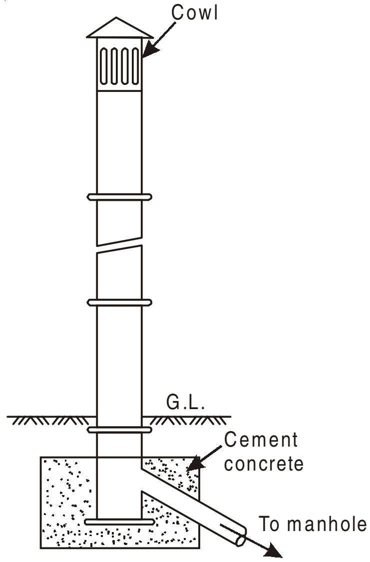


Fig. 24.4 *Ventilating shaft.*

24.6 TRAPS

Foul gases are produced in the sewers, drains and waste-pipes which may cause nuisance by entering in houses through house connecting pipe if their passage is not checked by some suitable devices. The devices which are used to stop the escape of foul gases inside or outside the houses are known as traps and generally consist of a bend tube which provides a water seal between atmosphere and the gas. The efficiency of the trap depends on the depth of water-seal, the deeper the seal, the more efficient will be the trap.

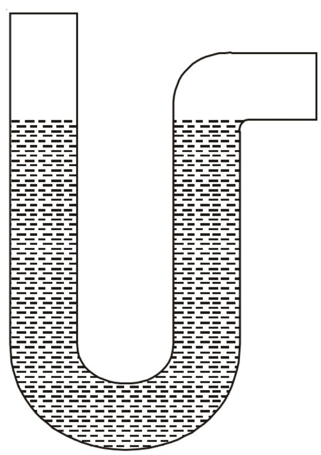
Different types of traps are employed in India which are described below:

26.6.1 P, Q and S Traps

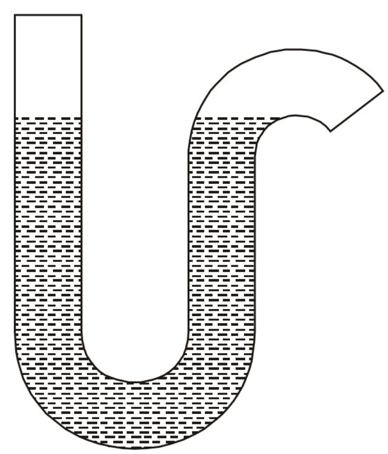
These types of traps are shown in Fig. 24.5. They essentially consist of a U-tube which retains water acting as a seal between the foul gas and atmosphere. P, Q and S names are given depending on the shape of the traps as shown in Fig. 24.5.

24.6.2 Intercepting Trap

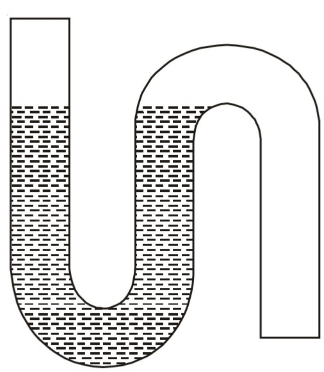
The sewage from every goes in street-sewers which carry it away from the city. The street-sewers contain foul gases in it and if their passages are not checked from street-sewer to the houses, they may enter in the house drain and cause nuisance. For this purpose a trap in one inspection chamber is provided at the top, having a cleaning eye with a plug, which disconnects the flow of gases into houses. Figure 24.6 shows this type of trap which is intercepting a house drain from the street-sewer, that is why it is called as intercepting trap.



(a) P-Trap



(b) Q-Trap



(c) S-Trap

Fig. 24.5

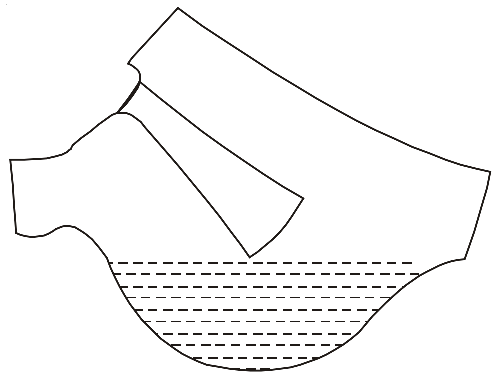


Fig. 24.6 *Intercepting trap.*

24.6.3 Gulley Trap

Figure 24.7 shows this type of trap, which is provided at different places to check the entry of sewer gases from sewer to a house. Water from sinks, bath etc., enter in through back inlet and unfoul water from sweeping of

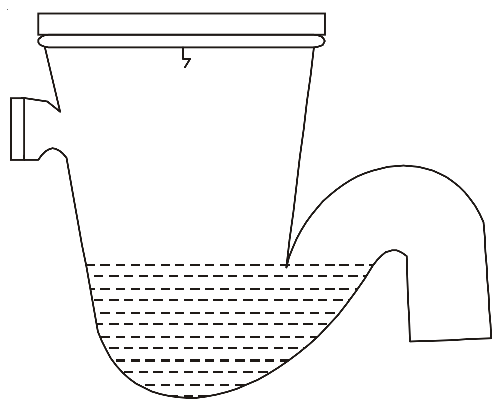


Fig. 24.7 *Gulley trap.*

rooms, or courtyards etc. enter from the top, where a coarser screen grating is filtred to check the solid matter like leaves, papers etc. which may block the sewer. The water seal checks the entry of gases from sewer.

24.6.4 Grease Trap

The sewer water mostly has grease, oils, fats, which, if not removed before it enters in drains and sewers, will stick to the interior surface of the conduit and become hard and cause great nuisance by obstructing the flow. To check the flow of these oily matters, some arrangements are made as shown in Fig. 24.8. It consists of a chamber having its outlet pipe fitted with a bend. These traps hold about 130 litres of water and are large enough to cool the

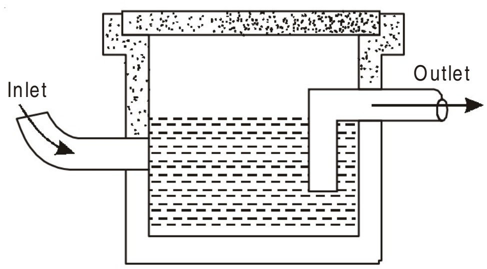


Fig. 24.8 *Grease trap.*

incoming wastes and permit separation of grease. The influent pipe should terminate at least 15 cm below the water level and the effluent pipe should take off near the bottom of the trap. The scum which is formed at the top water should be cleaned frequently for the satisfactory operation of trap.

24.6.5 Combined Silt and Oil Trap

Sewage in addition to oils and grease also contains sand, silt and soil matters, which should be removed before it enters in the sewer pipe, along with oil and grease. A trap which is used for this purpose is shown in Fig. 24.9 which

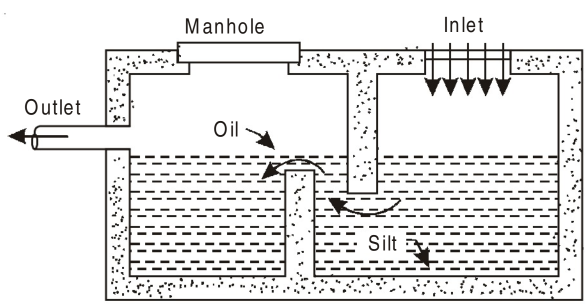


Fig. 24.9 *Combined silt and oil trap.*

has the arrangement for accumulation of sand and solid matters in the bed of the chamber and those of oils and greases at the top. It removes silt and oil at the same time therefore it is called *combined silt and oil trap.* It consists of two compartments. The sand and silt is collected in first compartment and the oils in the second.

24.7 FLUSHING TANKS

When the gradient of the sewers is flat and a good velocity is not available for the self-cleaning of the sewers, flushing tanks are provided. These tanks are usually provided at the beginning point of the sewers and may be either automatic or worked by hand. Water from these tanks is released at required intervals, which can be adjusted by the supply pipe tap, and flush the deposits in the pipe.

An automatic flushing tank is shown in Fig. 24.10. It consists of a masonry or concrete chamber fitted with a tap for the entrance of water into it for flushing purpose. A U-tube with a bell-cap connects the chamber with sewer.

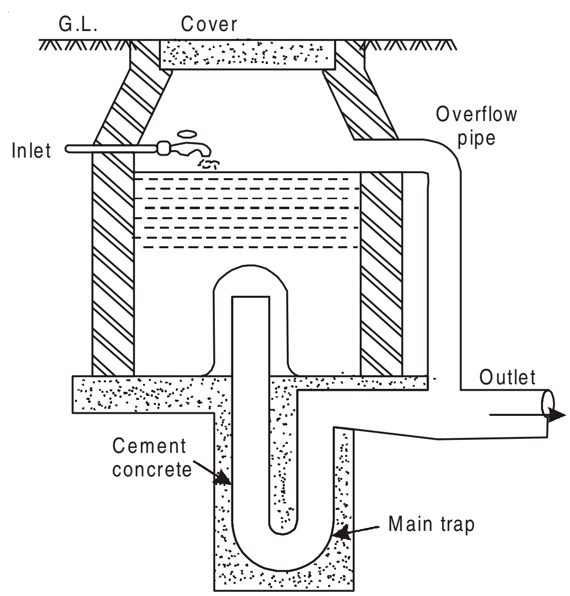


Fig. 24.10. *Automatic flushing tank.*

When the water level increases in the chamber, it also increases in the bell-cap. As soon at it reaches a certain level, siphonic action takes place and the whole water rushes to the sewer pipe and flushes it. The capacity of these tanks is usually 900 to 1,400 liters and it is so adjusted as to work twice of trice a day depending on the quantity of deposits.

QUESTIONS

24.1. (a) Why should the sewers be ventilated properly ?

(b) Describe in brief any one method used for cleaning small sewers.

24.2. What is the function of manholes in sewers ?

24.3. With the help of a neat sketch, describe the working of an Automatic Flushing Tank.

24.4. Write short notes on:

(a) Drop-manhole

(b) Trap

(c) Lamp-hole

(d) Inlets.

24.5. What is the function of a combined grease and silt trap ? Describe with the help of a neat sketch how it separates grease and silt from the sewage.

24.6. At what places does it become necessary to provide drop manholes? What are its main function ?

24.7. Explain why it is necessary to provide sewer appurtenances in sewer lines. Write down the salient features of any one of the sewer appurtenances which is most commonly used.

24.8. Write short note on Catch-Basins.

24.9. Write short note on Gulley trap.

Chapter 25

Excreta Disposal in Unsewered Area

25.1 GENERAL

India is a poor country, due to which it is not possible to have the water carriage system in all the towns, villages and cities. Indian people are also not sanitary-minded due to which even in the best buildings, bath-rooms and latrines are in the most insanitary conditions. Generally it has been seen that people do not give any attention during the construction of bath-rooms and latrines, therefore this portion of the building remains as neglected. The rural areas, scattered localities and isolated colonies which are not served by the piped water supply, always have a shortage of water, due to which the quantity of waste water is also small. The waste water from such areas can be easily disposed of by broad irrigation. As there is no sewerage system therefore some methods should be developed for the safe collection and disposal of human excreta from such areas. In this chapter, the methods of excreta in unsewered areas will be described.

25.2 PRIVIES

In conservancy system the human excreta is collected in various types of privies, few of which are :

(i) Pit privy
(ii) Bore-hole privy
(iii) Cesspools
(iv) Concrete vault privy
(v) Dug-well privy
(vi) Chemical toilet
(vii) Removable receptacle privy
(viii) Aqua privy.

25.3 PIT PRIVY

This is very economical and requires no operation. Figure 25.1 shows this type of improved privy. It essentially consists of a pit 1.3 × 1 m in plan and 1.5 to 2.8 m deep. At the top of this pit the squatting seat is provided in a compartment. The superstructure is of temporary nature. When the pit is

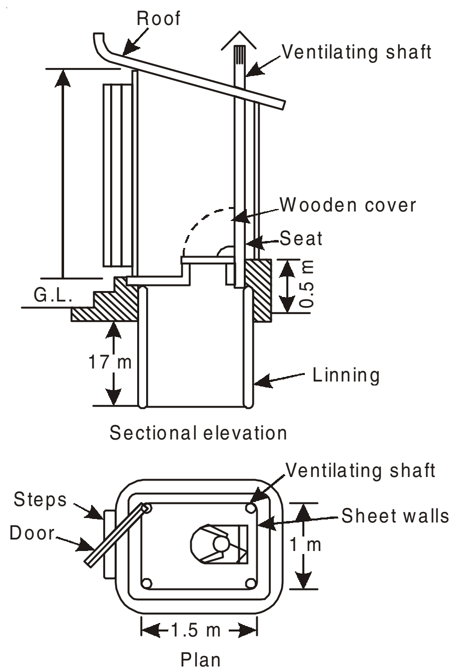


Fig. 25.1 *Pit privy.*

filled, it is closed from the top by 60 cm thick earth layer and a new pit is excavated by the side of it. The squatting pan along with the compartment is shifted to the new trench. A 10 cm diameter vent pipes is also provided to take the foul gases. If lime is applied frequently it will reduce the odours. Pit privy should be constructed 30 m away from the existing well in the nearby locality.

