CHAPTER 04

Bricks and Brick Masonry

4.1 Composition of Good Brick Earth

Following are the constituents of brick earth:

1. **Alumina**
   - It is the chief constituent of every kind of clay. A good brick earth should contain about 20 to 30 per cent of alumina.
   - This constituent imparts plasticity to earth so that it can be moulded. If alumina is present in excess, raw bricks shrink and warp during drying and burning.
2. **Silica**
   - A good brick earth should contain about 50 to 60 per cent of silica. Presence of this constituent prevents cracking, shrinking and warping of raw bricks. It thus imparts uniform shape to the bricks.
   - Excess of silica destroys the cohesion between particles and bricks become brittle.
   - Durability of brick depends on proper proportion of silica.
3. **Lime**
   - Lime not exceeding 5% is desirable in a good brick earth.
   - It should be present in a finely powdered state and not in lump.
   - Lime prevents shrinkage of raw bricks. Sand alone is infusible. But it slightly fuses at kiln temperature in presence of lime.
   - Excess of lime causes the brick to melt and hence, its shape is lost. Lumps of lime are converted into quick lime after burning and this quicklime slakes and expands in presence of moisture. Such an action results in splitting of bricks into pieces.
4. **Oxides of Iron**
   - About 5 to 6 per cent is desirable in good brick earth. It helps lime to fuse sand. It also imparts red colour to bricks.
   - Excess of oxide of iron makes the bricks dark blue or blackish.
   - If quantity of iron oxide is less then bricks become yellowish.
5. **Magnesia**

   A small quantity of magnesia in brick earth imparts yellow tint (colour) to bricks and decreases shrinkage. But excess of magnesia leads to the decay of bricks.

4.1.1 Harmful Ingredients in Brick Earth

1. **Lime**
   - It causes unsoundness in brick if present in excess amounts.
2. **Iron pyrites**
   - If iron pyrites are present in brick earth, bricks get crystallized and disintegrated during burning.
3. **Alkalies**
   - These are mainly in the form of soda and potash.
   - The alkalies set as a flux in the kiln during burning and they cause bricks to fuse, twist and warp.
   - As a result, the bricks get melted and they loose their shape.
   - If the alkalies remain in bricks then bricks will absorb moisture from the atmosphere when they are used in masonry.
   - Such moistures, when get evaporated, leaves behind grey or white deposits on the wall surface, the appearance of the building as a whole then gets seriously hampered.
4. **Pebbles**

   The presence of pebbles or grits of any kind are undesirable in brick earth because they will not allow the clay to get mixed uniformly and thoroughly which will result in weak and porous bricks.
5. **Organic Matter**

   Presence of organic matter in brick earth assists in burning. But if such matter is not completely burnt, bricks become porous.

4.1.2 Classification of Brick Earth

The brick earth is classified in the following three categories:

1. Loamy, mild or sandy clay

Alumina	27%
Silica	66%
Lime and magnesia	1%
Oxide of Iron	1%
Organic matter	5%
Total	100%

2. Marls, chalky or calcareous clay

Alumina	10%
Silica	35%
Lime and magnesia	48%
Oxide of iron	3%
Alkalies	4%
Total	100%

3. Plastic, strong or pure clay

Alumina	34%
Silica	50%
Lime and magnesia	6%
Oxide of iron	8%
Organic of matter	2%
Total	100%

4.2 Manufacture of Bricks

Four distinct operations are involved:

1. Preparation of clay
2. Moulding
3. Drying
4. Burning

1. **Preparation of clay**

Clay of bricks is prepared in the following order:

(i) **Unsoiling:** The top layer of soil, about 20 cm in depth, is taken out and thrown away.

(ii) **Digging:** Clay is then dug out from the ground. It is spread on the levelled ground. Height of heaps of clay is about 60 cm to 120 cm.

(iii) **Cleaning:** Soil should be cleaned of stones, pebbles, vegetable matter, etc.

(iv) **Weathering:** Clay is then exposed to atmosphere for softening or mellowing. The period of exposure varies from few weeks to full season.

(v) **Blending:** Clay is made loose and any ingredient to be added to it is spread out at its top. It is carried out by taking small portion of clay every time and by turning it up and down in vertical direction.

(vi) **Tempering :** In the process of tempering, clay is brought to a proper degree of hardness and it is made fit for the next operation of moulding.

Water in required quantity is added to clay and the whole mass is kneaded or pressed under the feet of men or cattle. Tempering should be done exhaustively to obtain homogeneous mass of clay of uniform consistency. For manufacturing good bricks on a large scale, tempering is usually done in a Pug mill. Diameter of pug mill at bottom is about 60 cm and that at top is about one metre.

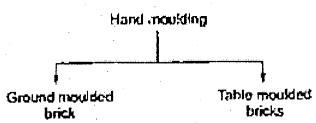
Do you know? The process of grinding clay with water and making it plastic is known as pugging.

2. **Moulding**

The clay which is prepared as above is sent for the next operation of moulding. Two types of moulding are hand moulding and machine moulding.

4.2.1 Hand Moulding

- In hand moulding, the bricks are moulded by hand i.e. manually.
- It is adopted where manpower is cheap and is readily available for the manufacturing process of bricks on a small scale.
- There are two types of moulds (a) wooden mould (b) steel mould.
- Steel mould is better than wooden mould.
- The bricks shrink during drying and burning. Hence the moulds are to be made larger than the size of fully burnt bricks.
- The moulds are therefore made larger by about 8-12% in all direction.



(a) Ground Moulded Bricks

- The ground is first made level and fine sand is sprinkled over it.
- The mould is dipped in water and placed over the ground.
- The lump of tempered clay is taken and it is dashed in the mould
- The clay is pressed or forced in the mould in such a way that it fills all the corners of mould.
- The bricks prepared by dipping mould in water every time are known as the slope-moulded bricks.
- Fine sand or ash may be sprinkled on the inside surface of mould instead of dipping mould in water is known as sand-moulded bricks.

(b) Table Moulded Bricks

- The process of moulding these bricks is just similar as hand moulded bricks.
- In this case the moulder (personnel) stands near a table of size about 2 m × 1 m.
- The bricks are moulded on the table and sent for the further process of drying.
- Efficiency of moulder decreases gradually because of standing at the same place for long duration.
- The cost of moulding is more than the hand moulding.

