BHUBANANANDA ODISHA SCHOOL OF ENGINEERING, CUTTACK

DEPARTMENT OF CIVIL ENGINEERING

LECTURE NOTE ON: BUILDING MATERIALS AND CONSTRUCTION TECHNOLOGY (TH-3) 3TH SEMESTER

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PART:A(BUILDING MATERIALS)

1.STONE

1.1 INTRODUCTION

Stone is a"naturally available building material" which has been used from the early age of civilization. It is available in the form of natural rocks which is cut to required size and shape and used as building block.The stones which are suitable for the construction of structures such as Dams,retaining walls,abutments,barrages,roads etc are known as building stones.

1.1.1 CLASSIFICATION OF ROCKS

Building stones are obtained from rocks occurring in nature are classified in three ways:

- 1. Geological classification
- 2. Physical classification
- 3.Chemical classification

1.GEOLOGICAL CLASSIFICATION

According to this classification, the rocks are of following types:

a) **Igneous rocks:-** Rocks that are formed by cooling of magma(molten or pasty rocky material) are known as igneous rocks.Eg. Granite,Basalt ,Dolerite etc.

Igneous rocks are recognized in th following three classes:

- a)Plutonic rocks
  Such rocks are formed due to cooling of magma at a considerable depth from earth's surface.It possesss coarsely grained crystalline structure.Ex:-Granite.

- b)Hypabassal Rocks
  Such rocks are formed due to cooling of magma at a relatively depth from earth's surface.It possess finely grained crystalline structure.Ex:-Dolerite.

- c)Volcanic rocks
  Such rocks are formed due to pouring of magma at earth's surface.these rocks are extremely fine grained in structure.Ex:- Basalt.

b) **Sedimentary rocks**: These rocks are formed by regular deposition of products of weathering on the pre-existing rock. Gravel, sandstone, limestone, lignite, gypsum etc. are examples of sedimentary rocks.

c) **Metamorphic rocks**: Previously formed igneous and sedimentary rocks undergo changes due to metamorphic action of pressure and internal heat for e.g. due to metamorphic action granite becomes gneiss.

2.PHYSICAL CLASSIFICATION: According to this classification, the rocks are of following types

- **Stratified rocks**: These rocks have layered structure or posess planes of stratification or cleavage. They can be easily split along these planes. E.g. Sand stone, lime stones, slate etc.
- **Unstratified rocks**: These rocks possess crystalline and compact grains. They can not be split along these planes. E.g. Granite, trap, marble etc.
- **Foliated rocks**: These rocks have a tendency to split along a definite direction only. The direction need not be parallel to each other as in the case of stratified rocks.
  Ex:-metamorphic rock.

3. **CHEMICAL CLASSIFICATION:** On the basis of their chemical composition, engineers prefer to classify rocks as:

- **Silicious rocks**: The main content of these rocks is silica. These are hard and durable. Eg. granite, trap etc.
- **Argillaceous rocks**: The main constituent of these rocks is argil i.e, clay. These rocks are hard and durable but brittle. Eg:- Slates, laterites.
- **Calcareous rocks**: The main constituent of these rocks is calcium carbonate. limestone is a calcareous rock of sedimentary origin while marble is a calcareous rock of metamorphic origin.

1.1.2 USES OF STONE

Stone can be used for the following purposes:

1) Construction of residential and public buildings.

2) Construction of walls, columns, dams, abutments, and bridges.

3) For architectural and ornamental requirements on the structure.

4) Used for road construction and railways.

5) Used as aggregate for concrete

6) Used in the form of facing for decoration.

7) Used for roofing purposes. Generally, slate is used because it is weather-resistive and durable.

8) Used in gabion walls and retaining walls to control landslides and floods respectively.

9) Used in the pavement for making sub-base and base course.

10) Used in the preparation of cement, sand, etc.

11) Used in stone arts, making statues, etc.

12) Used in the manufacturing of metals like iron.

13) Used as an alternative to sand, if there is no availability of sand.

13) They are also used as DPC(Damp Proof Course)

14) Used for making or constructing fireproof structures.

1.1.3 NATURAL BED OF STONE

Definition

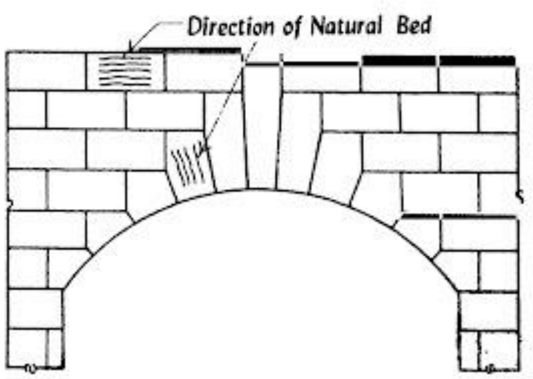
Building rocks are obtained from rocks.These rocks have a distinct plane of division along which stones can easily be split.This plane is known as natural bed of stone .

Importance

In stone masonry structures, generally, the observed rules are that the line or direction of natural bedding stones should be either perpendicular or perpendicular to the stone age, or that such a system would give maximum strength to the Stone Age.