25.4 BOREHOLE PRIVY

It is similar pit privy, the only difference is that in place of a pit, it has long 40 cm diameter hole. The depth of the bore hole should be 100 cm less than the ground water table, so that excreta may not pollute the ground water. The hole should be lined from inside. When the hole is filled up, it is covered by a thick layer of soil and another hole is dug by the side of it.

Figure 25.2 shows the essentials of improved borehole privy in which the hole is provided by the side of the latrine compartment and is connected to

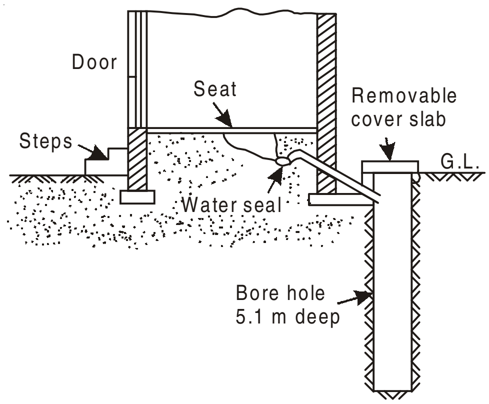


Fig. 25.2 *Bore-hole privy.*

the squatting seat by means of a trap. This improved type of privy will also avoid fly nuisance and odour.

25.5 CESSPOOLS

It essentially consists of pit or chamber lined with dry bricks or stones as shown in Fig. 25.3. One cesspool can serve the function of more than one building depending upon its capacity. The excremental matters flow through

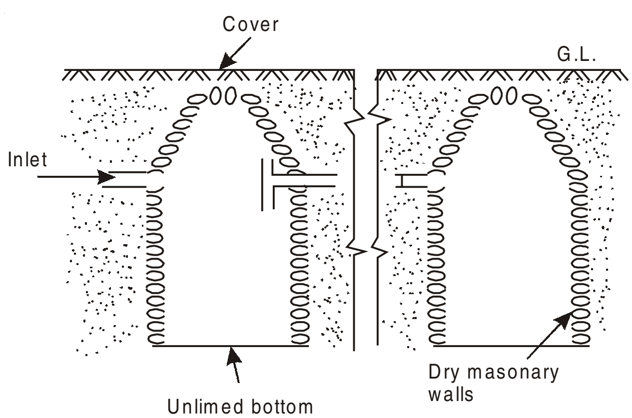


Fig. 25.3 *Cesspools.*

pipes from the water closets. When the cesspool is filled up, it is emptied and cleaned. The pumped materials are disposed of in a suitable manner.

25.6 CONCRETE VAULT PRIVY

In pervious soils and when water table is very close to the ground surface, it becomes difficult to construct borehole, pit or other types of privies, because the excremental matter will pollute the ground water. Under such circumstances concrete vault privy is most suitable.

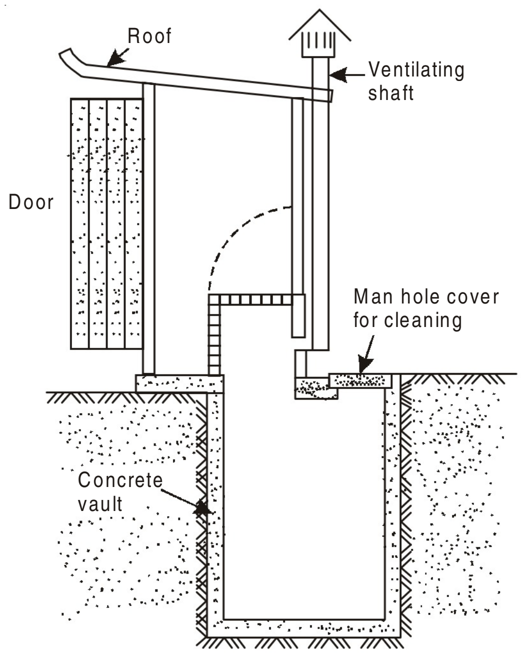


Fig. 25.4 *Concrete vault privy.*

Figure 25.4 shows the essentials of a concrete vault privy. If essentially consists of a water-tight concrete vault constructed in the ground. Squatting pan with compartment is placed over the concrete vault as shown. When the vault is filled up, it is emptied and cleaned. Squatting pan should be constructed in such a way that no water can enter the vault.

25.7 DUG WELL PRIVY

It is similar borehole privy only the difference is in the diameter of the hole. In dug-well privy 75 × 75 × 360 cm pit is excavated, which is lined with honey comb brick-work or stone-work, to absorb the liquid wastes.

25.8 CHEMICAL TOILET

This is the most satisfactory method of disposal of excreta without water carriage. In this privy a metal tank filled with concentrated solution of caustic soda is placed below the squatting seat. The excreta is totally sterilized and liquified when it comes in contact of strong caustic soda. When the metal tank is filled up, it is cleaned and emptied. The effluent of chemical toilet is clear and free from any odour and can be easily disposed of.

25.9 REMOVABLE RECEPTACLE PRIVY

This is a cheap type of privy and is mostly used in India in unsewered towns. It requires the services of sweeper for its daily cleaning. It essentially consists

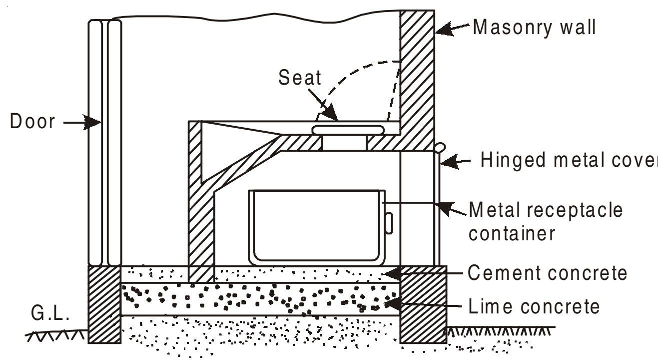


Fig. 25.5 *Removable receptacle privy.*

of a metal box placed below the squatting seat. The excreta is collected daily from this removable box by sweeper. Figure 25.5 shows this type of privy.

25.10 AQUA PRIVY

Most of the privies described above are of temporary nature and shifted when the privy is filled up with excreta. Therefore they cannot be constructed as a permanent structure.

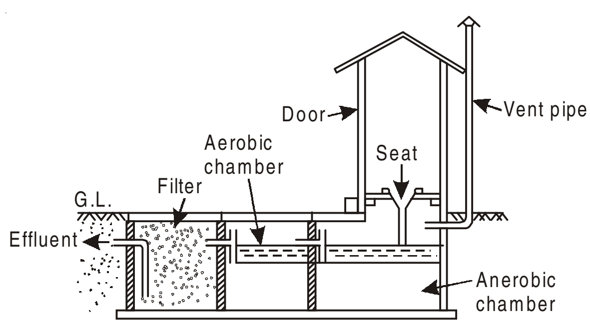


Fig. 25.6 *Aqua privy.*

Aqua privy or wet latrine is an improved type of privy, which makes it possible to provide a permanent structure. Such types of privies are very convenient for factories, villages, hill stations etc., no doubt they are more costly and requires some attendance.

Figure 25.6 shows the essential of an aqua privy. It essentially consists of underground masonry chamber. Latrine pans enclosed inside small rooms are fixed on the top of the masonry tank with the outlet ends hipped 8 to 10 cm in the liquid below. As the outlet ends of pans are dipped in water, foul gases cannot escape in the latrine rooms and no water is required for flushing it. The excreta directly goes in the masonry chamber and is digested aerobically. One more chamber is also provided by the side of it, in which aerobic action takes place and the sewage is digested. The effluent from second chamber is allowed to pass through a filter tank as shown in Fig. 25.6. The final effluent is very clear and can be utilized for irrigating gardens or directly disposed of in nearby water courses. Aqua privies are most suitable for localities having no piped water supply, because very small quantity of water is required for using it.

25.11 SEPTIC TANK

In unsewered urban, semi-urban and rural areas, the sewage of every house, institution, hotels, hospitals can be treated in a septic tank, the effluent from which is given secondary treatment either in a biological filter or on

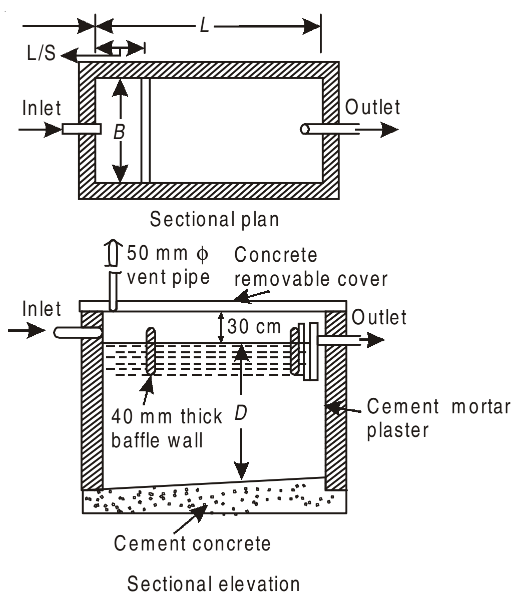


Fig. 25.7 *Septic tank.*

the land, or in subsurface disposal system. Care should be taken that the surface and subsoil water should not find its way into the septic tank.

Septic tanks may be constructed of brickwork, stone masonry or concrete or other suitable materials. The septic tank should be plastered inside with rich cement mortar in which some water proofing materials should be mixed up. The floor should be of 1 : 2 : 4 cement concrete and given slope towards the sludge outlet (if provided). Air-tight concrete or steel cover should be provided on the top of the septic tank. Manholes should be provided in the cover for inspection and cleaning of the tank.

Figure 25.7 shows the plan and sectional elevation of a septic tank which is most suitable for domestic purposes. The minimum width and liquid depth of septic tanks should be 75 cm and 100 cm repectively. The minimum liquid capacity should be one cubic metre. The length of tanks should be 2.4 times the width. Table 25.1 gives the suitable sizes of septic tanks which correspond to Fig. 25.7.

TABLE 25.1 *The sizes of septic tanks as per I.S. 2470 (Part I) 1963*

No. of Users	*Length L Metre*	*Breadth B Metre*	*Liquid Depth D Min. Metre*	*Liquid capacity to be provided m^3*	*Free Board Min. cm*	*Sludge to be removed m^3*	*Recommended Interval of cleaning*
1	2	3	4	5	6	7	8
5	1.5	0.75	1.0	1.12	30	0.18	5 months
			1.0	1.12	30	0.36	1 year
			1.05	1.18	30	0.72	2 years
10	2	0.9	1.0	1.8	30	0.36	6 months
			1.0	1.8	30	0.72	1 year
			1.4	2.52	30	1.44	2 years
15	2	0.9	1.0	1.8	30	0.64	6 months
			1.3	2.34	30	1.08	1 year
			2.0	3.6	30	2.16	2 years
20	2.3	1.1	1.0	2.53	30	0.72	6 months
			1.3	3.3	30	1.44	1 year
			1.8	4.55	30	2.28	2 years
50	4	1.4	1.0	5.6	30	1.8	6 months
			1.3	7.28	30	3.6	1 year
			2.0	11.2	30	7.2	2 years

For details of the septic tanks the reader must study the Indian Standards No. 2470 (Part I and II).

25.12 DESIGN OF SEPTIC TANKS

As septic tank is a settling-cum-digestion tank, it requires space for :

(i) Settling of incoming sewage

(ii) Digestion of the settled sludge.

(iii) Storage of digested sludge till it is taken out.

Design of space for settling. This is calculated for the average flow and detention period. Smaller tanks are designed on the basis of average flow and 24 hours detention period, while larger tanks are designed for 12 hours detention period.