4.2.2 Machine Moulding

- The moulding may also be achieved by machines.
- This process is economical when bricks in huge quantity are to be manufactured at the same spot in a short time.
- Moulding machines are broadly classified in two categories viz. Plastic clay machine and Dry clay machine.

(i) Plastic Clay Machine

- Such machines contain a rectangular opening of size equal to length and width of a brick.
- The pugged clay is placed in the machine and as it comes out through the opening it is cut into strips by wires fixed in frames.
- As the bricks are cut by wire they are also known as the wire cut bricks.

(ii) Dry Clay Machines

- In these machines, the strong clay is first converted into powder form.
- A small quantity of water is then added to form a stiff plastic paste.
- Then paste is placed in mould and pressed by machine to form hard and well shaped bricks.
- These bricks are known as the pressed bricks and they do not practically require drying.
- They can be sent directly for the process of burning.

Do You Know ? The wire cut and pressed bricks have regular shape, sharp edges and corners. They have smooth external surfaces. They are heavier and stronger than ordinary hand-moulded bricks. They carry distinct frogs and exhibit uniform dense texture.

3. **Drying**

- Moisture content is brought down to 2% for the burning operation.
- The damp bricks, if burnt, are likely to get cracked and distorted.
- For drying, bricks are laid longitudinally in stacks of width equal to two bricks.
- A stack consists of eight or ten tiers. Bricks are laid along and across the stack in alternate layers. All bricks are placed on edge.
- The bricks are generally dried by natural process.

- When bricks are to be rapidly dried on a large scale then artificial drying may be adopted.
- In such a case, the moulded bricks are allowed to pass through special dryers which are in the form of tunnels or hot channels or floors.
- The temperature is usually less than 120°C and the process of drying of bricks takes about 1-3 days depending upon the temperature maintained in the drier.

4. Burning

- When the temperature of dull red heat of about 650°C is attained, the organic matter contained in the bricks is oxidized and also the water of crystallization is driven away, but heating of bricks is done beyond this limit for the following purposes:
  - (i) If bricks are cooled after attaining the temperature of about 650°C, the bricks formed will absorb moisture from the air and get rehydrated.
  - (ii) The reactions between the mineral constituents of clay are achieved at higher temperature and these reactions are necessary to give new properties such as strength, hardness and low moisture absorption.
- When the temperature of about 1100°C is reached, the particles of two important constituent of bricks clay, viz. alumina and sand fuse themselves together resulting in the increase of strength and density.
- Heating is not desirable and if the temperature is raised beyond 1100°C, a great amount of fusible glassy mass is formed and the bricks are said to the vitrified.
- The burning of bricks is done either in clamps or in kilns.
- The clamp is a temporary structure and is used for small scale production of bricks.
- Kilns are permanent structures and they are adopted to manufacture bricks on large scale.
- Burning imparts hardness and strength to bricks and makes them dense and durable. Bricks should be burnt properly. If bricks are over burnt, they will be brittle and hence, break easily. If they are under burnt, they will be soft and hence, cannot carry loads.

(a) Clamps

- A piece of ground is selected. Its shape in plan is generally trapezoidal. Floor of clamp is prepared in such a way that short edge is slightly in the excavation and wider edge is raised at an angle of about 15° from ground level.
- Fuel may consist of grass, cow dung, litter, husks of rice or ground nuts etc. Thickness of this layer is about 70 cm to 80 cm. Wood or coal dust may also be used as fuel.
- A layer, consisting of 4 or 5 courses of raw bricks, is then put up. Bricks are laid on edges with small spaces between them for the circulation of air.
- A second layer of fuel is then placed and over, it another layer of raw bricks is put up
- Total height of a clamp is about 3 m to 4 m.
- When clamp is completely constructed, it is plastered with mud on sides and top and filled with earth to prevent the escape of heat.

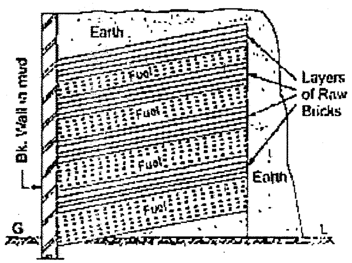


Fig. A typical brick clamp

- Clamp is allowed to burn for a period of about one to two months.
- It is then allowed to cool for more or less the same period as burning.

4.2.3 Advantages of Clamp Burning

1. The burning and cooling of bricks are gradual in clamps. Hence the bricks produced are tough and strong.
2. The burning of bricks by clamp proves to be cheap and economical.
3. No skilled labour and supervision are required for the construction and operation of clamps.
4. The clamp is not liable to injury from high wind or rain.
5. There is considerable saving of fuel.

4.2.4 Disadvantages of Clamp Burning

- Bricks are not of regular shape.
- It is a very slow process.
- It is not possible to regulate fire in a clamp.
- Quality of bricks is not uniform.

(b) Kilns: A kiln is a large oven which is used to burn bricks. The kilns which are used in the manufacture of bricks are of the following two types:

(i) Intermittent kilns
(ii) Continuous kilns

(i) Intermittent kilns: These may be over ground or underground and they are classified in two types:

(a) Intermittent up-drought kilns
(b) Intermittent down-drought kilns

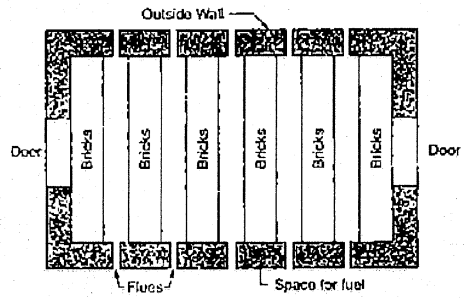


Fig. Intermittent kiln

(a) Intermittent up-drought kilns

- These kilns are in the form of rectangular structures with thick outside walls
- Flues are provided to carry flames of hot gases through the body of kiln.
- Top course is finished with flat bricks. Other courses are formed by placing bricks on edge.
- Strong fire is maintained for a period of 48 to 60 hours.

Disadvantages:

(i) The quality of burnt bricks is not uniform. The bricks near the bottom are over burnt and those near the top are under burnt.
(ii) The supply of bricks is not continuous.
(iii) There is wastage of heat as kiln is to be cooled down every time after burning.

