Unit 2

Doors, Windows and Ventilation – Location of Doors and Windows,
Technical Terms, Material for Door and Windows
Fire-resistant doors and windows
Prefabricated and modular construction techniques
Advanced scaffolding systems and safety measures
Form Work – Introduction to formwork, scaffolding

Doors

Introduction

A *door* may be defined as an openable barrier secured in an opening left in a wall for the purpose of providing access to the users of the structure. It basically consists of two parts, namely, frame and shutter. The door shutter is held in position by the door frame which in turn is fixed in the opening of the wall by some suitable means.

A *window* may be defined as an opening made in a wall for the purpose of providing day light, vision and ventilation. It also like door consists of *two parts* i.e. frame and shutter. The window frame is suitably fixed in the opening of the wall and the window shutter is held in position by the window frame.

Important Considerations for Doors and Windows

The important considerations to be observed in case of doors and windows are as follows:

1. **Purpose:** The main function of doors in a building is to serve as a connecting link between the various internal parts. The number of doors in a room should be kept minimum due to the fact that more number of doors will cause obstruction and reduce the effective usable carpet area of the room. The windows are generally provided to giv6e light and ventilation both to the interior parts of a building. When windows are provided for the purpos7e of light only, as in case of storage rooms, show rooms, etc., they may be fixed so that they cannot be opened. But when the windows are provided for light and ventilation, some or all the portion of windows must open. This can be achieved by providing suitable hinges at top, bottom8 or sides.

2. **Size:** In general, a door should have such dimensions as will allow the movement of the largest object likely to use the door. The minimum widths for interior doors, external doors and doors in public buildings such as hospitals, library, etc., are 800 mm, 1 m and 1.20 m respectively. Regarding height and width of a door, the general rule followed in India, is as follows:

Height = width + 1 m to 1.20 m approximately.
Width = 0.4 to 0.6 of height.

The size of window depends on the dimensions of the room, use of the room, location of the room, direction and speed of the wind, obstruction to light by neighbouring buildings and trees, dry bulb temperature, relative humidity, climatic conditions of the region, etc. Following general rules may be observed while deciding the size of window:

(i) Breadth of window = (1/8) × (width of room + height of room)
(ii) For 30 m^3 inside contents of the room, there should be at least one m^2 of window opening.
(iii) The total area of the window openings should be at least 15 per cent of the floor area of the room.
(iv) The total area of glass panels in the window openings should be at least 10 per cent of the floor area of the room.

(v) For public buildings, the provision of window openings should be more than the above requirements.

The BIS recommends that the size of door frame and window frame should be derived after allowing a margin of 5 mm all around an opening for convenience of fixing. The width and height of an opening is indicated by number of modules where each module is of 100 mm. Table 2.1 and table 2.2 show respectively the recommended dimensions by BIS for doors and windows:

Table 2.1
Recommended dimensions for doors

No.	Designation	Size of opening (mm)	Size of door frame (mm)
1	8 DS 20	800 × 2000	790 × 1990
2	8 DS 21	800 × 2100	790 × 2090
3	9 DS 20	900 × 2000	890 × 1990
4	9 DS 21	900 × 2100	890 × 2090
5	10 DS 20	1000 × 2000	990 × 1990
6	10 DT 21	1000 × 2100	990 × 2090
7	12 DT 20	1200 × 2000	1190 × 1990
8	12 DT 21	1200 × 2100	1190 × 2090

Table 2.2
Recommended dimensions for windows

No.	Designation	Size of opening (mm)	Size of window frame (mm)
1	6 WS 12	600 × 1200	590 × 1190
2	10 WT 12	1000 × 1200	990 × 1190
3	12 WT 12	1200 × 1200	1190 × 1190
4	6 WS 13	600 × 1300	590 × 1290
5	10 WT 13	1000 × 1300	990 × 1290
6	12 WT 13	1200 × 1300	1190 × 1290

The height of opening for door is considered from below the floor finish to the bottom of lintel. In the designation for door, the letters D, S and T represent respectively door, single shutter and double shutters. For instance, the designation 9 DS 20 denotes a door opening having width equal to 9 modules i.e. 900 mm and height equal to 20 modules i.e. 2000 mm. The door is with single shutter. In a similar way, the designation 12 DT 20 denotes a door opening having width equal to 12 modules i.e. 1200 mm and height equal to 20 modules i.e. 2000 mm. The door is of two shutters.

For the designation of windows, the letters W, S and T represent respectively window, single shutter and double shutters. For instance, the designation 6 WS 13 denotes a window opening with single shutter having width equal to 6 modules i.e. 600 mm and height equal to 13 modules i.e. 1300 mm. In a similar way, the designation 6 WT 12 denotes a window opening with two shutters having width and height each equal to 6 modules i.e. 600 mm and 12 modules i.e. 1200 mm.

3. **Location:** The doors and windows are generally located by the architect of the building. Following general rules may be observed while deciding the location of doors and windows:

(i) The doors should preferably be located near the corner of a room, at a distance of about 200 mm from the corner.

(ii) The sill of a window opening should preferably be located at a height of 700 mm to 800 mm from inside of the floor level.
(iii) The factors such as distribution of light, control of ventilation, prevalent direction of wind, privacy, etc., should be considered in the location of windows. (iv) The doors and windows should be located by keeping in view the interior decoration and the functional requirements of the room.

4. **Material:** The usual materials for doors and windows are wood, glass, plywood and metals. The wood is the most common material for doors and windows as it can be moulded in a variety of shapes and can thus present a decent appearance. The glass is used for panels to admit more light. The plywood can be used as a covering material. The metals, such as aluminium and steel, are now commonly used, especially for the windows. At places where wood is likely to be attacked by vermins, the R.C.C. frames may be provided for doors and windows.

The traditional wooden door shutters have inevitable problems of warping, rotting, painting and maintenance. They cannot therefore be considered suitable for bath rooms, toilets and kitchens where the water contact is continuous. The polyvinyl chloride or PVC is the wonder material from the plastic family and its use as door shutter is becoming popular because it provides total protection against corrosion, moisture, termites and chemicals. The PVC door shutters are made from multi-cavity hollow chamber sections and they are manufactured on computer aided machines under stringent quality control.

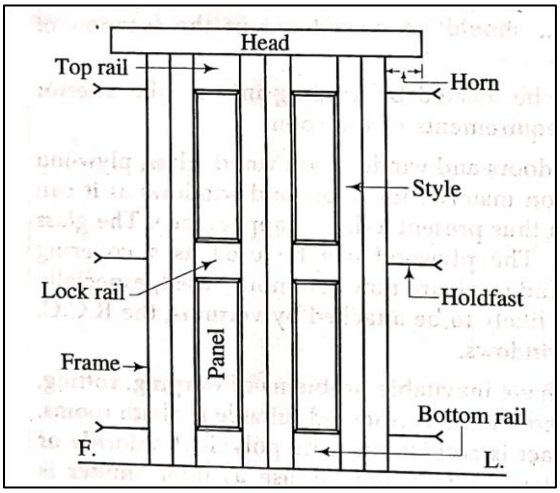
The use of PVC for doors and windows is also going to be popular because of the following advantages offered by such doors and windows:
(i) They are usually rust-proof, rot-proof, termite-proof and water-proof.
(ii) They are unaffected by coastal saline air, dry heat, sub-zero temperatures or tropical rains.
(iii) They do not fade, corrode, flake or warp and consequently, require no maintenance. All that is needed is an occasional cleaning with ordinary soap and water.
(iv) They provide an alternative to the wood.
(v) They provide better thermal insulation and may be considered as ideal for air-conditioned and heated rooms.
(vi) They restrict dust penetration through openings and hence prove ideal for operation theatres, computer rooms, food processing plants, electronics factories, pharmaceutical plants, etc.

5. **Other requirements:** The provision of doors and windows should also be made from various other considerations such as safety, entry of moisture, etc. The glazed shutter of an external door should be provided with steel grill of suitable design.

Similarly the openings of all external windows, especially those on ground floor, should be covered up by steel bars or grill of appropriate pattern. The shutters of external windows should open outside so as to check the entry of rain water inside the room. The weathersheds or projections of suitable material should be provided to all external doors and windows to prevent the entry of rain water inside the building. The windows must also provide insulation against heat loss and in some cases, against sound also. Some windows are also required to give facility for resisting a fire.

Technical Terms:

Fig 2.1(a) and fig 2.1(b) shows respectively a door and a window. The definitions of techoncal terms used in connection with the doors and windows are as follows:



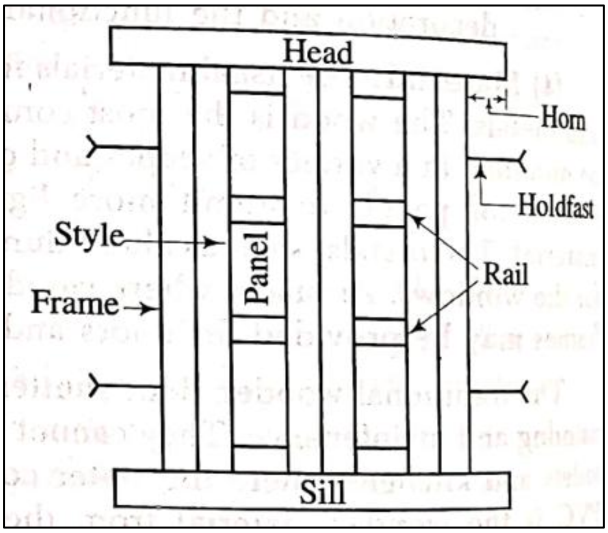


Fig. 2.1(a)
Doors

Fig. 2.1(b)
Windows

1) **Frame**: This consists of a group of members which form a support for a door or a window.
2) **Style**: This is the outside vertical member of the shutter of a door or a window.
3) **Head**: The top or uppermost horizontal part of a frame is known as the head.
4) **Sill**: The lowermost or bottom horizontal part of a window frame is known as the sill. The door frames are usually not provided with the sills.
5) **Top rail**: This is the topmost horizontal member of the shutter.
6) **Lock rail**: This is the middle horizontal member of the shutter where the locking arrangement is provided.
7) **Bottom rail**: This is the lowermost horizontal member of the shutter.
8) **Intermediate or cross-rails**: The additional horizontal rails fixed between the top and bottom rails of a shutter are known as the intermediate or cross-rails. A rail which is fixed between the top rail and lock rail is called the frieze rail.
9) **Panel**: This is the area of shutter enclosed between the adjacent rails.
10) **Holdfast**: This is generally in the form of a mild steel flat bar of section 30 mm × 6 mm and of length 200 mm. The three numbers of such holdfasts are provided on each side of the door frame and two numbers of such holdfasts are provided on each side of the window frame. They keep the frame in position.
11) **Horn**: This is a horizontal projection of head or sill beyond the face of the frame. It facilitates the fixing of the frame on the wall opening and its length is about 100 mm to 150 mm.
12) **Shutter**: The entire assembly of styles, panels and rails is known as the shutter.
13) **Sash**: This is a special type of frame, made of light sections and designed to carry glass. A sash consists of two vertical styles, a top rail and a bottom rail. A sash can be divided vertically or horizontally by providing bars. These bars are known as the sash bars or glazing bars.
14) **Mullion**: This is a vertical member which is employed to sub-divide a window or a door opening vertically.
15) **Transom**: This is a horizontal member which is employed to sub-divide a window opening horizontally.
16) **Louver**: This is a piece of timber which is fixed in an inclined position within a frame.
17) **Jamb**: The vertical wall face of an opening which supports the frame of door and window is known as the jamb.
18) **Reveal**: The external jamb of a door or a window opening at right angles to the wall face is known as the reveal.
19) **Rebate**: The depression or recess made inside the door frame to receive the door shutter is known as the rebate.
20) **Putty**: This is a mixture of linseed oil and whiting chalk. It is used for fixing glass panels.

21) Architrave: This is a strip of wood, usually moulded or splayed, which is fixed around the sides and head of openings. It thus helps in giving a decent appearance to the joint of frame with the masonry. It is used only when doors and windows are placed flush with the face of masonry.

TYPES OF DOORS

Depending upon the type of materials, arrangement of different components, method of construction, etc., the common types of doors used in the buildings can be grouped as follows:

(1) Ledged doors
(2) Ledged and braced doors
(3) Ledged and framed doors
(4) Ledged, framed and braced doors
(5) Framed and panelled doors
(6) Glazed or sash doors
(7) Flush doors
(8) Louvered doors
(9) Collapsible steel doors
(10) Revolving doors
(11) Rolling steel doors
(12) Sliding doors
(13) Swing doors.

1) Ledged doors: A ledged door is formed of the vertical brace known as the battens, which are secured by horizontal supports, known as the ledges shown in fig. 2.3.

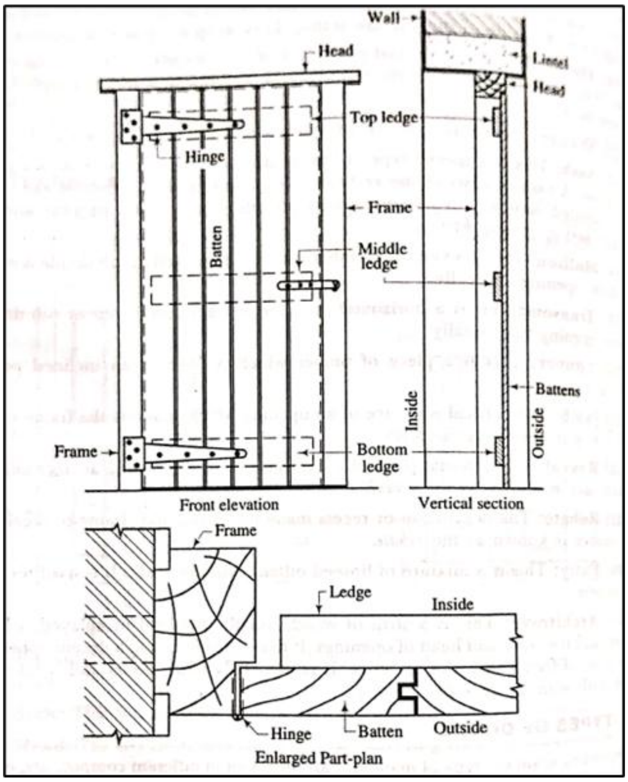


Fig. 2.3 Ledged doors

The battens are 100 mm to 150 mm wide and 20 mm to 30 mm thick. The ledges are generally 100 mm to 200 mm wide and 30 mm thick. The three ledges are generally employed—top, middle and bottom. The battens are secured by means of suitable joints and the shutter is hung on T-hinges which are fixed on ledges. This is the simplest form of door and it is used where strength and appearance are not important.

2) **Ledged and braced doors:** These are similar to the ledged doors except that the diagonal members, known as the braces, are provided as shown in fig 2.4. The braces are generally 100 mm to 150 mm wide and 30 mm thick. The braces give rigidity to the door and hence the doors of this type are useful for wide openings. The braces are usually housed in the ledges. It should be noted that the braces must slope upwards from the hanging side as they have to work in compression and not in tension.

