Chapter 6

Wall

A wall may be defined as a vertical member, the width (i.e length) of which exceeds four times the thickness. In contrast to this a column is an isolated load-bearing member, the width of which does not exceed four times the thickness.

Wall is one of the most essential components of a building. The primary function of a wall is to enclose or divide space of the building to make it more functional and useful. Walls provide privacy, afford security and give protection against heat, cold, sun and rain. Walls can provide support to floors and roofs. Therefore, walls should be so designed as to have provision of adequate strength and stability; weather resistance; durability; fire resistance; thermal insulation and sound insulation.

A distinction between various types of wall can be made in two different ways.

As to their position in the building: i.e walls in substructures, which include foundation walls and basement walls, and walls in superstructures, which include external walls and internal walls.

As to their function: i.e whether they are load bearing walls or partition walls. Load bearing walls (structural) are those carrying loads from beams and or from walls above. They must therefore posses' sufficient strength and stability. Partition walls on the other hand, do not have load-carrying function. They may be erected or removed without any effect on the structural parts of a building.

The function of the foundation wall is to transmit the load coming from the superstructure. In selecting the type of material for the making of foundation wall; two factors should be taken in to consideration: load bearing capacity, and resistance against effect of the under ground, such as swelling pressure, uplift pressure, chemical attack, etc.

The function of basement wall is o support vertical load (if load bearing); to resist lateral load and to protect the building from dampness. Whether a wall is load- bearing or not, it must satisfy certain requirements in different respect. In this regard, external wall must provide protection against wind and rain, should insulate heat, and be water repellent, fire resisting and capable of sound insulation.

External walls have generally to fulfill several purposes: for instance, the wall of an ordinary house usually has to support the first floor and the roof; keep the interior warm and dry and give protection from street noise and from fire. Some times the task of the wall may be simpler; for example, in a framed structure the wall will not have to support anything. Again, in some buildings such as warehouses, the wall may not have to provide thermal or sound insulation. In the majority of cases, however, it remains true that the wall has to satisfy simultaneously a number of different requirements.

When the wall is load bearing, its strength must be sufficient to carry the loads placed on it. These loads are calculated from the live and dead loads on the structure supported by the wall. Wind pressure must also be taken into account in the design of external walls, and indeed for panel walls in a framed structure, the principal strength requirement is the power to withstand wind load. Internal walls are basically required to separate rooms and therefore not all requirements discussed in the external walls are all required. However, they should have sufficient sound, heat insulating capacity and should be water repellent.

Materials for external walls

The materials employed depend on several factors, among which the following are more important: the material locally available; the standard of the house planned; the climatic conditions; the cost and aesthetic requirements; the laborers available and function of the wall to be constructed (load bearing or non-load bearing).

Fire resistance is normally required in an external wall, in order to reduce/prevent the spread of fires from one building to another, and their requirement has a bearing on the number and of windows, as well as on the materials used in the wall.

Types of external walls

In addition to the traditional materials such as wood and chika, brickwork, masonry walls, reinforced concrete, glass, metals and plastics are now being employed in the construction of external walls. External walls can be classified in different groups according to their structural functions and physical nature. The classification based on structural function is based on whether the wall is load bearing or non-load bearing. On the other hand, the many and various types of external walls can be usefully thought of as the following three groups, depending on their physical nature:*block construction; monolithic construction and composite construction.*

Walls composed of stones or bricks are of block construction. They are formed of fairly small units set in a matrix of cement mortar. The properties of such a wall depend on the material of which the block is composed and on the mortar. Walls made up of stone, brick, hollow concrete blocks, solid concreter blocks, etc. are included in this category.

5.4.1 Brick Masonry and Brick walls

The systematic arrangement of laying bricks and bonding together with mortar to form a unified mass which can transmit the superimposed load without failure is termed as brick masonry. Since bricks are light in weight, uniform in size and easier in handling; they are very convenient construction material for most of the structures, e.g. foundations, walls, retaining walls, columns, culvert, floors, etc. The strength of brick-work depends upon the quality of bricks and type of mortar used. Figure 4.1 shows the various parts of a typical brick.

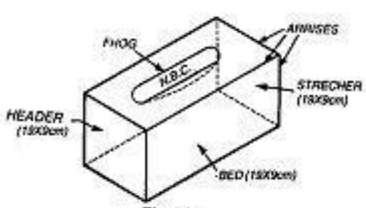
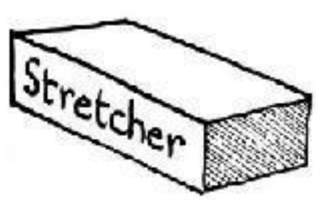
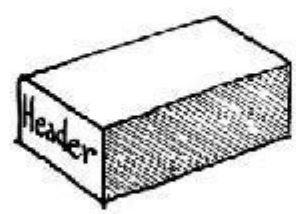


Fig. 4.1.





Brick walls are in widespread use, both as load-bearing walls and as non-load bearing walls in framed structures. Materials used in brick masonry construction are bricks and mortar.

To join the individual bricks together to produce a compact mass, a binding material is required. Mortars are used as binding materials in brick-works. Following are the commonly used mortars:
(1) Mud Mortar, (2) Lime Mortar, (3) Cement Mortar, (4) Lime-Cement Mortar, (5) Cement-Lime Mortar
The selection of mortar depends upon the type of finish desired, the superimposed load, the weathering agencies and the importance of the structure. For the construction of temporary buildings or structures, mud mortar is used and for important structures of permanent nature, the cement mortar is preferred.

Types of Bricks

The various kinds of bricks are:

Common brick: bricks, which are made of clay and burnt in the usual manner in kilns.

Facing brick: are generally selected first class bricks, which are used, for face work and it is essential to have uniform color, texture, size, etc.

Fire bricks: are made of special fire clays. They are used for lining in fireplaces, furnaces, etc. where high temperatures are prevalent and ordinary bricks get decomposed.

Glazed and colored bricks: colored bricks are used where special color treatment is needed or where ordinary bricks of uniform color are not available. Glazed bricks have one surface in white or any other color. These are used for exterior surfaces of walls or partitions, in dairies, hospitals, etc., where cleanliness is important.

The essential quality of brickwork is that it attains in one material reasonably good performance under loading. A brick wall is strong enough to carry fair loads and provides moderate thermal insulation. The clay brick is the most widely used walling material in Ethiopia. For ordinary building work, brick is undoubtedly one of the oldest forms of construction known for walls on account of the size in which it is made. It always ensures easy erection. One of the reasons for the continued widespread use of brick as an external walling material is the extent to which it retains its good appearance over a long period with a minimum of upkeep. Bricks can be produced in different sizes and shapes. The standard size of bricks produced in Addis Brick factory and Burayu Brick factory in Addis Ababa is 6 x 12x25cm (HXWXL). Typical forms of brick portion are shown in Fig. 6.1

Definitions

This important to be familiar with the following terminologies as regards to brick works.

(1) Course. A complete layer of bricks laid on the same bed is known as course and its thickness is equal to the thickness 'Of a brick plus the thickness of one mortar joint.

(2) Frogs. These are depressions provided in the face of the bricks.

There are two reasons for the provision of frogs :

(a) To form a key with mortar to prevent sliding of bricks on their beds.

(b) To reduce the weight of the brick and hence economy in the cost of transport.

(3) Bed. The bottom surface of the brick when it is laid flat is known as bed (190 x 90 mm.). It is the lower surface of the brick when laid flat.

(4) Stretcher. The side surface of a brick visible in elevation when the brick is laid flat is known as stretcher (190 x 90 mm). It is the longer face of the brick as seen in the elevation of the wall.

(5) Header. The end surface of the brick when it is laid flat (Fig. 4.1) is known as header (90 x 90 mm). It is the shorter faces of the brick as seen in the elevation of the wall.

(6) Arrises. The edges formed by the intersection of plane surfaces of a brick are known as arrises and in good quality bricks they are straight and sharp.

(7) Perpends. These are vertical joints between bricks either in longitudinal or cross directions (Fig. 4.2). They are also known as cross joints.

(8) Bed joints. The horizontal mortar joints between two successive courses are known as bed joints.

(9) Bat and closers. Standard bricks may be arranged in various ways to form walls, but in certain cases these bricks require to be reduced in size and altered in shape; this is achieved with the use of cutting tools. When a brick is cut to a reduced size it is known either as a "bat" or a "closer" according to its shape (Figs. 1.3 to 1.6) show the various "bats" and "closers". It may be observed that in the case of a bat the cut extends across the width of the standard brick while a closer generally has the cut extending from one header face to the other, except in the "King closer" when it runs from a header face to a stretcher face. The cut surfaces of bats and closers are usually concealed when properly arranged in a wall.

(10) Quoin. The external comer or angle or a wall surface is known as quoin.

(11) Facing, Backing and Hearting.

The exposed surface of a wall or structure is known as facing; the internal surface of the wall or structure is known as backing ; and the portion in between the backing and facing is called as hearting or filling.

(12) Lap. The horizontal distance between two perpends in two successive course is known as lap. It is the horizontal distance between the vertical joints of successive brick courses.

(13) Bullnose. The bricks with one edge rounded is known as single bullnose (Fig. 4.7) and the bricks with two edges rounded is known as double bullnose (Fig. 4.8) or cownose. Generally, it is for a

(14)Closer: It is a portion of a brick with the cut made longitudinally and is used to close up bond at the end of the course. A closer helps in preventing the joints of successive courses to come in a vertical line.

(15) King closer: It is portion of a brick, which is so cut that the width of one of its end is half that of a full brick, while the width at the other end is equal to the full width.

(16 Queen closer: It is a portion of a brick obtained by cutting a brick lengthwise with two positions.

Tools Used in Brick Masonry

The following are the commonly employed tools in brick masonry :

(1) Trowel. It is available in various sizes ranging from 5 to 30 cm. in length. Trowels are used for lifting and spreading mortar, for cutting of bricks and construction of joints. This is the most important tool in the construction of brick masonry (Fig. 4.9).

(2) Plumb Rule. It is a smooth wooden piece of2 m length, 10 cm. width and 1 cm. thickness. The longer edges are parallel. A plumb bob hangs from the top of the wooden piece. This is employed to check ,the vertical face of the wall erected (Fig. 4.10). '

(3) Bubble Tube. This helps in checking the horizontality of the floors, roofs, etc. (Fig. 4.11).

(4) Lines and Pins. A 10 m. (or more) long cord connects two metallic pins. This is stretched between two quoins of the wall to maintain the correct alignment of the corners (Fig. 4.12).

(5) Square. This is an adjectly right angle piece made of steel or wooden section. This is employed for checking perpendicularity during construction (Fig. 4.13).

(6) Brick Hammer. One end of the hammer is square and the other end is sharp edged. It is employed for cutting bricks to different shapes and sizes (Fig. 4.14).

(7) Four Fold Rule. This is a measuring scale which can be folded four times when not in use.

Some other tools such as bolster, gauge rod, straight edge, club hammer, jointer, etc. are also used in brick masonry.

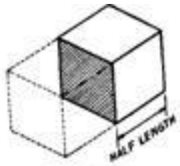


Fig. 4.3. Half bat.

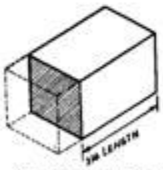


Fig. 4.4. Three quarter bat.

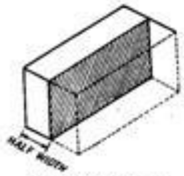


Fig. 4.5. Queen closer.

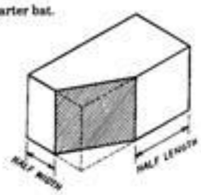


Fig. 4.6. King closer.

Fig. 4.7. Single Bullnose.

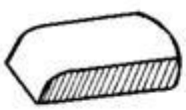


Fig. 4.8. Double Bullnose.

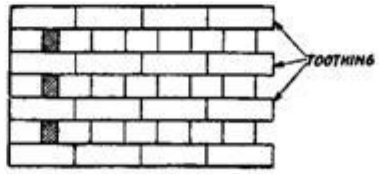


Fig. 4.16

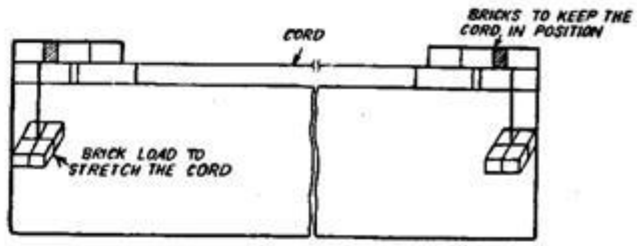
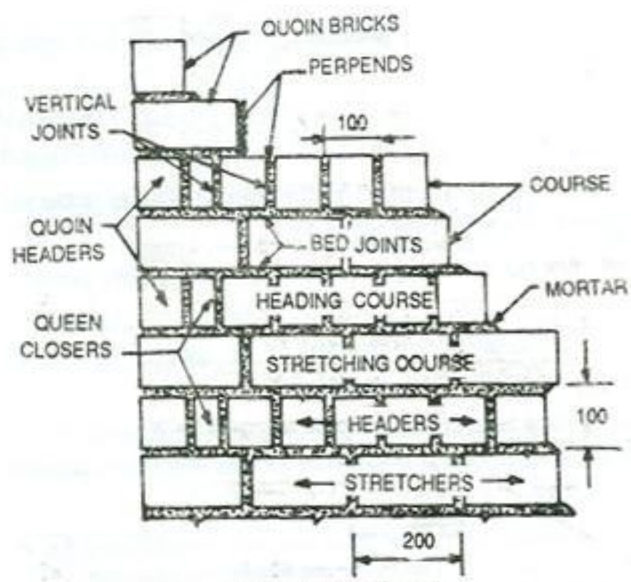
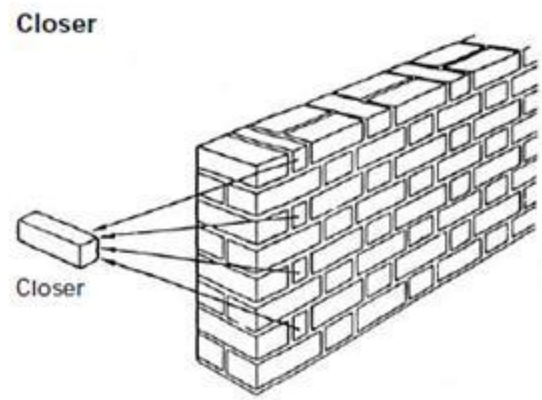


Fig. 4.17



(All Dimensions in mm)



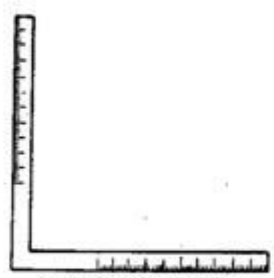


Fig. 4.13. Mason's square.

Fig. 4.11. Bubble Tube.

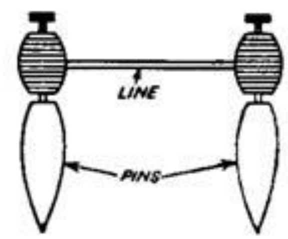


Fig. 4.12. Line and Pins.

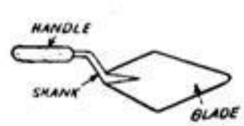


Fig. 4.9. Trowel.

Fig. 4.10. Plumb rule.

Fig. 4.14. Brick Hammer.

General Principles of Brick Masonry Construction

Besides the quality of the materials used, the workmanship and proper supervision also play an important role. The strength of the work depends upon all the three factors mentioned above. The following are the general principles which should be adhered to, for good brick masonry.

(1) The bricks used should be sound, hard and well-burnt with uniform color, shape and size. They should be free from cracks, flaws, holes, grits or lumps of lime. Clear metallic ringing sound should be produced when two bricks are struck against each other and they should not break when dropped from a height of 1 meter on the ground. The brick should not absorb water more than $1/6^{th}$ of their own weight when immersed in water for twenty-four hours.

(2) The bricks should be properly soaked in water for at least 8 hours, before they are used in the construction work. The following are the reasons for wetting bricks:
(a) Kiln dust is washed and bricks become clean. Clean bricks produce better joint and bond with mortar.
(b) Dry bricks quickly absorb water from the mortar. Sufficient water is required to complete the chemical reactions for setting cement mortar. Hence the absorption of water for cement mortar by dry bricks will render the brick masonry weaker.
(c) Wet bricks tend to spread the mortar under them more uniformly.
(3) All the bricks are laid on their beds with the frogs pointing upwards, unless stated otherwise.
(4) The use of brick-bats should be avoided unless it is essential for obtaining the specified bond.
(5) All the courses should be laid truly horizontal and all vertical joints should be truly vertical.
(6) Specified mortar of good quality should be used. The mortar should completely cover the bed and sides of the bricks. Proper care should be taken to obtain uniform mortar joint throughout the construction and the thickness of the joints should be always less than 12.5 mm.
(7) The walls should be raised uniformly in proper bond. No part of the wall should preferably rise more than 1 meter than rest of it. If it is unavoidable, the work should be raked back according to the bond.
(8) In one day, the height of brick masonry construction should not exceed 1.5 meters.
(9) The face joints are raked to a depth of 12 to 20 mm. while the mortar is green. This provides proper key for the plastering or pointing. In works where plastering or pointing is not to be done, the mortar joints are struck flush and finished at the time of playing itself.
(10) Fixtures like hold-fasts of doors and windows, etc. are embedded in cement mortar or cement concrete.
(11) The finished brick work should be kept wet for a period of at least two to three weeks in case lime mortar is used and for one to two weeks in case the cement is used.
(12) If it is planned to increase the length of the wall under construction at a future date, the wall is stopped with a toothed end (Fig, 4.16). This ensures continuous bondage between the old and the new work.
(13) Single scaffolding is used to carryout the brick-work at higher level. Some headers are removed to create supports for the scaffolding and they are filled up when the scaffolding is removed.
(14) In construction of a wall, first of all two end corners are carefully laid, and then in between portion of wall is built. A cord is stretched along the headers or the stretchers as illustrated in Fig. 4.17. It helps in keeping the alignment of the courses maintaining them in one level. Similarly, all others are built.