(b) **Intermittent down-drought kilns**

- These kilns are rectangular or circular in shape.
- They are provided with permanent walls and closed tight roof.
- The working of this kiln is more or less similar to the up-drought kiln.
- But it is so arranged in this kiln that hot gases are carried through vertical flues upto the level of roof and they are then released.
- These hot gases move downward by the chimney drought and in doing so, they burn the bricks.

Advantages:

- Bricks are evenly burnt.
- The performance of this kiln is better than that of up-drought kiln.
- There is close control of heat and hence such kilns are useful for burning structural claytiles, terra cotta etc.

(ii) **Continuous Kilns:** These kilns are continuous in operation. This means that loading, firing, cooling and unloading are carried out simultaneously in these. There are various types of the continuous kilns.

(a) Bull's trench kiln

(b) Hoffman's kiln

(c) Tunnel kiln

4.2.5 Bull's Trench Kiln

Section 1 — Loading

Section 2 — Empty

Section 3 — Unloading

Section 4 — Cooling

Section 5 — Burning

Section 6 — Heating

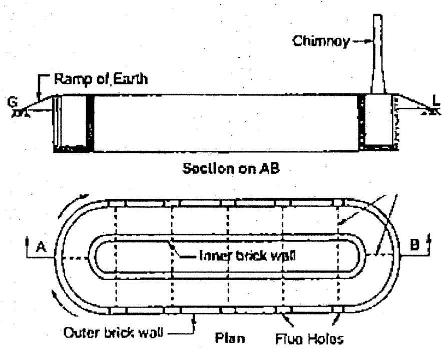


Fig. Bull's trench kiln

- This kiln may be of rectangular, circular or oval shape in plan
- It may be fully underground or partly projecting above ground.
- This is the most widely used kiln in India and it gives continuous supply of bricks.
- Bricks are arranged in sections. They are arranged in such a way that flues are formed. Fuel is placed in flues and it is ignited through flue holes after covering top surface with earth and ashes to prevent the escape of heat. Flue holes are provided in sufficient number on top to insert fuel when burning is in progress.

4.2.6 Hoffman's Kiln

This kiln is constructed over ground and hence, it is sometimes known as *flame kiln*. Its shape is circular in plan and it is divided into a number of compartments or chambers.

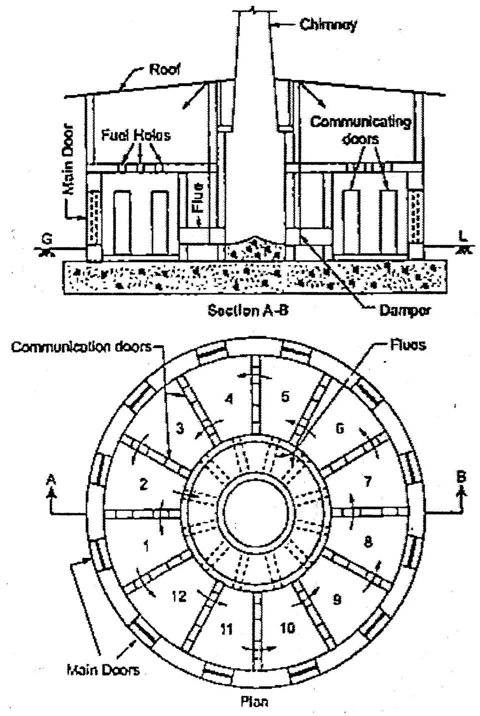


Fig. Hoffman's Kiln

Since it is provided with a permanent roof, the kiln can even function during rainy season.

Figure shows plan and section of the Hoffman's kiln with 12 chambers. Each chamber is provided with the following:

1. A main door for loading and unloading of bricks.
2. Communicating doors which would act as flues in open condition.
3. A radial flue connected with a central chimney.
4. Fuel holes with covers to drop fuel, which may be in the form of powdered coal, into burning chamber.

The main doors are closed by dry bricks and covered with mud, when required.

Table: Comparison between Bull's Trench Kiln and Hoffman's Kiln

S.No.	Item	Bull's trench kiln	Hoffman's kiln
1.	Burning capacity	About 3 lakhs in 12 days.	About 40 lakhs in one season.
2.	Continuity of working	It stops functioning during monsoon as it is not provided with a permanent roof.	It functions all the year with a permanent roof.
3.	Cost of fuel	High as consumption of fuel is more.	Low.
4.	Drying space	It requires more space.	It requires less space.
5.	Initial cost	Low.	High.
6.	Nature	It is semi-continuous in loose sense.	It is continuous in nature.
7.	Popularity	More popular because of less initial cost.	Less popular because of high initial cost.
8.	Quality of bricks	Percentage of good quality bricks is small.	Percentage of good quality bricks is more.
9.	Suitability	Suitable when demand of bricks in monsoon is not substantial.	Suitable when demand of bricks is throughout the year.

Table: Comparison between Clamp Burning and Kiln Burning

S.No.	No. Item	Clamp-burning	Kiln burning
1.	Capacity	About 20000-100000.	Avg. 25000
2.	Cost of fuel	Low as grass, cow dung, litter may be used.	High because coal dust is to be used.
3.	Initial cost	Very low as no structures are to be built.	More as permanent structures are to be constructed.
4.	Quality of bricks	The percentage of good quality bricks is small about 60%.	Percentage of good quality bricks is high about 90%.
5.	Regulation of fire	It is not possible to control or regulate fire during the process of burning.	The fire is under control throughout the process of burning.
6.	Skilled supervision	Not necessary through out the process of burning.	The continuous skilled supervision is necessary.
7.	Structure	Temporary structure.	Permanent structure.
8.	Suitability	For small scale.	For large scale.
9.	Time of burning and cooling	It requires about 2-6 months.	Actual burning time is 24 hours and 12 days are required for cooling of bricks.

4.3 Qualities of Good Bricks

1. The bricks should be table-moulded, well-burnt in kilns, copper-coloured, free from cracks and with sharp and square edges. The colour should be uniform and bright.
2. The bricks should be uniform in shape and should be of standard size.
3. The bricks should give a clear metallic ringing sound when struck with each other.
4. The bricks when broken or fractured should show a bright homogeneous and uniform compact structure free from voids.
5. The brick should not absorb water more than 20 per cent by weight for first class bricks and 22 per cent by weight for second class bricks, when soaked in water at room temperature for a period of 24 hours.
6. The bricks should be sufficiently hard. No impression should be left on brick surface, when it is scratched with finger or nail.
7. The bricks should not break into pieces when dropped flat on hard ground from a height of about one metre.
8. The bricks should have low thermal conductivity and they should be sound proof.
9. The bricks, when soaked in water for 24 hours, should not show deposits of white salts when allowed to dry in shade.
10. No brick should have the crushing strength less then 5.50 N/mm^2.