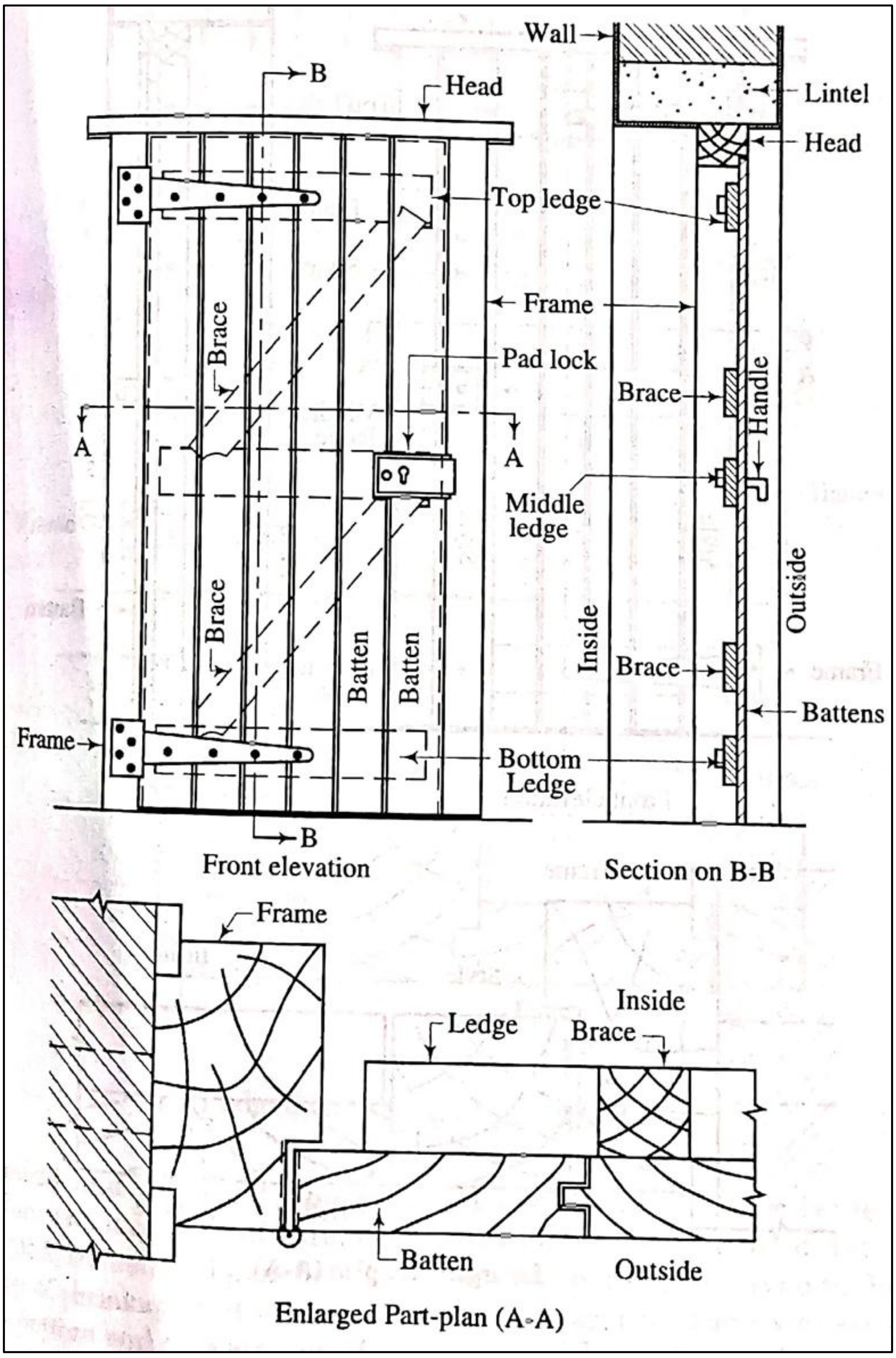


Fig. 2.4 Ledged and braced doors

3) **Ledged and framed doors:** In this type of doors, a framework for shutters is provided to make the doors stronger and better in appearance as shown in fig. 2.5. The styles are generally 100 mm wide and 40 mm thick. The battens and ledges are provided as usual.

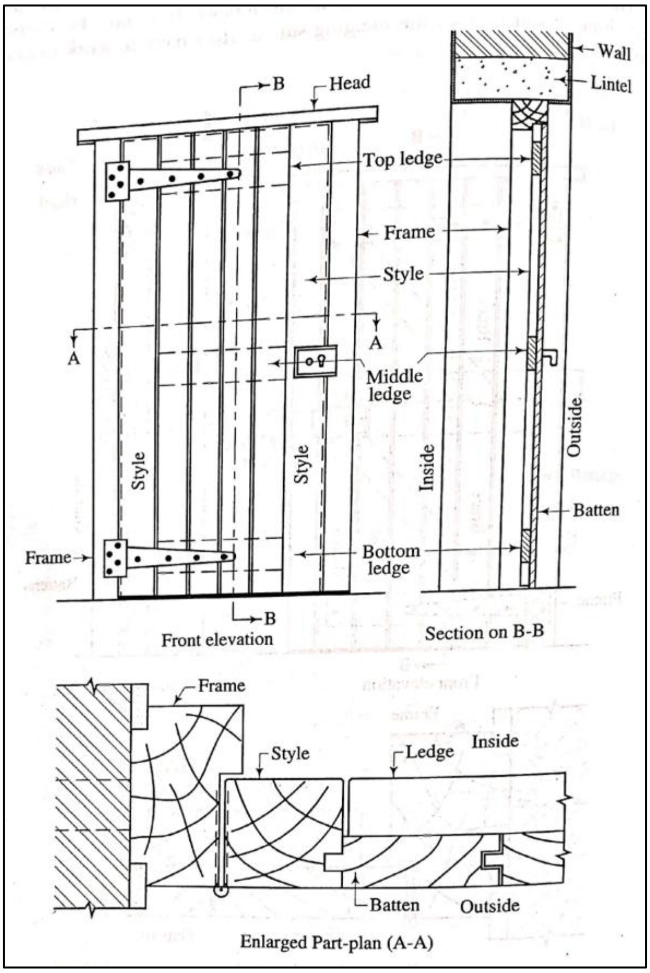


Fig. 2.5 Ledged and framed doors

4) **Ledged, framed and braced doors:** This is just similar to the above type except that the braces are introduced as shown in fig. 2.6. This type of door is more durable and stronger and hence it can be adopted for external use. The braces should incline upwards from the hanging side.

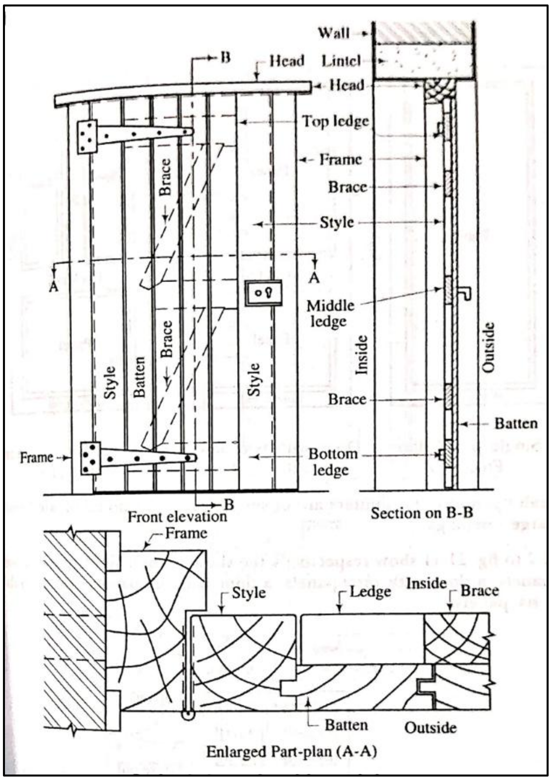


Fig. 2.6 Ledged, framed and braced doors

5) Framed and panelled doors: This is the most usual variety of door and it consists of a framework in which panels are fitted. Fig. 2.7 shows a double-leafed, framed and panelled door with four panels. This type of door reduces the tendency of shrinkage and presents a decent appearance. The styles are continuous from top to bottom and rails are joined to the styles. The mullions, if any, are joined to rails. The thickness of shutter depends on various factors such as type of work, situation of door, number of panels, etc. But the thickness of shutter is about 30 mm to 40 mm.

The thickness of panels is about 20 mm. The panels are secured in position by grooves made inside the edges of the framework. The number and size of panels depend upon the architect's design or owner's desire. But the number varies from one to six and panels are moulded to add to the beauty of the door.

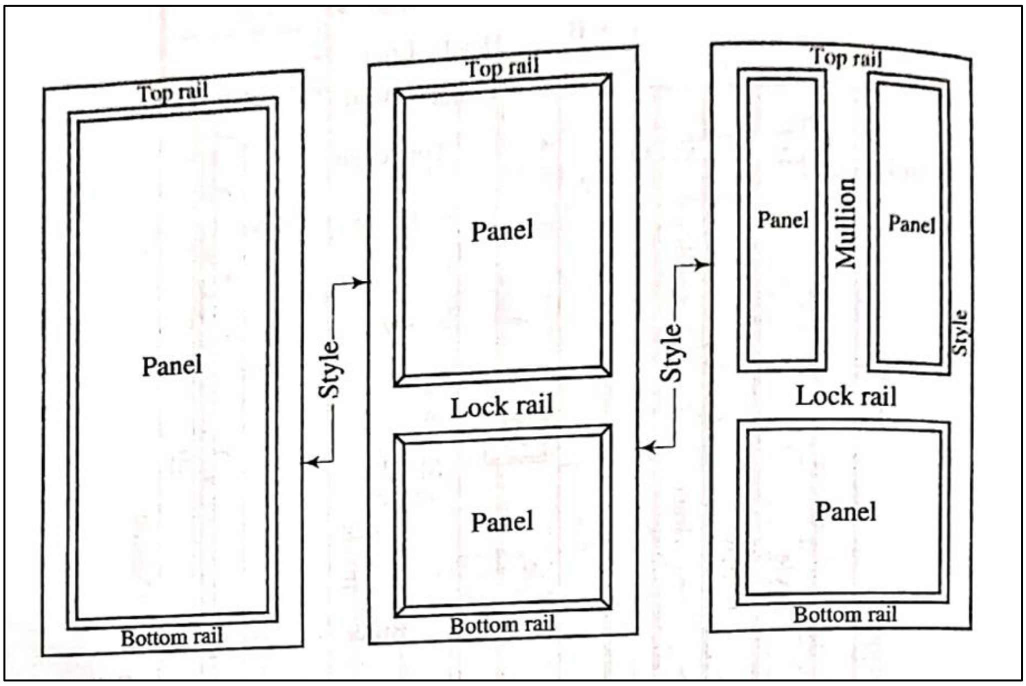


Fig. 2.7(a) Single Panel Door, Fig 2.7(b) Door with two panels, Fig 2.7(c) Door with three panels

For small openings, the shutters are of single leaf while double-leafed shutters are used for large openings. The shutters for a single panel door, a door with two panels, a door with three panels, a door with six panels and a double-leafed door with six panels.

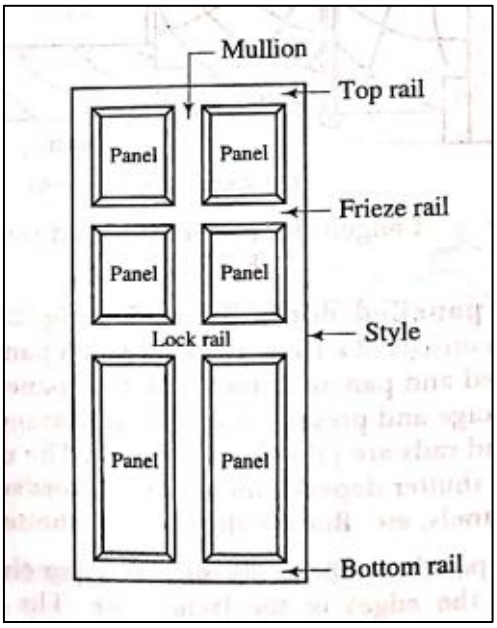


Fig. 2.7(d) Door with six panels

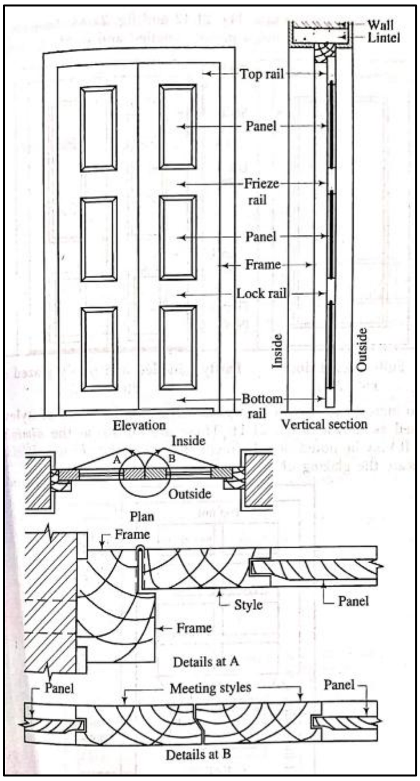


Fig. 2.7(e) Double-leafed door with six panels

6) **Glazed or sash doors:** In order to admit more light, in addition to that coming from the windows, the fully glazed or partly panelled and partly glazed doors are used.

Usually the ratio of glazed portion to panelled portion is 2:1. The glass is received into the rebates provided in the wooden sash bars and secured by nails and putty or by wooden beads fixed to the frame. Fig. 2.8(a) and Fig. 2.8(b) show respectively the shutters for a fully glazed door and a partly panelled and partly glazed door.

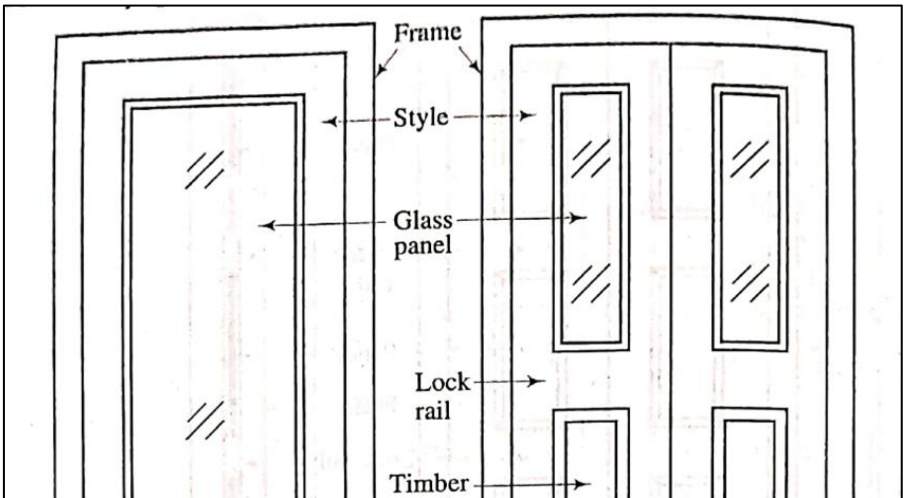


Fig 2.8(a) Fully glazed door, Fig 2.8(b) Partly panelled and partly glazed door

In order to increase the area of the glazed portion, the width of styles above lock rail is decreased as shown in fig. 2.8(c). These are known as the diminished styles or gunstock styles. It may be noted that the inclined lines at the corners of glass panel are drawn to indicate the glazing of glass panel.

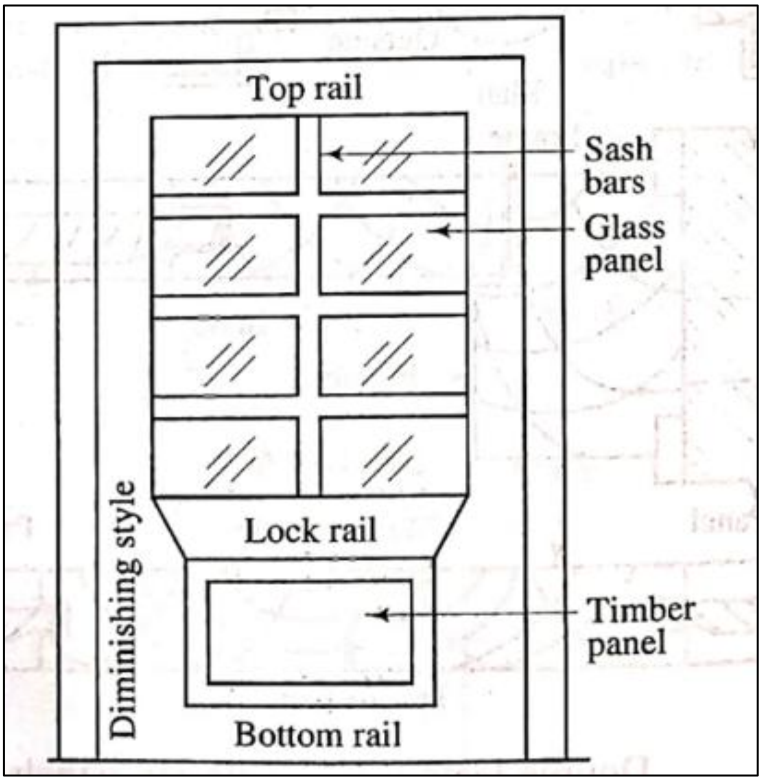


Fig 2.8(c) Door with diminishing styles

Fig. 2.8(c) The glazed or sash doors are useful for hospitals, offices, libraries, show rooms, banks, shopping units, etc.

7) **Flush doors:** A flush door consists of a framework of rails and styles and it is covered with plywood or hard-board. There are two varieties of flush doors-- a framed flush door and a laminated flush door. A framed flush door consists of styles, rails, horizontal ribs, vertical ribs and plywood as shown in fig. 2.9(a) and fig. 2.9(b). The holes in horizontal ribs are provided for ventilation. The vertical ribs rest on rails. The hollow space, instead of being kept empty, is sometimes filled up with granulated cork or any other light material.