Bonding

It will be understood that if the bricks in a wall were built one on top of the other with each joint immediately over that underneath, it could not be one interlaced mass. Therefore, walls are built in what is commonly known as bond. The overlapping arrangement of bricks in order to tie them together in a mass of brick-work is known as "bonding". It is the system of laying bricks in such a manner that there is no vertical joint in any row or course immediately above or below the one considered. This is necessary to ensure that each brick is interlaced so that together with the cementing material, the whole wall is one uniform mass.
Good bonding should have a minimum of vertical joints in any part of the work, and it should not be continuous in two successive courses since it is a source of weakness.

A wall having continuous vertical joints will act as independent column and not as one compact unit. Therefore, the superimposed load is not well distributed throughout the wall but there are chances of local settlements. This is always avoided to get a strong wall constructed (Figs. 4.18 to 4.20).

Bond distributes the superimposed load from, say, a beam placed upon any individual brick in wall, to an increasing number of bricks forming the wall below, and thereby reducing the tendency to settlement.

Fig. 4.18. Dotted line shows angle of distribution of load.

Rules for bonding

To ensure satisfactory bondage, the following points should be taken carefully:

(1) The lap should be one-forth of the brick.

(2) The bricks should be uniform in shape and size. The length of the brick should be equal to twice the width of the brick plus thickness of one mortar joint.

(3) The vertical joints should lie vertically above each other in the alternate courses.

(4) The stretchers should be used only in the facing, while hearting should be done in headers only.

(5) The centre line of the header should coincide with the centre line of the stretcher in the course below or above it.

(6) Least number of bats should be used.

Types of bonds

There are several kinds of bonds used in brick masonry. These include the following.

(1) Stretcher bond (2) Header bond (3) English bond (4) Double Flemish bond

(5) Single Flemish bond

(6) Garden-wall bond.

(a) English garden wall bond. *(b)* Flemish garden wall bond.

(7) Facing bond (8) Dutch bond

(9) Raking bond *(a)* Herring bone bond. *(b)* Diagonal bond.

(10) Zig.-Zag bond (11) English cross-bond (12) Brick on edge bond.

1. Stretcher Bond

In such type of bond, all the bricks are laid with their lengths in the longitudinal direction of the wall. As only stretchers are visible in elevation, this is known as stretcher bond. This bond is only useful for half brick thick partition walls. In thicker walls, this bond is not suitable as there is no proper bondage across the wall (Fig. 4.21).

2. Header Bond

In this type of bond, all the bricks are laid as headers towards the face of the wall. This is suitable for one-brick thick walls and also used for the construction of curved walls. It may be used for footings in foundations for better transverse load distribution (Fig. 4.22).

3. English Bond

In this type of bond, alternate course of stretchers and headers are laid. A queen closer is placed after the first header in the header courses to stagger the vertical joints of successive courses. This type of bond is very commonly used in all types of construction. The following points need attention in English bond construction:

(1) A header course should never start with a queen closer as it may get displaced easily. Always, a queen closer is provided after the quoin header.
(2) Each alternate header is centrally placed over a stretcher.
(3) There should not be continuous vertical joint except at the stopped end.
(4) If the thickness of the wall is an even number of half brick, the wall presents the same appearance on both the faces.
(5) If the thickness of the wall is an odd number of half brick, the' same course will present stretchers on one face and header on the other.
(6) The hearting of thicker walls consists of only headers.
(7) Since the number of vertical joints in the stretcher course is' half the number of joints in header course, the joints in the header course are made thinner than those in the stretcher course. Figs. 4.23 to 4.26 show the plans of alternate courses for various thicknesses of the walls.

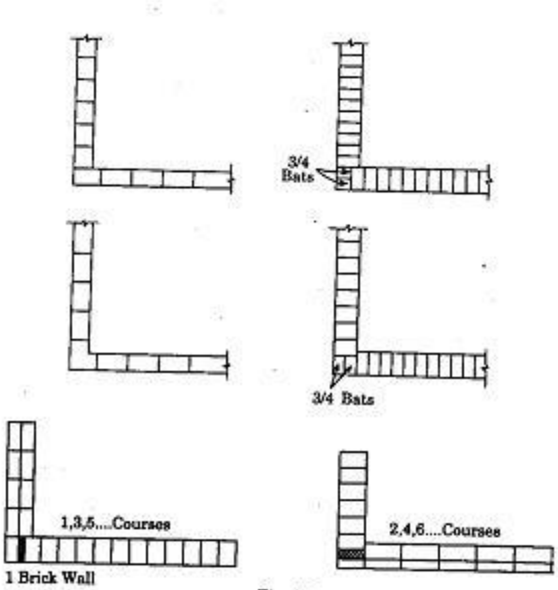


Fig. 4.23

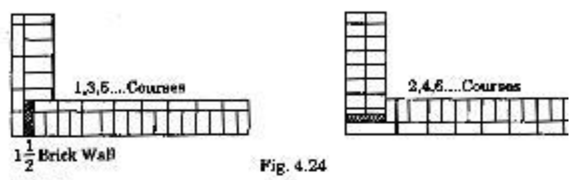


Fig. 4.24

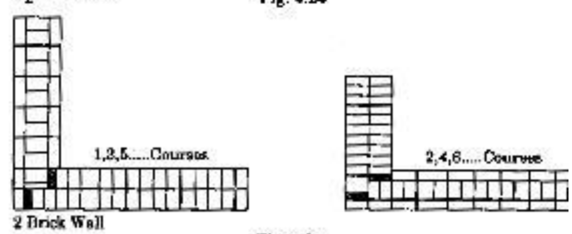


Fig. 4.25.

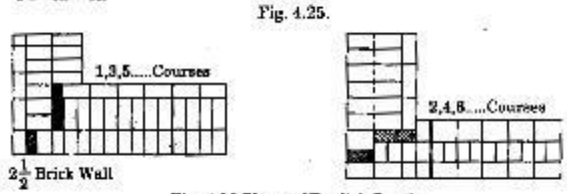


Fig. 4.26 Plans of English Bond

4. Double Flemish Bond

When alternately stretchers and headers are laid in each course, the arrangement is known as Double Flemish Bond. Appearance of this bond is better than the English bond. For walls equal to odd number of half bricks in thickness, bats are essentially used. This type of bond presents the same appearance both in the facing and backing. Following are the special features of this bond:
(1) In each course, stretchers and headers are alternately placed in both the facing and backing.
(2) The queen closer is placed next to the quoin header in alternate course, to break the continuity of the vertical joints.
(3) A header in any course is centrally supported over a stretcher below it:
(4) Bats are used for walls equal to odd number of half bricks. The alternate courses of the walls of various thickness in Double Flemish bond are illustrated in Figs. 4.27 to 4.29.

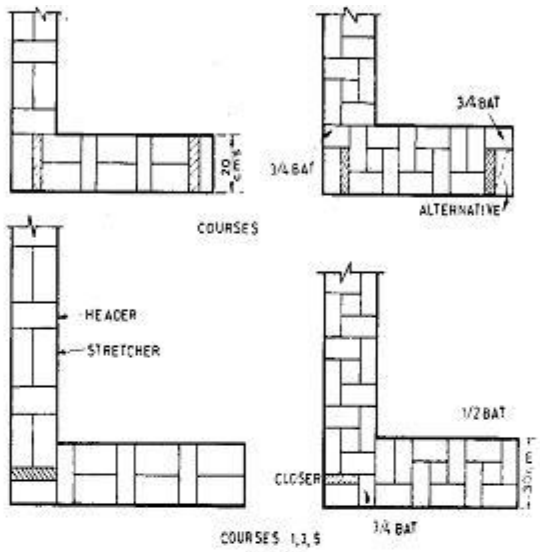


Fig. 4.27

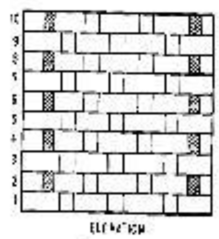


Fig. 4.28

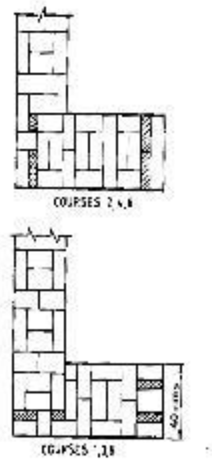


Fig. 4.29

Relative Merits and Demerits of English Bond and Double Flemish Bond

English bond is more compact and stronger than Double Flemish bond for the walls having thickness greater than 1~ bricks.

Double Flemish bond presents pleasing and better appearance in the facing.

In the construction of Double Flemish bond good workmanship and careful supervision is required.

Double Flemish bond is economical than English bond as a number of bats are utilized.

5. Single Flemish Bond

This bond has the advantages of both the types of the bond, *i.e.,* English bond as well as Double Flemish hond. In this type of bond, the facing of the wall consists of Flemish bond and the filling as well as backing consist of English bond in each course. The minimum thickness of the wall for this bond is 1.5 bricks. The following are the advantages of Single Flemish bond:

(a) The strength of English bond and appearance of Double Flemish bond are partly achieved.

(b) Good quality bricks can be used for facing in Double Flemish bond and cheaper bricks can be used as filling and backing in English bond.

The following are the disadvantages of this bond:

(a) This bond cannot be employed for walls having thickness less than 1~ bricks.

(b) A long continuous vertical joint is formed which renders the wall weaker.

(c) Skilled laborers are required for the construction.

Figs. 4.30 and 4.31 show the plan of walls in Single Flemish bond.

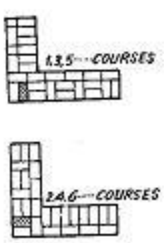


Fig. 4.30

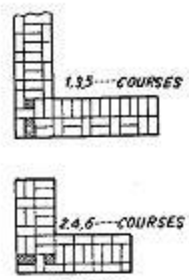
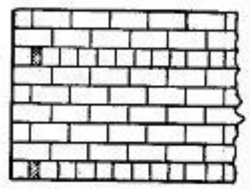
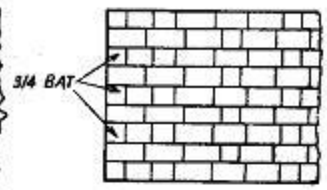


Fig. 4.31



English garden wall bond
Fig. 4.32



Flemish garden wall bond
Fig. 4.33

6. Garden Wall Bond

This type of bond is useful for the construction of garden walls, compound walls, boundary walls, etc. It is possible to construct one brick thick wall with uniform faces with economy, when this bond is employed. There are two types of garden wall bond:

(a) English garden wall bond *(b)* Flemish garden wall bond.

(a) English garden wall bond. This arrangement consists of one course of headers to three or five courses of stretchers. A queen closer is laid next to the quoin header of the heading course and the middle course of stretchers is started with a header, to give the necessary staggering of vertical joints. Fig. 4.32 shows the elevation of English garden wall bond.

(b) Flemish garden wall bond. In Flemish garden wall bond, each course consists one header to three or five stretchers. A~ bat is placed next to the quoin header in every alternate course to develop the necessary lap. A header is laid centrally over each middle stretcher in the lower course. This bond is also known as Sussex bond or Scotch bond. Fig. 4.33 illustrates this type of bond.

7. Dutch bond

This bond (Fig. 4.34) is a modification of English bond and produces stronger comers in the wall. Following are the special features of this bond.

(a) It consists of alternate courses of headers and stretchers.

(b) A3/4 bat is used as quoin in a stretcher course.

(c) A header is placed next to the 3/4 bat in every alternate stretcher course.

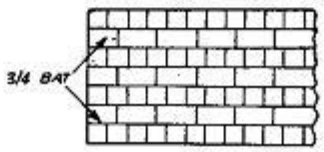
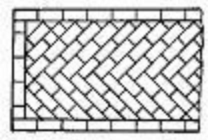
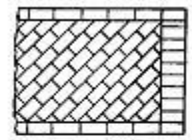


Fig. 4.34. Elevation Dutch Bond



Plan

Fig. 4.35. Herring bone Bond



Plan

Fig. 4.36. Diagonal Bond

8. Raking bond

In very thick walls, the longitudinal stiffness is less, as the number of headers used is more than the number of stretchers in between the facing and backing. To rectify this defect, the raking courses are laid at certain intervals along the height of the wall. The alternate courses of raking bonds are placed in different directions to get maximum strength in the wall. There are two types of raking bond:

(a) Herring Bone bond, *(b)* Diagonal bond.

(a) Herring bone bond. This bond (Fig. 4.35) is used for walls having thickness of more than four bricks or for paving, etc. In Herringbone bond, the bricks are placed at an angle of 45^0 from the central line in both the directions.

(b) Diagonal bond. Diagonal bond (Fig. 4.36) is useful for walls which are 2 to 4 brick thick. Brick in this bond are laid at every fifth or seventh course along the height of the wall. After the face bricks are laid, the internal placing of the bricks is done in one direction only at certain inclination. The angle of inclination is selected in such a way so that there is minimum breaking of bricks. The small triangular spaces at the ends are packed with bricks cut to the triangular shapes and suitable sizes required.

9. Zig-Zag bond

Zig-Zag bond is very similar to herring-bone bond with a difference that in this type of bond, the bricks are laid in zig-zag way. This is commonly employed for paving the brick floors. (Fig. 4.37). .

10. English Cross bond

This bond (Fig. 4.38) is similar to English bond with only difference that every alternate stretcher course has a header placed next to the quoin stretcher. This imparts beauty as well as greater strength.

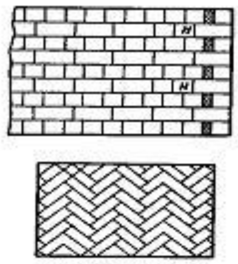


Fig. 4.37 and Fig. 4.38

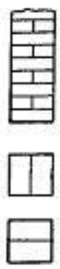


Fig. 4.39

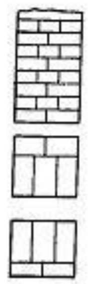


Fig. 4.40

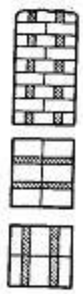


Fig. 4.41

12. Brick on edge bond

All the bricks are laid on edge in this bond. It is economical in the construction but weak in strength. Therefore, it is only used for the construction of partition or garden walls. In this bond, the bricks are placed as headers and stretchers in alternate courses in such a manner that headers are placed on bed and the stretchers are placed on edge forming a continuous cavity.

Bond in Columns

Columns may be constructed in various types of bond described earlier. In common practice brick columns are constructed in English bond or Double Flemish bond. Columns can be square, rectangular, circular, octagonal or any other shape. Circular or octagonal columns may be constructed or cut of molded brick to suit the shape and size. Normally such type of construction is done in the English bond. Figs. 4.39 to 4.44, illustrate various types of arrangements for different sizes of columns.

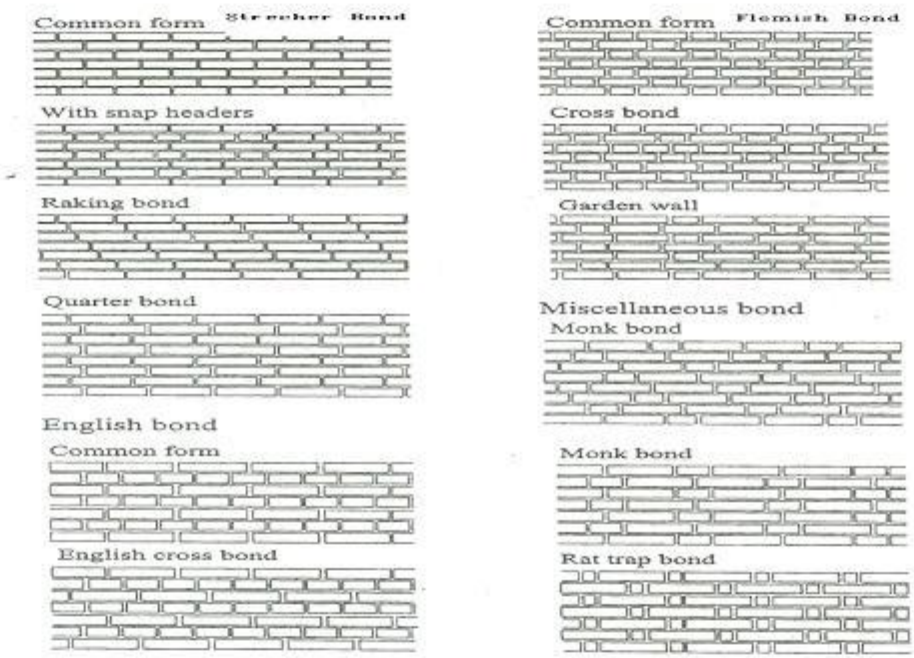


Fig.4. Types of Brick Bond in common use

Bonds at Junctions

Junctions are formed when two walls meet or intersect each other.