4.3.1 Strength of Bricks

Factors Affecting the Strength of Bricks:

1. Composition of brick earth.
2. Preparation of clay and blending of ingredients.
3. Nature of moulding adopted.
4. Care taken in drying and stacking of raw or green bricks.
5. Type of kiln used including type of fuel and its feeding.
6. Burning and cooling processes.
7. Care taken in unloading.

Do you know? The average crushing strength and tensile strength of hand moulded bricks are 60000 kN/m^2 and 2000 kN/m^2 respectively. The shearing strength of bricks is about one-tenth of the crushing strength.

4.4 Tests for Bricks

1. Absorption
   - A brick is taken and it is weighed dry. It is then immersed in water for a period of 16 hours.
   - Then weigh again and the difference in weights should not, in any case, exceed
     (a) 20 per cent of weight of dry brick for first class bricks.
     (b) 22.5 per cent for second class bricks.
     (c) 25 per cent for third class bricks.
2. Crushing Strength
   - Minimum crushing strength for first class bricks $\not<$ 10 N/mm^2 and for second class bricks $<$ 7.5 N/mm^2.
3. Hardness
   - In this test, a scratch is made on brick surface with the help of a finger or nail. If no impression is left on the surface, brick is treated to be sufficiently hard

4. Presence of Soluble Salts

- Soluble salts, if present in bricks, will cause efflorescence on the surface of bricks.
- It is immersed in water for 24 hours. It is then taken out and allowed to dry in shade. Absence of grey or white deposits on its surface indicates absence of soluble salts.
- If the white deposits cover about 10% surface, the efflorescence is said to be slight.
- When white deposit cover about 50% of surface then it is said to be moderate.
- If grey or white deposits are found on more than 50% of surface, the efflorescence becomes heavy and it is treated as serious.

5. Shape and Size

- Its shape should be truly rectangular with sharp edges.
- 20 bricks are randomly selected of standard size (19 × 9 × 9 cm). For good quality bricks, the results should be within the following permissible limits:

Length	–	368 cm to 392 cm
Width	–	174 cm to 186 cm
Height	–	174 to 186 cm

6. Soundness

- In this test, two bricks are taken and they are struck with each other.
- Bricks should not break and a clear ringing sound should be produced.

7. Structure

- It should be homogeneous, compact and free from any defects such as holes, lumps, etc.
- High duty fireclays can resist temperature range of 1482°C to 1648°C; medium duty fireclays can resist temperature range of 1315°C to 1482°C and low duty fireclays can resist temperature up to 870°C only.

4.4.1 Classification of Bricks

The bricks can broadly be divided into two categories:

4.4.2 Unburnt Bricks

The unburnt or sun dried bricks are dried with the help of heat received from the sun after the process of moulding. These bricks can only be used in the construction of temporary and cheap structures. Such bricks should not be used at places exposed to heavy rains.

4.4.3 Burnt Bricks

These are classified into four categories:

(i) First Class Bricks

- These bricks are table-moulded and of standard shape and they are burnt in kilns.
- The surfaces and edges of the bricks are sharp, square, smooth and straight.
- First class bricks have all qualities of good bricks.
- These bricks are used for superior work of permanent nature.

(ii) Second Class Bricks

- These bricks are ground moulded and they are burnt in kilns.
- The surface of these bricks is some what rough and shape is also slightly irregular.
- These bricks are commonly used at places where brick work is to be provided with a coat of plaster.

(iii) Third Class Bricks

- These are ground moulded and they are burnt in clamps.
- These bricks are not hard and they have rough surface with irregular and distorted edges.
- These bricks give dull sound when struck together.
- They are used for unimportant and temporary structures.

(iv) Fourth Class Bricks

- These are over burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundations, floors, roads, etc. because of the fact that the over burnt bricks have a compact structure and hence they are sometimes found to be stronger than even the first class bricks.

4.4.4 Colours of Bricks

The colours of bricks, as obtained in its natural course of manufacture, depend on the following factors:

1. Degree of dryness achieved before burning.
2. Natural colour of clay and its chemical composition.
3. Nature of sand used in moulding operation.
4. Quality of fuel used in burning operation.
5. Quantity of air admitted to the kiln during burning.
6. Temperature at which bricks are burnt.

4.4.5 Size and Weight of Bricks

In India:

- Standard size of bricks is 19 cm × 9 cm × 9 cm.
- Nominal size (with mortar) is 20 cm × 10 × 10 cm.
- The commonly adopted nominal size of traditional bricks is 23 cm × 11.4 cm × 7.6 cm.
- It is found that the weight of 1 m^3 of brick earth is about 1800 kg. Hence the average weight of a brick is about 3 to 3.50 kg.

Shape of Bricks:

(i) Bullnose Brick

- A brick moulded with a rounded angle is termed as a bullnose. It is used for a rounded quoin.
- A connection which is formed when a wall takes a turn is known as quoin.

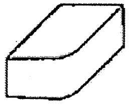


Fig. Bullnose Brick

(ii) Channel Bricks

- These bricks are moulded to the shape of a gutter or a channel and they are very often glazed.
- These bricks are used to function as drain.

(iii) Coping bricks

- These bricks are made to suit the thickness of walls on which coping is to be provided.
- Such bricks take various forms such as chamfered half-round or saddle-back.

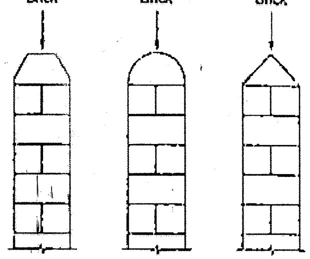


Fig. Brick Copings

(iv) Cownose Bricks

- A brick moulded with a double bullnose on end is known as cow nose.

(v) Curved Sector Bricks

- These bricks are in the form of curved sector and they are used in the construction of circular brick masonry pillars, brick chimneys etc.
- The perforation may be circular, square, rectangular or any other regular shape in cross-section.
- The water absorption after immersion for 24 hours in water should not exceed 15% by water.
- Compressive strength of perforated bricks should not be less than 7 N/mm^2 on gross area.