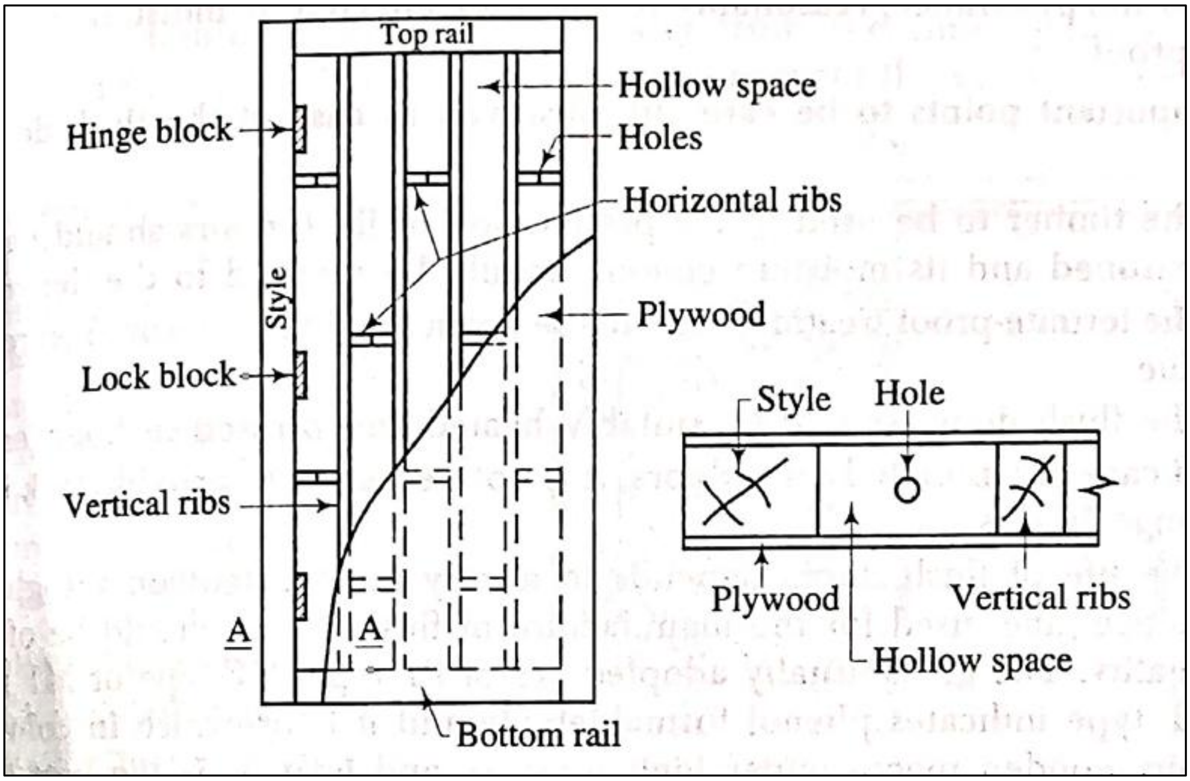


Fig. 2.9(a) Framed flush door, Fig. 2.9(b) Enlarged Section on A-A

A lock block and hinge blocks should be provided to the shutter to fix mortise lock and hinges. The flush doors, with hollow space, are light in weight and cheap. But as they are weak, they have practically become obsolete.

A laminated flush door consists of styles, rails, laminated core and plywood as shown in fig. 2.9(c) and fig. 2.9(d). The laminae of wood are glued together under great pressure. The plywood sheets on either side are also glued to the laminated core under great pressure. Thus a laminated flush door is heavy and requires more material for construction.

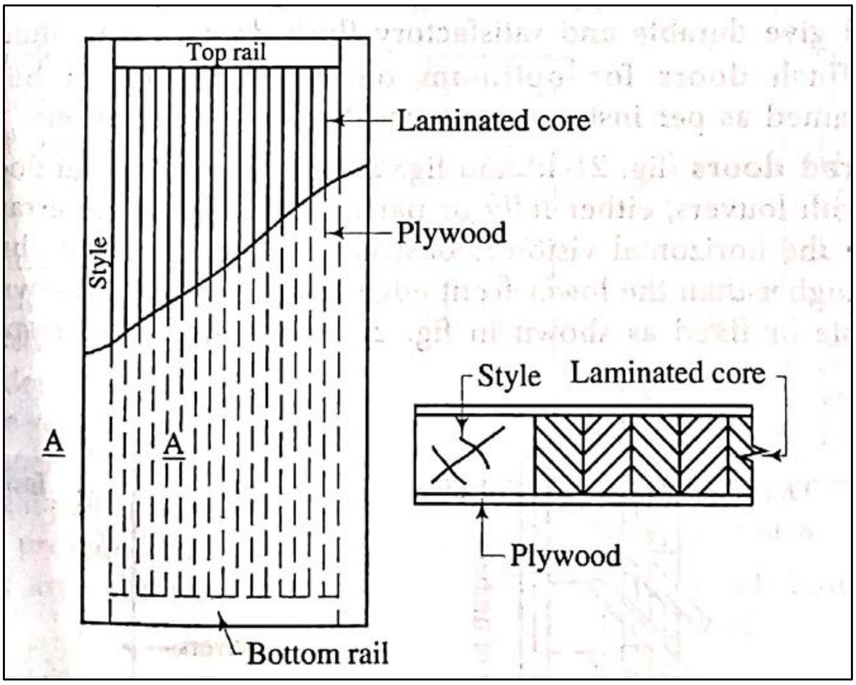


Fig. 2.9(c) Laminated flush door, Fig. 2.9(d) Enlarged Section A-A

The flush doors are prepared by specialist firms and they are therefore available in standard sizes. The thickness of plywood facing is about 6 mm on either side and total thickness of a flush door varies from 25 mm to 40 mm. The flush doors are now commonly used, especially for interior work. The flush doors are economical, easy to clean, better in appearance, reasonably strong, little affected by moisture, termite-proof and crack-proof.

8) **Louvered doors:** In this type of doors, the shutters are provided with louvers, either fully or partly. The louvers are arranged at such an inclination that the horizontal vision is obstructed. Thus the upper back edge of any louver will be higher than the lower front edge of the louver just above it. The louvers may be movable or fixed as shown in fig. 2.10(a) and fig. 2.10(b) respectively.

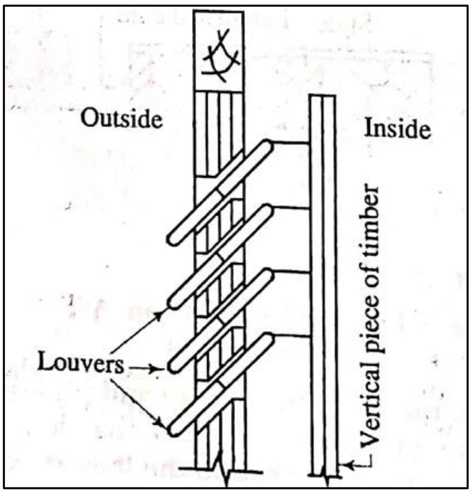


Fig. 2.10(a) Movable louvers

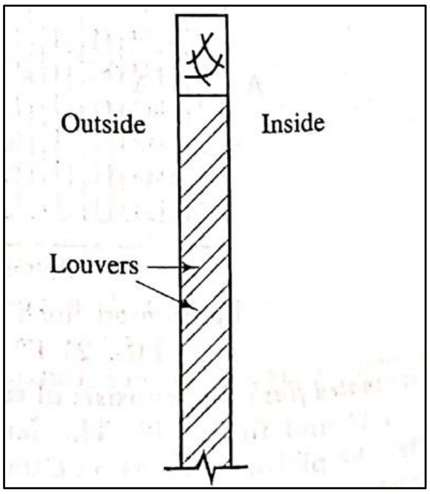
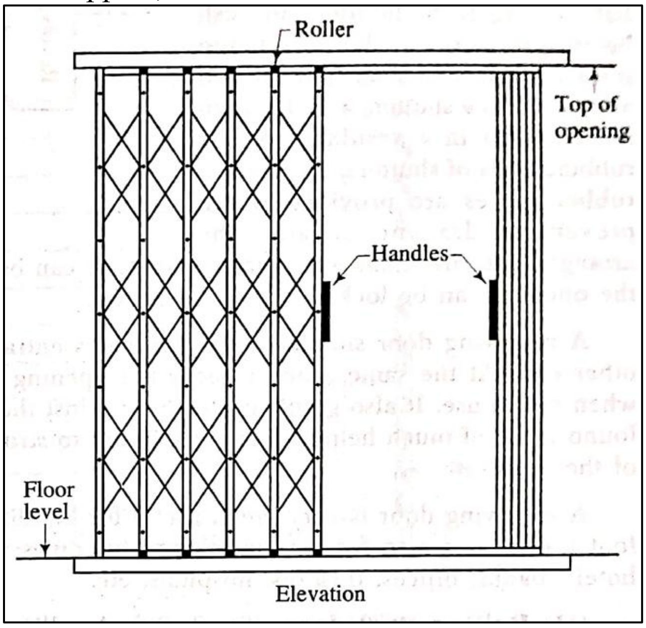


Fig. 2.10(b) Fixed louvers

In case of movable louvers, a vertical piece of timber is provided to which the louvers are attached through hinges. The upward or downward movement of the louvers can be carried out with the help of vertical piece of timber. The louvers may be either of wood or glass.
The louvers should be kept sloping away from the inner portion as shown in fig. 2.19 and fig. 2.20. This arrangement will prevent the entry of moisture from outside

The louvered doors allow free passage of air when closed and at the same time, maintain sufficient privacy. They are used for sanitary blocks of public buildings, residential buildings, etc. The louvers collect dust easily and therefore the louvered doors should be periodically cleaned.

9) **Collapsible steel doors:** A collapsible steel door consists of a mild steel frame. The two vertical pieces of mild steel channels, about 15 mm to 20 mm wide, are joined together with the hollow portion of the channel inside. A vertical gap of about 12 mm to 15 mm is thus created. Such pieces are spaced at about 120 mm centre to centre and are joined to one another by cross iron pieces as shown in fig. 2.11. The cross iron pieces are usually 10 mm to 15 mm wide and 15 mm thick. The rollers, mounted on horizontal piece, are provided at top and bottom ends of the vertical pieces. The door can be opened or closed manually by a slight pull or push. The door is also provided with handles, locking arrangement, stoppers, etc.



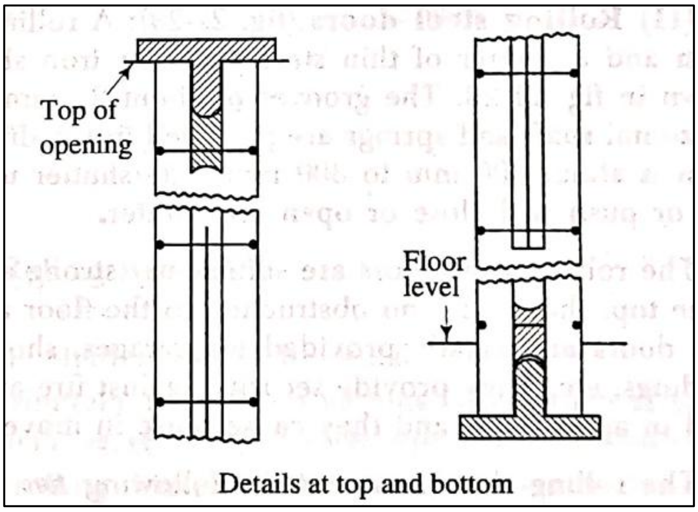


Fig.2.11 Collapsible steel doors

A collapsible steel door thus works without hinges and it is used for compound gates, residential buildings, schools, sheds, godowns, workshops, public buildings, etc. for providing increased safety and protection to the property. The collapsible steel doors are also recommended in situations where light and ventilation are desired even when the opening is closed.

10) **Revolving doors:** A revolving door essentially consists of a centrally placed mullion or pivot in a circular opening. The revolving shutters or leaves which are four in number are radially attached to the pivot as shown in fig. 2.12. The shutters may be fully glazed, fully panelled or partly panelled and partly glazed.

The central pivot is provided with ball bearing at the bottom and bush bearing at the top so that its rotation is smooth and without any jerk, friction and noise. The shutters and the pivot are enclosed in a vestibule. At the rubbing ends of shutters, the vertical rubber pieces are provided which prevent a draught of air. The arrangements are made such that the shutters can be folded when traffic is more and the opening can be locked when not in use.

A revolving door simultaneously provides entrance on one side and exit on the other end. At the same time, it keeps the opening automatically in closed position, when not in use. It also grants protection against the wind draught and it is therefore found to be of much help at places subjected to strong winds during most of the part of the year.

A revolving door is very much useful for buildings, where there is heavy rush of foot traffic, and also for air-conditioned buildings. Hence they are provided in big hotels, banks, offices, theatres, hospitals, etc.

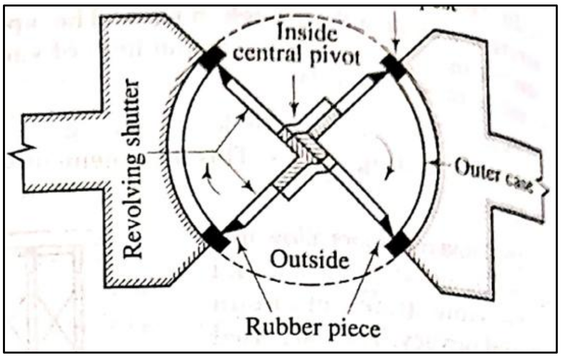


Fig 2.12 Revolving doors

11) Rolling steel doors: A rolling steel door consists of a frame, a drum and a shutter of thin steel plates or iron sheets of thickness about 1 mm, as shown in fig. 2.13. The grooves of about 25 mm thickness are left in the frame. A horizontal shaft and springs are provided in the drum at the top. The diameter of the drum is about 200 mm to 300 mm. The shutter usually rolls in turns. Thus a slight pull or push will close or open the shutter.

The rolling steel doors are sufficiently strong and as they can be easily rolled up at the top, they cause no obstruction to the floor as well as the opening. The rolling steel doors are usually provided for garages, show rooms, shops, godowns, factory buildings, etc. They provide security against fire and burglars. They are however not good in appearance and they cause noise in movements.

The rolling shutters are of the following two types:
(i) Pull-push type shutters
(ii) Mechanical gear type shutters.

(i) Pull-push type shutters: These shutters are suitable for areas less than 10 m^2 and they are operated by simply applying pull or push. The total weight of pull-push type rolling shutter is about 240 N per m^2.

(ii) Mechanical gear type shutters: These shutters are suitable for areas greater than 10 m^2 and they are operated by worm-gears, connecting rod and winding handle or by means of chain pulley blocks. The thickness of shutters is kept about 1.25 mm. The pulleys are interconnected with steel bars so that motion given by one pulley by the mechanical device is shared by all the pulleys. The total weight of mechanical gear type rolling shutter is about 280 N per m^2.

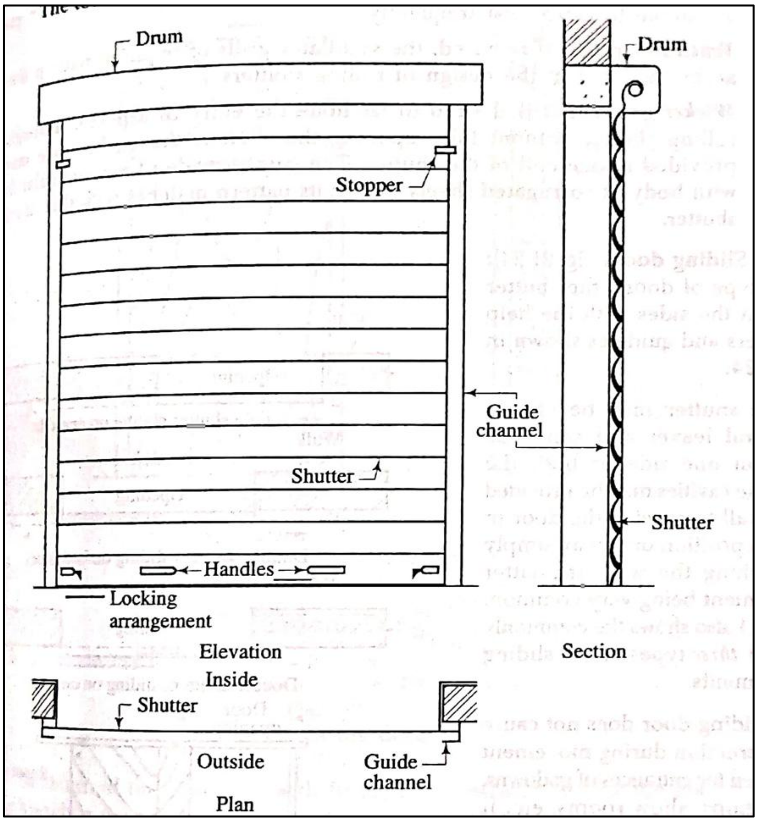


Fig. 2.13 Rolling steel door

12) **Sliding doors:** In this type of doors, the shutter slides on the sides with the help of runners and guide as shown in fig. 2.14.