If only the discharge from the latrines flows in the septic tanks, the average flow per capita per day may be taken as 45 litres. On the other hand, if all the waste water of the houses is to be treated in septic tank, the average flow should be taken 90 to 115 litres per capita per day depending on the water supply.

Design for digestion space. In the specific tank, the operation goes in natural way and there is no control over it, such as mixing, heating, etc., a provision of 0 0425 m^3 per capita should be done for it.

Design of space for storage of digested sludge. The digested sludge produced per capita in different periods is as follows:

Period of Cleaning	*Storage Capacity*
6 months	0.0283 m^3
1 year	0.049 m^3
2 years	0.0708 m^3
3 years	0.085 m^3

The design of space for storage of digested sludge is done on the basis of period of cleaning and the number of persons using the tank.

The total capacity of the septic tank thus may vary from 0.114 to 0.2 m^3/captia to 0.07 to 0.14 m^3/capita for smaller and large tanks respectively.

Illustrative Example. *Design a septic tank for 50 users, assuming the rate of water supply as 60 liters/head/day.*

Sol. Assuming the detention period as 24 hours and the time of cleaning the sludge as 3 years.

$$\text{Space required for settling} = \frac{50 \times 60}{1000} = 3.0 \text{ m}^3$$

$$\text{Space required for digestion} = 50 \times 0.0425 = 2.125 \text{ m}^3$$

Space required for storage of sludge

$$= 50 \times 0.085 = 4.25 \text{ m}^3$$

The total space required = 3.0 + 2.125 + 4.25

= 9.375 m^3 = (9.5 m^3), say

Provided free board of 30 cm.

Provide the septic tank of 4 × 1.4 × 2.0 metres **Ans.**

25.13 DISPOSAL OF SEPTIC TANK SLUDGE

The septic tank sludge may be delivered into a cesspool or into a suitable vehicle for removal from the site. It can also be disposed of in the same way as the sewage sludge.

25.14 TREATMENT AND DISPOSAL OF SEPTIC TANK EFFLUENT

Tank effluent of very large tanks is only given secondary treatment by passing it through biological filters. Effluent of small septic tank is not given any type of treatment before its disposal.

The septic tank effluent can be disposed of in any one of the following ways :

(i) By subsurface irrigation.
(ii) By surface irrigation.
(iii) By discharging into nearby water courses.
(iv) By soil absorption system.

The soil absorption system has the following method for the effluent:

25.14.1 Soakage Pit

This is also known as *seepage pit*. These are circular pits more than one metre in diameter and 1 m in depth below the invert of the inlet pipe. These

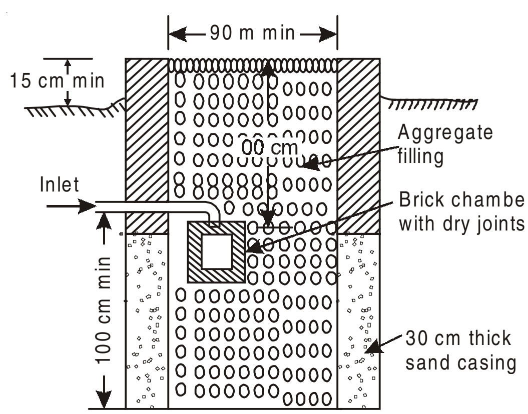


Fig. 25.8 *Soakage pit.*

pits are lined with dry bricks or stone and are filled with the brick-bats or coarse aggregate more than 7.5 cm size. In the case of large pits the top portion is reduced in size for the reduction in the size of the R.C.C. cover. Figure 25.8 shows the section through a soakage pit.

25.14.2 Leaching Cesspool

Cesspool has been described in Sec. 25.5. The same cesspool can be used for soaking the effluent of septic tanks. In this cesspool the bottom is made water-tight to retain the sewage and sludge while the upper portion is

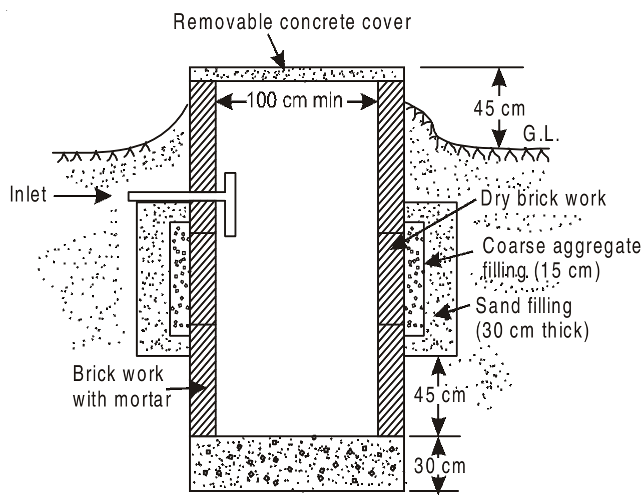
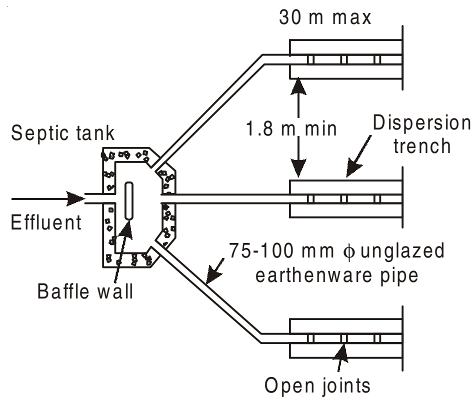


Fig. 25.9 *Leaching cesspool.*

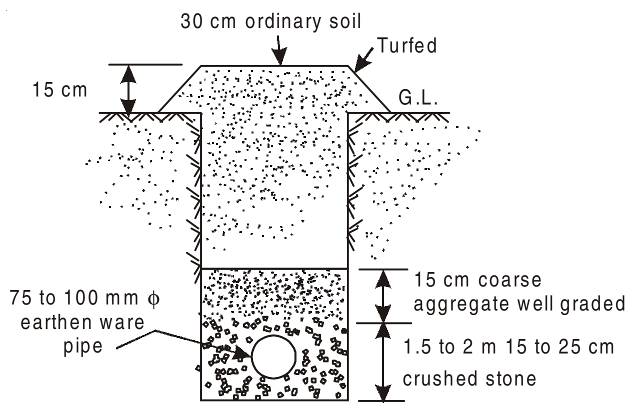
provided. With open joints from where effluent can get dispersed into the surrounding soil. The open jointed lining is surrounded by 15 cm coarse aggregate of 4 to 5 cm in size and an outer casing of 30 cm thick sand for the better distribution of supernatant effluent in the soil is also provided. Figure 25.9 shows the section through a Leaching cesspool.

25.14.3 Dispersion Trench

These are also called *soakage trenches.* Figure 25.10 shows the plan and section through dispersion trenches. The dispersion trenches should be 50 to 100 cm deep and 30 to 100 cm wide excavated to a slight gradient and are filled with 15 to 25 cm of washed gravel and crashed stones. Open jointed pipe of unglazed earthenware or concrete are laid down inside the trenches. The maximum internal diameter of these pipes should not be more then 74 to 100 mm. Each dispersion trench should not be longer than 30 m. The dispersion trenches should not be placed closer than 1.8 m. These pipes should be covered by 15 cm coarse aggregate over which graded aggregate is filled upto 15 cm above the general ground level as shown in Fig. 25.10.



(a) Plan of dispersion trench



(b) Enlarged section through a dispersion trench

Fig. 25.10

QUESTIONS

25.1. Describe the various methods of disposal of excreta in unsewered areas.

25.2. With the help of a neat sketch, describe the aqua privy.

25.3. Under what circumstances septic tanks are most suitable. With the help of neat sketches, describe the construction and operation of a septic tank.

25.4. Design a septic tank for 100 users. Assume all the data. Also draw a rally dimensioned sketch.

25.5. Write a short note on the disposal of septic tank effluent.

Chapter 26

House Plumbing

26.1 TECHNICAL TERMS

It is necessary to know the following technical terms relating to plumbing and sanitary fittings before studying the principles and the common practices used in the house plumbing and sanitary fittings.

26.1.1 Water Main (Street Main)

A water supply pipe vests in the administrative Authority for the use of public or community.

26.1.2 Water Outlet

A water outlet is the discharge opening for the water (a) to fixture ; (b) to atmospheric pressure; (c) to a boiler or heating system; (d) to any water-operated device or equipment requiring water to operate.

26.1.3 Water Supply System

The water supply system of a building or premises consists of the service pipe; and the necessary connecting pipes, fittings, control valves and all appurtenances in or adjacent to the building or premises.

26.1.4 Warning Pipe

An overflow pipe so fixed that its outlet is in an exposed and conspicuous position where the discharge of any water may be readily seen and where practicable outside the house or building.

26.1.5 Storage Tank

It is a tank or cistern for storage of water which is connected to the water main by means of a supply pipe.

26.1.6 House Plumbing

The practice, materials and fixtures used in the installation, maintenance, extension and alteration of all piping, appliances and appurtenances in connection with the house or premises.

26.1.7 Plumbing System

The plumbing system includes the water supply and distribution pipes; plumbing fixtures and taps ; soil, waste, vent pipes and antiphonage pipes; building drains and building sewers, including their connections.

26.1.8 Geyser

An appliance for heating of water with a water control on the inlet side and free outlet.

26.1.9 Available Head

The head of water available from a water main at the plinth level of the premises.

26.1.10 Back Flow

The flow of water or other liquid, mixtures into the distributing pipes of a potable supply of water from any source of sources other than intended source.

26.1.11 Air Gap

The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or fitting supplying water to tank, plumbing fixture or other device and the flood-level rim of the receptable in a water supply system.

26.1.12 Back-siphonage

The following back of used, contaminated or polluted water from a plumbing fixture or vessel into a water supply pipe due to a lowering of pressure in such pipe.

26.1.13 Downtake Tap

A tap connected to a system of piping not subject to water pressure from the water main.

26.1.14 Effective Opening

The minimum cross-sectional area at the point of water supply, measured or expressed in terms of :

(a) diameter of a circle,

(b) if the opening is not circular, the diameter of a circle of equivalent cross-sectional area.

26.1.15 Wash Out Valve

A device located at the bottom of the tank of the purpose of draining a tank for cleaning, maintenance etc.

26.1.16 Residual Head

The pressure available at the tail end of the distribution system.

26.2 STORAGE OF WATER

In the buildings, the storage of water is required for the following purposes:

(i) for supplying water to the consumers during non-supply hours ;

(ii) for reducing the maximum rate of demand on the water mains;

(iii) for storage of water during interruption due to damage, repair etc. of the water mains;

(iv) when the available head is insufficient to supply the water in each storey in multistory buildings.

The reservoirs, cisterns and storage tanks are generally constructed of cast iron, wrought iron galvanized mild steel plates. Sometimes R.C.C. storage tanks are also used. These tanks may be circular, square or rectangular in plan. The storage tanks may kept on the roof of the buildings or on the ground. The storage tanks should be water-tight and provided with an efficient mosquito-proof warning pipe. The outlet of this warning pipe should be placed in such a position so that the discharge of the water can be readily seen. One overflow pipe is also provided in the storage tank, Ball valve should be provided in the tank to control the flow of water in the tank. All the storage tanks should be provided with a scour or drain pipe near the bottom to clean the tank. The storage tanks are provided with outlet pipes to draw the water.

26.3 STORAGE CAPACITIES

The quantity of water to be stored depends on the following factors :

(i) rate of supply of water from waterworks;

(ii) type of buildings such as residential, public or industrial;

(iii) whether water supply is continuous or intermittent;

(iv) frequency of replenishment of overhead tanks, during the 24 hours.

Indian Standards Institution has recommended a minimum of 135 liters/head/day in residential buildings having full flushing system.

Tables 26.1 and 26.2 gives the storage capacities as per IS : 2065–1963.

TABLE 26.1 *Flushing storage capacities*

S.N.	*Classification of Buildings*	*Storage Capacities*
1	For tenements having common conveniences.	900 litres net w.c. seat.
2	For residential premises other than tenements having common conveniences	270 litres net for one w.c. seat and 180 litres for each additional seat in the same flat.
3	For factories and workshops	900 litres per w.c. seat and 180 litres per urinal seat
4	For cinemas, public assembly halls etc.	900 litres per w.c. seat and 350 litres per urinal seat

TABLE 26.2 *Domestic storage capacities*

S.N.	*Floor*	*Storage*	*Remarks*
For premises occupied as tenements with common conveniences			
1	Ground floor	Nil	Provided no downtake fittings are installed
2	1st, 2nd, 3rd, 4th and upper floors	500 litres per tenement	—
For premises occupied as flats or blocks			
1	Ground floor	Nil	Provided no dowtake fittings are installed
2	1st, 2nd, 3rd, 4th and upper floors	800 liters per tenement	—

Note 1. If the premises are situated at a place higher than the road level in front of the premises, storage at ground level should be provided on the same lines as on first floor.