(vi) Hollow Bricks

- These are also known as cellular or cavity bricks. Such bricks have wall thickness of about 20 mm to 25 mm. They are prepared from special homogeneous clay. They are light in weight about one third the weight of the ordinary bricks of the same size. These bricks can be laid almost about four times as fast as the ordinary bricks and thus the use of such bricks leads to speedy construction. They also reduce the transmission of heat, sound and dampness. They are used in the construction of brick partitioning.

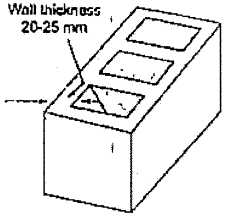


Fig. Hollow Brick

(vii) Paving bricks

- These bricks are prepared from clay containing a higher percentage of iron. Excess iron vitrifies the bricks at a low temperature. Such bricks resist better abrasive action of traffic. Paving bricks may be plain or checkered.

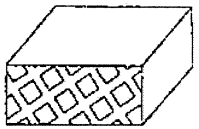


Fig. Chequered Brick

(viii) Perforated Bricks

- Perforated bricks are used in the construction of brick panels for lightweight structures and multi-storeyed framed structures.

Do You Know

- The perforated bricks are used in the construction of brick panels for lightweight structures and multi-storoyed framed structures.
- The compressive strength of perforated bricks should not be less than 7 N/mm^2 on gross area.

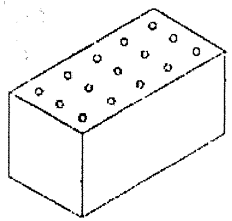


Fig. Perforated Brick

4.6 Fire-Clay

- Constituents of a good fire-clay are alumina and silica. The percentages of alumina varies from 25 to 35 and that of silica from 75 to 65. In any case, impurities such as lime, magnesia, iron oxide and alkalies should not exceed 5 per cent.
- Depending upon the fire resisting capacity, fireclays are classified into the following three categories:
  1. High duty fireclays
  2. Medium duty fireclays
  3. Low duty fireclays.

4.6.1 Fire Bricks

- These are made from fire clay. The process of manufacture is same as that of ordinary clay bricks.
- The burning and cooling of fire bricks are done gradually.
- These bricks are usually white or yellowish white in colour.
- The weight of a fire bricks is about 30-35 N.
- The fire bricks can resist high temperature without softening or melting.
- These bricks are used for linings of interior surface of furnaces, chimneys, kiln, ovens, fire places etc.
- The compressive strength of these bricks varies from 200-220 N/mm^2.
- The percentage of water absorption for these bricks varies from 5-10%.
- Following are the three varieties of fire bricks:

(i) Acidic Bricks

- These bricks are used for acidic lining.
- Following are the types of acidic bricks.
  - (a) **Ordinary firebricks:** These bricks are prepared from natural fire-clay and they provide a good material for acidic refractory lining.
  - (b) **Silica bricks:** These bricks contain a very high percentage of silica to the extent of about 95 to 97%. A small quantity of lime, about 1 to 2% is added to work as binding material. These bricks are moulded under pressure and burnt at high temperature. Silica bricks can withstand a high temperature up to about 2000°C.

(ii) Basic Bricks

- These bricks are used for basic lining and basic refractory materials are used in the manufacture of such bricks.
- Magnesia bricks are prepared from lime and magnesia rocks. Dolomite may also be adopted for the manufacture of these bricks.

(iii) Neutral Bricks

- These bricks are used for neutral lining.
- Following are the types of neutral bricks:
  - (a) **Chromite Bricks:** These bricks are prepared from a mixture of chrome, iron ore, ferrous oxide, bauxite and silica. Such bricks are unaffected by acidic or basic actions.
  - (b) **High Alumina Bricks:** These bricks contain a high percentage of alumina and they are found to be more inert to slags.

4.7 Brick Masonry

1. **Stretcher:** A stretcher is the longer face of the brick (i.e. 19 cm x 9 cm) as seen in the elevation of the wall. A course of bricks in which all the bricks are laid as stretchers on facing is known as a stretcher course or stretching course.

2. **Header:** A header is the shorter face of the brick (i.e. 9 cm x 9 cm) as seen in the elevation of the wall. A course of bricks in which all the bricks are laid as headers on the facing is known as header course or heading course.

3. **Lap:** Lap is the horizontal distance between the vertical joints of successive brick courses.

4. **Perpend:** A perpend is an imaginary vertical line which includes the vertical joint separating two adjoining bricks.

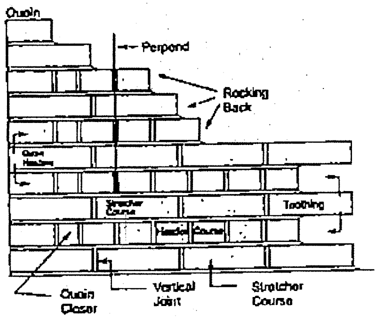


Fig. Elevation of a Brick Wall

5. **Bed:** Bed is the lower surface (19 cm x 9 cm) of the brick when laid flat.

6. **Closer:** It is a portion of a brick with the cut made longitudinally, and it used to close up bond at the end of the course. A closer helps in preventing the joints of successive courses (higher or lower) to come in a vertical line. Closers may be of various types as defined below.

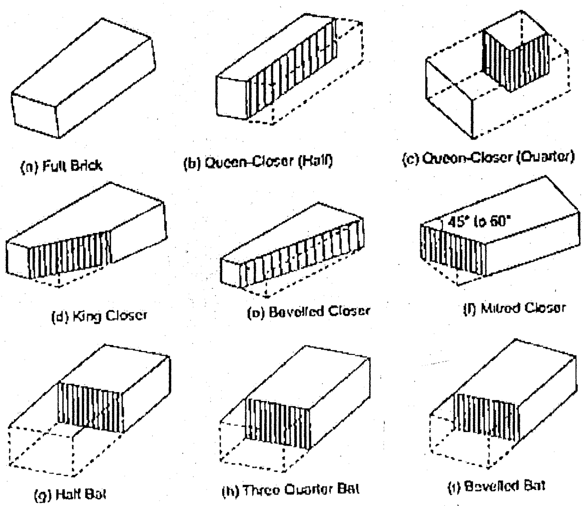


Fig. Various Forms of Brick Portions

7. **Queen-closer:** It is a portion of a brick obtained by cutting a brick lengthwise into two portions Fig. (b). Thus, a queen-closer is a brick which is half as wide as the full brick. This is also known as queen-closer-half.