The shutter may be of one or several leaves and can slide either on one side or both the sides. The cavities may be provided in the wall to receive the door in an open position or it may simply lie touching the wall, the latter arrangement being very common.

A sliding door does not cause any obstruction during movement and is used for entrances of godowns, sheds, shops, show rooms, etc. It is provided with handles, locking arrangement, stopper, etc.

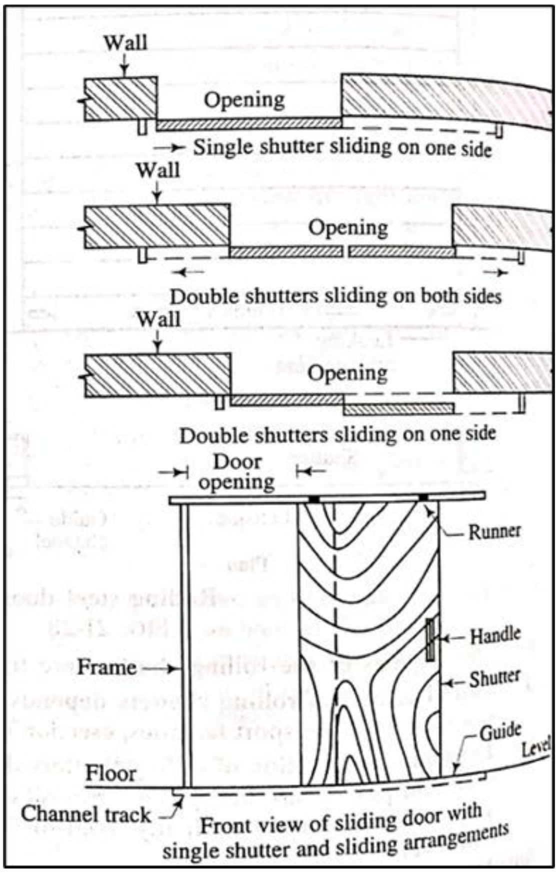


Fig. 2.14 Sliding doors

13) Swing doors: A swing door is provided with special hinges known as the double action spring hinges and thus the shutters of the door are held in closed position, when the door is not in use. The shutter may be of one or several leaves. When the door is to be used, a slight push is made and then the action of spring brings the shutter in closed position.

Fig. 2.15 shows the details of a swing door of size 0.90 m × 2.10 m with 35 mm thick flush shutter. The dimensions of peep hole are 150 mm × 300 mm and it is placed at a distance of about 450 mm from the top.

As the return of the shutter is with force, it is desirable to provide glazed shutters or alternatively a peep hole should be provided at the eye level to avoid the accident to the door users. The closing edges of the meeting styles should not be rebated and they should be made segmental. This type of door is widely used in passages of public buildings such as govt. offices, banks, etc.

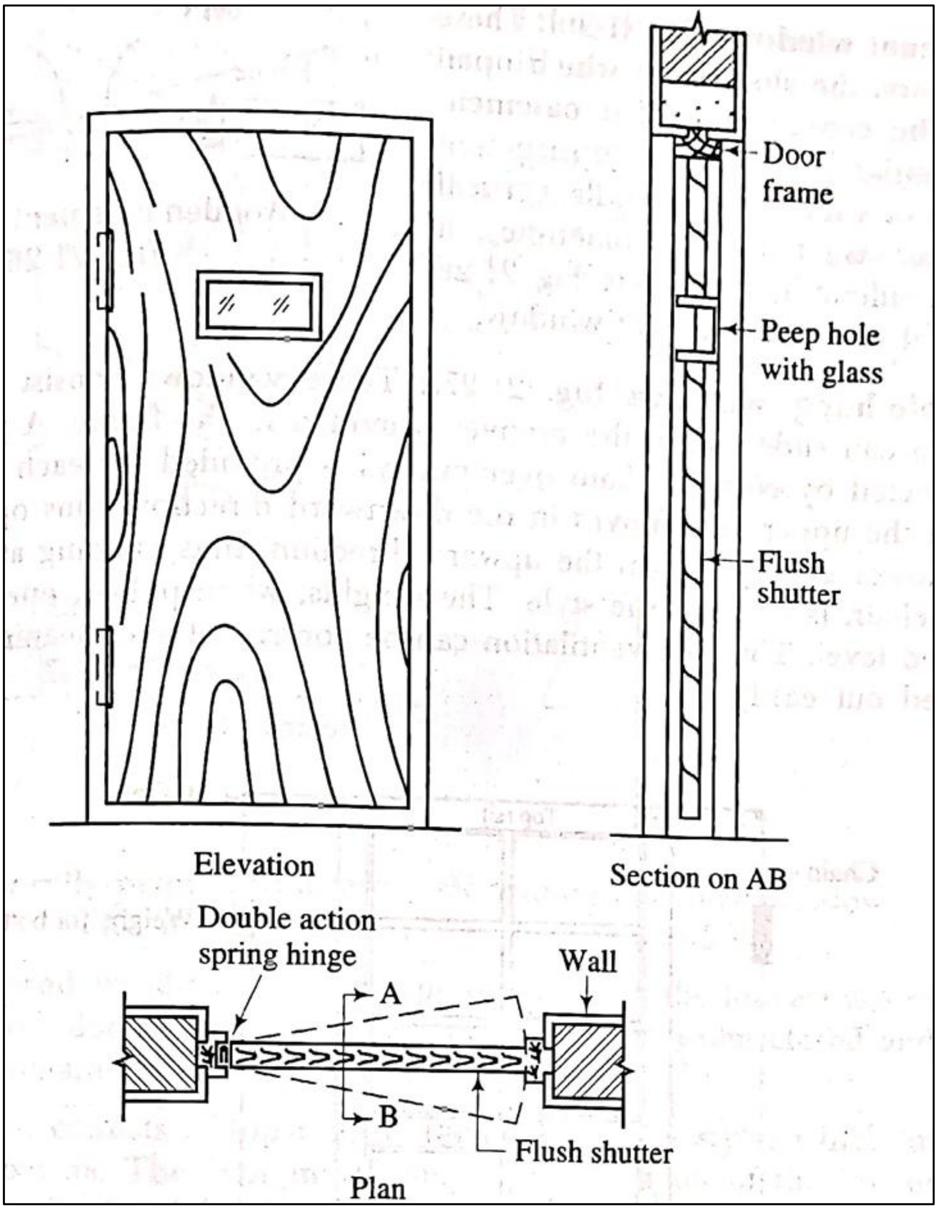


Fig. 2.15 Swing door

Windows

A *window* may be defined as an opening made in a wall for the purpose of providing day light, vision and ventilation. It also like door consists of *two parts* i.e. frame and shutter. The window frame is suitably fixed in the opening of the wall and the window shutter is held in position by the window frame.

Types of Windows

Depending upon the manner of fixing, materials used for construction, nature of operational movements of shutters, etc., the common varieties of windows used in the buildings can be grouped as follows:

(1) Casement windows
(2) Double-hung windows
(3) Pivoted windows
(4) Sliding windows
(5) Louvered windows
(6) Sash or glazed windows
(7) Metal windows
(8) Circular windows
(9) Corner windows
(10) Gable windows
(11) Dormer windows
(12) Bay windows
(13) Clerestorey windows
(14) Lanterns or lantern lights
(15) Skylights.

1) **Casement windows:** These are the windows, the shutters of which open like doors. The construction of a casement window is similar to the door construction and it consists of a frame, styles, rails, vertical and horizontal sash bars and sometimes, it also includes mullions and transoms. Fig. 2.1 shows a typical wooden casement window.

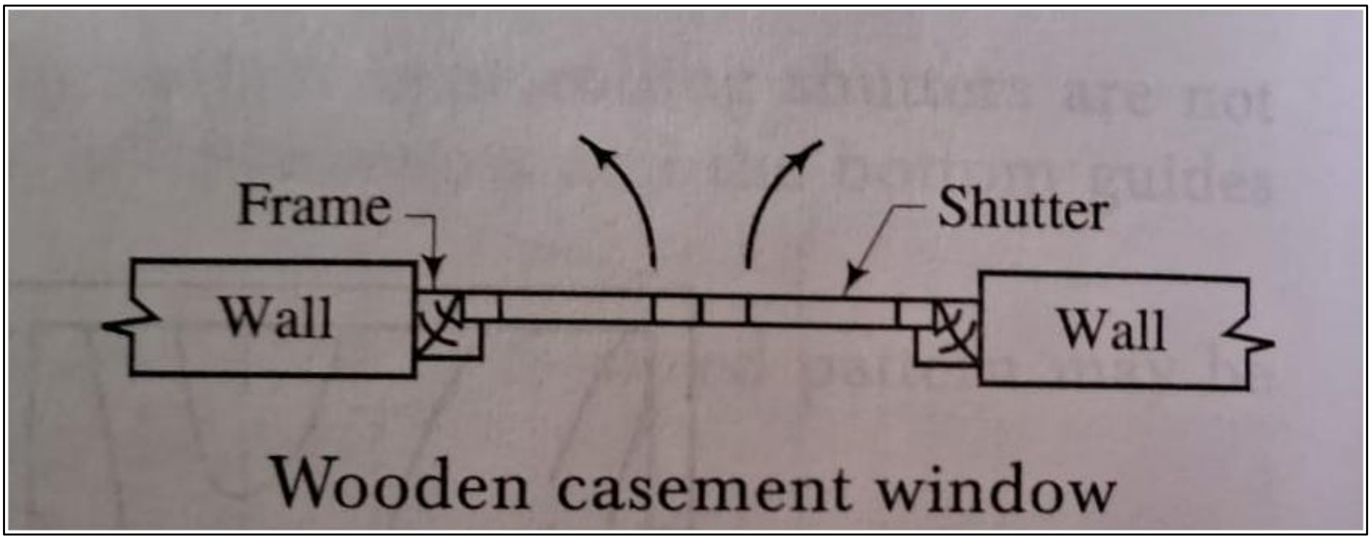


Fig. 2.1 Wooden Casement Windows

2) **Double-hung windows:** These windows consist of a pair of shutters which can slide within the grooves provided in the frame. A pair of metal weights connected by cord or chain over pulleys is provided for each sash. It is arranged that the upper sash moves in the downward direction, thus opening at the top and the lower sash moves in the upward direction, thus opening at the bottom. The cord or chain is fixed to the style. The weights, when pulled, open the sashes to the required level. Thus the ventilation can be controlled and cleaning of sashes can be carried out easily. As shown in fig. 2.2

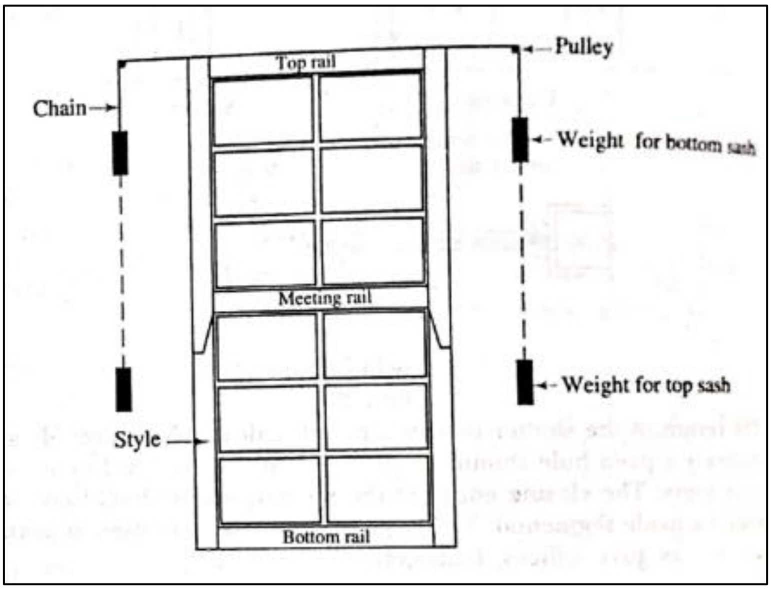


Fig. 2.2 Double-hung windows

3) **Pivoted windows:** In this type of windows, the shutters are allowed to swing round the pivots. The frame of a pivoted window is just similar to casement window except that no rebates are provided. The window may be vertically pivoted or horizontally pivoted as shown in fig. 2.3(a) and fig. 2.3(b) respectively. The pivoted windows are easy to clean and they admit more light than the side-hung windows.

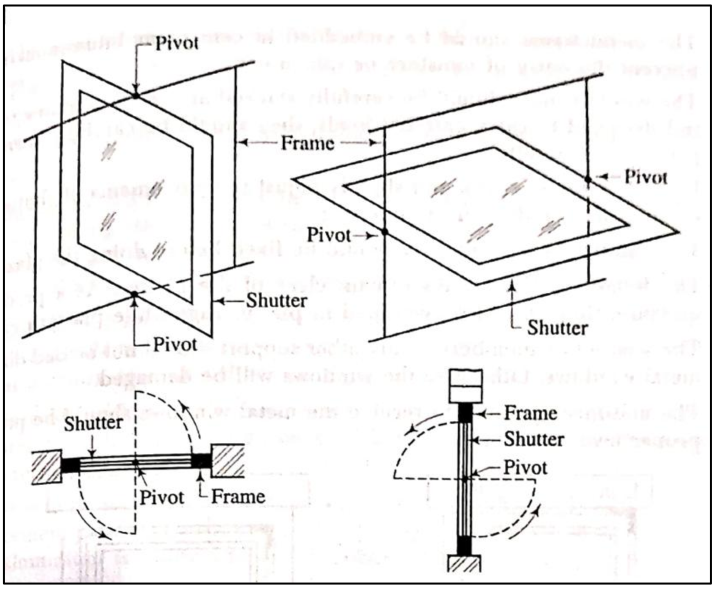


Fig. 2.3(a) Vertically pivoted window, Fig. 2.3(b) Horizontally pivoted window

4) **Sliding windows:** These windows are similar to the sliding doors and the shutters move on the roller bearings, either horizontally or vertically. Suitable openings are provided in the walls to receive the shutters when windows are opened out. Such windows are provided in trains, buses, bank counters, shops, etc.

5) **Louvered windows:** In this type of windows, the louvers are provided as in case of louvered doors. They allow free passage of air when closed and at the same time, they maintain sufficient privacy. The shutter consists of top rail, bottom rail and two styles which are grooved to receive the louvers. The economical angle of inclination of the louvers is 45° and they are generally fixed in position. If however they are to be raised or lowered, some mechanical operating device will have to be provided. The louvers should slope downward to the outside so that the rain water does not get entry to the inside of building.

6) **Sash or glazed windows:** These are fully glazed casement windows. The sashes are rebated to receive glass panels. The width and depth of rebates are about 15 mm and 5 mm respectively. The glass is secured in position either by putty or by small fillets, known as the glazing beads.

7) **Metal windows:** These are now-a-days widely used, especially for public buildings. The metal used in the construction may be mild steel, bronze or other alloys. The steel windows are manufactured in standard sizes and are widely used metal windows. The metal frame may be fixed direct to the wall as shown in fig. 2.4(a) or it may be fixed on a wooden frame as shown in fig. 2.4(b). In the former case, the lugs and plugs are provided to keep the frame in position. In the latter case, the screws are used to fix the metal frame with the wooden frame.