Note 2. The above storage may be permitted to be installed provided that the total domestic storage calculated on the above basis is not less than the storage calculated on the number of down-take fittings as per scale given below:

(a) Downtake pipe 70 litres each

(b) Showers 135 litres each

(c) Bath tubs 200 litres each

26.4 PIPES AND PIPE FITTINGS

Various types of materials which are used in the construction of sewer pipes have been described in Chapter 5. All those materials are also used in the construction of pipes required in house drainage. In house-drainage works stoneware, asbestos cement, lead and iron pipes are used.

For jointing, laying and fixing of soil waste, rain water and vent pipes of various types of fittings are required. Figure 26.1 shows the usual soil and rain water pipe and fittings.

26.5 FIXING AND JOINING, PIPES AND ACCESSORIES

Rain water, soil waste and vent pipes can be embedded in the walls and floors or fixed on them. When they are embedded no fixing devices are

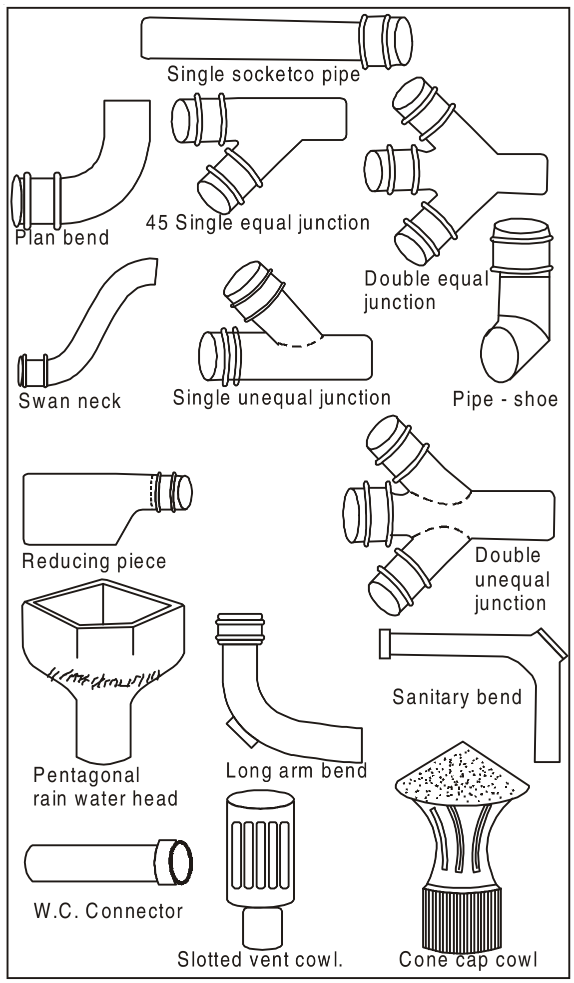


Fig. 26.1 *Soil and rain water fittings.*

required. But for case in repairs and maintenance usually they are fixed on the outside of walls. For fixing them special types of brackets are required. Figure 26.2 shows one most common type of fixing bracket having aluminium painted clips. These brackets fit closely round the pipe or accessory directly beneath the socket and have ears for securing to the face of the structure. When fixed, they present a neat appearance.

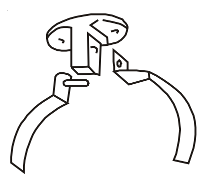


Fig. 26.2 *Fixing brackets*.

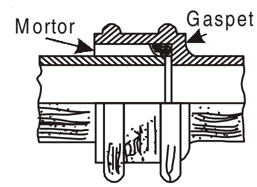


Fig. 26.3 *Method of joining A.C. pipe.*

The joining of pipes and accessories is done as follows. First a gasket or hemp yarn saturated with Bitumastic jointing compound is caulked to about 2.5 cm depth. Then the space between the collar and plain end is grouted with stiff mortar of cement. Figure 26.3 shows the method of joining A.C. pipe.

After fixing and joining all pipes and accessories must be tested for water tightness. This is done by dividing the whole work in sections and testing each section one by one.

26.6 TRAPS

Foul gases produced in the sewers, drains, waste-pipes may cause nuisance by entering in houses through house-connecting pipes, if their passage is not checked by some suitable devices. The devices which are used to stop the escape of foul gases inside or outside the houses are known as *traps.* The traps generally consist of a bend tube which provides a water seal between the atmosphere and the sewer gas. The efficiency of the traps depends on the depth of water seal, deeper the seal more efficient will be the trap.

The following are the requirement of a good trap:

(i) It should be made of non absorbent material.

(ii) It should provide sufficient depth of water seal all times (about 50 mm) having large surface area.

(iii) It should be self-cleaning and should not obstruct the flow of sewage.

(iv) It should be provided with access door for cleaning.

The water seal of the trap can break under the following conditions:

(i) If there is any crack in the bottom of seal or the joint is faulty.

(ii) If for a long time the seal is not in use, its water will evaporate in the atmosphere.

(iii) If due to blockage or any other reason there is increase in the pressure of the sewer gases, it will pass through the water of seal.

(iv) If partial vacuum is created in the sewer fittings, it will suck up the seal water. To avoid the breakage of seal due to this reason, the portion between the trap and the soil pipe should be connected to the vent pipe.

26.7 TYPES OF TRAPS

The following types of traps are most commonly used in practice.

26.7.1 P, Q and S-Traps

These traps are classified according to their shape. Figure 26.4 shows these traps. They essentially consist of U-tube which retain water acting as a seal between the foul gas and atmosphere.

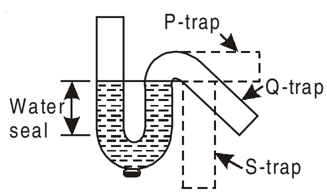


Fig. 26.4 *P, Q and S-traps.*

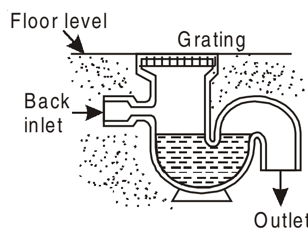


Fig. 26.5 *Gulley traps.*

26.7.2 Gulley Traps

This trap is provided at different places in the drain pipes. Waste water from sinks, bath etc. enters in through back inlet and unfoul water from the sweeping of rooms, courtyards etc. enters from the top, where a coarser screen grating is fitted to check the solid matter. Figure 26.5 illustrates a gulley trap.

26.7.3 An Intercepting Trap

The sewage from every house goes in street sewer which carry it away from the city. The street sewers contain foul gases in it and if their passages are not checked from street sewers to the houses, they may enter in the house drain and pollute the atmosphere. For this purpose a trap in one inspection chamber is provided outside the houses, which is called an *intercepting trap*. This trap is provided at top with a cleaning eye with a plug. Figure 26.6 shows this type of trap.

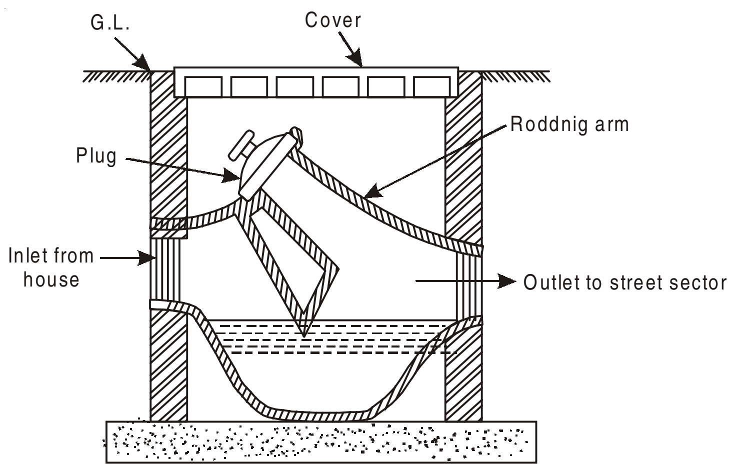


Fig. 26.6 *Intercepting trap.*

26.7.4 Anti-D Trap

P, *Q* and *S* traps are largely used for baths, sinks and laboratories. In such cases they are made with enlarged mouth so that the waste pipe may be thoroughly flushed out. But in these traps full bore of the trap is not interfered with by the discharge. These traps are made of ordinary circular sections.

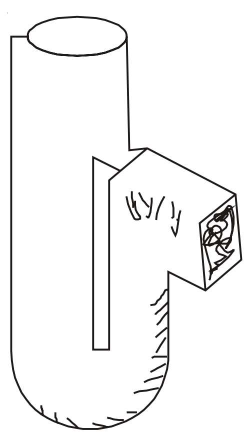


Fig. 26.7 *Anti-D trap.*

Anti-D trap is an improvement over the above traps which was made by Mr. Hellyer of England. By a series of experiments Mr. Hellyer found that the driven out of water by momentum of the discharge from the trap can be prevented by so shaping the trap that the water-holding portion is contracted and the outgo is larger and square in section. This trap also prevents siphonage action. Figure 26.7 shows the pictorial view of this type of trap. The water-way in the anit-D trap is reduced, which ensures the removal of all refuse, while the outlet being larger prevents the pipe from filling full and causing siphonic action.

26.7.5 Anti-Siphon Trap

There are several types of anti-siphon traps in the market, which are also called *resealing traps*. These traps avoid the connection to vent pipe and reduce this expensive work. Grevak trap which is most common is shown in Fig. 26.8. The construction of this trap is such that when water seal is subjected to the pull due to siphonic action, the heavier atmospheric pressure

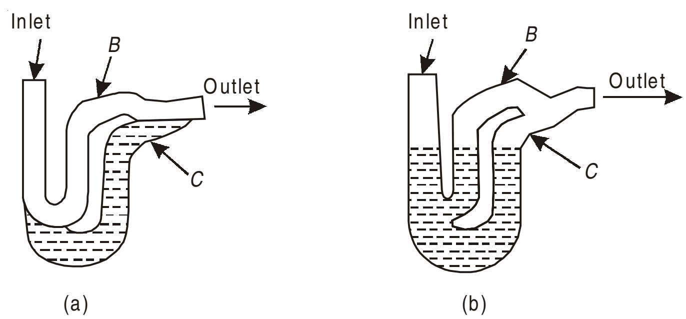


Fig. 26.8 *Grevak trap.*

on the inlet side presses the water down and the air can pass from by-pass tube *B* as shown in Fig. 26.8 (a) and the water is stored in trough *C*, when the pressure on both sides becomes equal, the water stored in trough *C*, falls back in the tube and seals it as shown in Fig. 26.8 (b).

26.8 HOUSE DRAINAGE PLANS

Before starting the plumbing work, it is most essential first to prepare the drainage plans. In the same way as detailed drawings are prepared before the starting of the construction of buildings, the detailed drainage plans should also be prepared.

The following points should be kept in mind while preparing the drainage plans :

(i) The drains should be laid in such a way so as to remove the sewage quickly from the building. The quick removal is governed by the fall of the pipes. The drains should be laid at such a slope that self-cleaning velocity is developed in them. The following slopes are usually sufficient:

1	in	40	for	10 cm	pipe
1	in	60	for	15 cm	pipe
1	in	90	for	23 cm	pipe

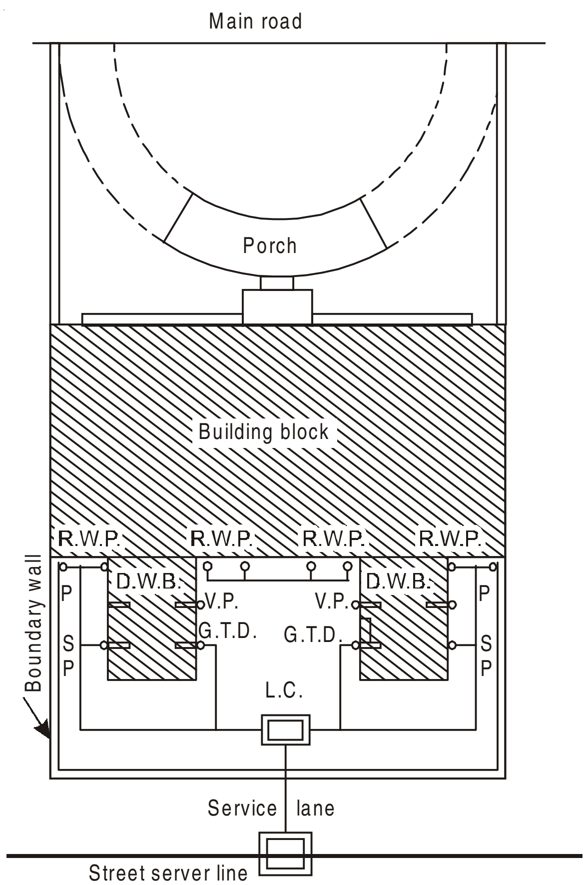


Fig. 26.9 *Typical drainage layout plant of a terrace house drained at back.*

(ii) All the drainage system should be properly ventilated on the house side. The ventilation pipe should be carried sufficiently high above the buildings. All the inspection chambers should be provided with fresh air inlets.