   When a queen-closer is broken into two pieces, it is known as queen-closer-quarter. Such a closer is thus a brick piece which is one-quarter of the brick size Fig. (c).

8. **King closer:** It is the 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 (Fig. d). It is thus obtained by cutting the triangular piece between the centre of one end and the centre of the other (adjacent) side. It has half-header and half-stretcher face.

9. **Beveled closer:** It is a special form of a king closer in which the whole length of the brick (i.e. stretcher face) is beveled in such a way that half width is maintained at one end and full width is maintained at the other end (Fig. e).

10. **Mitred closer:** It is a portion of a brick whose one end is cut splayed or mitred for full width. The angle of splay may vary from 45° to 60°. Thus, one longer face of the mitred closer is of full length of the brick while the other longer face is smaller in length (Fig. f).

11. **Bat:** It is the portion of the brick cut across the width. Thus, a bat is smaller in length than the full brick. If the length of the bat is equal to half the length of the original brick, it is known as half bat (Fig. g). A three-quarter-bat (Fig. h) is the one having its length equal to three-quarters of the length of a full brick. If a bat has its width beveled, it is known is beveled bat (Fig. i).

12. **Arris:** It is the edge of a brick.

13. **Bull nose:** It is a special moulded brick with one edge rounded (single bull nose) or with two edges rounded (double bull nose). These are used in copings or in such positions where rounded corners are preferred to sharp arises.

14. **Splays:** These are special moulded bricks which are often used to form plinth. Splay stretcher (plinth stretcher) and splay header (plinth header) are shown respectively.

15. **Dogleg or angle:** It is also a special form of moulded bricks which are used to ensure satisfactory bond at quoins which are at an angle other than right angle. The angle and lengths of the faces forming the dogleg vary according to requirements. These are preferred to mitred closer.

16. **Quoin:** It is a corner or the external angle on the face side of a wall. Generally, quoins are at right angles. But in some cases, they may be at angles greater than 90° also.

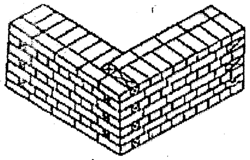
17. **Frog or kick:** A frog is an indentation in the face of a brick to form a key for holding the mortar. When frog is only on one face, that brick is laid with that face on the top. Sometimes, frogs are provided on both the faces. However, no frogs are provided in wire-cut bricks. A pressed bricks has two frogs (as a rule) and a hand-made brick has only one frog.

18. **Racking back:** It is the termination of a wall in a stepped fashion.

19. **Toothing:** It is the termination of the wall in such a fashion that each alternate course at the end projects, in order to provide adequate bond if the wall is continued horizontally at a later stage.

4.8 Bonds in Brick-Work

4.8.1 English Bond



$1\frac{1}{2}$ Brick wall

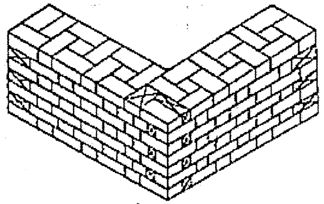
Fig. English Bond

This bond consists of alternate courses of headers and stretchers. In this arrangement, vertical joints in the header courses come over each other and the vertical joints in the stretcher courses are also in the same vertical line. For breaking of vertical joints in the successive courses it is essential to place queen closer, after the first header in each header course. The following additional points should be noted in English bond construction:

1. A header course should never start with a queen closer as it is liable to get displaced from this position.
2. In the stretcher course, the stretchers should have a minimum lap of 1/4th of their length over the headers.
3. In walls having thickness equal to an odd number of half brick, i.e., $1\frac{1}{2}$ brick thick walls or $2\frac{1}{2}$ brick thick walls and so on, the same course will show stretchers on one face and headers on the other.

4.8.2 Flemish Bond

In this arrangement of bonding brick work, each course consists of alternate headers and stretchers. The alternate headers of each course are centered over the stretchers in the course below. Every alternate course starts with a header at the corner. For breaking the vertical joints in the successive courses, closers are inserted in alternate courses next to the quoin header. In walls having thickness equal to odd number of half bricks, bats are essentially used to achieve the bond. Flemish bond is further divided into two different types viz. Single Flemish bond and Double Flemish bond.



$1\frac{1}{2}$ Brick wall

Fig. Flemish Bond

4.8.3 Double Flemish Bond

In this system of bonding brick work, each course presents the same appearance both in the front and back elevations. Every course consists of headers and stretchers laid alternately. This type of bond is best suited from considerations of economy and appearance. It enables the one brick wall to have flush and uniform faces on both the sides.

4.9 Comparative Merits and Demerits of English and Flemish Bond

1. For walls thicker than $1\frac{1}{2}$ brick, English bond is stronger than Flemish bond.
2. Flemish bond renders the appearance of the face work more attractive and pleasing.
3. Flemish bond is slightly economical as a number of bats can be used. This renders the use of broken bricks possible, but requires more mortar for additional joints.
4. The adoption of Flemish bond requires good workmanship and careful supervision. Thus extra attention is necessary to keep the vertical joints in alternate courses one above the other.

4.10 Other Types of Bonds

(i) **Stretcher Bond:** In this arrangement of bonding, all the bricks are laid as stretchers. The overlap, which is usually of half brick, is obtained by commencing each alternate course with a half brick bat. Stretching bond is used for half bricks wall only.

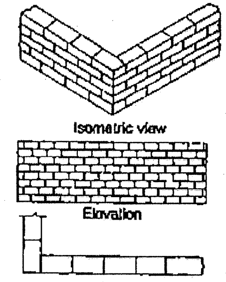


Fig. Stretcher Bond

(ii) **Header Bond:** In this type of bonding, all the bricks are laid as headers on the faces. The overlap, which is usually of half the width of the brick is obtained by introducing a three-quarter bat in each alternate course at quoins. This bond permits better alignment and as such it is used for walls curved on plan. This bond is chiefly used for footings in foundations for better transverse distribution of load.

(iii) **Garden Wall Bond:** This type of bond is suitably adopted for one brick thick wall which may act as a garden wall or a boundary wall.

(iv) **Facing Bond:** This arrangement of bricks is adopted for thick walls, where the facing and backing are desired to be constructed with bricks of different thickness. This bond consists of header and stretcher courses so arranged that one header course comes after several stretcher courses.