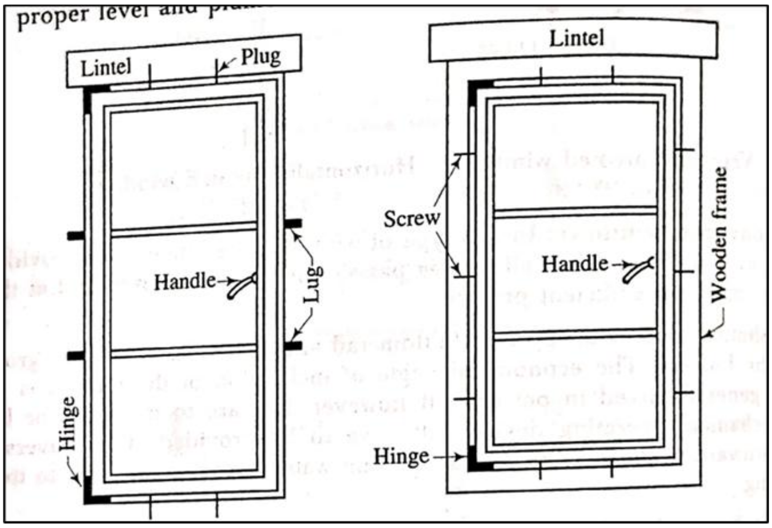


Fig. 2.4(a) Metal window fixed to the wall, Fig2.4(b) Metal window fixed on a wooden frame

Following are the advantages of the steel windows over the wooden windows:
(i) The steel windows are factory made products and hence they possess greater precision as compared to the wooden windows.
(ii) The steel windows are not subject to contraction or expansion due to weather effects as in the case of wooden windows.
(iii) The steel windows exhibit elegant appearance.
(iv) The members of steel windows are narrow and hence the steel windows admit more light and ventilation for the same area, as compared to the wooden windows.
(v) The steel windows are easy to maintain and their cost of maintenance is almost negligible as compared to that of the wooden windows.
(vi) The steel windows are highly fire-proof and termite-proof. (vii) The steel windows grant better facilities for providing different types of openable parts. (viii) The steel windows are more durable and stronger as compared to the wooden windows.

8) **Circular windows:** Circular windows: These are pivoted windows of circular shape. They are useful for factories, workshops, etc.

9) **Corner windows:** These windows are provided at the corner of a room as shown in fig. 2.5. They are placed at the corner of a room and thus they have two faces in two perpendicular directions. Due to such situation, there is entry of light and air from two directions and in many cases, the elevation of the building is also improved. However special lintel will have to be cast at the corner and the jamb post of the window at the corner will have to be made of heavy section.

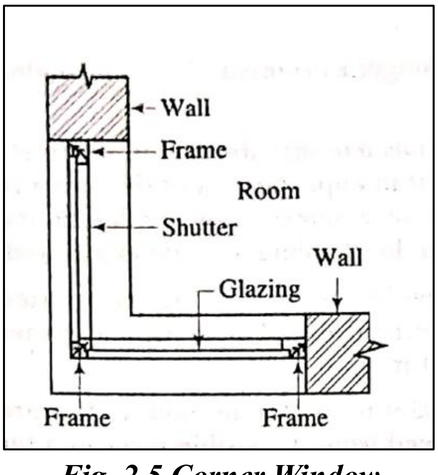


Fig. 2.5 Corner Window

10) Gable window: These are the windows which are provided in the gable ends of a roof as shown in fig.2.6.

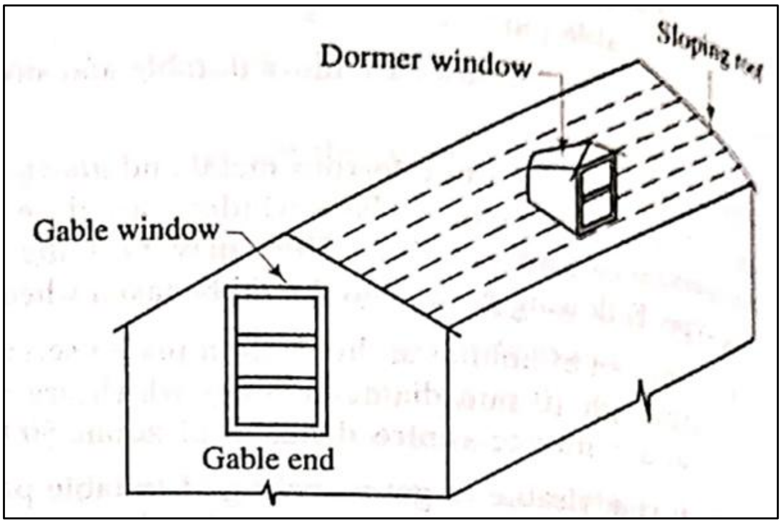


Fig. 2.6 Gable window and Dormer Windows

11) Dormer windows: These are the windows provided on the sloping roofs as shown in fig. 2.6. The main purpose of providing dormer windows is to admit light and air to rooms which are constructed within or below the roof slopes.

12) Bay windows: These windows project outside the external walls of a room. They may be square, splayed, circular, polygonal or of any shape. Fig. 2.7(a) and fig. 2.7(b) show respectively a square bay window and a splayed bay window. The projection of bay windows may start from floor level or sill level. These windows admit more light, increase opening area, provide ventilation and improve the appearance of the building.

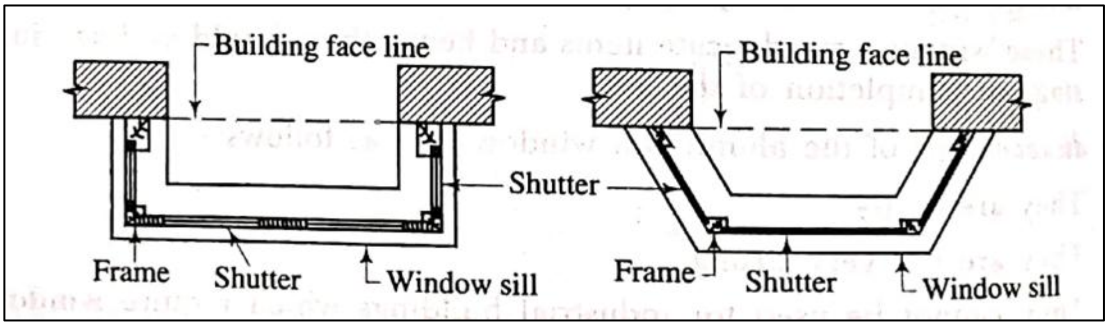


Fig. 2.7(a) Square Bay window, fig. 2.7(b)Splayed Bay window

13) Clerestorey windows: These windows are provided near the top of main roof as shown in fig. 2.8. The pivoted windows are used for this purpose. The clerestorey windows provide ventilation to the inside of the room as the front is blocked by the verandah. They also improve the appearance of building. The care should be taken to see that the upper part opens inside and the lower part opens outside. Otherwise the rain water will accumulate in the room.

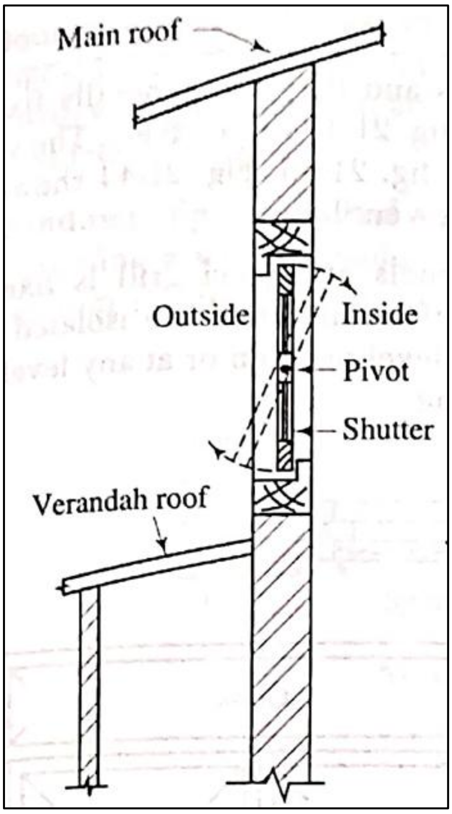


Fig.2.8 **Clerestorey windows**

14) Lanterns or lantern lights: These are the windows which are fixed on flat roofs to provide light to the inner portion of the building where light coming from the windows in the external walls is insufficient. They may be square or rectangular or curved. Fig. 2.9 shows a square lantern light. The glass panels are generally fixed. But if ventilation is also required in addition to light, the pivoted windows may be provided.

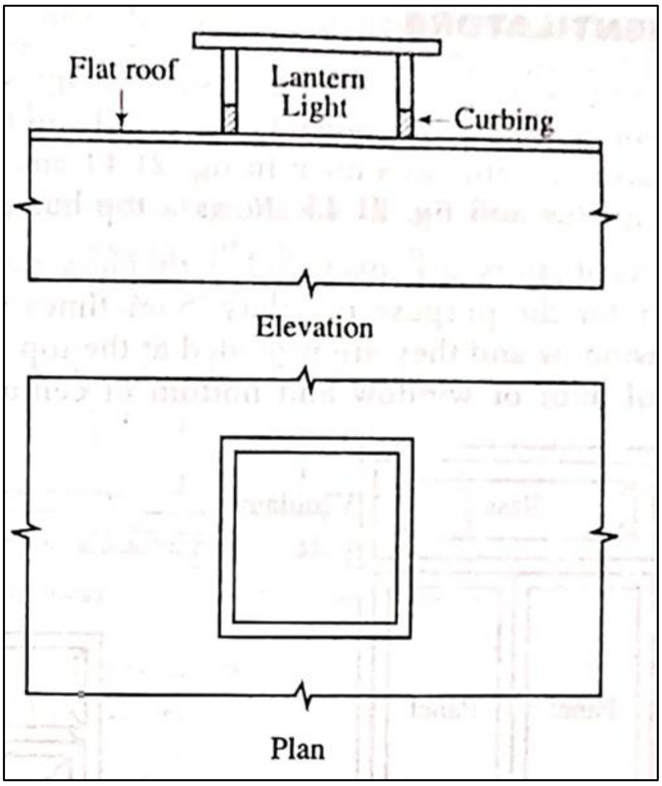


Fig. 2.9 Latern Light

15) **Skylights:** These are the windows which are provided on the sloping surface of a pitched roof. The common rafters are suitably trimmed and the skylight is erected on a curb frame as shown in fig. 2.10. As skylights are mainly meant for light, they are usually provided with the fixed glass panels. The opening of skylight is properly treated by lead flashing to make water-proof the roof area surrounding the opening.

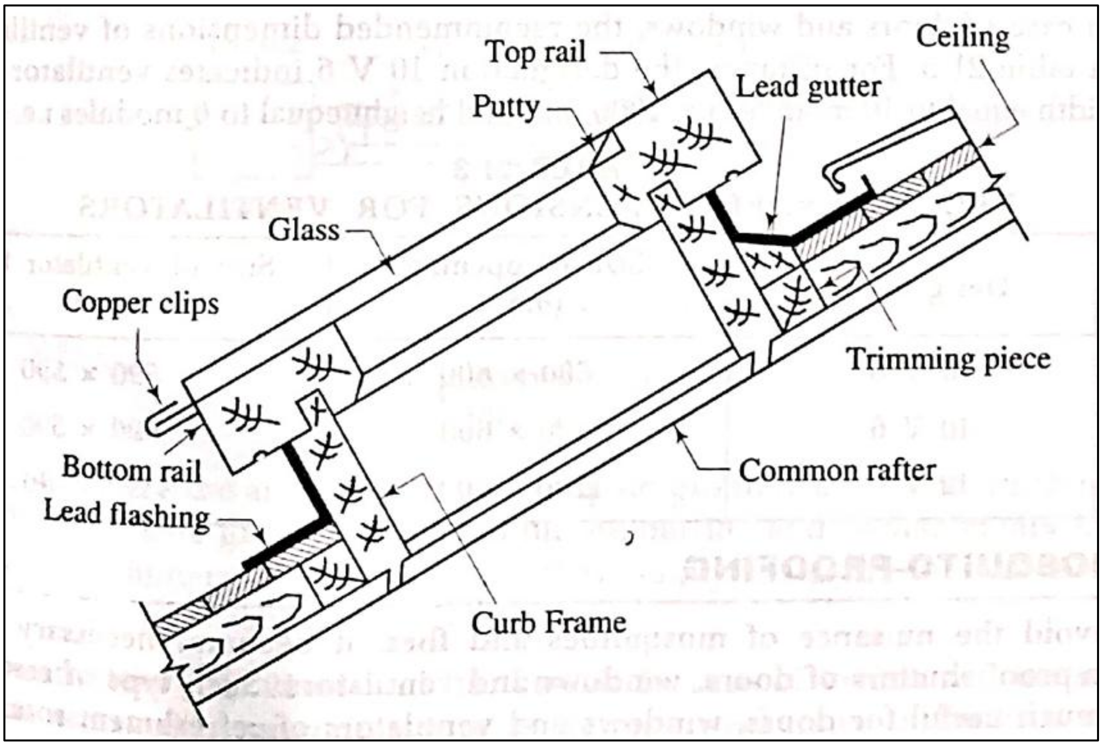


Fig. 2.10 Skylights

Ventilators

The ventilators are windows of small heights and they are generally fixed at the top of door or window as shown in fig. 2.11 and fig. 2.12 respectively. The ventilators may be also movable as shown in fig. 2.13 and fig. 2.14. Fig. 2.15 shows a pivot-hung ventilator and fig. 2.16 shows a top-hung ventilator.

The ventilators are provided with glass panels and steel grill is fixed in the ventilator for the purpose of safety. Sometimes the ventilators are isolated from the door or window and they are provided at the top level of room or at any level between the top of door or window and bottom of ceiling.

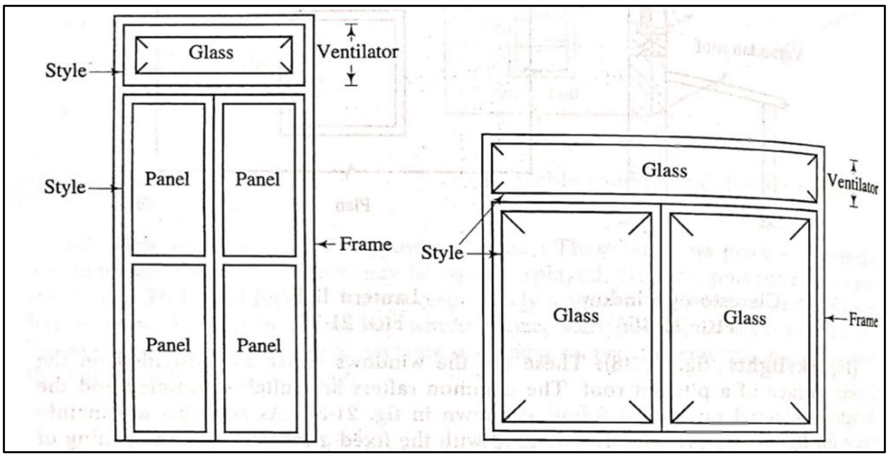


Fig. 2.11 Door with ventilator, ***Fig. 2.12 Window with ventilator***

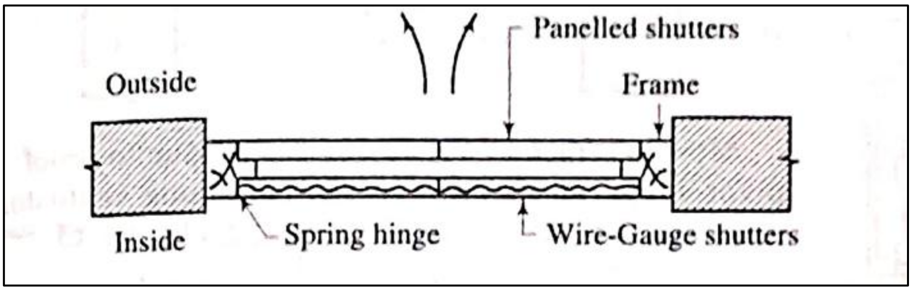


Fig. 2.13 Mosquito-proof door

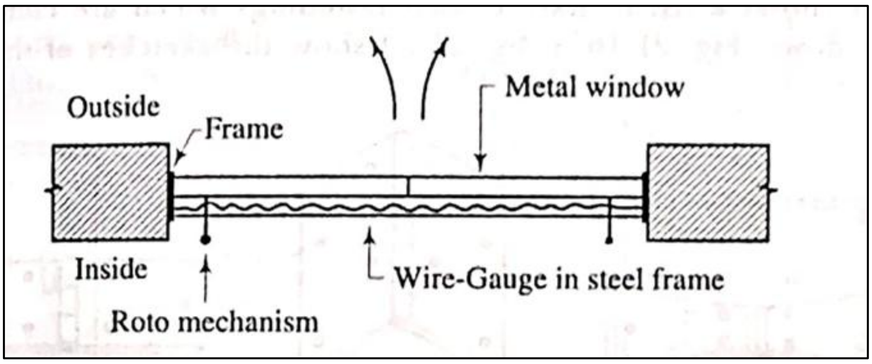


Fig. 2.14 Mosquito-proof window

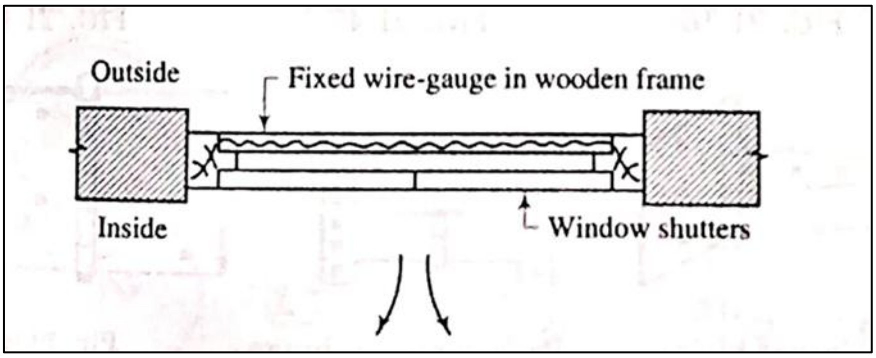


Fig. 2.16 Mosquito-proof window

Necessity of Ventilation

The term ventilation is used to mean the free passage of clean air in a structu In other words, the removal of all vitiated air from a building and its replaceme with fresh air is known as ventilation. It is important from the engineering view poi for the following reasons:

i. If the room is not properly ventilated, there will be excessive quantity o carbon dioxide in the air. The more the amount of carbon dioxide, the more difficult is the breathing. It is observed that breathing is difficult when the amount of carbon dioxide by volume is about 6 per cent and a man loses consciousness when it reaches about 10 per cent or so. For comfortable working, the carbon dioxide content should be limited to about 0.6% by volume.
ii. The ventilation is required to control dust and other impurities in the air. This is the main cause of insisting proper ventilation in the industrial buildings.
iii. The ventilation is also required to suppress odours, smoke, concentration of bacteria, etc.

iv. The proper and sufficient ventilation results in absence of condensation. The difference of temperature between the outside air and the inside air tends to the deposition of moisture on the room surfaces. This is known as the condensation and it can be effectively controlled by the provision of suitable ventilation of the room.
v. For removal of body heat liberated or generated by the occupants, the ventilation is necessary.
vi. In order to prevent the formation of conditions leading to suffocation in conference rooms, committee halls, cinema halls, big rooms, etc., the proper ventilation of such premises must be made.