The following factors need consideration at the time of building junctions:

(i) The header course of the cross wall goes inside the stretcher course of the main wall.

(ii) Alternate courses of the cross wall are only for the abutting main wall.

A junction may be classified as:

1. Right-angle junction,

(a) Tee-junction.

(b) Cross-junction.

2. Squint junction.

1. Right-angle junction

(a) Tee-junction

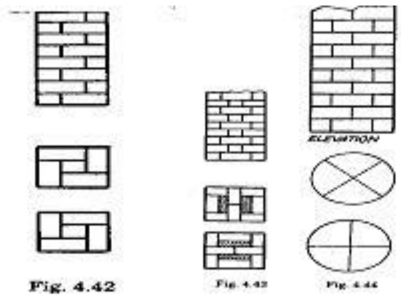
This type of junction forms the shape of English letter T in plan. Tee-junctions can be constructed in various bonds described earlier and the connecting walls may be of same or different thickness. Figs. 4.48 and 4.49 show Tee-junctions in English bond and Fig. 4.50 shows Tee-junctions in Double Flemish bond.

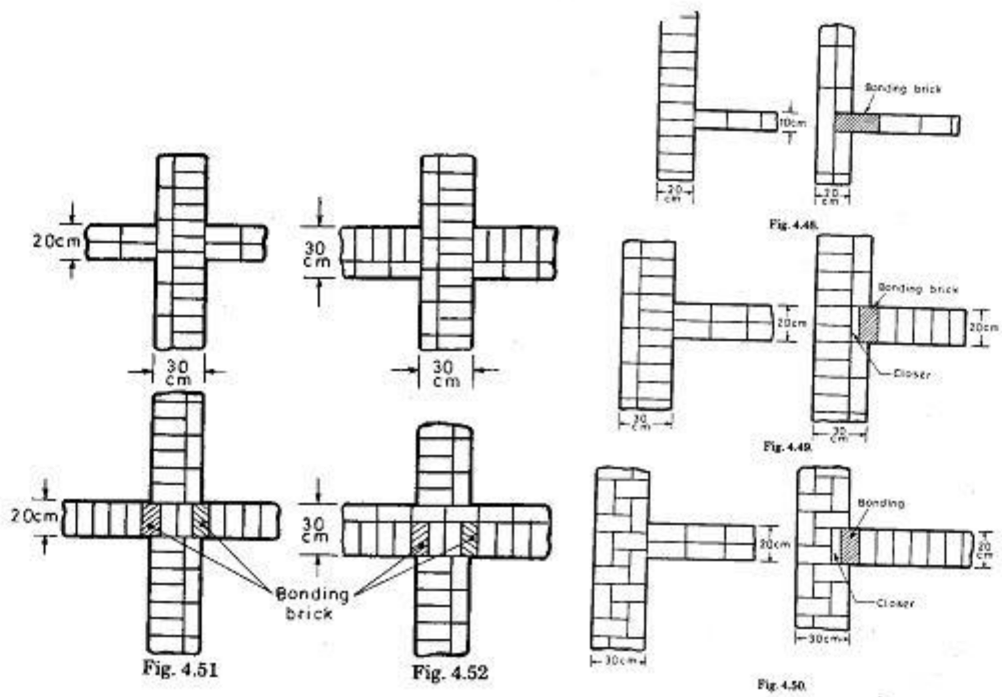
(b) Cross-junction

A cross-junction is formed when two continuous walls intersect each other (Figs. 4.51 and 4.52).

2. Squint Junction

When two walls meet each other at an angle other than a right angle, a squint junction is formed. The junctions may be built in English bond or Double Flemish bond. The heading course of the main wall is bonded into stretching course of the cross wall. The alternate stretching course of the squint wall simply butts against the heading course of the main wall. These junctions are rarely used in brick work due to great difficulty in the construction. Figs. 4.53 to 4.58 show the arrangement of bricks at squint junctions of various wall thicknesses in English bond and DoubleFlemish-bond.





Bonds at Quoins

The corner which is formed when a wall takes a turn is called quoin. The following are the classifications of quoins;

(1) Right-angle or Square quoins.

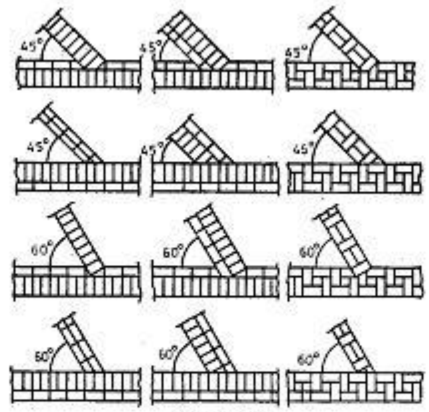
(2) Squint quoins,

(a) Obtuse Squint quoins. *(b)* Acute Squint quoins.

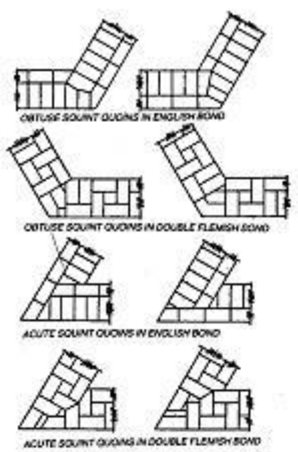
The general principle of bonding is the same as discussed earlier. In forming the required angle at the junction, standard bricks have to be cut to the desired shape or special bricks are used so as to achieve facility in obtaining the maximum lap with minimum cutting.

(1) Right-Angle Quoins

This type of quoin is formed when a wall takes a turn at 90^0. English bond or Double Flemish bond may be used at right-angled quoins. Care is taken so that no vertical continuous joints are formed. Figs. 4.23 to 4.31 show some bonding arrangements for right-angled quoins.



Squint Junction
Figs. 4.53 to 4.58.



Figs. 4.59 to 4.62.

(2) Squint Quoins

When two walls meet at an angle other than a right angle, the quoin formed is known as squint quoin. The important factors to be considered at the time of its construction are as follows :

(i) Maximum lap should be provided with minimum cutting of bricks.

(ii) Long continuous straight joints should not be formed.

(iii) The number of cut bricks to be used should be least possible.

(a) Obtuse Squint Quoins

In obtuse squint quoins, the angle formed on the inside of the wall is between 900 to 180^0 .Figs. 4.59 to 4.60 show obtuse squint quoins in English bond and Double Flemish bond.

(b) Acute Squint quoins

In this type of quoins, the angle formed on the inside of the wall is less than 90^0• Fig. 4.61 illustrates an acute Squint in English bond and Fig. 4.62 illustrates an acute Squint in Double Flemish bond.

Brick Laying

Brick laying is an art to lay the bricks properly. Brick-works are systematically laid with careful attention to the bonding, jointing, finishing, etc. The general principles of laying of brick masonry is practically same whether it is to be laid in walls or columns of footings, etc. but some special considerations are given to the individual components. The detailed procedure of laying bricks in different structures is described briefly as follows :

1. Walls

(a) Selection of bricks. Bricks are selected for various parts of the walls, *i.e.* for facing, hearting and backing. The bricks for facing should be of uniform size, uniform colour and good quality.

(b) Stacking of bricks. The bricks should be stacked in regular stacks of 1000 bricks in such a way that their edges or corners are not damaged.

(c) Soaking of bricks in water. Before the bricks are laid in the walls, they are well soaked in water for at least 8 hours. The following are the reasons for wetting bricks:

(i) Mortar can be spread more evenly on such bricks. *ii)* The bricks adhere better to the mortar.

(iii) Dry bricks will quickly absorb water from the mortar. This is dangerous when using cement mortar as enough water is required for setting of the cement mortar.

(iv) Wetting of bricks washes the kiln dust from them. A clean brick will produce a better joint and bond with mortar.

(d) Placing of mortar on foundations. Mortar is placed and spread on the foundation concrete top and should be at least 15 mm thick. The mortar is spread in the area which is to be covered by the corners of the wall. The corners of the wall are constructed first and then the in between portion is constructed.

(e) **Laying first course.** The mason should lay one brick at corner and should press it on the mortar so as to have only 10 mm joint between the concrete and the brick. Then the first closer is covered with mortar on the sides and placed gently against the first brick so as to have a 10 mm horizontal joint with the foundation also 10 mm vertical joint with the first brick. The excess mortar oozes but is cleaned off and the level of the bricks placed till now is checked (Figs. 4.65 to 4.68).

If the bricks are not exactly in level, they are lightly hammered. The edges of the bricks must be at a correct distance away from the edges of the foundation concrete.

Other bricks are placed in the same manner, *i.e.* they are covered with mortar on the sides and pushed into place, the level and their edge line should be also checked.

(f) **Laying second coarse**. The mortar is once again spread over the first course to a depth at least 10 mm. End stretcher is placed first on the mortar joint which is 10 mm thick. Mortar is placed on the end of the other structures and they are pushed into the place. The level and plumbness are checked for the second course.

The rest of the courses-required for the corner are placed in a similar manner. Since the wall in between is constructed with corners as a guide, the plumbness and the alignment of the bricks in the corners must be carefully checked. The bricks should not be moved after they are placed. The built up corners will hiive an appearance like Fig. 4.69.

(g) **Construction in between portion of walls**. This is done by stretching a cord along the stretchers or headers as shown in Fig. This cord provides a guide in keeping the alignment of the courses and maintaining them in one level. All other courses are built one after the other in a similar manner.

(h) As soon as the wall has been erected upto the height of the corners previously constructed, other corners of the building are constructed.

(i) After the walls have been erected to a height about 1.5 metres, the masons cannot work from the ground level and require platform for working which is known as scaffolding. This is described in detail in chapter 21.

(j) All the walls should be uniformly raised as far as practicable.

However, it must be checked that the difference in level between two walls in the building is not more than one metre. It is essential to avoid unequal settlement.

(k) All the joints should be cleaned and finished smooth after each day's work.

(l) If all the walls cannot be taken to the same height in a building, the higher portions should be stepped so as to have a proper bond with the masonry to be constructed afterwards.

(2) Columns

The bricks are laid according to anyone of the bonds described earlier in this chapter. The second course is also laid as shown in the figures of the bonding. The laying of mortar, pressing of bricks, finishing of joints, etc. are exactly done in the same way as described above. However, it is essential that absolute plumbness of a column must be insured and also that the central line of the column with respect to the other parts of the building is maintained in the correct position. Columns are not loaded till the mortar has set and has developed sufficient strength to withstand the loads.

Joints in Brickwork

In masonry structures, the joints are the weakest parts. To obtain the brickwork of good strength, the joints need special care at the time of construction.

If joints are properly made and finished, the appearance of brickwork is greatly improved. Most of the defects in brick masonry joints occur on account of improper application of mortar. The following are some of the important points regarding the joints in the various courses of brickwork:

(a) Bed joints in stretcher courses. Mortar for bed joints are spread evenly and must be quite thick. It is a general practice that mortar is not spread ahead for a distance greater than five or six brick lengths. This avoids the drying of mortar and also keeps the mortar plastic so that the bricks can set well with it. The bricks should be passed on the mortar and tamped with a travel (Fig. 4.70).

(b) Head joints in stretcher courses. These joints must be completely filled with mortar. Mortar should be pressed on the end of each brick to be laid. The bricks are placed on the mortar bed and pushed into place till the excess mortar gets squeezed out. Alternately, the mortar may be applied to the bricks already laid and then push in the next brick. The mortar which oozes out is removed with a trowel (Fig. 4.71).

(c) Cross-joints in header courses. Cross joints are carefully laid and should be full of mortar. Before each header is placed, the edge of the brick (Fig. 4.72) should be covered fully with all the mortar that will stick

to it. The header is pushed into its position so that mortar oozes out above the cross joint, as well as at the bed joint. The excess mortar is removed with a trowel.

(d) Closer joints in stretcher courses. The last brick to be laid in a wall along stretchers should be placed in such a way that the head joints are completely filled up with mortar (Fig. 4.73). With the bed joints already made, mortar is applied to the ends of the bricks *'A'* and *'B'* which have been laid previously. Mortar is also put on both ends of the closer brick. The closer is then pushed inside without disturbing the bricks already laid. The excess mortar is removed. The similar procedure is followed in laying the closer bricks in header course (Fig. 4.74).

Finishing of Joints

The object of finishing the joints is to impart better look to the brick work and to make it more waterproof. Merely drawing one edge of trowel along the joints is detrimental for brickwork as it may disturb the adhesion between the mortar and brickwork. The finishing of joints as the brickwork proceeds is termed as jointing whereas finishing of joints after the brickwork has been completed is known as pointing. This will be described in its own chapter.

Brick Coping

Copings are provided at the top of parapets, garden walls, boundary walls, etc. to protect the walls from rain water. The essential quality of a coping is that it should efficiently throw off rain water. Figs. 4.75 to 4.79 show several types of brick copings commonly used. Sometimes specially molded bricks copings commonly used. Sometimes specially molded bricks such as bullnosed, half-rounded, chamfered, or saddle backed are provided as copings. They give better appearance and shed off the water easily. Tiles or stone creasing/plate are sometimes introduced in between the bricks on edge to drop off the rain water ,easily. Rich mortar is used for the construction of copings. '

Brick Sills

The purpose of providing window. sill is to give a suitable finish to the, window opening and to project the external wall below such opening. The following factors are considered at the time of construction of a brick sill.

(1) Suitable slope is provided to the top of the sill and it is properly throated to throw off the water outside. The projection of sill, if given, should not be less than 50 mm.

(2) The top surface of the window sill is smoothly finished.

(3) It should be constructed in suitable course, such that the uniformity of the work as a whole is not disturbed.

(4) Damp-proof course may be provided below window sills to check the entry of moisture inside the main wall.

For the construction of brick sills, bricks are placed on edge with suitable slope. Sometimes slightly projected tiles are inserted below them to have a better appearance. Specially moulded bricks with throatings are also used for the construction of brick sills.

Brick Corbels

Brick corbels are projecting bricks from a wall and are constructed to provide better appearance and to support beams, trusses, lintels, etc. The following factors need consideration to ensure the stability of a brick corbel:

(a) The maximum projection of the corbel should not be more than the thickness of the wall.

(b) The maximum projection of each corbel course should be limited to a quarter brick at a time.

(c) In general practice header bond is used for the construction of brick corbel.

(d) The brick corbels may be continuous or discontinuous. The discontinuous corbels are used to carry heavy concentrated loads and sometimes a bed plate of stone or cement concrete is used for effective distribution of loads.

Some typical brick corbels are illustrated in Figs. 4.80 and 4.81.

Brick Jambs

Jambs are vertical faces of opening left in walls to fix doors, windows, fire places etc. Jambs may be classified as follows:

(a) Square *(b)* Splayed
(c) Rebated *(d)* Moulded

Square jambs are actually square stopped ends and the bonding is for square stopped ends according to the thickness of wall in which the jambs are formed. Square jambs permit rain and wind to enter freely into the room, when the pointing or plaster turns defective.

Rebated jambs have got recesses to receive the door frame and provide protection from weather action. The return face of jambs is termed as a "reveal" ; a rebated jambs has two reveals.

The splayed jambs with reveals are provided to improve the architectural appearance and to allow sufficient light into the rooms. English bond or Flemish bond can be used for its construction. Recesses may be 50 mm or 100 mm. deep.

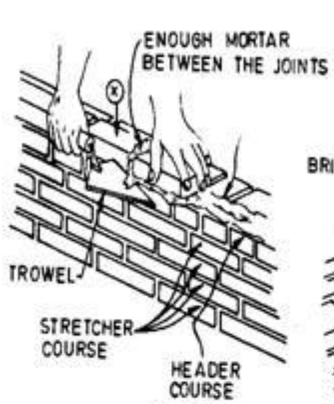


Fig. 4.70

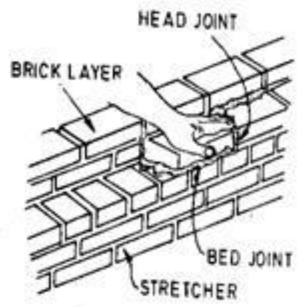


Fig. 4.71

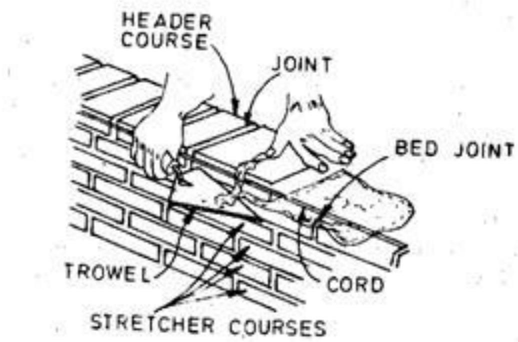


Fig. 4.72

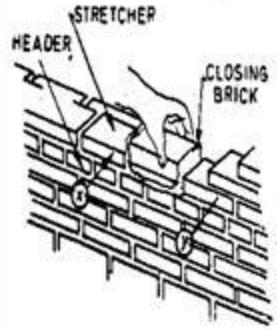


Fig. 4.73

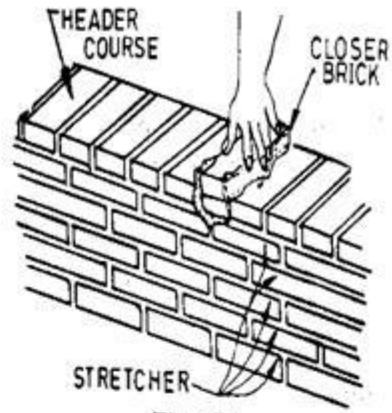
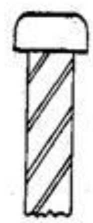
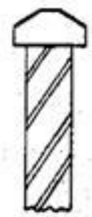


Fig. 4.74



Bullnose

Fig. 4.75



Chamfered

Fig. 4.76

Stone Creasing

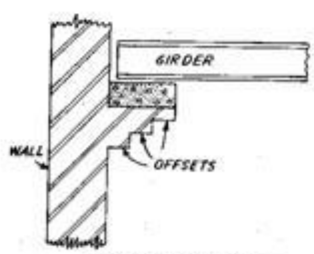
Fig. 4.77

$\frac{1}{2}$ Round

Fig. 4.78

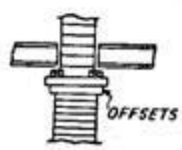
Saddle Back

Fig. 4.79



A typical-Brick Corbel to support girder

Fig. 4.80



A typical Brick Corbel to support girders

Fig. 4.81

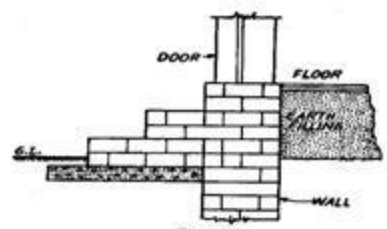


Fig. 4.82

Brick Steps

All external doors and entrances from verandahs are provided with one or more steps to reach plinth level from the ground level. Ordinarily brick steps are used for this purpose. Strong, hard and durable bricks of standard dimensions are used. The top surface of each step is provided with slight slope to dispose off water. The brick work is done in proper bond and in cement mortar. The two probable arrangements for the construction of brick steps are shown in Figs. 4.82 and 4.83.