(iii) All the drains should be laid in such a way so as to ensure their safety in future.

(iv) The drain should be laid in such a way that in future extension can be done easily if desired.

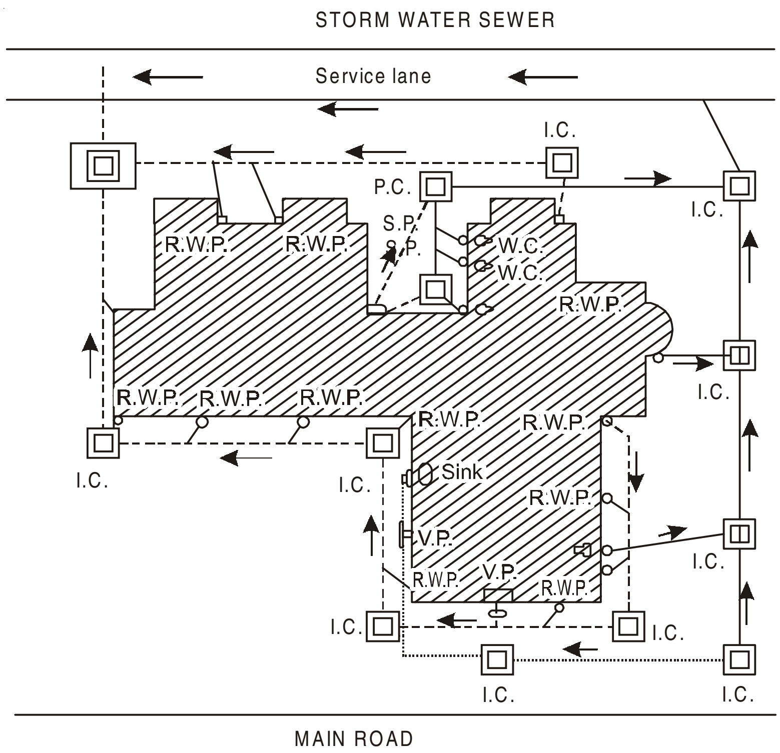


Fig. 26.10. *Typical drainage layout of a large building.*

(v) If the quantity of sewage flowing in a pipe is small, an automatic flushing tank may be provided on its top for flushing it.

(vi) All the rain water pipes, sweeping from house and bath water should discharge over gulley traps and should be disconnected from the drain.

(vii) All soil pipes should be carried direct to the manholes without gulley traps.

Figures 26.9 and 26.10 show typical drainage layout plans.

QUESTIONS

26.1. Define the following terms:

Warning pipe ; house plumbing; available head; back siphonage ; effective opening; residual head.

26.2. (a) Under what circumstances storage of water is required in building?

(b) On what factors the quantity of stored water depends ? What flushing storage capacities are recommended by I.S.I.

26.3. Write a short note on the pipe and pipe-fittings.

26.4. Write a short note on the fixing and jointing of pipes and accessories.

26.5. What are tlie requirements of good trap ? Under what circumstances tlie water seal of the traps can break and what are the preventive measures for it.

26.6. Write a short note on the various types of traps.

26.7. What do you understand by the house drainage plans ? Write a short note on it with the help of typical drainage plans.

Chapter 27

Sanitary Fittings

27.1 GENERAL

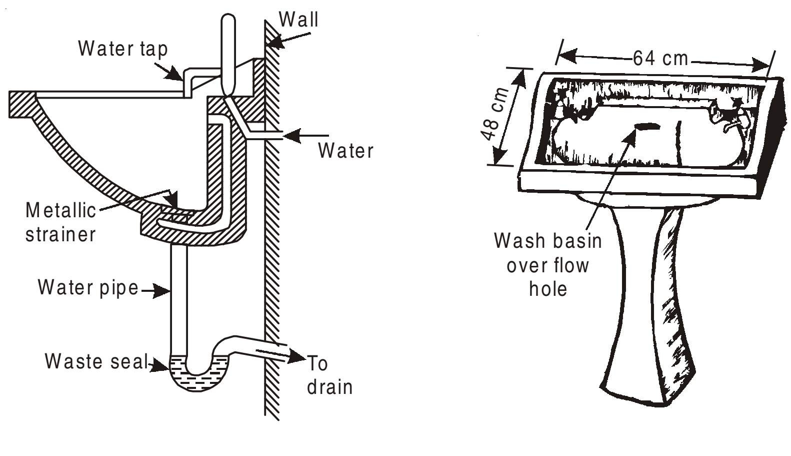
In the buildings, various types of sanitary fittings are required to collect the waste water. These all fittings can be broadly classified as :

1. **Ablution Fittings**
   - (a) Wash basins
   - (b) Sinks
   - (c) Bath tubs
   - (d) Flushing cisterns
   - (e) Drinking fountains.
2. **Soil Fittings**
   - (a) Water closets
   - (b) Urinals
   - (c) Slope sinks.

All types of sanitary fittings should be fixed against an external wall, so that the apartment in which they are placed can be provided with natural light and air, and also their wastes can be easily collected in drains. The floors of the rooms in which sanitary fittings are fixed should be of a non-absorbent material with curved angles at the junction with walls for sanitary point of view.

27.2 WASH BASIN

The wash basins are available in various patterns and sizes in the market. There are mostly two patterns: (a) Flat back for mounting on walls; (b) Angle back for fixing at the junction of two walls. Flatback basins are provided with double or single tap holes. All the wash basins should be of one pieces construction and should have slotted overflow hole. All the internal angles are designed so as to facilitate cleaning. The wash basins are provided with a circular waste hole in the bottom as shown in Fig. 27.1. The basins are provided with an integral soap holder recess which drains into the bowl.



(a) Sectional view of wash basin (b) Isometric view of wash basin

Fig. 27.1 *Wash basin.*

Wash basins are made of fire-clay, stoneware, earthenware of vitreous china. But nowadays steel, aluminium and plastic wash basins are also available in the market which are very popular. In plan the basins may have rectangular, square, circular, oblong, circular quadrant etc., shape depending on the choice. Again these may be supported on the brackets fixed on the wall or supported on the pedestals.

For holding water in the bowl these are provided with tapering rubber plugs, which can be fitted in the outlet. This plug is fixed to a chain secured by a stay.

The usual sizes of wash basins are :

Pattern	*Size*
Flash back	630 × 450 mm
	550 × 400 mm
Angle back	600 × 480 mm
	440 × 400 mm

27.3 SINKS

These are rectangular shallow receptacles suitable for kitchen of laboratory. Figure 27.2 shows a kitchen sink which is mostly used. It is of one piece construction, provided with or without rim. The floor of the sink is given a slope towards the waste outlet. The sinks are provided with circular waste hole. All the kitchen sinks are provided with a draining board which is fixed on the user. Weir type overflow slots are also provided in some sinks.

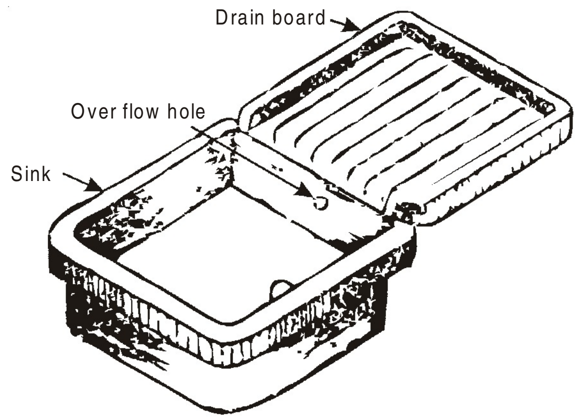


Fig. 27.2 *Kitchen sink.*

The usual dimensions of the sinks are:

Kitchen sinks	600 × 450 × 150 mm 600 × 450 × 250 mm 700 × 450 × 250 mm
Laboratory sinks	400 × 250 × 150 mm 450 × 300 × 150 mm 500 × 350 × 150 mm 600 × 400 × 200 mm

The sinks are made of glazed earthenware or stoneware. The height of the top of the sink from the floor should be 90 cm.

27.4 BATHS

Baths may be made of various materials, such as enameled iron, plastic, cast iron porcelain enameled, marble or fire clay etc. For high class residential buildings marble, plastic of enameled iron baths are used. For public places glazed fire-clay or porcelain enameled cast iron baths used. Vitreous enameled pressed steel baths are also available in the market. Previously copper baths were used but nowadays they have become obsolete. In future aluminium alloy baths are coming which will replace old baths.

Figure 27.3 shows the section through a bath. The bath may be parallel or taper, the latter type being more popular. It is provided with one outlet of 4 to 8 cm and one inlet pipe for filling it. In some cases two taps are provided one for hot and another for cold water supply. The both should also be provided with one overflow pipe to take excessive water. The waste pipe of bath is provided with a trap, to prevent the foul gases from entering in the bath-room.

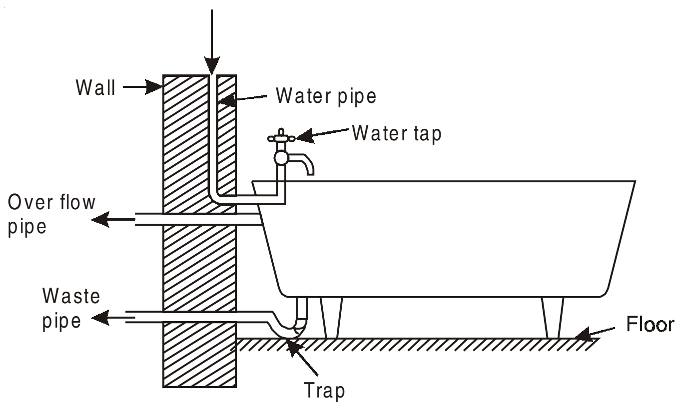


Fig. 27.3 *Section through a bath.*

The usual dimensions of bath are : length 1.7 to 1.35 m, width 70 to 70 cm, depth near waste pipe side 43 to 45 cm, overall height with feet 58 to 60 cm.

27.5 FLUSHING CISTERNS

These are used for flushing water closets and urinal after use. There are several varieties of the flushing cisterns. *High-level cisterns* are intended to operate with a minimum height of 1.25 cm between the top of the pan and the underside of the cistern. *Low level cistern* are intended to operate at a height not more than 30 cm between the top of the pan and the underside of the cistern. Cistern may be of cast iron, glazed earthenware, glazed vitreous ware or pressed steel or any other impervious material. Nowadays plastic cisterns are also available in the market.

Following two types of cisterns are common nowadays:

(i) Bell type without valve.

(ii) Flat bottom type fitted with valve.

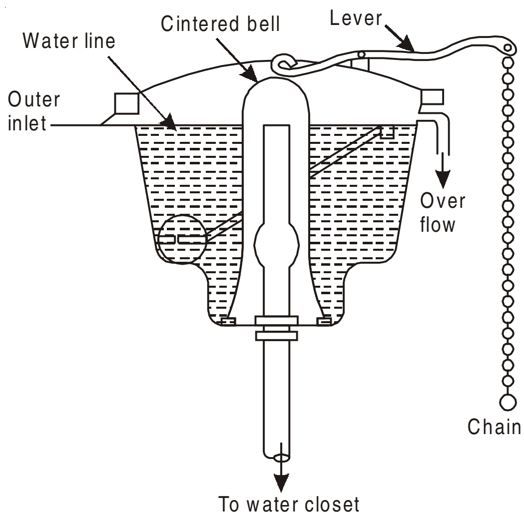


Fig. 27.4 *Flushing cistern bell type.*

Figure 27.4 shows the bell type flushing cistern. The bell is kept over the outlet pipe, the inlet end of which is slightly above the water level. When the chain in pulled the bell is lifted causing the water to spill over the outlet pipe and starting the siphonic action due to which the whole water rushes towards the outlet and flushes the W.C.