Factors Affecting Ventilation

Following factors affect the ventilation from the view point of comfort to the Persons and therefore should be considered carefully:
(l) Air changes
(2) Humidity air
(3) Quality of
(4) Temperature
(5) Use of building

(1) Air changes: (1) Air changes: Where people are working, the air has to be moved or changed to cause proper ventilation of the premises. The minimum and maximum rates of change of air per hour are one and sixty respectively. If the rate of air change is less than one per hour, it will not create any appreciable effect of the ventilation system. On the other hand, if the rate of air change is more than sixty per hour, it will result in discomfort due to high velocities of air. From practical considerations and effective working of the ventilation system, the desired value of rate of air change is three and preferably five per hour or so.

The rate of air change will depend upon the volume of structure, type of activity in the premises, number of persons occupying the premises, etc. It will also depend on the velocity of incoming fresh air and quantity of heat, moisture and odour present in the room. The fans may be used to increase the air movement. The ventilating system as a whole should be such that there is smooth movement of air currents and that there is no stagnation of air at any spot in the room.

(2) Humidity: When a certain volume of air at a certain temperature contains as much water vapour as it can, it is said to be saturated air. Generally, the air is not saturated at all the times. But it contains a certain amount of water vapour in it. The ratio of amount of water vapour present to the amount it would have contained, had it been saturated, is known as the relative humidity, the temperature being same. Thus, the relative humidity of saturated air is 100 per cent.

The criteria of relative humidity of air also affects the ventilating system of the structure. For working at temperature of 21°C, a range of 30 to 70 per cent of relative humidity is desirable. The value of relative humidity is obtained by comparing dry-bulb and wet-bulb temperatures. For higher temperatures, the low humidity and greater air movements are necessary for removing greater portion of heat from the body.

(3) Quality of air: The purity of air plays an important role in the comfort of persons affected by ventilation system. The air should be free from odours, organic matter, inorganic dust and unhealthy fumes of gases such as carbon monoxide, carbon dioxide, sulphur dioxide, etc. All the above impurities depend on the habits of occupants, volume of the room, source of ventilating air, etc. The ventilating system should be so designed that it gives comfort to the occupants by giving pure air. Thus, the entry of ventilating air should not be situated very near to latrines, kitchens, urinals, stables, chimneys, etc. The existence of pure air in buildings improves the health of occupants, assists in perfect combustion of fuel and preserves the materials of which the building is constructed.

(4)Temperature: It is quite evident that the incoming air for ventilation should be cool in summer and warm in winter before it enters the room. The usual difference of temperature between inside and outside is kept as about 8°C to 10°C.

With regard to the human comfort, the term effective temperature is used. It is an index which combines the effects of air movements, humidity and temperature. It indicates the temperature of air at which sensation of same degree of cold or warmth will be experienced as in quiet air fully saturated at the same temperature. Thus, if two rooms have the same effective temperature, no change of temperature will be experienced by a person when he suddenly leaves one room and enters the other.

(5) Use of building: The quantity of fresh air to be supplied to a room depends on the use of building and it is to be decided by taking into consideration various factors such as number of occupants, type of activity, period of working, age of occupants, etc. Table 2.3 shows the minimum rates of fresh air for some types of buildings.

Table 2.3
Minimum Rates of Fresh Air

No.	Nature of building	Rate of fresh air in m3 per head per hour
1	Factories, workshops	15
2	Schools	23
3	Restaurants, dining halls	25
4	Assembly halls, canteens, shops, offices with light activity	28
5	Theatres, hospitals	35
6	Residential buildings	50
7	Gymnasiums	80

Requirements of a Good Ventilating System

Following are considered to be the desired requirements of a good ventilating system:

a. It should be so designed that the required quantity of fresh air is admitted in the premises and that the vitiated air is extracted from the premises.
b. The value of desired relative humidity should be maintained.
c. The effective temperature should be properly maintained with regard to the human comfort.
d. The air movements should be uniform and it should be seen that pockets of stagnant air are not formed.
e. The incoming air should be free from impurities such as dust, odour, etc.
f. The ventilating system should be such that it results in overall satisfactory performance.

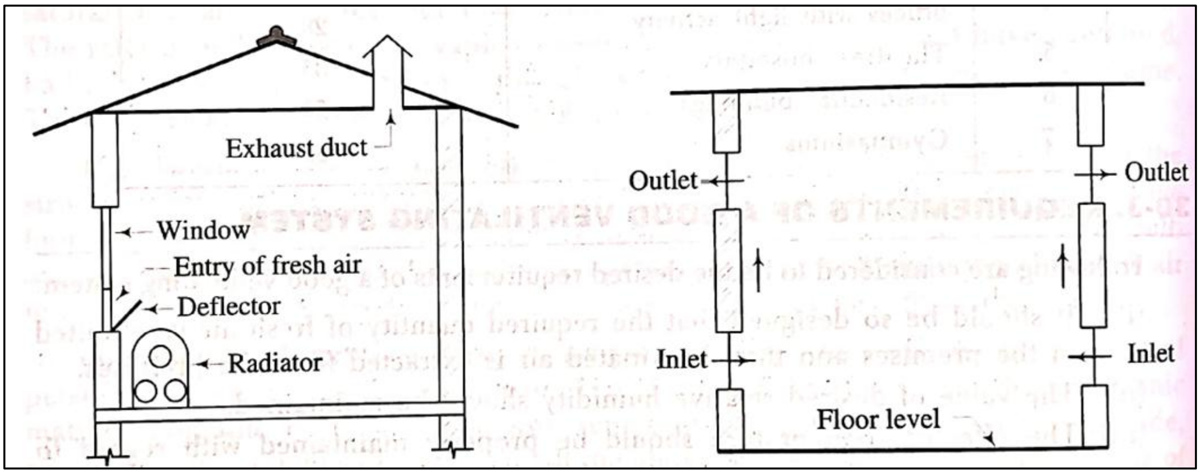
Types of Ventilation

The systems of ventilation may broadly be divided into the following two categories:
(1) Natural ventilation
(2) Mechanical or artificial ventilation.

(1) Natural ventilation: In this system of ventilation, the use is made of doors, windows, ventilators and skylights to make the room properly ventilated. This system is useful for small buildings and it cannot be adopted for big offices, theatres, auditoriums, etc. The only advantages of this system are that it is economical in the sense that no special equipment is necessary for making the room adequately ventilated and that it affords living under natural conditions. The important points to be remembered in connection with natural ventilating system are:

i. The location, size and type of windows play a great role in imparting natural ventilation to the room. The windows also supply light and afford protection against weather. All these functional requirements should be properly correlated while deciding the location of windows in a room.
ii. The efficiency of roof ventilators depends on their location, wind direction and height of building.
iii. It is found that the window ventilation with a combination of radiator, deflector and exhaust, can give better results. The radiators are situated below the sill level of the windows and they extend for the full length of the window.

The windows, deflectors and radiators should be properly manipulated for achieving the desired effects. The exhaust duct is provided near the ceiling of the opposite wall and it is taken out of the roof to act more or less like a chimney. The windows open from bottom and the deflectors may be of curved vanes.



(2) Mechanical or artificial ventilation: In this system of ventilation, some mechanical arrangement is adopted to provide enough ventilation to the room. This system has become popular due to recent change in notion regarding ventilation. At present, the ventilation is required not merely to furnish warm air or cool air. But the ventilation system should provide air of such qualities regarding humidity, temperature, etc. as to make the room comfortable at all times during the year. The system is costly, but it results in considerable increase in the efficiency of the persons under the command of the system. This system is adopted for big offices, banks, industrial plants, theatres, auditoriums, etc. Following are the five methods of the artificial ventilation:
(i) Exhaust system
(ii) Supply system
(iii) Combination of exhaust and supply systems
(iv) Plenum process
(v) Air-conditioning.

Fire-resistant doors and windows

Introduction:

Fire-resistant doors and windows are essential elements of a building's passive fire protection system, which aims to control and contain fire without the use of active mechanical devices. Unlike fire extinguishers or sprinklers, these components work continuously by limiting the movement of fire, smoke, and hot gases through openings in walls and partitions.

During a fire, doors and windows are the weakest points through which flames and smoke can spread rapidly from one compartment to another. Fire-resistant doors and windows are specially designed and tested to withstand high temperatures for a specified period, such as 30, 60, 90, or 120 minutes, without losing their structural integrity. This delay in fire spread helps in maintaining compartmentation within the building.

The primary purpose of fire-resistant doors and windows is to provide sufficient time for safe evacuation of occupants, reduce panic, and allow fire-fighting operations to be carried out effectively. They also help in protecting escape routes such as staircases, corridors, and lift lobbies, ensuring these areas remain usable during a fire emergency.

In addition to life safety, fire-resistant doors and windows play a vital role in minimizing damage to property and structural elements. By confining fire to a limited area, they prevent total building collapse and reduce financial losses. Hence, the use of fire-resistant doors and windows is mandatory in modern buildings as per national and international fire safety codes and building regulations.

Construction of Fire-Resistant Door

1. Door Leaf: The door leaf is the main fire-resisting component of a fire-resistant door. It is generally made of galvanized steel sheets or fire-treated timber. The steel sheets are usually 0.9 mm to 1.2 mm thick and are folded to form a rigid panel.

Inside the door leaf, a fire-resistant core material is provided, such as mineral wool, vermiculite board, honeycomb core, or calcium silicate board. These materials have low thermal conductivity and can withstand very high temperatures. The core delays heat transfer and prevents deformation of the door during fire exposure.

2. Door Frame: The door frame supports the door leaf and transfers loads to the surrounding wall. It is made of pressed steel sections or fire-treated hardwood.

The frame is firmly fixed into the RCC or masonry wall using anchor bolts or holdfasts. The gap between the frame and wall is filled with fire-stop mortar or intumescent sealant to prevent fire and smoke leakage. A properly fixed frame ensures that the door remains stable and functional during fire conditions.

3. Intumescent Seal: An intumescent seal is a heat-activated fire seal provided along the edges of the door leaf or inside the frame rebate.

Under normal conditions, the seal remains inactive. When exposed to high temperatures (about 180–200°C), it expands many times its original thickness. This expansion closes the small gaps between the door and frame, thereby blocking the passage of flames, smoke, and hot gases. This seal plays a crucial role in maintaining the fire rating of the door.

4. Fire-Rated Hardware: All hardware used in a fire-resistant door must be fire-rated and tested. This includes:

- Fire-rated hinges that support the door under high temperature
- Door closer to ensure the door automatically closes after use
- Fire-rated lock or panic bar for safe and quick evacuation
- Use of non-fire-rated hardware can lead to failure of the entire fire door assembly.

Function of Fire-Resistant Door:

During a fire, the fire-resistant door performs several critical safety functions. The door leaf and core material resist flame penetration and restrict the passage of heat from the fire-affected area to the safe side. At the same time, the intumescent seal expands due to heat and seals all gaps, preventing smoke and hot gases from spreading.

The door closer ensures the door remains in the closed position, which is essential for effective fire containment. By controlling fire, smoke, and heat movement, the fire-resistant door delays the spread of fire for the rated duration, provides safe evacuation time, and helps fire-fighting personnel carry out rescue operations efficiently.

Fire-Resistant Windows:

A fire-resistant window is a specially designed glazed opening that is capable of withstanding fire exposure for a specified period of time without allowing flames, smoke, or hot gases to pass through. Unlike ordinary windows, it is tested as a complete fire-rated assembly consisting of glass, frame, and glazing system. Fire-resistant windows help in maintaining fire compartmentation while also providing visibility and natural light during normal use.

Construction of Fire-Resistant Windows:

1. Fire-Resistant Glass: Fire-resistant glass is the most critical component of a fire-resistant window. It is specially manufactured to withstand high temperatures and thermal shock.

Types of fire-resistant glass

Wired Glass: Contains a steel wire mesh embedded within the glass. During fire, the wire holds the glass in position and prevents it from shattering.

Ceramic Glass: Can withstand very high temperatures without cracking and remains stable under sudden temperature changes.

Laminated Fire Glass: Consists of multiple layers of glass bonded with a fire-resistant interlayer that reduces heat transfer.

Gel-Filled Fire Glass: Contains a transparent gel layer that expands when exposed to heat, forming an insulating barrier against fire.

These glasses prevent flame penetration and limit heat radiation for the rated duration.

2. Window Frame: The window frame provides structural support to the fire-resistant glass and ensures proper fixing to the wall.

Materials used:

Steel frames:

- Fire-rated aluminum frames with thermal breaks
- Fire-treated timber frames

Fixing method: The frame is rigidly fixed into RCC or masonry walls using anchor bolts or suitable fasteners. The gap between the frame and wall is sealed with fire-stop sealant or mortar to prevent fire and smoke leakage. A properly installed frame ensures that the window remains intact and stable during fire exposure.

3. Glazing System: The glazing system holds the fire-resistant glass securely within the frame and plays a vital role during fire conditions.

Components include: Intumescent glazing tape: Placed between the glass and frame; it expands when heated and seals gaps.

Fire-rated beading: Made of steel or fire-resistant material to retain the glass in position.

Non-combustible spacers: Prevent glass movement and failure.

During fire, the glazing system prevents glass fallout, seals openings, and maintains the fire integrity of the window.

Function of Fire-Resistant Windows

During a fire, the fire-resistant glass resists flame penetration, while the intumescent glazing materials expand and seal gaps. The frame remains stable and fixed, preventing collapse of the window assembly. As a result, the window delays the spread of fire and smoke, protects adjacent compartments, and provides critical evacuation and rescue time.

Advantages of Fire-Resistant Doors and Windows

1. Saves Human Life: The most important advantage of fire-resistant doors and windows is life safety. By restricting the spread of fire, smoke, and hot gases, they provide valuable time for occupants to evacuate safely. Since smoke inhalation is the main cause of death during fire accidents, these systems play a crucial role in reducing casualties.

2. Controls Fire Spread: Fire-resistant doors and windows help in containing fire within a specific compartment of the building. They prevent flames and heat from spreading rapidly to adjacent rooms, floors, or escape routes. This compartmentation significantly reduces the intensity and area of fire damage.

3. Improves Evacuation Safety: By protecting staircases, corridors, lift lobbies, and fire exits, fire-resistant doors and windows ensure that escape routes remain usable for a longer duration. This orderly and safe evacuation reduces panic and allows occupants to exit the building efficiently during emergencies.

4. Protects Property: By delaying the spread of fire, these systems limit damage to structural elements, equipment, and interior finishes. Containment of fire to a smaller area reduces repair costs and financial losses, and in some cases prevents total collapse of the building.