Brick Parapets

Parapets are the upper portions of walls which extend above the roof level. The main objects to provide parapet are:

(a) To cover the back gutters, etc.

(b) To improve the architectural appearance.

(c) To protect human beings from falling down the roof, if access to roof is provided.

The top of a parapet is covered by copings to through off water falling on it. Its construction is similar to that of ordinary masonry wall.

Reinforced Brickwork

Brick masonry or Plain brickwork is weak in tension and cannot carry appreciable amount of tensile stresses as the bricks get pulled apart at the mortar joints. Reinforced concrete is a structural material, which can be put to all type of uses, but owing to its high cost, it is not economical to use it for members, which carry a small load and yet cannot be made of plain brick work. To increase the load carrying capacity of plain brickwork, steel reinforcement is introduced between the mortar joints. This type of brickwork can withstand tensile and shear stresses if the loads are not unduly great.

Reinforced brick work can take up tensile and shear stresses upto reasonable amount. Following are the advantages of reinforced brickwork construction:

(a) It is cheap, strong and durable. *(b)* It is fire-proof construction.

(c) It is easy to construct.

(d) It can resist appreciable amount of tensile and shear stresses.

Types of Reinforced Brickwork

(1) Walls

Reinforcement may consist of iron bars of expanded metal mesh. Standard patented expanded metal meshes are available in different widths and different gauges. This metal is available in coils, which can be spread while the brickwork is being laid. Mortar is evenly spread on the brickwork is laid over it. Unusually, the metal mesh is provided at every third course. Figure 6.4 shows steel mesh reinforcement in wall.

Another type of reinforcement, which is used for walls, is hoop iron (Fig. 4.84). These are steel flats about 2.5 to 3 cm in width and are from 1.5 to 2.5mm in thickness. These flats are dipped in molten tar to increase their resistance against rusting and are immediately sanded so as to increase the grip with the mortar Fig. 4.85. Generally, two strips of hoop iron are used for header brick and one hoop iron for stretcher brick, and every sixth course is reinforced. Special bricks are used to provide vertical reinforcement in walls (as illustrated in Fig. 4.86).The points at the corners are hooked as shown in Fig. 6.5.

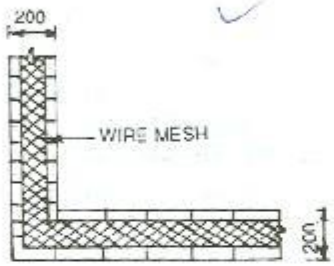
Another form of reinforcement employed for walls which have to withstand pressure e.g. retaining walls, is the placing of vertical reinforcement passing through opening made in special types of bricks. These bricks may have one or two holes extending to the required level. Vertical mild-steel bars are then placed in the holes,

(2) Columns. Special types of bricks are used for the construction of reinforced columns. Vertical reinforcing bars are placed between these bricks. The steel plates of about 6 mm thickness are provided at every fourth course- and the steel bats are fixed in the foundation concrete block in Fig. 4.87.

(3) Lintels. Steel bars of 6 to 12 mm diameters are provided longitudinally in between the vertical joints of bricks lintels. To take up the vertical shear, 6 mm diameter steel stirrups are used at suitable intervals.

(5) Beams. Reinforced beams are constructed in the same way as R.B. slabs. In case of R.B. beams steel bars up to 25 mm diameter are used as reinforcement.

To all types of reinforced brick work, it is essential to embed the steel reinforcement in rich investment mortar with proper cover so that reinforcement is not corroded. Corrosion will result to expansion of the point and subsequent cracking. The bricks should also be of high quality, processing high compressive strength so that optimum use is made of all material.



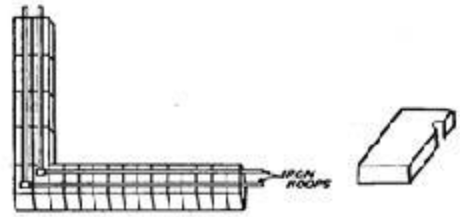
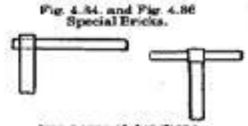
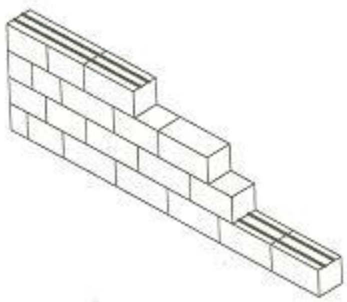


Fig. 4.84. and Fig. 4.86
Special Bricks.



Iron hoops at Junctions
Fig. 4.85



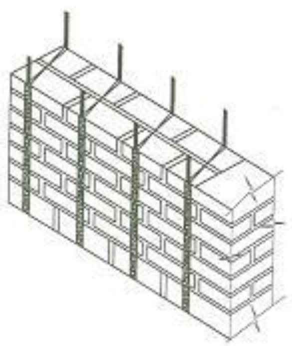
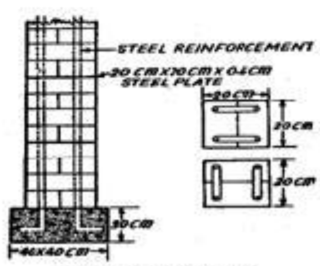


Figure 6.4 Steel mesh reinforcement in walls



Reinforced Brick Column
Fig. 4.87

Strength of brick works

Until very recently there was little reliable scientific data available on the strength of brickwork. Empirical knowledge, based on long practical experience, was embodied in sets of rules laying down the thickness of solid brick work required for walls of various heights, and for the degree of lateral; support required from cross-walls or piers. For instance, half brick walls are not to be used as structural walls, but only as partitions.

Further it should be remembered that the strength of a wall is no greater than its weakest point. Since brick is laid with a mortar joint, the specification of the mortar joint is greater importance if the brick work is to give a satisfactory performance. Broadly, it is important that the mortar should be specified (and mixed) in relation to the brick with which it is to be used, and should be comparable in strength and density with the brick itself. A strong, dense brick usually requires a strong dense mortar.

Bricks should be well damped before use, in order not to absorb the moisture form the mortar during the brick laying process as the strength of the mortar would be thereby reduced. In addition, the walls should be kept well damp at least for three days, in order to let the mortar harden without premature loss of moisture.

Working Stresses in Reinforced Brickwork

Safe compressive stress in bricks Shear in brickwork	=30 kg/sq. cm
Shear in brick work	=5kg/sq. cm
Safe tensile stress in steel	=1400kg/sq.cm
Bond stress between steel and mortar	=6 to 7 kg/sq.cm
Ratio of modulus of elasticity of steel and brick	=40:1

Thickness of Walls in Brickwork

The various types of loads which act on walls are as follows:

(a) Self-weight of the wall.

(b) Dead load due to floor or roof slabs, beams etc. *(c)* Wind pressure acting on the roof and wall.

(d) Live load. The live load depends on the type of building.

(e) Earth pressure if wall is constructed below ground level.

If total load coming over the wall is calculated, we can find out the thickness of wall. If the area of wall is *A*, the total load coming over it is Wand *P* is allowable compressive strength of the brick masonry;

then, $A = \frac{W}{P}$ or $T * L = \frac{W}{P}$ Where T is thickness of wall and L is length of wall.

or $T = \frac{W}{P * L}$

or $T = \frac{W}{P}$ if length considered is unity.

Since most of the time, the loads acting on the walls are eccentric, the walls are made thicker. In this case the maximum pressure per unit area is determined by the following formula:

$$\text{Pressure per unit area} = \frac{P}{T}\left(1 \pm \frac{6e}{T}\right)$$

Where, *P* = load per unit length of wall, *T* = thickness of the wall, and e = eccentricity of the loads.

The expression $\text{Pressure per unit area} = \frac{P}{T}\left(1 + \frac{6e}{T}\right)$ gives maximum compressive stress that will develop in masonry and it should be less than the safe compressive strength of the masonry. The

expression $\text{Pressure per unit area} = \frac{P}{T}\left(1 - \frac{6e}{T}\right)$ gives minimum compressive stress that will develop in masonry and it should be positive or at the most equal to zero for no tension at any section of wall.
From these expressions the wall thickness can be calculated but the following factors also affect the thickness of the wall:
(a) Quality of the materials.
(b) Overall height.
(c) Height between floors.
(d) Spacing of buttresses and cross walls, *(e)* Function of walls.
(j) Character of occupancy.
(g) Windows and door opening, recesses, etc.

Joints in brick work

Joints are the weakest part of masonry structure and unless special care is paid to them, the brickwork cannot be of good strength. Appearance of brickwork also depends on the proper laying and finishing of joints. Most of the defects in brick masonry joints occur on account of improper application of mortar. The purpose of finishing the joints is to improve the appearance of brickwork and to make it more waterproof. The finishing of joints as the brickwork proceeds is termed as *jointing* whereas finishing of joints after the brickwork has been completed is called *pointing.*

The edges of the joints in brickwork will be deficient in hardness and density. The expansion and construction of the brick is liable to cause the mortar in the joint crack or loosen the brick from the mortar. The mortar near the exposed face is, therefore, prone to dislodgment. Unless the wall is to be plastered, it is necessary to refill very compactly the surface joints for a depth of about 2-3 cm with a neat mix of cement mortar of proportion 1:1. This process is known as pointing. The term pointing is applied to the finishing of mortar joints in masonry. In exposed masonry, joints are considered to be the weakest and valuable spots from which rain water or dampness can enter.
Causes of failure of brick masonry
Brick masonry may fail due to the *following* causes: by crushing, if it is overloaded; by bearing along any horizontal plane or by rupture along a vertical joint under vertical loads. Care against crushing can be taken by providing adequate dimensions. Shearing along any horizontal plane is prevented by providing a strong mortar. Rupture along a vertical plane is avoided by breaking vertical joints in brickwork.
Defects in Brickwork
Following are the common defects that occur in brickwork:
(a) **Use of weaker materials**. Use of weaker materials forms small depressions with nodules of friable materials at the joints. It creates expansion and cracking in brickwork.
(b) **Sulphate in mortars**. Sulphates attack the mortar causing expansion of mortar points and finally resulting in cracking of brickwork, and damage of mortar. The failure is due to chemical reaction between sulphates present in bricks and the aluminum ingredients of portland cement and it is accelerated in the

presence of moisture. Bricks free from sulphates should be used and proper damp-proofing should be done to check this type of defect.

(c) **Corrosion of iron and steel**. Exposed iron and steel are corroded when they come in contact with water or moisture. The volume of corroded iron and steel is increased and hence cracks in the brick masonry are formed. Therefore, it is advisable to give a protective cover of 10 to 20 mm. cement mortar over reinforcing steels. For partially embedded steel, paint or bitumen should be applied in the unbonded portion.

(d) **Crystallisation of salts**. It forms while deposit on the surface of the brickwork and may cause disintegration of brickwork. The salts may come from the bricks used with the soil contact, sea-water, or other weathering agencies.

(e) **Linear changes due to variation in moisture contact.**

Shrinkage cracks develop in the brickwork due to the first long spell of dry weather after the construction. The stepped cracks appear on the surface but they never continue below damp-proof course. Good quality bricks should be used in the construction and the work should be protected from rain during the construction to avoid this type of defect.

(j) **Frost action**. The volume of water is increased when it is frozen. Due to this phenomenon, the cracks are caused in the brickwork. This defect is considerably reduced if the water accumulation is prevented.

Maintenance of Brickwork

(1) ***Cleaning***. Brick masonry may be cleaned with steam or hot water jets. This is useful for fine textured and hard burnt bricks. (2) ***Re-pointing old brickwork***: this may be needed to improve the appearance of an old brick work and make it watertight. Mortar gets lost due to rain, wind, heat, freezing, etc. Before re-pointing old brick work, the joint of the old mortar has to be cleaned to a depth of at least 3 cm. It is done as follows:

(a) The old mortar is removed from joints to a depth of at least 3 mm. The old mortar is loosened with small hammer and removed out with steel brush to make the surface clean.

(b) Water is sprinkled over the joints and the new mortar is put with the trowel. It is fmally finished with the pointing tool to give the desired shape.

(c) Proper curing is done for 2 to 3 weeks.

(3)***Removal of Efflorescence***. Efflorescence is the whitish crystalline substance, which appears on the surface of walls due to the presence of salts in lime, cement, sand bricks and sometimes even in water used in the construction work. Magnesium sulphate, calcium sulphate, sodium and potassium sulphate etc., being soluble in water are deposited on the brickwork surface as eftlorescence as a result of alternate drying and wetting of the brickwork by rain and sun and by rise and fall of ground water table. In fact salts come in the brickwork along with water from below and are deposited on the brickwork in layer after evaporation. Since moisture movement is one ofthe causes for eftlorescence, it can be reduced to a great extent by suitable damp prevention of building. When a newly constructed wall dries out, the soluble salts dissolved by moisture are drawn to the surface through the pores. These soluble salts absorb moisture from atmosphere and on drying, they get deposited in patches of white crystalline substance as sown in Fig. 6.7. The surface gets disfigured by ugly damp patches of efflorescence.

Efflorescence can be removed by scrubbing the wall with water and a hard steel brush. If this is not successful, a 10% solution of muriatic acid may be used instead of water. However the wall should be rinsed clear with water or a weak ammonia solution immediately after the treatment.

(4) ***Repainting.*** Repainting is required for the surfaces which were earlier painted and have been damaged by weathering agencies. The old paint is removed by hard steel brush and water or steam. Then the new paint is applied in the desired colour and tint.

Definition

Stone masonry is the art of building the structure in stones. It may be adopted for the construction of foundations, columns, walls, beams, lintels, arches, floors, etc. of a building. Dams, retaining wall and other structures can also be built up in stones. Stones are available in nature and after properly cutting and dressing to the proper shapes, they provide strong, durable and economical material for the construction. But stones are not available everywhere. Its transportation and handling cost is considerably high, which restricts its use.

It should be noted that stone walls can stand compressive loads only. Cracks in the walls are often caused by tensile or shearing stresses, which cannot be absorbed by the wall.

There is a wide choice of natural stone suitable for walling including igneous rocks (e.g basalt, trachyte) and sedimentary rock (e.g sandstone, limestone). Aesthetic consideration will often play an important part in deciding the stone to be used in a particular building. For instance basalt is used for walls which may be exposed to moisture, such as in foundation wall. Sandstone and limestone are usually employed for all kinds of walls above ground level.

In considering a masonry wall, it is important to ensure that the mass will act as much as possible as a unit, and consequently the mortar used for bedding should be carefully chosen to be compatible in strength and porosity with the type of stone employed.

Comparison between Stone Masonry and Brick Masonry

(1) Stone masonry possesses higher strength, durability and weather resisting qualities than brick masonry.

(2) Stone has higher crushing strength than brick. This makes stone suitable for the construction of dams, piers, docks and other marine structures.

(3) In monumental buildings which require heavy moldings with large projections and carvings, stone is suitable whereas brick can be used only for light ornamental work of lesser importance.

(4) Stone masonry is more water-tight than the brick masonry.

(5) Well textured stone masonry of superior quality needs no treatment to improve its appearance. The apparent defects of brick masonry can be only concealed by plastering,

(6) Generally stone masonry is not damaged by chemicals present in the environment and salts present in water or sewage whereas exposed brick masonry reacts and gets disintegrated.

(7) The use of stone masonry is only restricted to hilly areas due to high cost. Brick masonry is cheaper as bricks can be locally manufactured.

(8) Complicated lifting appliances are required to handle the stone blocks and bricks can be conveniently moved by manual labor.

(9) Construction of brick masonry is quick as the uniform size and regular shape of bricks facilitates in maintaining proper alignment. Whereas, the dressing and handling of stones need more time and extra labour in the construction of stone masonry.