(v) **Raking Bond:** This is another type of bond in brick work in which the bonding bricks are laid at any angle other than zero or ninety degrees. This arrangement helps to increase the longitudinal stability of thick walls built in English bond.

(vi) **Diagonal Bond:** This bond is best suited for walls which are 2 to 4 brick thick. This bond is usually introduced at every fifth or seventh course along the height of the wall. In this bond, the bricks are placed end to end in such a way that extreme corners of the series remain in contact with the stretchers.

(vii) **Dutch bond:** This bond is a modification of the old English cross bond and consists of alternate courses of headers and stretchers.

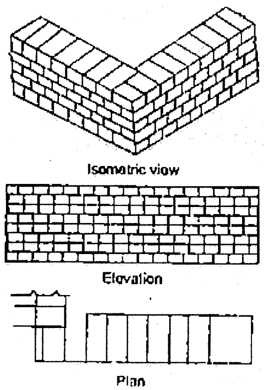


Fig. Header Bond

Slenderness Ratio (λ)

- Max (λ) of load bearing wall shall be

No. of Storeys	Maximum Slenderness Ratio (λ)	
	Cement Mortar	Lime Mortar
Upto 2	27	30
> 2	27	17

Slenderness ratio (S_R) is the minimum of $\frac{h}{t \times k_s}$ or $\frac{L}{t}$

where k_s = stiffening coefficient, h = effective thickness,
L = effective length, t = effective thickness

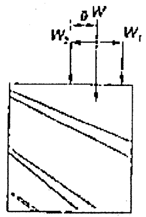


Fig. Eccentricity of loading

4.10.1 Eccentricity of Loading

When a wall of thickness 't', carrying axial load 'W_1' and eccentric load 'W_2' at eccentricity 'e', per unit length of wall. The resultant load W will have an eccentricity $\bar{e}$ which can be found by taking moments around the centroid of the section.

$$W\bar{e} = W_1.0 + W_2 \times e$$

$$\bar{e} = \frac{W_2.e}{W_1 + W_2}$$

$\bar{e}$ = equivalent eccentricity

$\frac{\bar{e}}{t}$ = eccentricity ratio

Ratio of height to width of brick or block (h/b)	Factor
0.75	1.0
0.1	1.2
1.5	1.6
2.0-3.0	2.0

4.10.2 Shape Factor

- **Tensile stress in Masonry:** For mortar not weaker than a 1 : 1 : 6, cement : lime : sand mix or equivalent, the permissible tensile stress in bending shall not exceed 1 kg/cm^2.
- **Permissible shear stress:** For a mortar not weaker than 1 : 1 : 6 mix, the permissible shear stress shall be taken as 1.5 kg/cm^2.
- **Dispersion of concentrated load:**

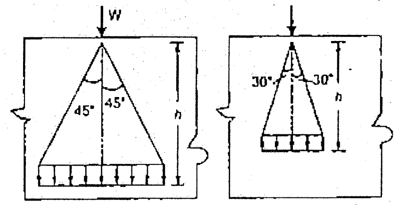


Fig. Dispersion of Concentrated load

- As per IS code, dispersal angle of 30° is more appropriate since brick strength of bricks in India is rather low, resulting in less arching and greater load on lintels.

Table: Mix proportion and strength of commonly used mortars for masonry

S. No.	Minimum compression strength		Mortar type
	kg/cm^2	N/mm^2	
1	100	10	H_1
2(a)	75	7.5	H_2
2(b)	60	6	
3(a)	50	5	M_1
3(b)	30	3	
4(a)	30	3	M_2
4(b)	20	2	
4(c)	20	2	
5(a)	7	0.7	L_1
5(b)	7	0.7	
6	5	0.5	L_2

Table: Effective Height of Wall (National Building Code of India, SP-7: 1970)

S.No.	Condition of Support	Effective Height (H)
1.	Adequate lateral support and partial rotational restraint at top and bottom. For example, where the floor (or roof) has a direction of span at right angles to the wall, so that the reaction to the load of the floor or roof is provided by the walls; or where the concrete floors have a bearing on walls irrespective of the direction of span.	0.75 H
2.	Adequate lateral support and partial rotational restraint at either top or bottom and lateral restraint at other end. For example, fully braced construction which it itself adequately supported and incorporates: (a) timber floors immediately below or above a reinforced concrete floor, and (b) roof trusses above a reinforced concreted floor or the like.	0.85 H
3.	Adequate lateral support at top and bottom where the floors (or roofs) have a direction of span parallel with the wall, top and bottom, and do not bear on it, or fully braced construction which it itself adequately supported and which incorporates roof trusses and timber upper storey floors.	1.00 H
4.	Adequate lateral support and partial rotational restraint at bottom and no lateral support or rotational restraint at the top (where the wall has no lateral support at top construction not fully anchored or not fully braced)	1.50 H
5.	Free standing non load bearing members.	2.00 H

Table: Effective Length of Walls

S.No.	Condition of Support	Effective Height (H)
1.	Where the wall is continuous and supported by cross wall or buttresses and there is no opening within one eighth of the wall height, h or H (which ever is less) from the face of the supporting wall or buttress.	0.8 L
2.	Where the wall is supported by a buttress or cross wall at one end and continuous with buttress or cross wall supports at the other end.	1.0 L
3.	Where the wall is supported at each end by a buttress or across wall.	1.0 L
4.	Where the wall is free at one end and supported by a buttress or cross wall at the other end.	1.5 L

Objective Brain Teasers

Q.1 A first class brick when immersed in cold water for 24 hours should not absorb water more than
(a) 15% (b) 20%
(c) 22% (d) 25%

Q.2 Crushing strength of a first class brick should not be less than
(a) 3.5 N/mm^2 (b) 7.0 N/mm^2
(c) 10.5 N/mm^2 (d) 14.0 N/mm^2

Q.3 The main function of alumina in brick earth is
(a) to impart plasticity
(b) to make the brick durable
(c) to prevent shrinkage
(d) to make the brick impermeable

Q.4 The percentage of alumina in a good brick earth lies between
(a) 5 to 10% (b) 20 to 30%
(c) 50 to 60% (d) 70 to 80%

Q.5 Excess of alumina in brick earth makes the brick
(a) impermeable
(b) brittle and weak
(c) to lose cohesion
(d) to crack and warp on drying