Figure 27.5 illustrates the flat bottom type flushing cistern provided with valve. When the chain is pulled, it lifts the disc which also suddenly lifts the water above it and starts the siphonic action. The valve allows the water to rush in the outlet pipe.

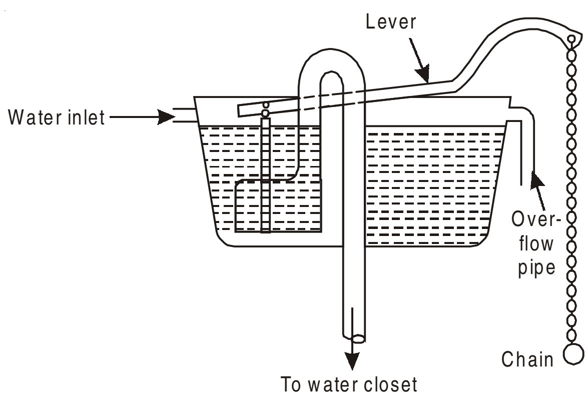


Fig. 27.5 *Flat bottom flushing cistern.*

The flushing cisterns are provided with inlet pipe, over-flow pipe and automatic closing float ball valve.

27.6 WATER-CLOSET

This is a sanitary appliance to receive the human excreta directly and is connected to the soil pipe by means of a trap.

The water closets are classified as follows :

(A) Squatting type or Indian type

(i) Long pan pattern (length 450, 580, 680 mm)

(ii) Orissa pattern (length 580, 639, 680 mm)

(iii) Rural pattern (length 425 mm)

(B) Wash-down, Pedestal or European type

Figure 27.6 shows the section through and Indian type water closet. This is manufactured in two different pieces : (a) squatting pan and (b) trap. The pan is provided with an integral flushing rim of suitable type. The inside of the bottom of the pan should have sufficient slope towards the outlet for quick disposal during flushing.

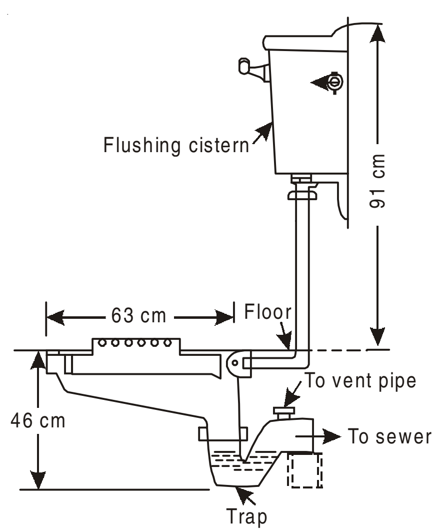


Fig. 27.6. *Indian type water closet.*

These are made of vitreous china. The inner portion is glazed to make it easy in cleaning. The pan is connected to the flushing cistern by means of a fiushing pipe. The top of the trap is connected to the anti-siphon or vent pipe.

Figure 27.7 shows the pictorial view of an Indian type water closet.

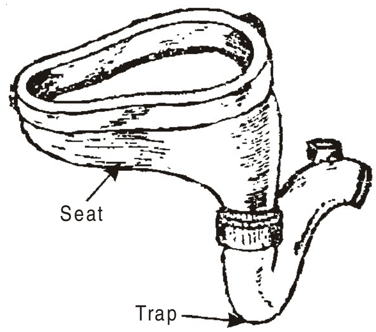


Fig. 27.7 *Pictorial view of Indian type water-closet.*

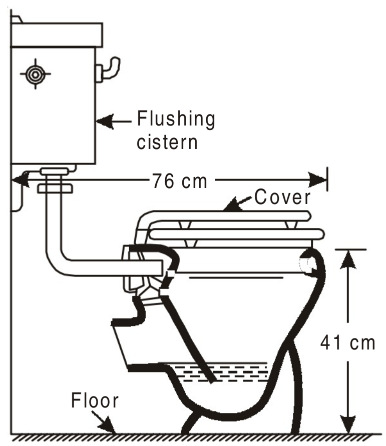


Fig. 27.8 *Section through a wash down type water closet.*

Figure 27.8 shows the section through a wash-down type water closet which is most commonly used in high class buildings. It is provided with a

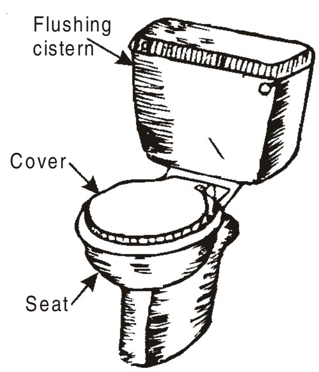


Fig. 27.9 *Isometric view of an European type water closet.*

wide flushing rim and 5 cm trap. It is one piece construction in which the pan and trap are no separate. It is provided with an inlet of supply horn for connecting to the flushing pipe. It may be provided with *P* or *S* trap as desired. These types of water closets require less space than squatting pattern type and can be flushed by low level cisterns. Nowadays siphonic water closets are very popular. Figure 27.2 shows the isometric view of such a water closet.

27.7 URINALS

Urinals can be made in any of the following patterns and sizes.

S.N.	*Pattern*	*Sizes*
(a)	Bowl shape	
	(i) Flat back	430 mm min × 260 mm min × 350 mm min
	(ii) Angle back	340 × 430 × 265 mm
(b)	Slab	Single 450 × 1000 mm
		600 × 1000 mm
(c)	Stall	Single 1140 × 460 × 400 mm
(d)	Squatting plate	600 × 350 mm and
		450 × 350 mm

Bowl type urinals are of one piece construction. Each urinal is provided two fixing holes on the side of fixing it on the wall. At the bottom an outlet horn is provided for connecting it to the trap. The inside surface is regular and smooth for ensuring efficient flushing. The bottom of the urinal is provided with sufficient slope from the front towards the outlet for efficient drainage of the urinal. Bowls type urinal are also provided with flushing rim which is connected by flushing pipe to the flushing cistern. Figure 27.10. illustrates a bowl type urinal.

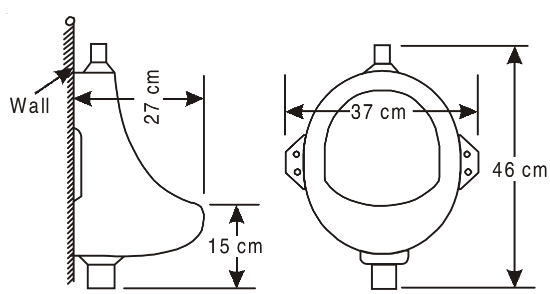


Fig. 27.10 *Bowl type urinal.*

Figure 27.11. shows the isometric view of two bowl type urinals placed in position.

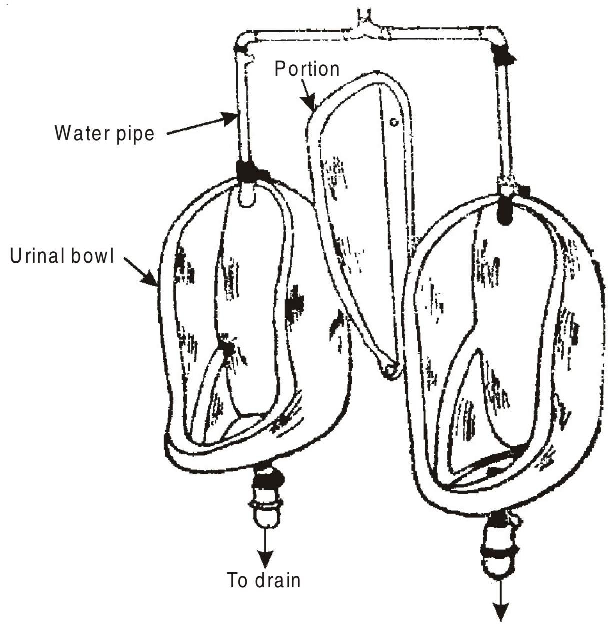


Fig. 27.11 *Isometric view of two bowl type urinals placed side by side.*

The slab and stall type urinals are manufactured either as a single urinal or as range of two or more and are used in public places such as cinema houses, restaurants, railway stations, offices etc.

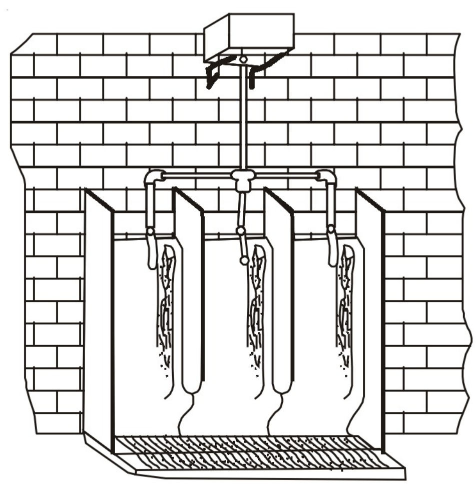


Fig. 27.12 *The slab and stall type urinal.*

The squatting plate urinals are mostly used in ladies laboratories and are one piece construction.

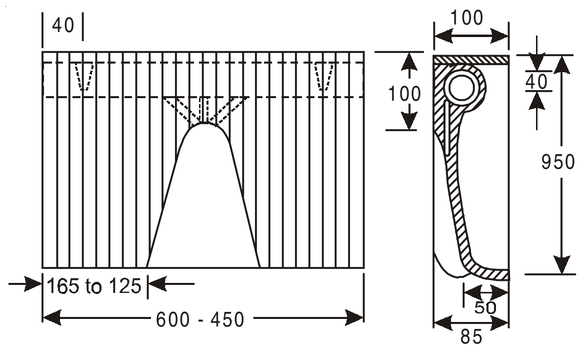


Fig. 27.13 *Squatting plate urinal.*

27.8 REQUIREMENTS FOR SANITARY FITTINGS*

The requirement for sanitary fittings depends on the persons using them and the circumstances, type of building etc. For calculating the number of sanitary fittings required the following table can be used.

TABLE 27.1 *Office buildings*

Fitments	*For Male Personnel*	*For Female Personnel*
Water closets	1 for every 25 persons	1 for every 15 persons
Ablution taps	1 in each W.C.	1 in each W.C.
Drinking fountain	1 for evry 100 persons	1 for every 100 persons
Urinals	Nil upto to persons 1 for 7 to 20 persons 2 for 21 to 45 persons 3 for 46 to 70 persons 4 for 71 to 100 persons For 101 to 200 persons add @3% For over 200 persons add @ 2.5%	Same as for male personnel
Wash basins	1 for every 25 persons	
Baths	Preferably 1 on each floor	
Cleaner's sinks	1 per floor	

* For requirements for other types of buildings such as cinema houses, restaurants, halls, factories etc., see I.S. 1172—1963. *'Code of Basic Requirements for Water Supply, Drainage and Sanitation'.*

QUESTIONS

27.1. Name the various types of sanitary fittings. Describe any one with the help of a neat sketch.

27.2. Write short notes on :

(i) Wash Basin

(ii) Bath

(iii) Sink.

27.3. With the help of neat sketches, describe the flushing cisterns.

27.4. With the help of neat sketches, describe the construction and function of water closets.

27.5. Write a short note on various types of urinals used in India.

Chapter 28

Sewage Treatment

28.1 GENERAL

After collecting the sewage, it becomes necessary to dispose it of safely. The sewage treatment is very important as otherwise the sewage will breed germs of diseases and become a nuisance to the inhabitants of the locality. The sewage treatment consists of treating the sewage in such a way that the sewage may be disposed of in a safe place and should be converted into useful manure. Also the cost of the treatment plant should be as little as possible. The first step in the treatment of sewage is screenings. Actually speaking, the treatment of sewage starts only after screening. In the following lines each step of the treatment process is briefly described.

28.2 SCREENING

Screening is the first operation of pre-treatment because it is necessary to eliminate floating matters which may clog pumps and interfere with the next treatment by being an obstruction. Fine screening is also done before biological treatment in place of settling tanks. Some common types of screens which are mostly used are as follows.