(10) The brick masonry is more fire-resisting than stone masonry. (11) More skilled laborers are required in the construction of stone masonry than in the brick masonry.

(12) First class bricks have all qualities for good construction works and due to this fact brick masonry is being used more frequently than stone masonry.

Materials Used for Stone Masonry

The following two materials are used in stone masonry : (1) Stones (2) Mortar.

(1) Stones.

The stones must be hard, tough, durable and free from any defect. Its selection for a particular work is mainly governed by its availability and the importance of the structure. The common types of stones employed for stone masonry are as follows:

(a) Granite. Granite is a very tough and hard stone and hence its dressing is difficult. It is difficult to employ this stone for ordinary buildings and other decoration works. Granite is chiefly used for the construction of light houses, bridges walls of docks, harbors and other marine works. Though granite is very strong but it is badly affected by fire. Any type of carving cannot be done on granite.

(b) Marble. Marble is a metamorphic rock and is made from limestone. It is available in many colours such as white, grey, blue, black, yellow, etc. Dressing and carving can be done conveniently on marble. Marble takes good polish and used for monumental buildings. This is a very costly stone.

(c) Limestone. They are calcareous rocks and contain carbonate of lime. They are available in various colours and dressing or carving can be done easily on them. They are used in the construction of walls, steps, floors, etc. but they are damaged by the presence acid fumes.

(d) Sandstone. Sandstone is sedimentary rock and contains lime, silica, magnesia, alumina and iron oxide besides sand and quartz particles. The strength of sandstone depends on cementing material. Sandstone may be of various colors such as white, gray, red, yellow, green, deep blue, etc. Good jali-work can be done on fine grained sandstone. Large grained sandstones are generally hard and used for ashlar work. They can be worked conveniently to take any ornamental shape. Sandstones are used in the construction of columns, walls, steps, facing, etc.

(e) Slate. Slate is a metamorphic rock. Slates can be split into thin sheets along its cleavage or bedding planes. The surface of slate is very smooth and contains alumina and silica. Slate is found in many colours such as black, green, grey, deep blue, etc. Grains of good slate are fine. It is hard and tough. Water absorption capacity of slate is low. In India

soft. and rough variety of slate is found which is used for flooring. Good quality slates are used for roofing.

(2) Mortar.

Mortar is binding material for stone blocks used in the construction of stone masonry. Cement or lime is mixed with sand and water to form a uniform paste. The selection of suitable mortar depends upon the load coming on the structure, strength desired and the colour of the stone used to obtain good combination of colours on the face work. It is a general practice to use 1 : 3 cement mortar in stone masonry. Sometimes about 10 to 15% of cement is replaced by hydrated lime to improve the workability of the mortar. Some stones like limestone get stains when ordinary cement mortar is used, in such cases the use of a non-staining white Portland cement is recommended. If about 10 to 15% of lime is replaced by cement in a mortar, it is known as lime-cement mortar. This increases the strength of the lime mortar and makes it more plastic.

Defects in Stones

Following are the common defects of stones and the stones used in the stone masonry should be free from such defects

Before using a stone in a building, the following defects should be checked.

(1) Vents. They are small fissures in the stone which makes it liable to decomposition.

(2) Sand holes and clay holes. They are holes or cracks in stone which are filled with loose sandy or clayey materials. These loose materials decompose when subjected to weathering action.

(3) Mottle. When some chalky substances are present in the stone, it presents spotted appearance and such stones are unsuitable for use in face work.

(4) Shakes. They are very fine cracks in the stone and filled up with calcite which forms hard veins of dark colour. This gives unpleasant appearance to the stone surface.

Cutting and Dressing of Stones

Stones found in nature have to be quarried from their thick beds. Bigger blocks ofxough stone is obtained from quarry. They are in irregular shape and non-uniform in size. Hence they require cutting in proper shape and size and then finally they are dressed by chisels, hammers and other tools to get the desired surface finish. The main aims of dressing stones are as follows:

(i) To give the desired shape to the stone pieces.

(ii) To make the joints between two stones very thin and thus to reduce the expenditure of mortar.

(iii) To improve the appearance of stone surface.

The different types of surface finish for stone masonry described below:

(1) Scabling. Irregular edges and projections are broken by a scabling hammer to bring the stone in shape roughly (Fig. 5.38).

(6) Reticulated finish. Irregular type of sinking is done in the central portion of the stone. The depth of cut is about 6 mm (Fig. 5.43).

(7) Vermiculated finish. In this case, the sinking is more curved and gives worm eaten appearance (Fig. 5.43). This is a costly finish as it requires more labour.

(8) Punched finish. On the stone surface, small depressions are provided by help of punch. A series of hollows and sides are produced on the stone surface (Fig. 5.45).

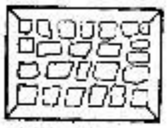
(9) Combed finish. This type of finish is only given to soft stones.

A steel comb with a number of teeth is dragged on the stone surface to make marks as illustrated in Fig. 5.46. The direction of marks may be varied.


Fig. 5.45 Punched

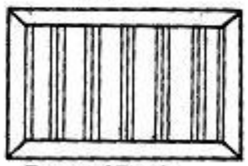

Fig. 5.46 Combed


Fig. 5.47 Rubbed

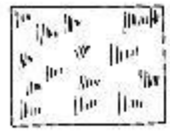

Reticulated Finish
Fig. 5.43


Vermiculated Finish
Fig. 5.44


Tooled Finish
Fig. 5.41


Furrowed Finish
Fig. 5.42


Hammer Dressed
Fig. 5.38


Hammer Dressed Finish
Fig. 5.39


Rough Tooled Surface
Fig. 5.40


Polished
Fig. 5.48

(10) Moulded finish. To improve the appearance of the stone blocks various types of mouldings are made by machines or by hand.
(11) Rubbed finish. Smooth surface finish is obtained by rubbing two pieces of stones together. Water and sand is poured between the two rubbing surfaces. Machines can be also employed for rubbing the stones (Fig. 5.47).
(12) Chisel-draughted margins. This type of finish gives better appearance and uniform joints can be constructed. The margins are chamfered, pitched or squared. Boasted or tooled finish is provided on them.
(13) Polished finish. The surtaces of stones like marbles, granites, etc. can be polished with hand or machine (Fig. 5.48).

Selection of Surface Finish
The following factors should be considered in selection of a surface finish:
(a) Type of masonry *(b)* Type of stone
(c) Architectural effect required *(d)* Atmospheric conditions
(e) Finance available.
The hammered finish is suitable for hard stones. The tooled finish can also be obtained on hard stones. Whereas polishing cannot be done on stones such as sandstone or limestone. Polished surfaces are useful in bathrooms, hospitals and in public building but they require high maintenance.
Terms Used in Stone Masonry

(1) Natural Bed. The stones are obtained from rocks and the rocks have a clear plane of cleavage along which stones can be split with little effort. This plane is known as natural bed. In stone masonry, the natural bed of stone is kept perpendicular to the direction of expected pressure.
(2) Corbel. It is a stone piece projecting beyond wall to support a structural member such as truss, beam, etc. (Fig.5.1).
(3) Cornice. It is a moulded course of stone placed at the top of wall. Sometimes ornamental treatment is also given to it (Fig. 5.2).
(4) Weathering. A slope is provided to the top surface of stones used for coping, cornice and still to drain off the water immediately. This is known as weathering. The term weathering is also used to indicate the wearing of stones due to action of weather (Fig. 5.2).
(5) Throating. A small groove i,S cut on the underside of sill,coping, cornice and projected chajja to discharge the rain water without trickling down to the walls (Fig. 5.2 and Fig. 5.3).
(6) String course. The horizontal projections provided at suitable levels between plinth and the cornice to break the monotony of a plane appearance are known as string courses.
(7) Cramp. It is a metal connection employed in stone masonry construction. Sometimes slate is also used for this purpose.
(8) Lacing course. A wall of irregular small stones is strengthened by placing horizontal courses of big, regular and uniform size stones at suitable intervals. The course is known as lacing course (Fig. 5.4).
(9) Through Stones. They are stones extending through the entire thickness of wall and they are used at certain intervals to act as bonding stones for increasing the stability of the wall (Fig. 5.5).
(10) Reveals. The exposed vertical surfaces perpendicular to the door or window frames are called as reveals.
(11) Stoolings. They are the horizontal seatings to receive jambs and mullions.
(12) Rubble Masonry. A stone masonry which is roughly finished is known as rubble masonry.
(13) Ashlar Masonry. The stones to be used are properly cut in uniform size and dressed with fine finish. They are joined together in proper bond and the mortar thickness is thin and uniform throughout the masonry. Such constructions in stone masonry is known as Ashlar Masonry.

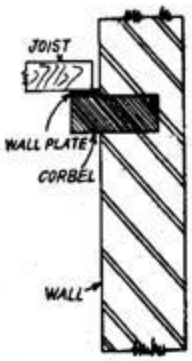
Tools Used in Stone Masonry

(1) Trowel. It is used to lift and spread mortar while laying stone pieces and it is very similar to the bricklayer's trowel.
(2) Spirit level. It is used to check the horizontality of the surfaces.
(3) Square. It is fabricated by steel flat and each arm is about 0.5 metre long. It is employed to set out right angles.
(4) Plumb rule and bob. It is used to check the verticality of walls.
(5) Line and pins. It is employed to maintain'the alignment of the work in progress.
(6) Spall hammer. It is a heavy hammer and is used for rough dressing of stones in the quarry (Fig. 5.6).
(7) Mallet. It is a wooden hammer used to drive wooden headed chisels (Fig. 5.6).
(8) Scabbling hammer. It is employed to break small projections or bushing of stones (Fig. 5.7).
(9) Iron hammer. It is used for carving of stone.

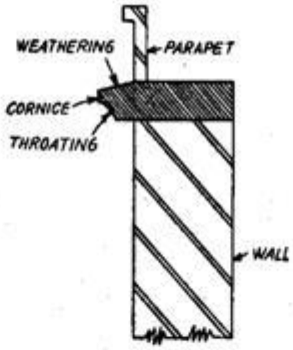
(10) Bevel. It has two slotted blades of steel and fixed with each other with thumb-screw. It is used to set out angles (Fig. 5.8).
(11) Pick axe. It is long head pointed at both ends. It is used for rough dressing of stones and to split the stones in the quarry (Fig. 5.10).
(12) Crow bar. It is employed to displace the stones from its position in the quarry (Fig. 5.11).
(13) Pitching tool. It is employed to make the stones of required size (Fig. 5.12).
(14) Gauge. It is used to dress stones for string course, cornice coping, etc. (Fig. 5.13).
(15) Punch. It is used to dress roughly the stones (Fig. 5.14).
(16) Point. It is used for roughly dressing the hard and tough stones (Fig. 5.15).
(17) Nicker. It is employed to draw fine chisenines on the stone surface.
(18) Chisels. They are used to dress stones. They are of different shapes and the blows are given by mallet or hammer. Hard stones are dressed with 'claw chisels'. It has an edge with a number of teeth (Fig.5.16).
(19) Jumpers. They are employed for boring holes (Fig. 5.20).
(20) Wedge,and feathers. They are small conical wedges and curved plates. They are used for spliting the stones after have been bored by jumpers .
(21) Hand saw. It is employed to cut soft stones (Fig. 5.17).
(22) Cross-cut saw. It is used to cut hard stones (Fig. 5.18). (23) Frame saw. It is employed to cut large blocks of stones (Fig.5.19).
(24) Gad. It is small steel wedge for spilting stones. (Fig. 5.21).
(25) Drag. It is employed to level a stone surface (Fig. 5.22).

Joints in Stone Masonry

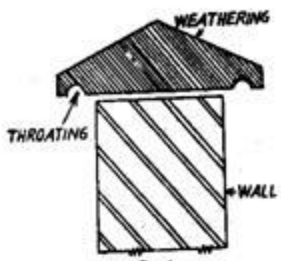
Following types of joints are commonly used in stone masonry :
(1) Butt joint
(2) Rebated or lapped joint (3) Tabled joint
(4) Tongued and grooved joint (5) Rusticated joint
(6) Saddled joint
(7) Dowel joint
(8) Pluggedjoint
(9) Cramped joint.



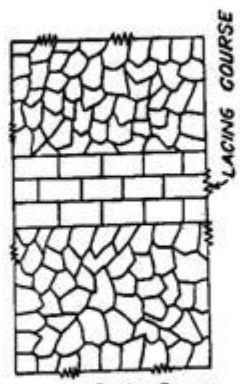
Corbel
Fig. 5.1



Cornice
Fig. 5.2



Coping
Fig. 5.3



Lacing Course
Fig. 5.4

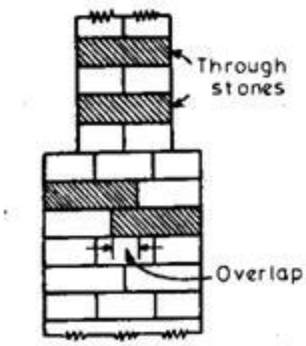
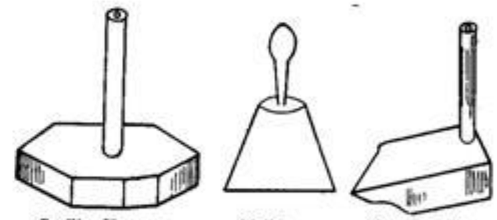
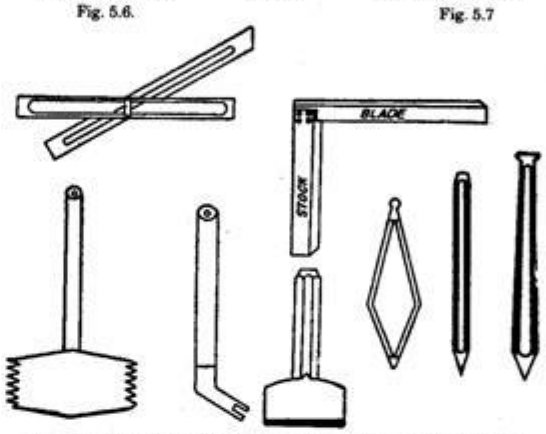


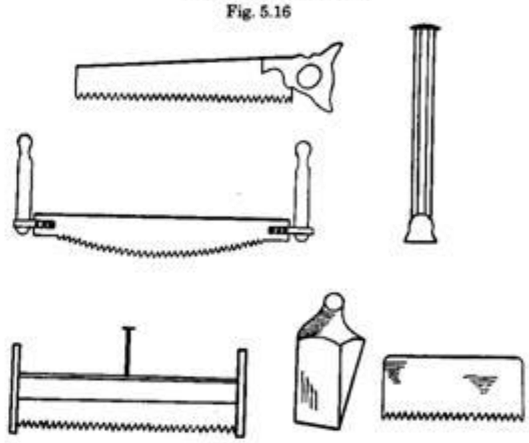
Fig. 5.5. Through Stone


Spalling Hammer Mallet Scabbling Hammer
Fig. 5.6. Fig. 5.7



Separated Pick Crowbar Pitching Tool Gauge Punch Point
Figs. 5.8 to 5.15.

Fig. 5.16


Figs. 5.17 to 5.22.

General Principles of Stone Masonry Construction

(1) The stones employed in construction should be hard, tough and durable. It must confirm with the specifications of the work.

(2) All the stones are placed on their natural bed such that the pressure should act normal to the bedding plane.

(3) The stones are drenched in water before they are used. This avoids absorption of moisture from the mortar by stones.
(4) The stone surfaces should be properly dressed as per specifications of the work.
(5) The construction of stone masonry should be carried out in proper bond with enough number of through stones.
(6) The bonding stones and headers should not be in a dumpbell shape.
(7) Heavy and flat stones are put under the ends of girders or roof truss to transmit the loads uniformly.
(8) Finely dressed stone pieces are protected during further construction by providing timber boxing.
(9) The good quality mortar in the specified proportion should be used.
(10) Double scaffolding is adopted for working at higher level.
(11) As far as practicable, the construction work of stone masonry should be raised uniformly. Otherwise toothing or stepping should be provided in the masonry (Figs. 5.36 and 5.37).
(12) The verticality of the wall erected should be checked by a plumb-bob. The battered faces are checked by suitable wooden template.
(13) Stone masonry should not be designed to take tensile stresses.
(14) The use of small stone chips or broken stones should be avoided.
(15) After the completion of the work, it should be cured with water for a period of two-three weeks.

Classification of Stone Masonry

The stone masonry can be broadly classified as follows:
(1) Rubble Masonry. Undressed or roughly dressed stones are used in this type of masonry work. The joints are considerably wide.
(2) Ashlar Masonry. Carefully dressed stones of uniform size are used and the joints between stone blocks are very thin and uniform.
Each of them may be further sub-divided as follows:
(1) Rubble Masonry:
(a) Uncoursed Random Rubble *(b)* Coursed Random Rubble *(c)* Uncoursed squared Rubble *(d)* Coursed squared Rubble *(e)* Built to regular courses (f) Polygonal *(g)* Flint *(h)* Dry Rubble.
(2) Ashlar Masonry:
(a) Ashlar Fine *(b)* Ashlar rough tooled *(c)* Ashlar rock or quarry faced *(d)* Ashlar chamfered *(e)* Ashlar block in course (f) Ashlar facing.

(1) Rubble Masonry.