Q.6 The process of mixing clay, water and other ingredients to make brick is known as
(a) kneading (b) moulding
(c) pugging (d) drying

Q.7 **Number of bricks required for one cubic metre of brick masonry is**

(a) 400 (b) 450
(c) 500 (d) 550

Q.8 **The frog of the brick in a brick masonry is generally kept on**

(a) bottom face (b) top face
(c) shorter side (d) longer side

Q.9 **The most important purpose of frog in a brick is to**

(a) emboss manufacturer's name
(b) reduce the weight of brick
(c) form keyed joint between brick and mortar
(d) improve insulation by providing 'hollows'

Q.10 **King closers are related to**

(a) doors and windows
(b) king post truss
(c) queen post truss
(d) brick masonry

Q.11 **The approximate proportion of dry cement mortar required for brickwork is**

(a) 60% (b) 45%
(c) 30% (d) 10%

Q.12 **For flatly laid single brick soling, what is the number of bricks required of nominal size 20 cm × 10 cm × 10 cm, with 1.2 cm wide cement mortar all around and with allowing up to 1% wastage for 10 m² area?**

(a) 400 (b) 410
(c) 425 (d) 440

Q.13 **What is the number of traditional bricks required for 10 m³ of brickwork with standard thickness of cement mortar (1 : 3 to 1 : 5, as the case may be)?**

(a) 4750 (b) 4850
(c) 4950 (d) 5050

Q.14 **Modular bricks are of nominal size 20 × 10 × 10 cm and 20% of the volume is lost in mortar between joints. Then what is the number of modular bricks required per cubic meter of brickwork?**

(a) 520 (b) 500
(c) 485 (d) 470

Q.15 Consider the following statements:

Maximum slenderness ratio of load-bearing masonry walls for a dwelling having more than two storeys shall not exceed

1. 12, if lime mortar is used.
2. 18, if cement-lime mortar 1 : 2 : 9 is used.
3. 24, if cement mortar 1 : 6 is used.

Which of these statements are correct?

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

Q.16 Brick masonry walls and columns of a building are to be protected from earthquake. The earthquake proofing is done by providing

(a) cross walls
(b) less openings
(c) under-reamed piles
(d) a steel band at corners above windows below ceiling

Q.17 An arrangement for temporarily supporting a structure from beneath for safety, is known as

(a) jacking (b) underpinning
(c) supporting (d) hauling

Answers

1. (b)	2. (c)	3. (a)	4. (b)	5. (d)
6. (a)	7. (c)	8. (b)	9. (c)	10. (d)
11. (c)	12. (c)	13. (c)	14. (d)	15. (d)
16. (d)	17. (b)			

Hints & Solution

11. (c)

For 1 m³ volume of brick work, the bricks required are 500. Therefore mortar needed

$= 1 - 500 \times 0.19 \times 0.09 \times 0.9 = 0.23 \text{ m}^3$.

Add 15% extra for frog filling, brick bonding and wastage.

Volume of wet mortar $= 0.23 \times 1.15 = 0.265 \text{ m}^3$

1 m^3 of wet mortar $= 1.25 \text{ m}^3$ of dry mortar

$\therefore 0.265 \text{ m}^3$ wet mortar $= 0.33 \text{ m}^3$ of dry mortar

Dry mortar as a percentage of brick work

$$= \frac{0.33}{1} \times 100 = 33\%$$

12. (c)

Though it is given that 1.2 cm wide cement mortar is provided all around the brick but considering 1.2 cm total width of cement mortar on opposite faces of brick. So number of bricks required for 10 m² area,

$$N = \frac{10 \times 10^4}{(21.2 \times 11.2)} = 421.16 \text{ bricks}$$

Also it is given that 1% wastage is allowed. So no. of bricks required

$N' = N \times 1.01$

$= 421.16 \times 1.01$

$\simeq 425$ bricks

So option (c) is correct.

But as per question is should be

$$N' = 1.01 \times \frac{10 \times 10^4}{22.4 \times 12.4} \simeq 364 \text{ bricks}$$

14. (d)

Nominal size of modular bricks

$= 20 \text{ cm} \times 10 \text{ cm} \times 10 \text{ cm}$

Actual size of modular brick

$= 19 \text{ cm} \times 9 \text{ cm} \times 9 \text{ cm}$

Mortar required for 1 m³ brickwork

$$= 1 - \left(\frac{1}{0.2 \times 0.1 \times 0.1} \times 0.19 \times 0.09 \times 0.09\right)$$

$= 1 - 0.7695 = 0.2305 \text{ m}^3$

Volume of mortar lost between joints = 20%

$\therefore$ Volume of set mortar

$$= 0.2305 + 0.2305 \times \frac{20}{100} = 0.2766 \text{ m}^3$$

Actual volume of bricks $= 1 - 0.2766$

$= 0.7234 \text{ m}^3$

$\therefore$ Number of modular bricks

$$= \frac{0.7234}{0.19 \times 0.09 \times 0.09} = 470$$

15. (d)

For a wall, the slenderness ratio shall be the effective height divided by the effective thickness and stiffening co-efficient (K_h) or the effective length divided by the effective thickness, whichever is less.

Thus, $S_R = \frac{l}{t \times K_h}$ or $\frac{l}{t}$, whichever is less. In case of a load bearing wall, slenderness ratio shall not exceed the values given in Table below.

Table: *Maximum Slenderness ratio for a load bearing wall*

No. of Storeys	Maximum Slenderness Ratio	
	Using Portland Cement or Portland Pozzolana Cement in Mortar	Using lime mortar
(1)	(2)	(3)
Not exceeding 2	27	30
Exceeding 2	27	12

16. (d)

To resist earthquake loads

(i) shear wall may be provided

(ii) a horizontal runner called band may be provided for bringing the walls together. They may be roof band, lintel band, gable band or plinth band depending upon the level at which it is used.

17. (b)

The placing of new foundation below and existing foundation of the process of strengthening the existing foundation is known as the underpinning of foundations. The structure is held well supported in a secured manner and the footings are relieved from the load. Sometimes the structures are to be temporarily supported. This is achieved by an arrangement called shoring. It is necessary to support the super-structure when large openings are required to be made in the main walls. There are three different types of shores :

(i) Raking shores
(ii) Flying shores
(iii) Dead shores

All these types of shores support the structure from side.

■■■■