28.2.1 Coarse Screens

These consist of nearly 10 mm steel bars placed at 4.3 cm centre to centre spacing. These screens are placed vertical or at an inclination of 30° to 60° to the horizontal, to check heavy floating pieces of timber, dead animals, etc.

28.2.2 Medium Screens

These screens are also constructed with steel bars but the space between bars is nearly 6 to 4 cm to check the flow of further small things.

28.2.3 Fine Screens

Usually these are constructed with slotted non-corrosive metal plates having 0.07 × 1.5 cm to 0.15 × 1.5 cm holes for checking small particles to flow in the sewage. These types of screens are generally in the form of drums of discs which are rotated continuously by means of electric motors and require continuous cleaning to prevent their clogging.

28.3 GRIT CHAMBER

In India washing of utensils with sand, earth, ashes or crushed brick-bats has become the custom, therefore large quantity of grit goes in the sewage. As the grit is hard, tough and heavy, it will wear out pipes and pumping machinery and cause obstructions in sewage treatment process if not removed.

Figure 28.1 shows plan and sectional elevation of a grit-chamber. It consists of a 10 to 17 metre long narrow open channel to remove sand and grit from the sewage. The sewage flows in this chamber horizontally with a constant velocity between 0.24 to 0.3 metre per second so that larger and

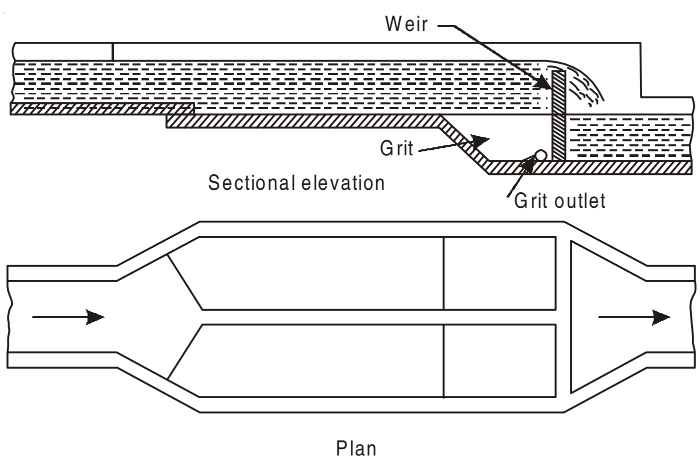


Fig. 28.1. *Grit chamber.*

heavier suspended solids may settle down in the bottom but lighter organic solids can escape out with the sewage. Usually the depth of liquid in these chambers is kept 1 to 1.3 metre. Weir type outlet is provided in these chambers along with proportional flow weir and venturi devices. In case of very large quantity of sewage many such chambers are constructed parallel to each other. These chambers can be cleaned hydraulically, mechanically or manually.

28.4 SKIMMING TANKS

These tanks are used for removing oil, grease and fats of the sewage. Figure 28.2 shows the cross-section and longitudinal section of a typical skimming tank. This is in the form of long, trough-shaped structures. Tank surface is

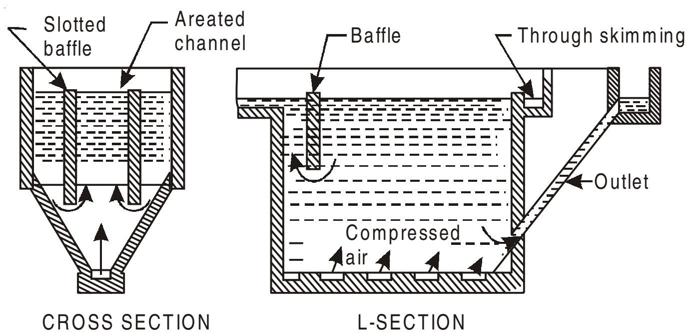


Fig. 28.2 *Skimming tank.*

made as large as possible, and the sides of narrow down at a steep angle. Detention period of 3 min. is enough in this tank. Compressed air is blown from diffuser holes provided at bottom to keep heavy solids from settling and to separate grease, oil and fats from sewage. By the agitation of compressed air, all oily matters rise upward and are collected in the side compartment from where they are removed. The sewage goes out from narrow inclined outlet as shown in Fig. 28.2.

28.5 DETRITUS-TANKS

These are rectangular or square continuous flow settling tanks used for removing grit and fine sand at one time. This combined settling is done by giving slightly longer dentention period about 3 to 4 minutes and maintaining 0.3 metre per sec. velocity. The settled solids are removed by mechanical scrapers continuously.

28.6 SEDIMENTATION-TANKS

Very fine suspended solids which are not removed by screens and floatations, are taken out in sedimentation tanks. Sedimentation processes are employed in a number of ways as :

(i) In grit chambers to separate heavy mineral solids.

(ii) In preliminary, sedimentation tanks to remove settleable solids from sewage before its discharge into water.

(iii) In final, settling tanks to remove flocculated solids.

Sedimentation tanks of continuous flow type are commonly used. They may be rectangular or circular in plan with horizontal, radial or vertical flow or sewage in them, with specially designed inlets, sewage enters in these tanks and after flowing at continuous slow velocity, sewage is taken out be weir-type outlets.

28.7 BIOLOGICALTREATMENT

After sedimentation the next process is to filter the sewage. In this process the biological treatment takes place and the sewage is digested. The sewage is treated by aerobic bacteria and aerobic bacteria. If the decomposition of sewage takes place in the absence of oxygen, the aerobic bacteria act on sewage and convert it into liquid, gas and sludge. If the decomposing of sewage takes place in the presence of oxygen, the aerobic bacteria act on sewage. In practice the aerobic action takes much more time than aerobic, therefore the sewage is always treated by aerobic bacteria. When the sewage is filled over a thick sand bed all the organic impurities are retained on the surface, while the water is drained out as effluent. The impurities held by sand bed come in contact with air and the aerobic bacteria eat them. This aerobic action is done in the following three types of sewage units:

(i) **Fill and draw beds.** These are also known as *contest beds.* These are filled with sewage, allowed to stand full, drained and rest. Air is passed through them. The aerobic bacteria act on organic matter and decompose it.

(ii) **Percolated beds or trickling filters or sprinkling filters.** Sewage is sprayed on the surface of these filter beds from fixed or moving nozzles. The sewage then trickles over the contact media downward through the beds. Natural currents of air, induced by the difference in the temperature of the atmosphere and the sewage, sweep through the beds and keep aerobic action continuous.

(iii) **Contact aerators or aerated beds.** These are also known as Emscher filters. Sewage flows horizontally in these tanks and compressed air is passed from the bottom which aerates the sewage an supplied necessary oxygen for the biological films.

28.8 ACTIVATED SLUDGE-PROCESS

In early times attempts were made to purify the sewage by blowing air into it and activated-sludge-process was discovered, and was named so on the following observations :

(i) that floc having living organism is formed when compressed air is passed in sewage.

(ii) if the circulation of compressed air is stopped the floc settles down as a sludge.

(iii) if now fresh sewage is added in the tank the quantity of settled sludge is increased and fresh sewage is also digested.

This is the simple principle of activated-sludge process which is nowadays mostly used in the treatment of sewage. Figure 28.3 shows the operations of activated sludge plant.

In continuous plant, different operations are as follows :

(i) Required amount of sludge from final settling tank is mixed in the sewage before it enters in the aeration tank.

(ii) Continuous aeration of the sewage is done in aeration tank to keep it aerobic.

(iii) Sedimentation of sludge and sewage is done in the final settling tank.

(iv) Excess activated sludge from the final settling tank is mixed in sewage before preliminary sedimentation.

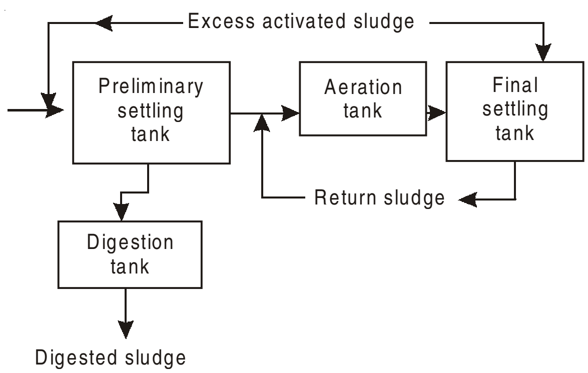


Fig. 28.3. *Flow Diagram.*

The performance of activated sludge process remains the same in winter and in summer. No fly-nuisance is created at the plant.

28.9 SLUDGE DIGESTION

Sewage sludge is obtained from various types of sewage treatment plants. The effluent obtained from these units is disposed of in the nearby water courses or used irrigation. Sewage sludge contains large quantity of food for bacteria and other micro-organisms which convert organic matters into simple and more stable substances. Dissolved oxygen of fresh sludge is quickly exhausted and digestion starts and less stable solid matters, sludge liquid and gases are produced.

Sludge digestion tanks are used for taking out water from sewage. In these tanks sludge is filled and after the digestion action has taken place the effluent is taken out for discharging in nearby water courses. The gases which are produced in these tanks can be utilized as fuel-gases for heating and lighting purposes.

28.10 NECESSITY OF SEWAGE DISPOSAL

In every city and village different kinds of wastes are produced everyday. These wastes include water from bath-rooms, sinks, laboratory basins and different industrial processes, animal and human excreta, house and street sweeping etc. If these discharged waters are not taken out from the city and are allowed to remain in the locality, cow-dungs, leaves, organic matters, etc., will be mixed in it. These will be collected in the city and mosquitoes, flies and bacteria etc., will be born in them due to the decomposition, and disease will spread in the city.

In addition to this, it will cause nuisance and water may reach the foundations of structure and endanger their stability. If this water is not removed, it will deteriorate the beauty of the city and will percolate in the ground and will pollute the ground water. Due to all these necessities, the disposal of sewage is essential.

28.11 AIMS AND OBJECTS OF SEWAGE DISPOSAL

The following are the aims and objects of sewage disposal:

(1) Proper disposal of human excreta to a sage place, before it starts decomposition and causes insanitary condition in the locality.

(2) To take out all kinds of waste from the locality, immediately after its use, so that mosquitoes, flies, bacteria etc. may not breed in it.

(3) Finally disposal of sewage on land or in nearby water courses after treatment so that receiving land or water may get deteriorated and become unsafe for further use.

(4) As far as possible the fertilizing elements of sewage may be used in growing crops through sewage farming and getting some income in addition to the disposal of sewage.

(5) In unsewered localities, the disposal of sewage from individual houses should be done by septic-tanks and other devices in such a way so that effluent can be utilized for private gardening purposes, if required.

(6) If sewage is disposed of on land, it should have such a treatment, that it may not affect the sub-soil water in any way.

QUESTIONS

28.1. (a) State and explain the objects of sewage disposal.

(b) What do you understand by the term 'Screening' in sanitary engineering? Describe the different types of screens mentioning the circumstances in which they are used.

28.2. With the help of a neat sketch describe the working of a Grit chamber.

28.3. Write short notes on the following :

(a) Skimming tanks

(b) Detritus tanks

(c) Sedimentation tanks

(d) Trickling-filter.

28.4. Write short notes on the Activated sludge process.

28.5. Explain the function of activated sludge process. Explain why the disposal of sewage is necessary. What will happen if the sewage is not disposed of?

28.6. What are the aims and objects of sewage-disposal ?

PART 5

Chapter 29 General Surveying

G
E
N
E
R
A
L

S
U
R
V
E
Y
I
N
G

Chapter 29

General Surveying

29.1 GENERAL

The art of making such measurements as will determine the relative positions of points on the surface of the earth in order that the shape and extent of any portion of earth's surface may be ascertained and delineated on a map or plan, is known as surveying. Essentially it is a process of determining positions of points in a horizontal plane.

Note. No doubt, levelling is the process of determining positions of points in a vertical plane. But however, in its comprehensive sense, the term 'Surveying' includes levelling.

29.2 OBJECTS OF SURVEYING

The objects of surveying is the preparation of plan or map. In other words objects of surveying is to prepare plan of the ground surface, showing the relative positions of the objects represents to certain scale.

Preparation of plan includes the following:

(i) Chaining
(ii) Levelling
(iii) Traversing etc.

Surveying may be broadly divided in the following two general classes:

(i) Geodetic Surveying
(ii) Plane Surveying.

29.2.1 Geodetic Surveying

This class of surveying is also known as trigonometrical surveying. In this surveying the curvature of the earth is necessarily taken into account because surveying is done on large scale i.e., large distances and areas are taken into consideration. It is due to the fact that the earth is spheroidal in shape and the line connecting two points on the surface of the earth is curved or is an arc of great circle as shown in Figure 29.1.