In this type of masonry stones of irregular sizes and shapes are obtained from the quarry and directly used in the construction work. Only in some cases the quarry stones are broken and shaped to suit the requirement. Either the stone surfaces are undressed or very roughly dressed. The following factors should be considered for all types of rubble masonry :

1. All stones should be well watered before being used in the masonry.
2. Stone blocks from opposite faces should make bond with each other.
3. The facing stones should have full joints for a determined distance from the face.

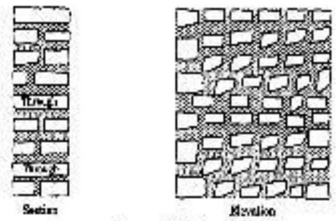
4. Number of headers used should be sufficient in each course and they should be inserted for enough depth into the walls.
5. The height of stone is never more than its minimum horizontal dimension.
6. The facing and backing should have sufficient bondage.
7. Stones are placed on their widest side such that they should not act as a wedge.
8. Small stone chips or pebbles should not be used in bed joints. *(i)* The use of feather edged stones with insufficient tails is avoided.
9. The width of the face stone should be more than the height of the course.
10. Quoins in coursed rubble masonry is the same height as the course.
11. After the masonry is laid it should be cured for a period of 2 to 3 weeks.

***(a)* Uncoursed Random Rubble.**

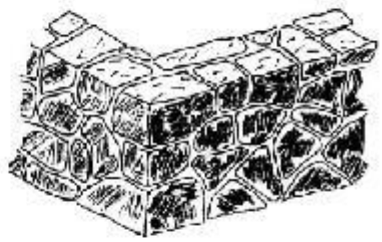
It is the cheapest type of stone masonry. Stone blocks are not dressed but used in the masonry as obtained from the quarry. Merely weak corners and edges are removed with mason's hammer. The vertical joints are not constructed in plumb. Bigger stone blocks are used at quoins and jambs to increase the strength of the masonry. For each square metre of face work, one through stone is used. They have a cross-section of 400 sq. em and run to full depth of the wall or at least half metre depth when the depth of wall is more (Fig. 5.49).

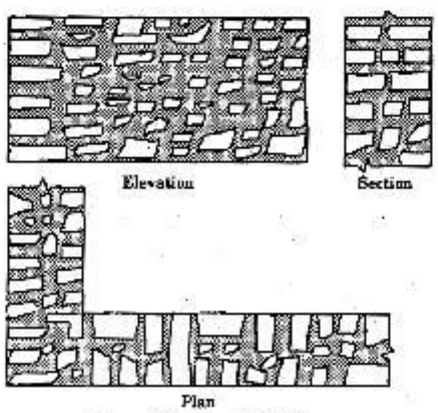
***(b)* Coursed Random Rubble.**

In course rubble masonry stones of 50 to 200 mm size are employed. Stones of equal height are used in every course of the stone masonry. This is commonly adopted in the construction of public buildings, residential buildings, abutments and piers of ordinary bridges. The joints are about 15 rom thick. The width of the header is more than the height and is inserted into the wall at least three times its height. Small stones may be used between the header but they are not smaller than 50 mm in thickness. Two or three stone pieces may be placed one above the other to maintain the uniform thickness of a course. The quoins have the same height as that of the course and are about 500 mm long. (Fig. 5.50).



Uncoursed Random Rubble
Fig 5.49.





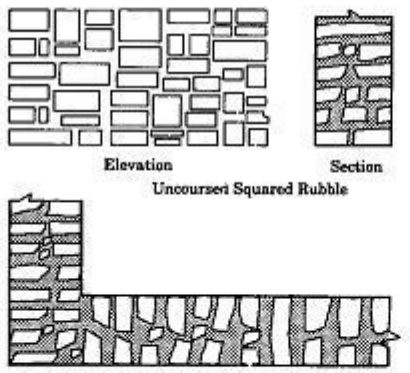
Coursed Random Rubble
Fig. 5.50

***(c)* Uncoursed Squared Rubble.**

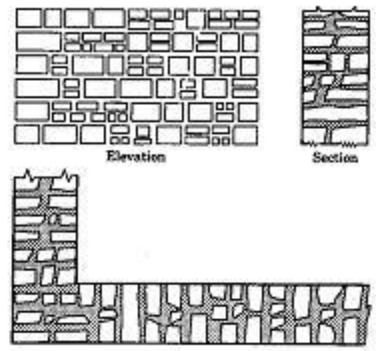
The stone blocks are made roughly square with hammer blows. They are of varying sizes and placed in irregular pattern. The facing stones are generally given hammer dressed finish or tooled finish. A more uniform joint is made in the facing and better appearance is obtained by arranging stones in series. Large sizes stones are employed as quoins and the use .of chips in the bedding is avoided (Fig. 5.51).

***(d)* Coursed Squared Rubble.**

The stone blocks used the facing are made square with hammer blows and the backing is constructed in uncoursed random rubble and bonded to the facing. The facing stones are laid in courses of uniform height. The height of courses may be reduced in the upper portion of the wall but in no case the lower course should be thinner than the upper courses. The construction of backing and facing should be carried out simultaneously. For thicker walls flat bedded stones are laid on their beds in the hearting. Stone chips may be used when the mortar used is very thick but no dry hollow space should remain in the masonry (Fig. 5.52).



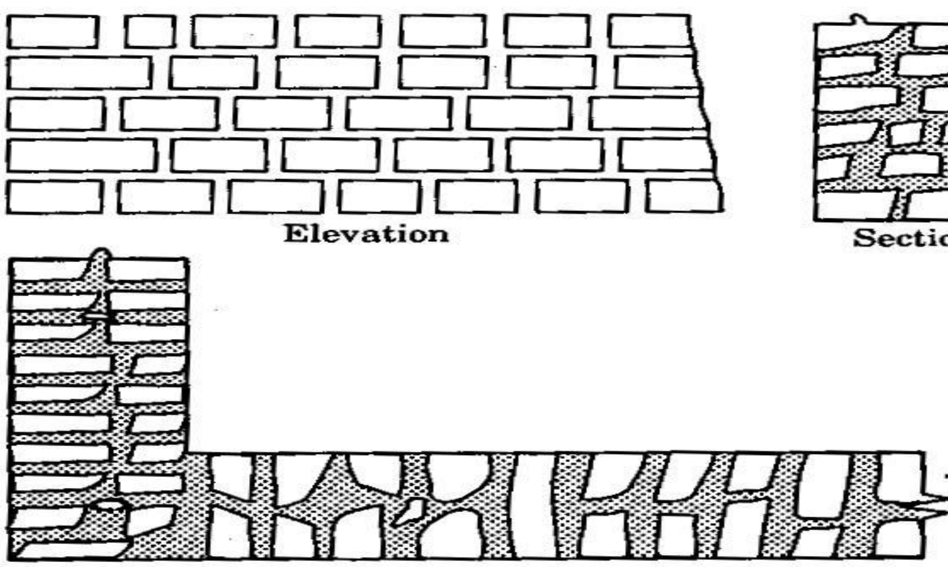
Plan of Course
Fig. 5.51.



Plan
Coursed Squared Rubble
Fig. 5.52.

***(e)* Built to regular courses.**

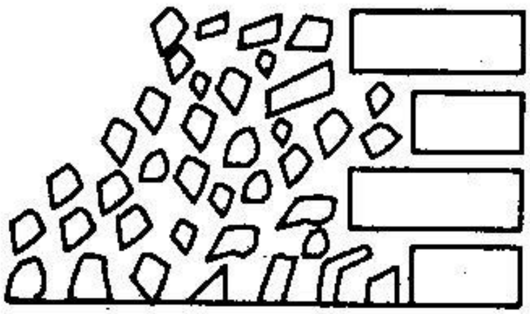
All stones used in a course are of uniform height. The height of a course should not be less than 150 mm. No course should be thicker than the course below it. The stone beds are hammer or chisel dressed for a minimum depth of 100 mm from face. Stone blocks are more in breadth than the height. Through stones are put at 2 metres distance in each course. Stones are placed in such a way, that vertical joints of two consecutive courses do not coincide with each other. The quoins have the same heights as the height of the courses (Fig. 5.53).



Plan
Built to Regular Courses
Fig. 5.53.

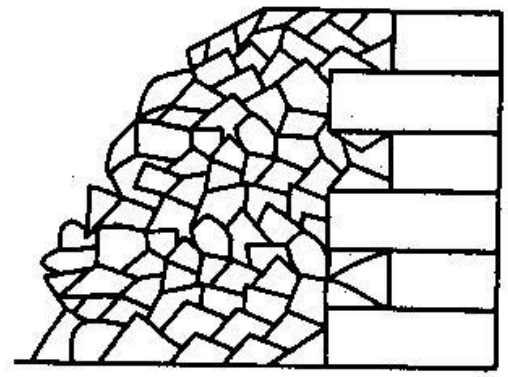
(f) Polygonal Rubble.

As the name indicates the stones are roughly dressed as irregular polygons. The stones are placed to break joints as much as practicable and long vertical joints are avoided in the facing. Small chips are not used to support the facing stones. In inferior type of work the thickness of mortar joint is more but in superior work the thickness of mortar joint is very fine and' uniforms (Figs. 5.54 and 5.55).



Inferior Type

Fig. 5.54



Superior Type

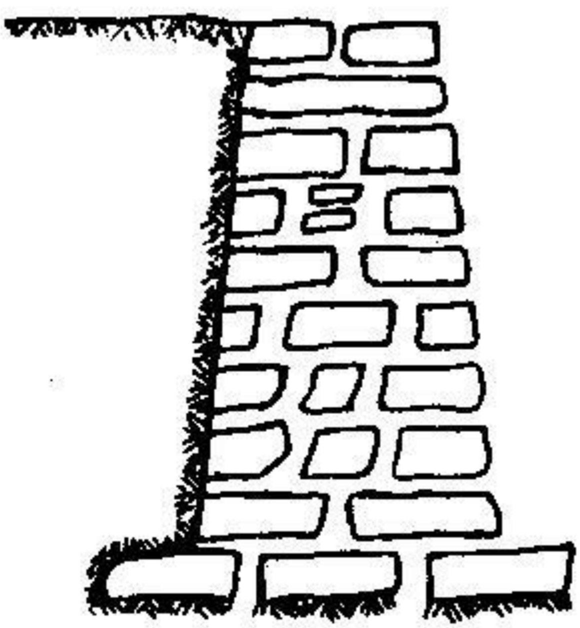
Fig. 5.55

Polygonal Rubble

***(g)* Dry Rubble.**

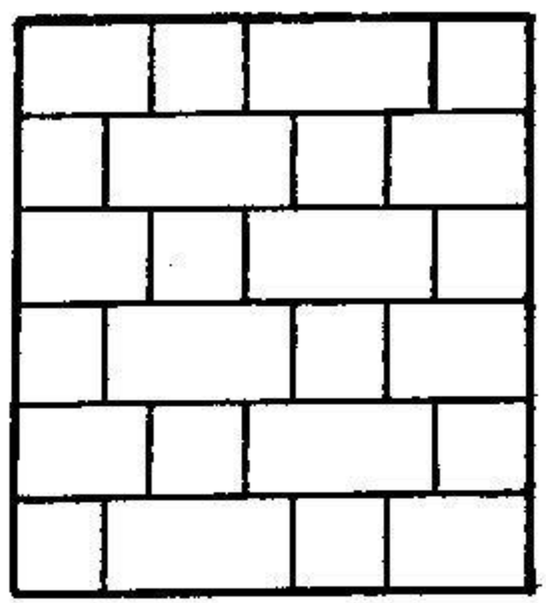
It is random rubble masonry without any mortar.

Stone blocks are kept in courses as usual without laying mortar in between them. Hollow spaces around stones are tightly packed by smaller pieces of stones. The stones employed in such work are carefully selected to make the walls stable. They are roughly hammer dressed and have maximum bedding area. Through stones are provided in each course at an interval of 2 metres. Dry rubble masonry is employed in the construction of retaining walls, pitching earthen dams and canal slopes, etc. (Fig. 5.57).



Dry Rubble Retaining Wall

Fig. 5.57



Ashlar Fine

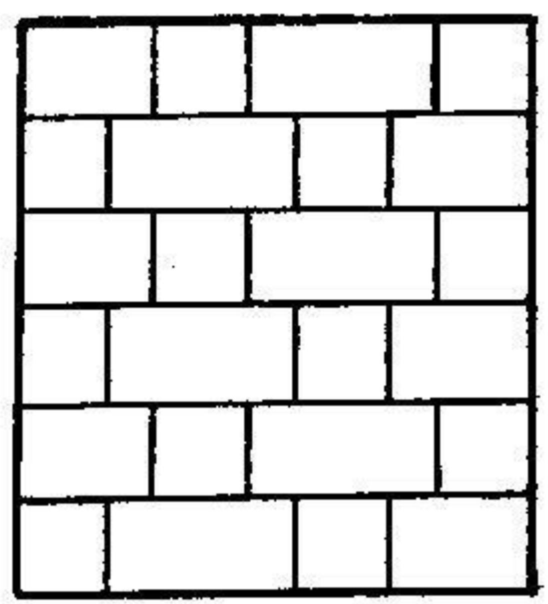
Fig. 5.58

(2) Ashlar Masonry

This type of masonry is built from accurately dressed stones with uniform and very fine joints of about 3 mm thickness. This is the best quality of masonry work and too much expensive. Different type of appearance can be obtained by placing the stone blocks in the desired patterns. The backing of thickness walls may be constructed either in ashlar masonry or rubble masonry. The sizes of stone blocks to be used are selected in conformity with the size of the wall to be constructed.

***(a)* Ashlar fine**

In this type of stone masonry the stone blocks are finely chisel dressed, on all beds and side joints. The faces are perfectly true shape and finish to get the desired pattern. The construction is carried out in proper bond and the joints thickness never exceed 3 mm. Courses are properly maintained and it is seldom less than 300 mm and it is a general practice to keep the height of courses uniform throughout the work. The face stones are normally laid as header and stretchers alternately. Though stones extend to the full thickness of wall when the wall thickness is less than 750 mm. The height of the stones used is never less than their breadth. The length of the stones is never less than twice its height. All the joints are either vertical or horizontal (Fig. 5.58).



Ashlar Fine

Fig. 5.58

***(b)* Ashlar rough tooled**

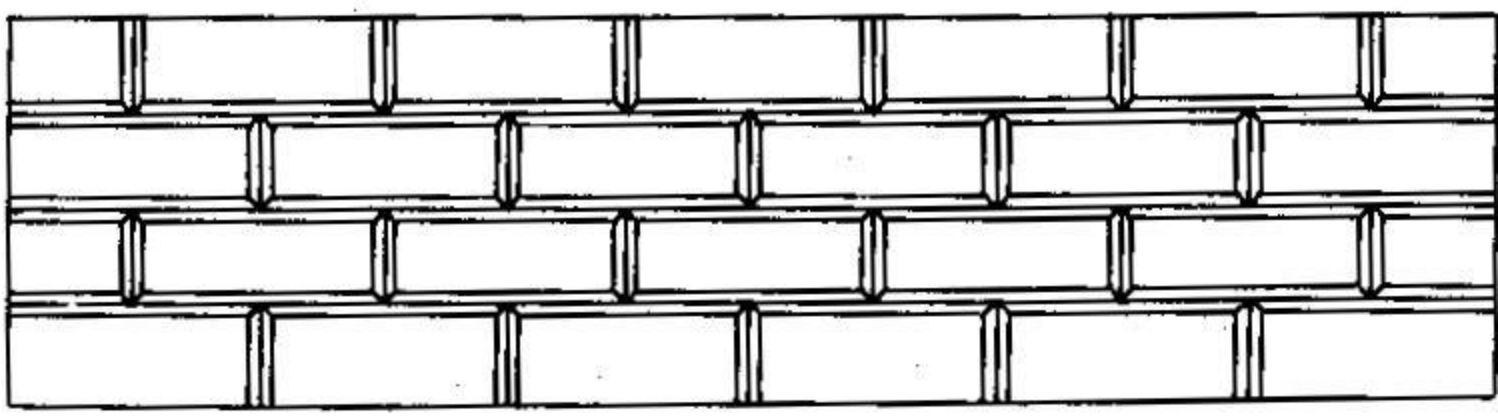
The beds and sides of the stone blocks are finely chisel dressed and the exposed faces of the stone have a fine dressed chisel drafting of about 25 mm wide all round the edges. The space of face stone enclosed by the chisel draft is roughly tooled. Thickness of the joints can be upto 6 mm in such type of works. Other specifications are similar to the ashlar fine masonry.

***(c)* Ashlar rock or quarry faced**

The exposed faces of the facing stones between the chisel drafting all round, are left undressed as obtained from the quarry. However, the projections more than 80 mm are broken by hammer. Other specifications are similar to the ashlar rough tooled masonry.

(d) **Ashlar chamfered**

It is very similar to the quarry faced masonry with a little difference. The edges round the exposed face of each stone block are bevelled at an angle of *45°* for a depth of 25 mm. The remaining exposed surface of the facing is left undressed with projections restricted to only 80 mm (Fig. 5.59).



Ashlar Chamferred

Fig. 5.59.

(e) **Ashlar block in course.**

This type of construction is commonly employed in heavy engineering works, retaining walls, sea-walls, temples, bridges etc. This type of masonry is an intermediate approach between the rubble masonry and ashlar masonry. The stone faces are hammer dressed and the depth of courses is between 200 to 300 mm. The mortar joints can have a thickness upto 6 mm.