5. Mandatory for Code Compliance: Fire-resistant doors and windows are mandatory as per fire safety regulations such as the National Building Code (NBC) and relevant Indian Standards. Their use ensures legal compliance, approval from fire authorities, and certification of buildings for occupancy.

Below is a detailed, exam-oriented explanation of the limitations of Fire-Resistant Doors and Windows, written in clear technical language and suitable for theory answers.

Limitations of Fire-Resistant Doors and Windows

1. Higher Cost: Fire-resistant doors and windows are more expensive than conventional doors and windows due to the use of special fire-rated materials, such as fire-resistant glass, mineral wool cores, intumescent seals, and certified hardware. In addition, testing, certification, and compliance with fire safety standards increase the overall cost. This higher initial investment may be a limitation, especially for small-scale projects.

2. Requires Skilled Installation: Proper performance of fire-resistant doors and windows depends heavily on correct installation. Installation must be carried out by trained and experienced personnel strictly following the manufacturer's tested system. Any improper fixing, misalignment, or use of non-approved materials can reduce the fire rating and lead to failure during fire conditions.

3. Needs Regular Maintenance: Fire-resistant doors and windows require periodic inspection and maintenance to ensure continuous effectiveness. Components such as door closers, hinges, intumescent seals, and glazing systems may wear out or get damaged over time. Lack of maintenance can compromise their fire resistance and make them unreliable during emergencies.

4. Ineffective if Left Open or Damaged: Fire-resistant doors are designed to perform only when they are closed. If doors are left open, blocked, or held by wedges, they cannot prevent the spread of fire or smoke. Similarly, damaged frames, broken glass, or missing seals can significantly reduce their effectiveness, making them unsafe during fire incidents.

Prefabricated and Modular Construction Techniques

Introduction

Prefabricated and modular construction techniques are modern construction methods in which building components or complete units are manufactured in a controlled factory environment and then transported to the construction site for assembly. These techniques aim to improve construction speed, quality control, safety, and sustainability, while reducing dependence on on-site labor and weather conditions.

With increasing demand for fast, economical, and sustainable construction, prefabrication and modular construction have become widely adopted in residential, commercial, industrial, and infrastructure projects.

Definition

Prefabricated Construction: Prefabricated construction is a method in which individual building components such as walls, beams, columns, slabs, staircases, and panels are cast or fabricated off-site and then assembled at the site.

Modular Construction: Modular construction is an advanced form of prefabrication where entire building modules or units (rooms or sections) are manufactured off-site and installed on a prepared foundation at the site.

Principle of Prefabricated and Modular Construction

The basic principle is:

- Manufacture off-site
- Transport safely
- Assemble on-site

This method relies on:

- Standardization of design
- Mass production
- Accurate planning and coordination
- Mechanized construction

Types of Prefabricated Construction

Based on Structural System

(a) Panel System

- Wall panels, floor panels, and roof panels are prefabricated.

- Panels are assembled to form the building.
- Commonly used in housing projects.

(b) Frame System

- Prefabricated beams and columns form a structural frame.
- Panels are used as infill walls.
- Suitable for multi-storey buildings.

(c) Slab and Beam System

- Precast slabs and beams are produced off-site.
- Used in bridges, industrial buildings, and warehouses.

Based on Material Used

- Precast concrete
- Steel structures
- Timber prefabrication
- Light gauge steel framing (LGSF)

Modular Construction Technique

Description

In modular construction, complete modules such as bedrooms, toilets, kitchens, or office units are built in factories with:

- Structural framework
- Electrical wiring
- Plumbing
- Finishes

These modules are then transported and stacked or connected on-site.

Types of Modular Construction

(a) Permanent Modular Construction (PMC)

- Used for permanent buildings
- Modules are integrated into the main structure

(b) Relocatable Modular Construction

- Modules can be dismantled and reused
- Used for site offices, classrooms, and temporary housing

Construction Process

Prefabricated Construction Process

1. Design and standardization
2. Casting or fabrication of components in factory
3. Curing and quality control
4. Transportation to site
5. Erection and assembly using cranes
6. Jointing, grouting, and finishing

Modular Construction Process

1. Site preparation and foundation work
2. Simultaneous module fabrication in factory

3. Transportation of modules
4. Placement using cranes
5. Connection of modules
6. Final finishing and services integration

Advantages of Prefabricated and Modular Construction

1. Faster construction time due to parallel site and factory work
2. Better quality control under factory conditions
3. Reduced construction waste
4. Less dependence on skilled on-site labor
5. Improved safety at site
6. Environmentally sustainable construction
7. Cost-effective for large-scale projects

Limitations of Prefabricated and Modular Construction

1. High initial investment for factories and equipment
2. Transportation difficulties for large components
3. Limited flexibility in design changes
4. Requires precise planning and coordination
5. Joint leakage issues if not properly designed

Applications of Prefabricated and Modular Construction

1. Mass housing projects
2. High-rise residential buildings
3. Hospitals and schools
4. Industrial buildings
5. Bridges and flyovers
6. Site offices and portable structures

1. Mass Housing Projects

Prefabricated and modular construction techniques are widely used in mass housing schemes due to their ability to deliver large numbers of dwelling units in a short time. Standardized wall panels, slabs, staircases, and complete room modules are manufactured in factories and assembled on-site. This method ensures uniform quality, reduced construction time, and cost efficiency, making it ideal for affordable housing, government housing projects, and rehabilitation schemes.

2. High-Rise Residential Buildings

In high-rise buildings, prefabrication helps in speedy construction and better structural accuracy. Precast columns, beams, slabs, and façade panels are used to reduce on-site work. Modular bathroom and kitchen units are often employed to improve quality and reduce errors. This technique minimizes formwork, curing time, and labor dependency, making it suitable for tall residential structures in urban areas.

3. Hospitals and Schools

Hospitals and educational buildings require fast construction with high quality and strict safety standards. Prefabricated and modular systems allow parallel construction of modules and site preparation, significantly reducing project duration. Modular construction is especially useful for operation theatres, classrooms, wards, and laboratories, as services like electrical, plumbing, and HVAC can be pre-installed under controlled conditions, ensuring hygiene, accuracy, and safety.

4. Industrial Buildings
Industrial structures such as factories, warehouses, power plants, and process buildings commonly use prefabricated components like steel frames, precast columns, beams, roof trusses, and wall panels. These systems provide large column-free spaces, high load-bearing capacity, and rapid erection. Prefabrication ensures durability and precision, which are critical in industrial environments.

5. Bridges and Flyovers
Prefabricated construction is extensively used in bridges and flyovers to minimize traffic disruption and speed up infrastructure development. Components such as precast girders, deck slabs, piers, and parapets are manufactured off-site and assembled using cranes. This technique improves construction quality, reduces on-site casting time, and enhances safety during execution.

6. Site Offices and Portable Structures
Modular construction is highly suitable for temporary and semi-permanent structures like site offices, labor camps, security cabins, and portable classrooms. These modules are easy to transport, quick to install, and reusable. They can be dismantled and relocated as per project requirements, making them economical and flexible for short-term use.

Advanced Scaffolding Systems and Safety Measures

Scaffolding is a temporary structure used in construction to provide safe access and support for workers and materials at various heights.

Introduction
In the normal activities of the building construction, it becomes necessary to have some type of temporary structure or support so as to proceed with the work. These temporary arrangements take up the form of scaffolding, shoring and underpinning.

When the height above floor level exceeds about 1.50 m a temporary structure, usually of timber, is erected close to the work to provide a safe working platform for the workers and to provide a limited space for the storage of plant and building materials. The temporary framework is known as a scaffolding or simply a scaffold and it is useful in construction, demolition, maintenance or repair works.

Need for Advanced Scaffolding Systems

- Increase in high-rise and complex structures
- Requirement of faster construction schedules
- Improved worker safety regulations
- Need for higher load-bearing capacity
- Reduction in erection and dismantling time

Component parts of a scaffolding

An ordinary scaffolding consists of the following parts:
(1) Standards: These are the vertical members of the framework and they are supported on the ground or drums or embedded into the ground.
(2) Ledgers: These are the horizontal members parallel to the wall.

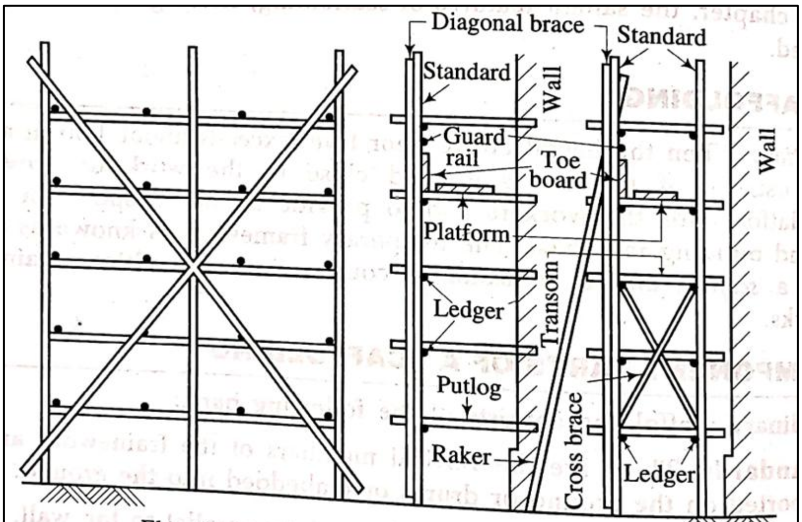
(3) Putlogs: These are the transverse pieces which are placed on the ledgers and which are supported on the wall at one end. They are at right angles to the wall.
(4) Transoms: These are putlogs, but their both ends are supported on the ledgers.
(5) Braces: These are the diagonal or cross pieces fixed on the standards.
(6) Bridle: This is a piece which is used to bridge an opening in a wall and it supports one end of the putlog at the opening.
(7) Guard rail: This is a rail provided like a ledger at the working level.
(8) Toe board: This is a board placed parallel to the ledgers and supported between putlogs. It is provided to work as a protective measure on the working platform.
(9) Raker: This is an inclined support.
The various members of a scaffold are secured by means of devices such as nails, bolts, rope, etc.

Types of Scaffolding

1. Single Scaffolding / Bricklayers Scaffolding
2. Double or Masonry Scaffolding
3. Cantilever or Needle Scaffolding
4. Suspended Scaffolding
5. Trestle Scaffolding
6. Steel Scaffolding
7. Patented Scaffolding

1. Single Scaffolding / Bricklayers Scaffolding

This is the most common type of scaffolding and is widely used in the construction of brickwork. It consists of a single row of standards placed at a distance of about 1.20 m from the wall. The distance between the successive standards is about 2 to 2.50 m. The ledgers are then fixed to the standards at a vertical distance of about 1.20 m to 1.80 m.
The putlogs, with one end on the ledger and the other end on the wall, are then placed at a horizontal distance of about 1.20 m to 1.80 m. The braces, guard rail and toe board are fixed as shown in fig. 14-1 and fig. 14-2. This type is also sometimes known as the putlog scaffolding.



Elevation
Scaffolding
FIG. 14-1

Section
Single scaffolding
FIG. 14-2

Section
Double scaffolding
FIG. 14-3

2. Double or Masonry Scaffolding

This scaffolding is stronger than the single scaffolding and it is used in the construction of stonework. The framework is similar to the single scaffolding except that two rows of standards are provided. The distance between the face of the wall and the first row of standards is about 200 mm to 300 mm and the distance between the two rows is about one meter. The rakers and cross braces may be provided to make the scaffolding more strong as shown in fig. This type is also sometimes known as an independent scaffolding. As shown in fig 14-3.

3. Cantilever or Needle Scaffolding

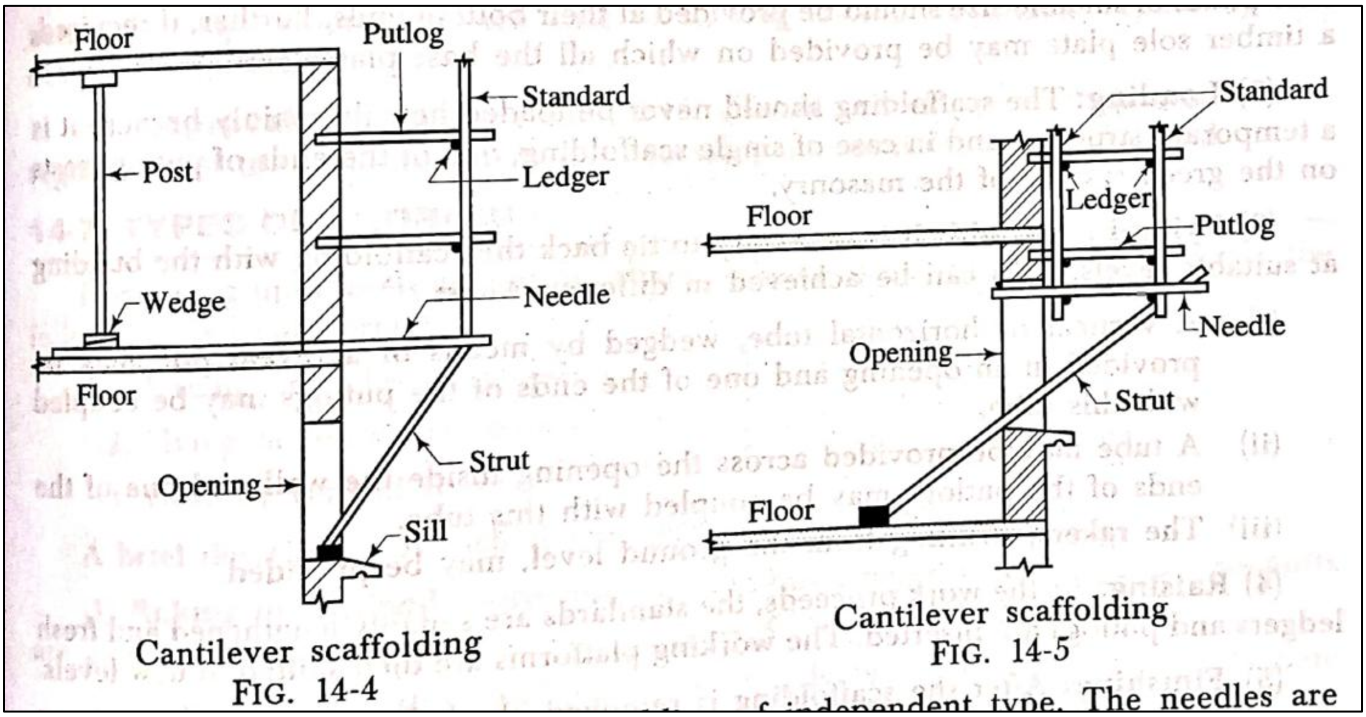
This type of scaffolding is useful under the following circumstances:

(i) The proper hard ground is not available for the standards to rest.

(ii) It is desired to keep the road or pavement near the face of wall, clear of obstruction caused by the scaffolding.

(iii) The construction work is to be carried out for upper parts of a multi-storeyed building.

In this type of scaffolding, the general framework may be of single scaffolding type or of double scaffolding type. But the standards are supported by a series of needles or ties which are taken out at floor levels or through openings or through holes kept in the masonry.



Cantilever scaffolding
FIG. 14-4

Cantilever scaffolding
FIG. 14-5

Fig. 14-4 shows a cantilever scaffolding of putlog type. The needles are supported at the floor levels and strutted through projections such as sills, cornices, string courses, etc. The inner end of the needle projects sufficiently inside and is well strutted between the floors as shown.

Fig. 14-5 shows a cantilever scaffolding of independent type. The needles are passing through the openings and are strutted on the floors through the openings as shown. The suitable timber blocks should be interposed at the ends of struts on the floor levels.

4. Suspended Scaffolding

This is a very light type of scaffolding and can be used only for the maintenance works such as painting, pointing, whitewashing, distempering, etc. The working platform is suspended from the roofs by means of ropes, wires or chains and arrangements are made such that the platform can be raised or lowered. This type of scaffolding does not create any obstruction on the ground and it is the most effective as it always provides the optimum level for working.

5. Trestle Scaffolding

In this type scaffolding, the working platform is supported on movable contrivances such as ladders, tripods, etc., mounted on wheels. This type of scaffolding is useful for minor repairs or painting work inside the rooms and the maximum height upto which this type of scaffolding can be adopted is about 5 m from the supporting surface.