These arcs on plan require spherical trigonometry, characterized by:

(i) High precision

(ii) Large area and distances

(iii) Use of refined methods

(iv) Refined instruments.

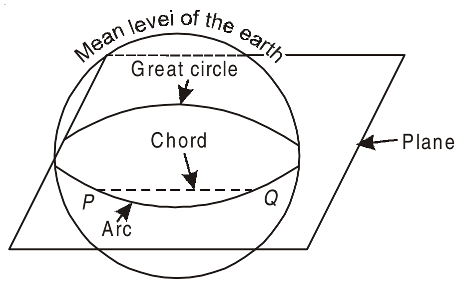


Fig. 29.1

The object of Geodetic survey is to determine precise positions of a system of points, widely distant from control stations, on the surface of the earth.

The Geodetic surveying is conducted by Government agencies. In India it is conducted by Survey of Indian Department.

29.2.2 Plane Surveying

The extension of surveying in this class is not very large. Plane surveying, therefore, does not include any account of curvature of earth's surface. In this surveying small areas are surveyed and surface of the earth is considered as a plane. The line connecting any two points in this plane is, therefore, treated as straight line and angles of polygon's as plane angels.

These lines on plane, therefore, require the knowledge of simple geometry and plane trigonometry.

The degree of accuracy required in this survey is comparatively low. Roughly 260 km^2 area is treated as a plane.

29.3 CLASSIFICATION OF SURVEYING

Survey may be classified as follows :

(i) Classification based upon the nature of the field of survey:

(a) Land Survey

(b) Marine of Navigation Survey

(c) Astronomical Survey.

(ii) Classification based upon methods employed in survey:

(a) Triangulation Survey

(b) Transverse Survey.

(iii) Classification based upon object of survey:

(a) Archeological surveys for unearthing relics of antiquity.

(b) Geological surveys for determining defferent strata in the earth's crust.

(c) Marine surveys for exploring mineral wealth such as gold, coal etc.

(d) Military surveys for determining points of strategic importance both offensive and defensive.

(iv) Classification based upon the instruments employed:

(a) Chain survey

(b) Theodolite survey

(c) Tacheometric survey

(d) Compass survey

(e) Plane table survey

(f) Photographic survey

(g) Aerial survey.

Land survey may be further sub-divided as :

(a) **Topographical Survey**—for determining features of a country e.g., hills, valleys, rivers etc.

(b) **Cadastral Survey**—for additional details e.g., boundaries, houses, pathways etc.

(c) **City Survey**—for laying out plots and constructing streets, water supply systems and sewers.

(d) **Engineering Survey**—for determining quantities and for collecting data for the design of engineering works e.g., roads, railways, reservoirs etc.

The engineering survey may be further sub-divided into the following three classes:

(i) **Reconnaissance Survey**—for determining the feasibility and rough cost of the scheme.

(ii) **Preliminary Survey**—for collecting more precise data to choose the best location for the work and to estimate exact quantities and costs.

(iii) **Location Survey**—for setting out the work on the ground.

29.4 PRINCIPLES OF SURVEYING

The two fundamental principles of survey are as follows :

(1) **To work from the whole or part.** The object of the system is to prevent the accumulation of error and to control and localize minor errors.

(2) To fix the positions of new stations by at least two independent processes. The new stations are fixed from points already fixed by

(a) linear measurements

(b) angular measurements

(c) both linear and angular measurements.

29.5 INSTRUMENTS USED IN CHINA SURVEY

The following instruments are mostly used to conduct the chain survey of given area.

1. Chains:

(*a*) **Metric Chain**

(20 M or 30 M)

—Made of 4 mm dia. M.S. galvanized wire.

(a_1) **20 M Chain**

— Links–100

— Each link – 20 cm apart.

— Brass tallies are provided at every 5 m length

— Swivel joint at the handle made of brass

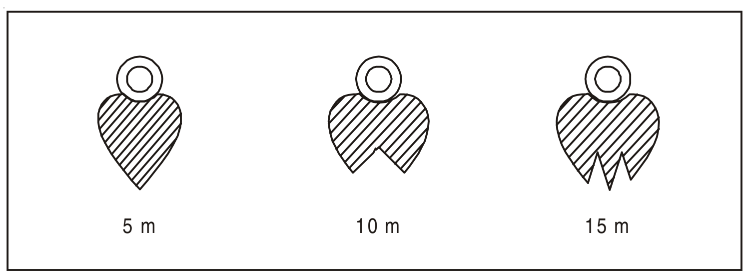


Fig. 29.2

(a) **30 M Chain**

— Links—150

— Each link—20 cm apart.

— Other details are similar to 20 m chain.

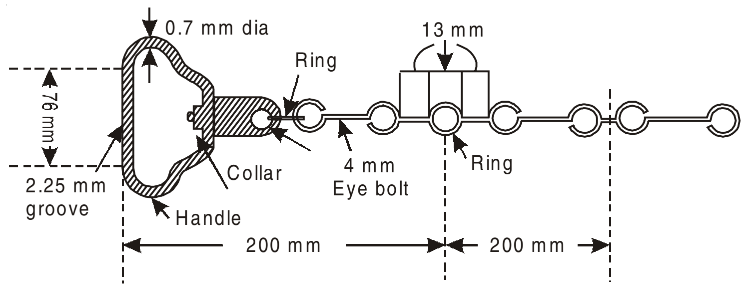


Fig. 29.3

(b) **Gunters Chain** — 66 ft long—100 links
— Each link 0.66 ft long
— Very convenient for measuring distances in miles.

(c) **Revenue Chain** — Generally used measuring fields in Cadastral survey
— 33 ft long
— 16 links
— $2\frac{1}{16}$ feet (on link length)

(d) **Engineers Chain** — 100 ft long
— 100 links
— Each link 1 ft long
— Used in Engineering Survey Works. The distance measured by Engineering Chain are recorded in feet and decimals.

2. Tapes

The tapes commonly used in survey are divided into following four classes:

(a) Cloth or linen tape
(b) Metallic tape
(c) Steel tape
(d) Invar tape.

(a) **Cloth tape** — Used for taking subsidiary measurement such as offsets. It is every light and handy. It is easily effected by dampness. It shrinks after wetting. It is little used in surveying.

(b) **Metallic tape** — Measures are made in lengths 2, 5, 10, 20, 30 and 50 m.
— The tape is made of yarn and metal wire in the warp and only yarn in the weft.
— Covered by leather coverings.

(c) **Steel tape** — Measure are 1, 2, 10, 30 and 50 m.
— Made of steel or stainless steel.
— Outer end is provided with a ring to facilitate withdrawal.
— The length includes the length of ring.

(d) **Invar tape** — Used for work of the highest precision.
— Generally used as measurement of base lines in triangulation survey.
— Made of alloy steel and nickel (3.6%) having coeff. of thermal expansion 0.00000012 for 1°C.
— 6 mm wide obtained in lengths 30, 50 and 100 m.
— Not used in ordinary works.

3. **Pegs, Ranging Rods and Offset Rods**

(a) Pegs. Made of wood used to mark the position of stations. Hard timber is used to make the pegs.

(b) Ranging rods. Used for marking the position of stations and for ranging the survey lines. They are made of well seasoned timber of teak, blue pine, sisso or deodar.

(c) Offset rods. It is similar to ranging rod except it is having a hook at the top and a vertical slot at the centre of rod.

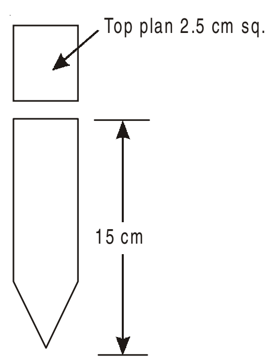


Fig. 29.4

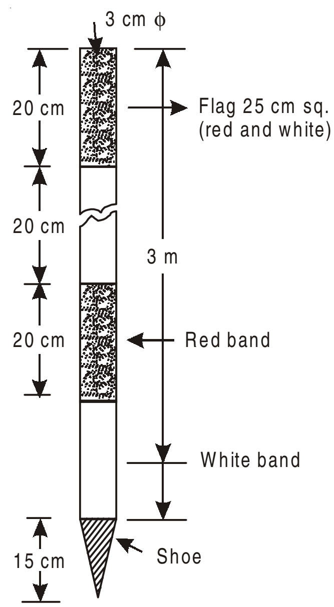


Fig. 29.5

4. **Arrow and Plumb bob :**

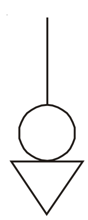


Fig. 29.6

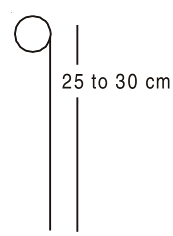


Fig. 29.7

5. **Optical square or cross staff:**

These instruments are used for finding foot or perpendicular from a given point to a line and settling out right angle at a given point on a line.

The following are the forms of cross staffs:

(a) Open cross staff

(b) French cross staff

(c) Adjustable cross staff

(d) Optical square.

6. **Pencils, chalks, field notes etc.**

Chain Survey (Field work)

Chain survey may be done in the following steps :

1. Reconnaissance
2. Marking station
3. Reference sketches
4. Running survey lines
5. Plotting a chain survey
6. Inking, Colouring and North point.

29.5.1 Reconnaissance

The preliminary inspection of the area to be surveyed is known as reconnaissance.

The surveyor should have thorough knowledge of the ground and its principal features. He should walk over the whole area and thoroughly examine the ground so as to decide upon the best possible arrangement of the work. He should note the various boundaries, the positions of buildings, roads, streams various difficulties that may intervene in chaining and ranging etc. He should note the suitable positions of survey stations and their intervisibility. He should estimate the length and angle of survey lines.

During the reconnaissance surveyor should prepare a neat hand sketch known as key plan fairly resembling the plan of ground showing details of work.

29.5.2 Marking Stations

After noting the key plan on the field book survey sations are marked on the ground as follows:

(i) The ranging rods are fixed vertically at different positions if survey is proposed to be finished in a single day.

(ii) By driving in firmly a wooden peg at each sation with 2.5 to 4 cm standing out of the ground, if the survey is extensive.

(iii) By filling the hole made by pressing shoe of the ranging rod into the ground, with cement mortar and driving a nail, if the ground is infested with white ants.

(iv) By driving flush nails or spikes about 10 cm long and 1.25 cm sq. or round, or by cutting cross, if the surface is hard.

(v) By embedding a stone below the surface of the ground with a cross marked on its top.

29.5.3 Reference Sketches

The marked stations are now located by means of measurements known as ties. These measurements are taken from three permanent ground points which are definite and easily recognized, such as corners of buildings, roads and poles etc.

The measurements should be taken to the nearest 0.5 cm and carefully recorded by means of sketch called reference or location sketch.

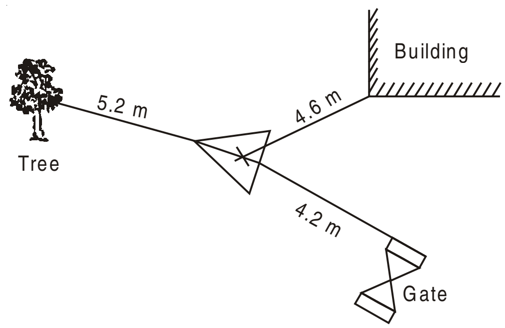


Fig. 29.8 *Location sketch.*

Two measurements are sufficient to recover the position of station, but the third serves as check.

29.5.4 Running Survey Lines

Now ranging is done between two stations by means of fixing ranging rods at different positions. The rods are adjusted in such a way that they are on the same line to that of ranging rods at stations one and two. Now chain is stretched in between guide stations (1) and (2) on the guideline ranging rods. The surveyor now takes offsets on both sides of the chain with the help of cross staff or tape, and notes in the field book. The process of ranging, chaining and offsetting is repeated till last station is reached.

29.5.5 Plotting

A suitable scale is choosen and size of paper is decided. The paper is drawn with border lines. Now the positions of plan, title, north line, scale etc., should be so arranged that the complete plan will appear to the best advantage. A survey should always be plotted looking to north direction. The plan is now plotted on a tracing paper to the scale and after checking it is traced on the drawing sheet.

QUESTIONS

29.1. What are the objects of surveying ? Write short notes on Geodetic Surveying and Surveying.

29.2. Write in detail what instruments are used in surveying.