(f) **Ashlar facing**

The facing is constructed in stone masonry and the backing may be in brick masonry, rubble masonry or concrete masonry. This type of composite construction reduces the expenditure to a great extent. The facing stones are rough tooled or chamfered and the height of courses is never less than 200 mm. The width of the stone is 1.5 times its height.'. The bonding stones extend to the full width of the wall when wall thickness is less than 750 mm and for thicker walls, the bonding stones should overlap each other by at least 150 mm. In each course they are put 2 metres apart. The facing and the backing are constructed simultaneously (Fig. 5.60).

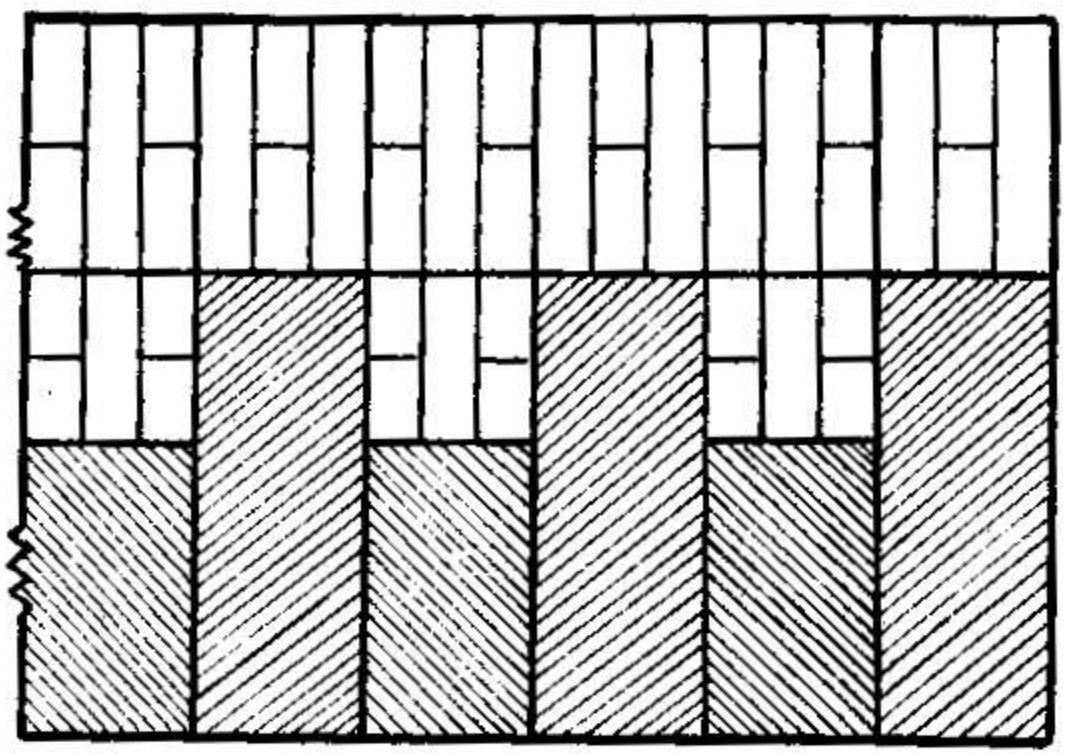


Fig. 5.60.

Some Structural Members Built of Stones

(1) Plinth and plinth courses.

The horizontal projecting course at ground level is known as plinth. Sometimes it is also used to denote the height of ground floor level from the ground. The pitch courses are provided to protect the inside of the building from rain water besides improving the architectural beauty. The plinth courses can be constructed with stones or special moulding for better architectural appearance. Little slope is provided at the top surface of the stone to drain of the rain water.

(2) Steps.

Steps are provided at the entrance of the building to rise from ground level to the plinth level. The steps can be constructed in the stone masonry but now-a-days they are rarely used. Stone steps can be provided various architectural shapes. Stones used for such purpose should be hard, tough and durable. It should be able to take polishing.

(3) Window Sills.

Window sills are provided to drain out water falling on the window. They may be constructed in brick masonry or stonemasonry. Special moldings are given to check water from falling on the wall. It can also serve as a support for the vertical members of wooden window frames.

(4) Parapets and Copings.

They can also be constructed in stone masonry. Rubble masonry or ashlar masonry can be used in their constructions and this depends on the type of masonry used for the surrounding works. Copings are made from stones in various shapes. Throating is provided to prevent water from trickling down the face of the wall. Mouldings can be provided to the face end of the copings to improve the appearance.

(5) Miscellaneous.

Cornice, string, courses frieze, flooring, etc. can also be constructed from stones. They are mainly used to enhance the architectural beauty of the buildings.

Maintenance of Stone Work

(1) Stains. Stains are of various types and origin. They can be removed easily if they are not old and their origin is known. Iron stains can be removed by washing the stained area with solution of 1 kg. of oxalic acid mixed in 10 litres of water. The surface is rubbed with brush and clean water after 3 to 4 hours. To remove Very dark and deep stains, one part of sodium citrate is mixed with six part of water and this solution is sprinkled on the stained surface. Finally the surface is coated with a thin layer of sodium hydrosulphate crystals. After 1-2 hours the surface is cleaned with fresh water. Smoke and fire stains are cleaned by rubbing the stained surface with powered pumice. This treatment is done several times to obtain a clean surface. Oil stains are removed by scrubbing the surface with benzene or petrol.

(2) Efflorescence. This type of defect is common with certain types of mortars. It can be checked by providing proper drainage of the building. It can be removed by scrubbing the surface with water and hard brush. Sometimes 10% solution of muriatic acid is used in place of ordinary water. But the surface is finally cleaned by the fresh water.

(3) Repair of cracks. Cracks in the stone masonry are repaired by grouting. Grouting is only done after the settlement causing the cracks has stopped. Small cracks are cleaned by wire brush and thin blade. Cement paste ofthick consistency is forced into the cracks by a cement gun made for this purpose. Large cracks are racked out and an inverted V-groove is formed for a minimum depth of 10 mm. Cement mortar (1 : 2) grout is forced into the cracks. Sometimes aluminium powder is added in the grout to make a tight fit for the grout.

(4) Water-proofing. Colourless water-proofing compounds are used as washing coat to the stone masonry to keep them free from efflorescence, damp and frost action. Water proofing materials having resins are not suitable for stone masonry. Water-proofing substances derived from heavy petroleum distillates, fatty oils or insoluble soaps are best suited.

Concrete block is the precast masonry unit made out of homogeneous concrete mix whether hollow or solid, intended to use in construction of load bearing walls and non-load bearing walls. Now-a-days concrete blocks are widely used for the construction of building walls because of their large sizes, uniformity in design, easy handling and placing, and attractive appearance. Various materials and different methods of manufacture of the blocks are being developed regularly. The production is quick and quality is controlled by the adoption of machine with large manufacturing capacity. The curing is also very fast when steam curing is adopted. There are various types of concrete or masonry units which varies with the shapes and sizes in which they are produced.

The block walls may be finished by a water proof rendering in order to provide a satisfactory external appearance. The advantage of using blocks is that by using units larger than bricks, the amount of mortar necessary for fitting the joints is greatly reduced. For instance, in common brick masonry works, the amount of mortar required is estimated to be 1/3 of the total volume of the wall. When using larger size blocks, for instance 20x20x40 cm blocks, the quantity of mortar required is only 5-10% of the total wall volume.

Blocks are generally economical to by and economical from workmanship point of view. For example, a single laborer might work more areas than he could work on brick. The block may be either solid or hollow. A block wall surface may be finished either by painting or some other method of plastering in the same way as stone or brick walls. The finishing material to be chosen depends on the kind of surface of the blocks as well as on climatic conditions.

According to the recommendation for the Concrete Association of India, the face thickness of the concrete blocks should not be less than 50 mm. It is suggested that the cores should be at least two in number and they should have preferably oval shapes.

The following are the various types of surface finishes:

(1) Common finished surface. Coarse to fine texture is obtained by changing the mix properties and by the selection of suitable aggregates. Colored aggregates may be also used. If desired, the aggregates can be exposed by the treatment of the surface with dilute acids or by scrubbing the surface while the concrete has not set completely.

(2) Glazed finish. The concrete are given glazed finish in the manner similar to glazing of tiles. These are generally used for decorative works and are water-resistant.

(3) Slumped finish, A concrete of desired slump is poured into the forms. As the forms are removed, the concrete block slightly slumps down. This produces exterior surface and are used on the face work.

(4) Specially faced block. Sometimes better and shining materials like marble are used on the face of the concrete block which increases the architectural appearance of the blocks. They have shining and smooth appearance and can be used at several places like hospitals, cinemas, public buildings, offices, etc.

(5) Split blocks. They are produced by dividing the blocks into two parts lengthwise. The surface obtained is rough and aggregates are visible on face. This makes it essential to select suitable aggregates and to have good blending. These are used for decorative face works.

(6) Colored finishes. To enhance the appearance sometimes various types of pigments are mixed in the concrete used for the production of hollow blocks. At times the colorful paints are also employed on the face of the blocks to have a glittering appearance.

Manufacture of Concrete Blocks

The procedure of manufacture is similar to that of ordinary concrete masonry. However, the following facts need special attention:

(1) The aggregates should be properly graded. Generally, the mixture of fine aggregates (60%) and coarse aggregates 6 to 12 mm size (40%) is used. Use of very fine sand is not desirable. The fineness modulus of the mixture should range from 2.9 to 3.6.

(2) In concrete mix 1 : 6 cement to combined aggregate ratio should be maintained.

(3) The hollows are kept vertical when molding is done by hand.

The concrete should not possess a very lean consistency. The concrete block is removed from the mould when it has sufficiently set.

(4) The block is kept undisturbed on the molding platform for at least 24 hours.
(5) The better finish and high strength machine molding should be adopted.
(6) The blocks are cured under shade for at least 24 hours. Then the blocks are kept immersed in water for at least seven days. They are dried for about one month after curing before they are used.
(7) Proper compaction should be done carefully.
(8) The minimum strength of a block should be 30 kg per sq. m.

Laying of Concrete Masonry
Walls.
The concrete blocks are available in standard sizes. Hence it is essential to check whether any cutting of blocks is required or not ? This is done by laying a course of concrete blocks without any mortar between the desired lengths of the wall. They are placed with suitable clearance meant for the mortars.
First of all, a mortar bed is spread on the foundation concrete. It is leveled and smoothened to attain uniform thickness everywhere. The corner block is placed accurately in its position. Mortar is applied to the ends of other blocks and are placed by the side of the corner in turn.
Similarly, all the corners are laid and the in-between gap is filled up. Then the level of the masonry wall is checked. The verticality of the other courses is checked by plum bob.
The successive courses are laid in such a way that verticality of the joints is broken. A storey rod is used to guide the courses. The face of the masonry is pointed by running a tool along the joints after the mortar becomes stiff but before it has set. The surface of the joint may be V-shaped or concave.
Only well-dried blocks are used in the construction. The blocks are not immersed in water before laying in the walls. Only sides of the joints are slightly wetted. Rich mortar should be used and the joints are about 5 mm to 20 mm thick. At the junction of load bearing and non-load bearing walls, corrugated metal ties are used. The joints between the two walls are not inter-bonded.
Columns
Columns are either built as an integral part of the walls or built separately. They are constructed of standard stretcher and corner blocks. The hollows within the blocks are generally filled up with concrete. (Fig. 8.12).
Window and Door Openings. The blocks used in jambs have one hollow near the opening which is normally filled with concrete. The door and window frames are fixed with screws to wooden plugs left in the masonry and fixed in the lintel with small dowels of mild steel. A course of solid concrete block masonry is provided under the doors and windows, which is inserted into the adjacent walls to a distance of at least 300 mm on either side. Sometimes a precast concrete sill of solid section is also used. Lintels are formed of hollow channel shaped blocks filled with concrete and have steel reinforcement at their bottom surface.
Expansion Joints. Due to the expansion and contraction of the blocks, the masonry may develop cracks. Therefore, controlled joints are introduced at definite intervals (at about 5 to 10 meters spacing). These restrict the movement of the concrete masonry units. They are placed at the junctions of load bearing and non-load bearing walls or at the junctions of walls and columns, etc. There are several types of controlled joints. At each joint, an elastic compound consisting of a mixture of chalk, sand and linseed oil is used. This

may be covered by the cement to match the colour. The thickness of the joint is 5 to 10 mm. Two G. 1. strips 150 x 50 mm in size is provided at every alternate joint for better bond with the main walls.

Reinforced Walls. Steel reinforcement may be placed at the horizontal joints for developing higher strength in walls. The expansion cracks due to moisture and temperature changes are also restricted with the provision of steel reinforcement. Two horizontal bars of 6 mm diameter are provided one each on the face of the wall. This reinforcement may be curtailed at the top and bottom courses of window or door openings. Sometimes, welded steel mesh is also employed as reinforcement of walls.

walls.

Damp Prevention of Exterior Walls

Walls constructed of good concrete are able to prevent free leakage but the water may penetrate through the joints. Two coats of neat cement slurry or 10 mm thick plaster of 1 : 4 cement mortar makes the masonry reasonably water-proof. If painting on walls has to be done, it should be done on completely dry walls. Dampness can be also checked by placing suitable drip courses, proper window sills and by making the joints properly.

Hollow concrete block masonry is employed in domestic buildings, schools, churches, and other public buildings. It is very suitable for low cost houses.

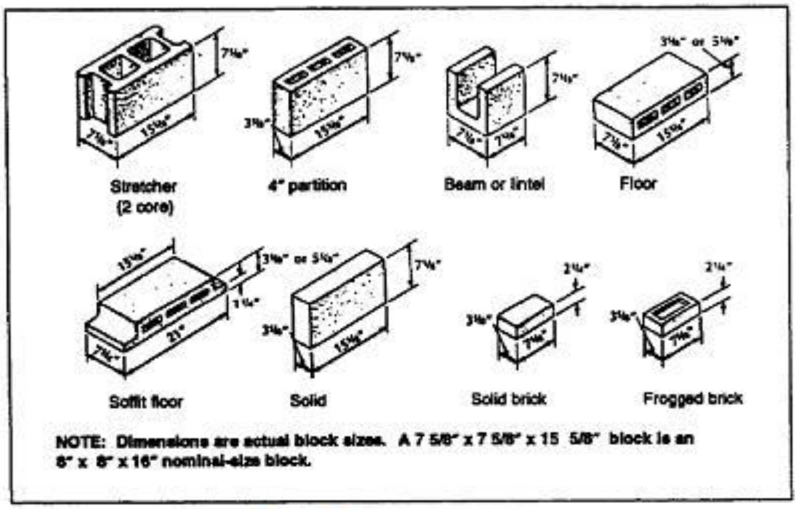


Figure 2-1. Types of concrete blocks

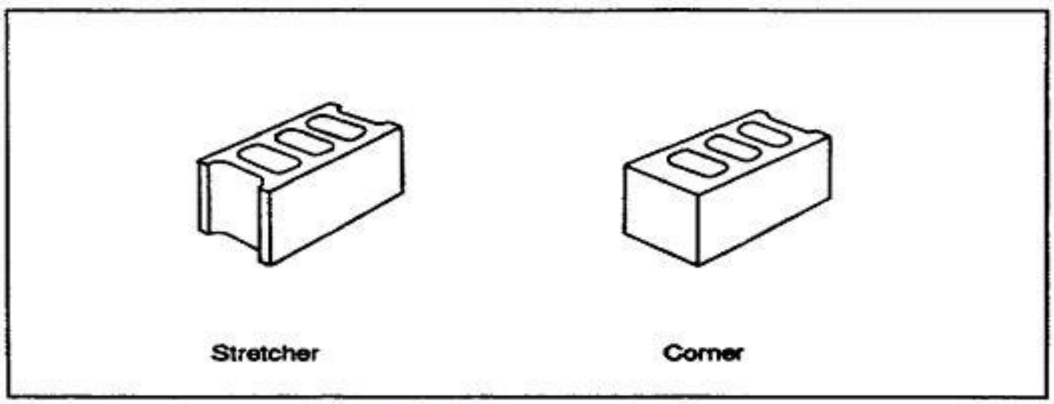
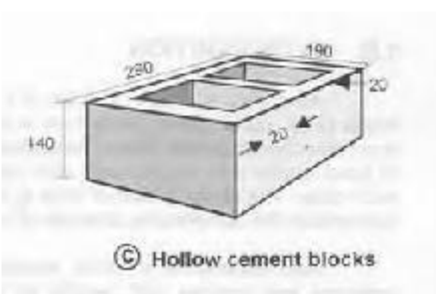
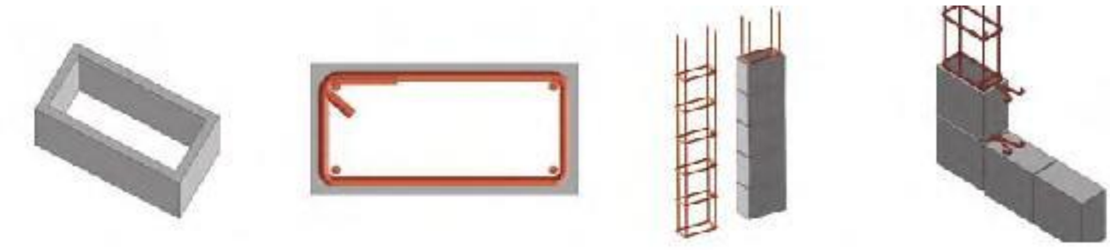


Figure 2-3. Standard blocks

FULL HCB

The full hollow block used in the construction of walls of condominium buildings has a size of L=32 cm x W=16 cm x H=19 cm. This size of the HCB is reduced in comparison to the usual sizes used in Ethiopia.