6. Steel Scaffolding

In place of timber, the steel tubes can be effectively used for the scaffolding work. The diameter of the tubes is about 40 mm to 50 mm and the thickness is about 5 mm. The tubes are available in standard lengths with special couplings and set-screws. The advantages of steel scaffolding are manifold. The scaffolding can be used upto any height; it is strong and more durable; it can be easily erected and dismantled; it possesses high scrap value and it is resistant to fire. However the disadvantages are that the initial cost is high, it requires skilled labour and it also requires periodical painting.

7. Patented scaffolding:

Now-a-days, the various patented scaffoldings made of steel, with special types of couplings and frames, are available. Usually the working platform is supported on a bracket which can be adjusted to any suitable height.

Points to be attended to in scaffolding

Following important points should be carefully attended to in the scaffolding work:

(1) Bedding of standards: If standards are not resting on the firm ground, the base-plates of suitable size should be provided at their bottom ends. Further, if required, a timber sole plate may be provided on which all the base-plates rest.

(2) Loading: The scaffolding should never be loaded heavily mainly because it is a temporary structure and in case of single scaffolding, one of the ends of putlogs rests on the green surface of the masonry.

(3) Tying-in scaffold: It is necessary to tie back the scaffolding with the building at suitable levels. This can be achieved in different ways:

(i) A vertical or horizontal tube, wedged by means of a reveal pin, may be provided in an opening and one of the ends of the putlogs may be coupled with this tube.

(ii) A tube may be provided across the opening inside the wall and one of the ends of the putlogs may be coupled with this tube.

(iii) The rakers, strutting from the ground level, may be provided.

(4) Raising: As the work proceeds, the standards are suitably lengthened and fresh ledgers and putlogs are inserted. The working platforms are then shifted to new levels.

(5) Finishing: After the scaffolding is removed, the holes of putlogs in the wall should be immediately filled up.

Safety Measures in Advanced Scaffolding

Design and Planning Safety

- Scaffolding must be **designed by a competent engineer**
- Load calculations should include:
  - Dead load
  - Live load
  - Wind load
- Scaffolding should comply with IS 3696, OSHA, and NBC guidelines

Erection and Dismantling Safety

- Only **trained and certified workers** should erect scaffolding
- Proper sequence must be followed
- Use of **personal protective equipment (PPE)** is mandatory
- Area below should be barricaded during erectio

Structural Stability Safety

- Use of base plates and sole plates on firm ground
- Proper bracing and tying to structure at required intervals
- No overloading of platforms
- Proper anchorage and support

Platform and Fall Protection Safety

- Platforms should be fully decked
- **Guard rails, mid-rails, and toe boards** must be provided
- Use of safety harnesses for work at height
- Non-slip platform surfaces

Inspection and Maintenance Safety

- Daily visual inspection before use
- Periodic detailed inspection by competent person
- Immediate repair or replacement of damaged components
- Removal of loose materials from platforms

Advantages of Advanced Scaffolding Systems

- High safety standards
- Faster construction
- Reusable and durable components
- High load-bearing capacity
- Suitable for complex and high-rise structures

Limitations

- Higher initial cost
- Requires skilled labor
- Transportation and storage issues
- Improper use can still cause accidents

Applications

- High-rise building construction
- Bridge and flyover construction
- Industrial plants and refineries
- Maintenance and repair works
- Shipbuilding and power plants

Form Work – Introduction to formwork

When concrete is placed, it is in a plastic state. It requires to be supported by temporary supports and casings of the desired shape till it becomes sufficiently strong to support its own weight. This temporary casing is known as the formwork or forms or shuttering. The term moulds is sometimes used to indicate formwork of relatively small units such as lintels, cornices, etc. For circular work such as arch, dome, etc., the term centering is generally used.

In the early days, the job of formwork was carried out by the carpenter with available timber and nails as best as possible with the approach of rule of thumb. The formwork techniques have also developed side by side along with the growth in the development of concrete construction. With the technological advancement and introduction of new materials of formwork, more rational approach is being made in the design of formwork.

Requirements of formwork

Following are the requirements of a good formwork:

(1) Easy removal
(2) Economy
(3) Less leakage
(4) Quality
(5) Rigidity
(6) Smooth surface
(7) Strength
(8) Supports.

(1) Easy removal: The design of formwork should be such that it can be removed easily with least amount of hammering. This will also prevent the possible injury to the concrete which has not become sufficiently hard. Further, if the removal of formwork is easy, it can be made fit for re-use with little expenditure.
The operation of removing the formwork is commonly known as the stripping and when the stripping takes place, the components of the formwork are removed and then re-used for another part of the structure. Such forms whose components can be re-used several times are known as the panel forms.
Sometimes the forms are prepared for individual non-standard members and structures. Such forms do not have repeatable elements.
In some cases, the formwork cannot be stripped from the structure and it forms part of the structure itself. All such forms are known as the stationary forms.

(2) Economy: It is to be noted that the formwork does not contribute to the stability of the finished structure and hence, it will be desirable to bring its cost to a minimum consistent with safety. The various steps such as reducing number of irregular shapes of forms, standardising the room dimensions, use of commercial parts of commercial sizes, putting the formwork in use again as early as possible, may be taken to effect economy in the formwork. The formwork should be constructed of that material which is easily available at low cost and which can safely be reused for several times.

(3) Less leakage: The formwork should be so arranged that there is minimum leakage through the joints. This is achieved by providing tight joints between adjacent sections of the formwork.

(4) Quality: The forms should be designed and built accurately so that the desired size, shape and finish of the concrete is attained.

(5) Rigidity: The formwork should be rigid enough so as to retain the shape without any appreciable deformation. For visible surface in the completed work, the deflection is limited to 1/300 of span and that for hidden surface, it is limited to 1/150 of span. It should be noted that a rigid formwork will be robust and stiff enough to allow repeated use.

(6) Smooth surface: The inside surface of formwork should be smooth so as to turn out a good concrete surface. This is achieved by applying crude oil or soft soap solution to the inside surface of formwork. This also makes the removal of formwork easy.

(7) Strength: The formwork should be sufficiently strong enough to bear the dead load of wet concrete as well as the weights of equipments, labour, etc. required for placing and compacting the concrete. This requires careful design of the formwork. The over-estimation of loads results in expensive formwork and the under-estimation of loads results in the failure of formwork. The loads on vertical forms are to be assessed from various considerations such as density of concrete, dimensions of section, concrete temperature, slump of concrete, reinforcement details, stiffness of forms, rate of pouring of concrete, etc.

(8) Supports: The formwork should rest on sound, hard and non-yielding supports.

Cost of formwork

The cost of formwork plays a significant role in the cost of concrete. It varies from 30% to 40% of the cost of concrete for ordinary structures and may go as high as 50% to 60% for special structures such as dams, bridges, etc.

The four components contributing to the total cost of formwork are as follows:
(i) cost of formwork material;
(ii) cost of erecting, placing and removal of formwork;
(iii) cost of joining material such as nails, wires, etc.; and
(iv) cost of labour for fabrication of formwork.
In general, it can be stated that careful watch should be kept on the cost of formwork and all attempts should be made to bring down the cost of formwork to a minimum so as to achieve overall economy in the concrete work.

Materials used for preparing formwork

The usual materials which are employed in the preparation of formwork are steel and timber. The formwork is also sometimes prepared from aluminium, pre-cast concrete or fibre glass for cast-in-situ members involving curved surfaces.

(1) Steel formwork: The steel is used for formwork when it is desired to re-use the formwork several times. The initial cost of steel formwork is very high. But it proves to be economical for large works requiring many repetitions of the formwork. The erection and removal of steel formwork are simple and it presents a smooth surface on removal.

Following are the advantages of steel formwork over timber formwork:
(i) It can be re-used several times, nearly ten times more than timber formwork.
(ii) It does not absorb water from the concrete and hence, the chances of the formation of honey-combed surface are brought down to the minimum level.
(iii) It does not shrink or distort and hence, it is possible to achieve higher degree of accuracy and workmanship by its use as compared to the timber formwork.
(iv) It is easy to install and to dismantle and hence, there is saving in the labour cost.
(v) It gives excellent exposed concrete surfaces requiring no further finishing treatment. The surface obtained by the use of timber formwork invariably requires plastering for getting the desired finish of the concrete surface.
(vi) It possesses more strength and is more durable than the timber formwork.
(vii) The design calculations for the steel formwork system can be made precisely because of the known characteristics of steel.

(2) Timber formwork: When formwork is required for small works requiring less repetitions, the timber is preferred to steel. The timber formwork is cheap in initial cost and it can be easily adopted or altered for a new use. The timber to be used as formwork should be well-seasoned, free from loose knots, light in weight and easily workable with nails without splitting.

Following facts in connection with the timber formwork should be remembered:
(i) The timber is to receive wet concrete. Hence, the timber formwork should be neither too dry nor too wet. If it is too dry, the timber will swell and get distorted when wet concrete is placed on it. This will affect the workability of concrete and honeycomb surface will appear on removal of the formwork. On the other hand,

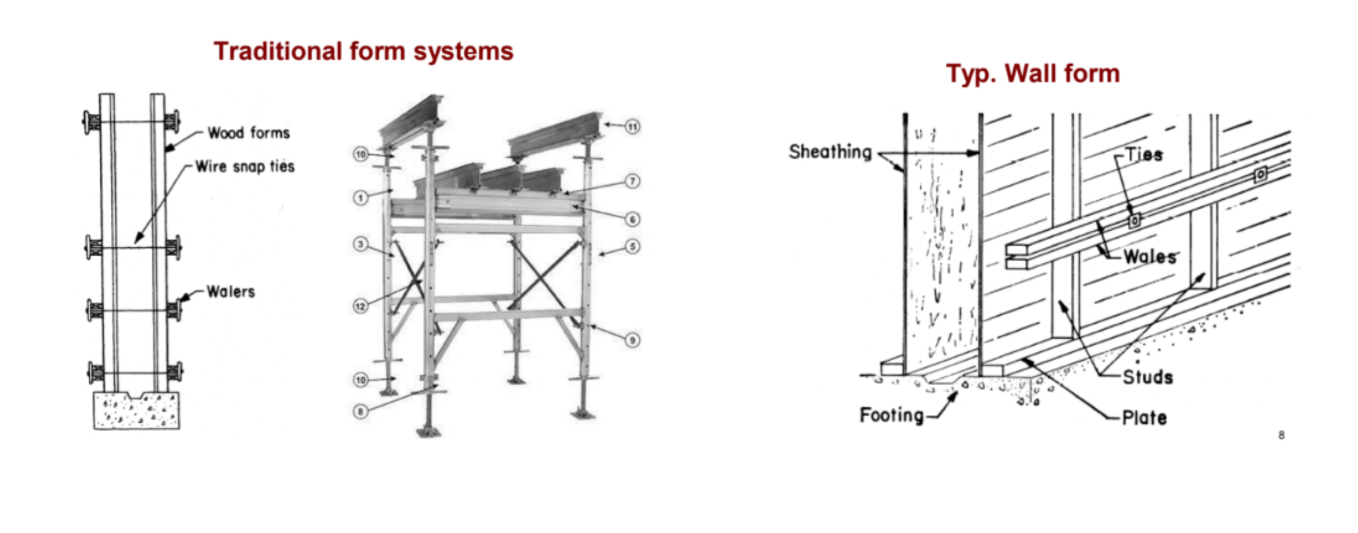
if it is too wet, the timber will shrink in hot weather resulting in gaps in the formwork through which concrete will flow out. Hence, the ridges will be formed on the concrete surface. It is found that a moisture content of about 20% is appropriate for the timber formwork.
(ii) The dimensions of components of the timber formwork will depend upon the loads to be carried and the availability of timber sections. But generally, the latter is the governing factor as the former can be adjusted by suitable spacing of the supports.
(iii) The minimum nails should be used in timber formwork and the nail heads should be kept projecting so as to facilitate easy removal.
(iv) The timber formwork proves to be economical for buildings with minimum number of variations in the dimensions of the rooms. Thus, the cutting of timber pieces is brought down to the minimum.
(v) It is the common practice to support formwork for slab in buildings with timber ballies which are cut to approximate sizes with wedges below them for final adjustments. It leads to the formation of weak points which are seldom prevented from displacement. The timber ballies are generally not straight and they do not transmit the load axially.

Failure of formwork

Following are the general rules to avoid the failure of formwork for concrete structures:
(i) Adequate reshores must be provided immediately and concurrently with stripping operations.
(ii) If high shoring is not suitably strengthened by diagonal braces, there are chances for formwork failure to occur.
(iii) Forms are continuously supported structures and must be provided with uniform bearing at each support.
(iv) Work should be carried out under the strict and direct supervision of skilled persons or engineers only.
(v) Design should provide for possible shocks and vibrations.
(vi) Difficult-to-perform details should be avoided as they may become a starting point for failure.
(vii) Stripping and reshoring should not be carried out in an unbalanced way to avoid unnecessary stresses in freshly laid concrete.
(viii) Posts used to counter-balance load compression must be wedged with extreme care to ensure form support remains undisturbed.

Maintenance of formwork

The formwork, once removed, should be carefully cleaned and stored. The maintenance of formwork is essential for its re-use and overall economy. The damaged components should be repaired and the formwork should be stored in a location which is not exposed to wind, rain, moisture, etc. so as to avoid adverse effects.



Types of formwork

1. Timber Formwork
2. Plywood Formwork
2. Steel Formwork
3. Aluminium Formwork

1. Timber Formwork: Timber formwork is the traditional and most commonly used type of formwork. It is made from wooden planks, battens, and plywood sheets.

- Easy to fabricate and dismantle
- Can be made into any shape
- Suitable for small projects

Advantages

- Low initial cost
- Easily available
- Flexible for irregular shapes

Limitations

- Short life span
- Poor surface finish compared to steel/aluminium
- Not economical for repeated use

Applications

Small buildings, repair works, irregular concrete shapes.

2. Plywood Formwork: Plywood formwork uses waterproof plywood sheets fixed on timber or steel frames. It improves the surface finish compared to timber formwork.

- Smooth surface finish
- Lightweight
- Reusable (20–30 times)

Advantages

- Reduces concrete leakage
- Less labor required
- Better durability than timber

Limitations
- Costlier than timber
- Edges require protection from moisture

Applications
Slabs, beams, columns, and walls.

3. Steel Formwork: Steel formwork consists of steel plates supported by angles and channels. It is strong, durable, and suitable for mass construction.
- High strength and rigidity
- Excellent surface finish
- Long service life

Advantages
- Highly reusable (100+ times)
- Accurate dimensions
- Fire-resistant

Limitations
- High initial cost
- Heavy and requires cranes

Applications
Bridges, flyovers, large housing projects.

4. Aluminium Formwork: Aluminium formwork is a lightweight modular system used for fast construction of buildings. It is widely used in mass housing projects.
- Light in weight
- Modular and repetitive system
- Quick assembly and stripping

Advantages
- High speed of construction
- Smooth finish (plaster often not required)
- Reusable (200+ times)

Limitations
- Very high initial cost
- Not suitable for design changes

Applications
High-rise residential and mass housing projects.

Advantages and Limitations of Formwork

Advantages of Formwork

1. Provides Desired Shape and Size: Formwork gives accurate shape, size, and alignment to concrete members such as beams, slabs, columns, and walls. Proper formwork ensures dimensional accuracy of the structure.

2. Supports Fresh Concrete: Formwork safely supports wet concrete and construction loads until the concrete gains sufficient strength. This prevents deformation, collapse, or cracking of concrete elements.

3. Improves Surface Finish: Good quality formwork produces a smooth and uniform concrete surface, reducing the need for plastering and finishing work, thereby saving time and cost.

4. Speeds Up Construction: Modern formwork systems such as steel, aluminium, and modular formwork allow faster erection, stripping, and reuse, which significantly increases construction speed.

5. Ensures Safety at Site: Formwork also acts as a working platform for laborers. Properly designed formwork reduces the risk of accidents during concreting operations.

6. Reusability and Economy: Steel and aluminium formwork can be reused many times, making them economical for large and repetitive projects such as mass housing and high-rise buildings.

Limitations of Formwork

1. High Initial Cost: Modern formwork systems like steel, aluminium, and modular formwork require high initial investment. This may not be economical for small or one-time projects.

2. Requires Skilled Labour: Proper erection, alignment, and stripping of formwork require trained and experienced workers. Poor workmanship can lead to defects in concrete and safety hazards.

3. Time-Consuming for Small Works: For small-scale construction, formwork erection and dismantling may be time-consuming and uneconomical compared to traditional methods.

4. Risk of Failure if Improperly Designed: If formwork is not designed to carry expected loads, it may fail during concreting, causing accidents, structural defects, and material loss.

5. Storage and Maintenance Issues: Reusable formwork requires proper storage, cleaning, and maintenance. Poor maintenance reduces its life and surface quality.