Walls of monolithic construction could either be load bearing or not. The modern concrete wall and the primitive mud wall are composed of materials, which are placed in a plastics state into a mold. When the material is set, the mold is removed, leaving a monolithic wall.

Concrete walls can be plain or reinforced. The two great advantages of concrete walls are its strength and the freedom it gives in design. Thin section of reinforced concrete wall can carry comparatively high loads. For example a reinforced concrete wall of 15cm thick will take the loads from a building several storey in height. Freedom of design is expressed by the ease with which it can be made to take up curved or other complex shapes. Because concrete walls are generally thin section they require heat insulation in area of cold climate, like in North Europe. Because not only they are generally thin but also because of the inferior heat and cold insulating properties of the concrete, and the insulation procedures involved, concrete walls are both expensive and not easy to carry out in such areas. Reinforced concrete wall thickness may be from 8cm up, and the cost is generally higher than for a stone wall but the strength of the structure is considerably higher.

Panel walls are used wherever the load bearing function of the wall are taken over by a framework, which leaves the spaces in between the uprights to be filled. Various types of composite walls have been designed for use in framed structures, principally with the object of reducing weight. Generally they consist of two or more layers or sections each of which fulfills a specific purpose. There are for instance, those, which consists of sheeting (panel) supported on alight sub-frame, which may span vertically from floor to floor, or horizontally from post-to-post, across the opening in the main fame.

Some of the requirements, which would be fulfilled by composite walls, are resistance to wind pressure; protection against wind and rain and providing satisfactory appearance. Thermal insulation and interior finish are generally given by an inner lining quite independent of the outside skin.

Unlike brickwork or masonry, panel walls have no intrinsic or characteristic performance, but are infinitely variable. By the appropriate choice and design of its different elements, the composite wall can be made to have any required combination of properties within wide limits.

The architectural character of a wall of framed construction is very different from that of a wall built of brick work or masonry. The dominant feature of the panel wall is the pattern set up by the framing; while a wall of brick or masonry, on the other hand, is essentially a mass, pierced here and there by openings. They may consist of stiff sheet materials such as plywood or weather board fixed to timber or other frames, or to a continuous core material such as a foamed plastic.

The function of the internal wall is to separate the internal spaces within a building into separate rooms. Sometimes the internal walls are also used to give support to the floors above, or to the roof. Such walls are load bearing and form part of the structural system of the building. Walls which are not load- bearing and whose sole function is the division of space are sometimes called partitions.

Partition walls

Partition walls are thin internal walls whose main function is to divide the space within a building into rooms or areas. These can be load-bearing or non load-bearing but with the sole purpose of division with strength and stability, sound insulation and fire resistance.

The various types of non load-bearing partitions include brick partitions; hollow clay block partitions; glass portions; concrete partitions; metal lath partitions; solid plaster partitions; corrugated sheet partitions and timber partitions.

Types of internal wall

As mentioned in the previous section, internal walls can be load bearing or non-load bearing. Load bearing walls are nearly always constructed or bricks or blocks of concrete. They generally fulfill the sound-proof and fire proof requirements. Non-load bearing internal walls are generally of the panel type.

For a load bearing internal wall, strength is, of course, an important factor in design, a partition, on the other hand, need only be strong enough to support itself under normal conditions of service. Weather exclusion and thermal insulation do not arise as criteria in the design of internal wall. Instead sound insulation and fire resistance are important requirements. An internal wall separating two adjoining spaces must often provide a barrier to the passage of sound from one to another.

A cavity wall consists of two separate walls called leaves or skins of brickwork with a cavity in between and connected together by metal ties or special bonding bricks. This type of construction is ideally suitable for places where prevention of dampness from exterior, high insulting value against heat and sound and economy are desired.

The two leave of a cavity wall may be of equal thickness if it is a non-load-bearing wall or the thickness of the inner leaf may be increased to meet the desired structural requirements. The inner and outer leaves of the wall should not be less than 10cm in thickness throughout the height of the wall.

For a cavity wall to be effective, it is absolutely essential that the inner leaf is entirely disconnected from the outer leaf, except for ties. The cavity varies from 4-10 cm. the inner and outer leaves of the wall are securely tied together with suitable bonding ties of adequate strength. Strong non-corrodeable ties of wrought iron or mild steel thoroughly galvanized, dipped in hot tar and sanded are used. Copper or bronze metal ties are used whenever excessive corrosion is anticipated. These ties should be placed at intervals not exceeding 1 m horizontally and 40 cm vertically. Special bonding bricks of terracotta are also sometimes used as ties. A cavity wall is built with an outer facing of specially selected face brick and the inner leaf is made of common bricks. The ties are placed wherever the joints coincide.

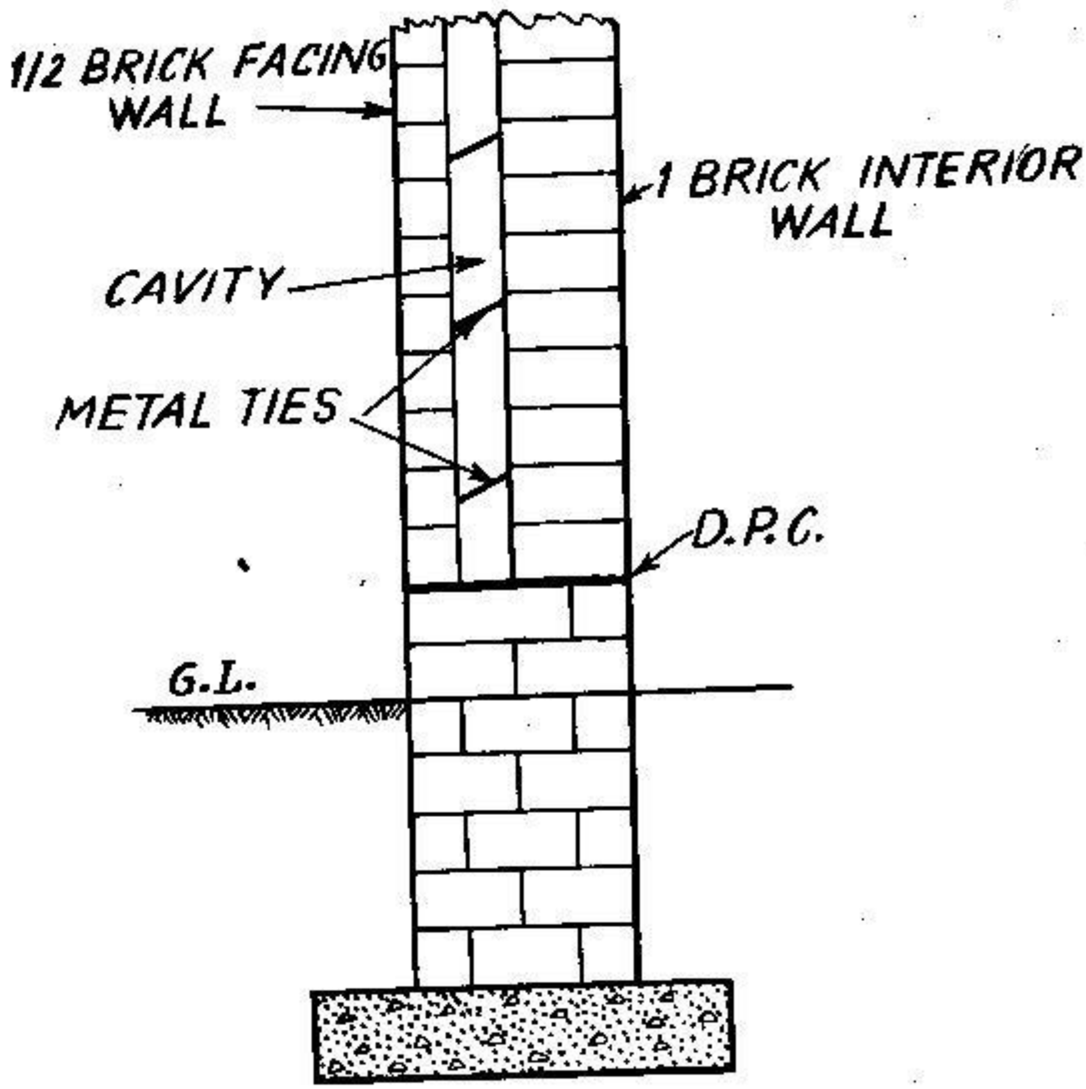
The cavity wall may extend down to the concrete foundation, which means that water in the soil can pass into the inner face of the wall

Advantage of Cavity wall

Damp prevention: For instance a 20cm solid brick wall will not prevent dampness but 10cm inner and outer leaves and 6cm cavity in between will prevent dampness effectively.

Insulation: a cavity wall reduces the heat transmission from external to internal faces or vice versa. Thus the room will be warmer in winter and cooler in summer.

Acoustics: Cavity wall reduces sound and noise pollution.



Openings in Walls

Openings are invariably left in the walls for the provision of doors, windows, cupboards, etc. These openings are bridged by the provisions of either a lintel or an arch. Thus both lintels as well as arches are structural members designed to support the loads of the portion of the wall situated above the openings. The ancient Greeks used post and lintel construction to erect many of their outstanding structures. Stone was used as the primary building materials, therefore its great weight and its weakness in flexural strength considerably limited the application of post and lintel construction.

ARCHES

An arch is normally a curved member composing of a mechanical arrangement of wedge shaped building units up holding each other by mutual pressure of their own weight and maintained in equilibrium by reaction from supports called abutment However, arches of steel or reinforced concrete are built in single units or rigid nature, without the use of wedge shaped units. Bricks or masonry arches may be flat.

Typical elements of an arch and the following technical terms are used in arch work.

Intrados: This is the inner curve of an arch.
Soffit: It is the inner surface of an arch. Sometimes,
Intrados and soffit are used synonymously.
Extrados: It is the outer curve of an arch.
Voussoirs: These are wedge shaped units of masonry, forming arch.
Crown: It is the highest part of extrados.
Key: It is the wedge shaped unit fixed at the crown of the arch.
Spandril: This is a curved-triangular space formed between the extrados
And the horizontal line through the crown.
Abutment: This is the end support of an arch
Skew back : This is the inclined or splayed surface on the abutment, which is so prepared to receive the arch springs.
Springing points: These are the points from which the curve of the arch springs.
Springing line: It is an imaginary line joining the springing points of either end.
Springer: It is the first voussoir at springing level and as immediately adjacent to the skew back
Arcade: It is a row of arches in continuation
Pier: This is an intermediate support of an arcade.
Haunch: It is the lower half of the arch between the crown
Ring: It is a circular course forming an arch. An arch may be made of one ring or more than one ring.
Impost: It is the projecting course at the upper part of a pier or abutment to stress the springing line
Bed joint: These are the joints between the voussoirs, which radiate from the centre.
Centre or striking point: This is the geometrical centre point from where the arches forming the extrados, arc rings and intrados are described or struck.

Span: It is the clear horizontal distance between the supports,

Rise: It is the clear vertical distance between the highest point on the intrados and the springing

Depth or height: It is the perpendicular distance between the intrados and extrados.

Thickness (or breadth of soffit): This is the horizontal distance, measured perpendicular to the front and back faces of an arch

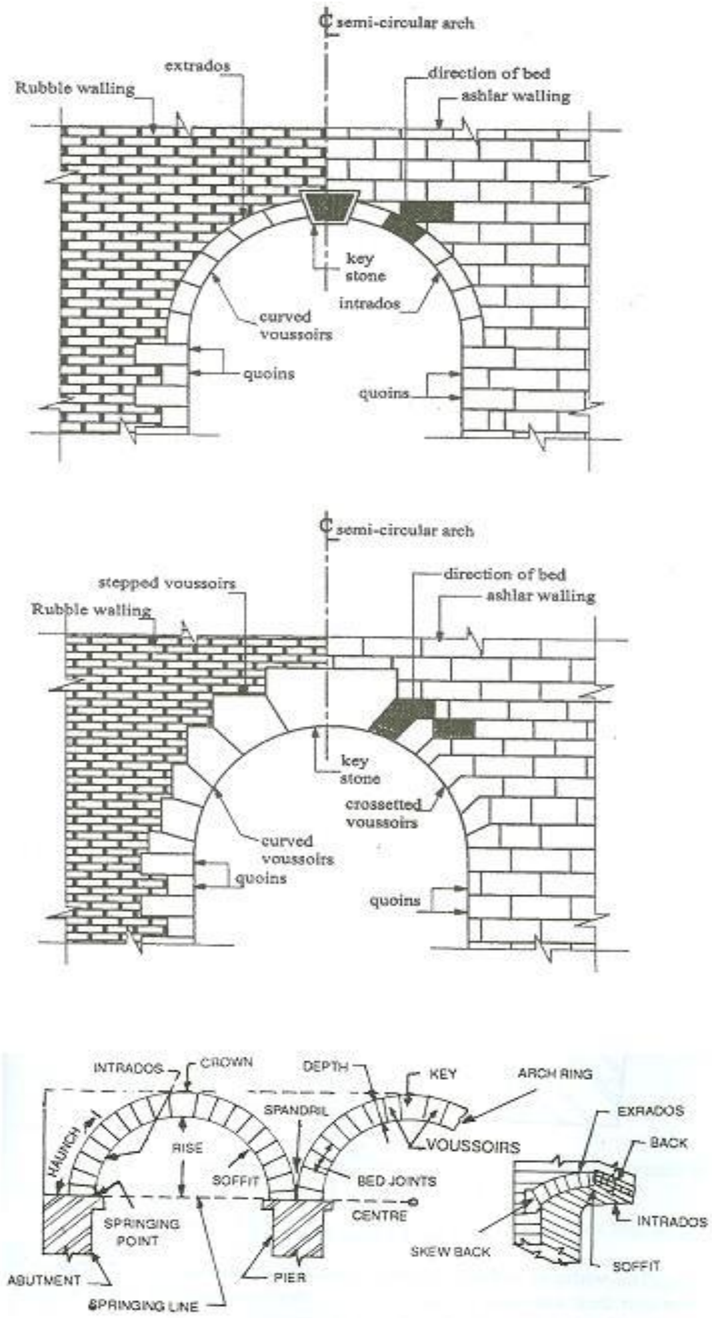


Fig. Parts of an arch

Different types of an arch:

1. Based on construction material:

2. Stone arch
3. Brick arch
4. concrete arch
5. Metal arch
6. Timber arch

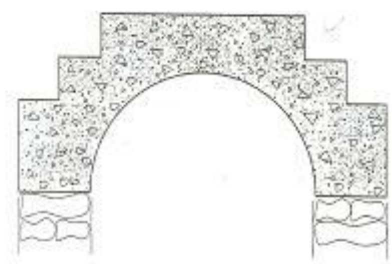


Fig. Typical concrete arch lintel

A) Based on geometry

1. **Circular arch(a)**
2. **Horseshoe arch(b)**
3. **Half-circular arch©**
4. **Stilted arch(d)**
5. **Quarter arch(e)**
6. **Flat arch (f)**
7. **Parabolic(g)**
8. **Elliptical(h)**

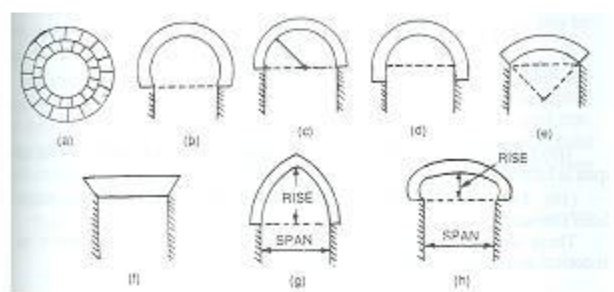


Fig. Different Types of arches based on their geometry.

LINTELS

A lintel is a horizontal member which is placed across the opening. Lintels are easy to build and the supporting walls need not be very strong. However, a proper bearing for lintel ends is very necessary. At least 10cm length of bearing is a minimum requirement. If the span of the lintel exceeds 1.2m, the end bearing should have a minimum of 15cm. For very long spans, the bearing for the lintel end should equal at least to its depth.

Types of Lintel

Lintels are classified according to the materials of their construction.

Timber lintels: Timber lintels are the oldest type of lintels and are commonly used nowadays. They cannot take greater load and are vulnerable to fire. Timber lintels are costly wherever timber is not available and subject to decay if not properly ventilated.

Stone lintels: stone lintels are not widely used, as the type of stone needed for this work is not available at all places. Dressed stone lintels give good architectural appearance. Stone is very weak in tension and cracks if subjected to vibratory loads. Hence stone lintels should be used with caution where shock waves are quite common.

Brick lintels: Plain brick lintels are not structurally strong and they are not used in large openings and where loads are heavy. Instead, reinforced brick lintels are used where loads are heavy and/ or span is more.

Steel lintels: Steel lintels are provided where the opening is large and where the super imposed loads are also heavy. When used singly, the steel joist is either embedded in concrete or cladded with stone facing so as to increase its width to match with the width of the wall.

Reinforced: Reinforced concrete lintels have replaced practically all other types of lintels because of their strength, rigidity, fore resistance, economy and ease in construction. Reinforced concrete lintels can be used on any span and they may be cast in place or are also available as precast units.

Assignment 6

Describe different types of brick bonding used for construction of wall.