This can be checked by pouring water and checking the directions of the layers. A magnifying glass is also be used for this purpose.

An experienced worker can easily detect and verify the direction of the natural bed of the stones with the resistance of the chisel. The stones break easily along these natural beds. With regard to natural bedding, the stones are placed under different circumstances as follows:



Natural bed of stone

1) Arches:

In these types of stone vaults, the stones are placed with the radial of their natural beds as shown in Fig. With such alignment, the pressure or force of the upper arch weight acts normal or perpendicular to the direction of the natural bedding stone arch.

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2) Cornices, string courses, etc.:

In the case of cornices, stones are partially unsupported, string courses, etc. They should therefore be placed perpendicular to the direction of the natural beds. This principle is not good for cornerstones. In such cases, it is desirable to incorporate stones without natural beds.

3) Walls:

The stones should be placed in the walls with the direction of their natural beds.

1.2 QUALITIES OF GOOD BUILDING STONE

There is no single stone which satisfies all the characteristics or qualities of good building stones. The qualities of the stones which are used for different purpose varies based on the nature of work for which the stones are selected. Although a stone does not meet all the requirements of a good building stone, the parameters for classifying it as a good building stone are as follows:

Appearance & Colour

- The stones which are to be used for face work must be decent in appearance.
- The stones used for architectural purposes must be capable of preserving the uniformity of colour for a longer time.
- A good stone must be free from clay holes, bands or spots of colour.
- The stones should also have the ability to receive good polish.
- The stones used in exposed positions must be light coloured rather than dark coloured as the durability of dark coloured stones are less than light coloured stones.
- The red and brown shades of Sedimentary rocks are due to the presence of excess of oxides of iron. The presence of oxides of iron is responsible for causing rust stains. This also results in disintegration. Hence, a good building stone must possess less concentration of oxides of iron.

Durability

- A good building stone must be durable. The durability of a stone depends upon the structural formation, chemical composition and cementing material.
- A good building stone must be capable of resisting the adverse effects of natural forces like wind, rain and heat.
- A stone is said to be durable if it is compact, homogeneous, free from any material affected by hydrochloric and sulphuric acids and possess negligible water absorption.
- The stones used in building possess good weathering quality if the sharp edges and corners are preserved and if the chisel marks on the stone faces are distinctly visible.

Hardness

- The stones used in floors, pavements, aprons of bridges and weirs of rivers must be able to resist abrasive forces caused by movement of men and materials over them. Such stones are to be tested for hardness.
- A good building stone must be sufficiently hard.
- For a good building stone, the percentage of wear must be less than 3%.

- The coefficient of hardness, determined using the hardness test (Dory's testing Machine), must be greater than 17 for a stone to be used in road work. The stone is of medium hardness if its hardness value is between 14 and 17. If the hardness value is less than 14, then the hardness of the stone is said to be poor. The stone with poor hardness must not be used in road work.

Crushing Strength

- Stones used in the structures are usually subjected to compressive load. Hence, a good building stone must be strong in compression. A good building stone must possess high strength to resist the load coming over it.
- Generally all the stones possess a considerable degree of strength to be used for building construction. But for the construction of heavy structures, the crushing strength of the stones are to be tested before use.
- Stones having compact fine crystalline texture are stronger. Igneous rocks are more stronger than sedimentary rocks.
- The compressive strength of the most building stones lie between 60 and 200 N/mm^2. For a good structural stone, the crushing strength must be greater than 100 N/mm^2.

Stone	**Crushing Strength (N/mm^2)**
Basalt	150 to 185
Diorite	90 to 150
Granite	75 to 127
Syenite	90 to 150
Trap	330 to 380
Laterite	1.8 to 3.1
Limestone	54
Sandstone	64
Shale	0.2 to 0.6
Gneiss	206 to 370
Slate	75 to 207

Toughness

- Toughness of the stones is the ability to resist impact forces.
- A good building stone must possess sufficient toughness to sustain stresses developed due to vibrations. The vibrations in the structure may be due to the presence of machineries or due to the moving loads.
- The road construction demands the use of tougher stone aggregates.
- The toughness of a stone is determined by impact test. Stones having toughness index between 13 and 19 are medium tough while the stones with toughness index less than 13 are poor stones.

Specific Gravity

- The specific gravity of building stone depends on its weight and strength. The heavier and stronger the stone, more is its specific gravity.
- The specific gravity of good building stone must be between 2.4 and 2.8. Stones of specific gravity less than 2.4 are unsuitable for building construction.
- The stones of higher specific gravity must be used for the construction of dams, retaining walls, docks and harbours as they are more compact and less porous. But, lighter stones are preferred for the construction of domes, roofs, etc.,

Facility of dressing

Stones should be such that they can be dressed easily and economically.

Texture

A good building stone should have crystalline structure.stones with such texture are strong and durable.

Porosity and water Absorption: Porosity depends on the mineral constituents, cooling time and structural formation. A porous stone disintegrates as the absorbed rain water freezes, expands, and causes cracking. Permissible water absorption for some of the stones is given in Table 1

Table 1 24-Hours Water Absorption of Stones by Volume

S.No. Types of Stone : Water absorption (% not greater than)

1. Sandstone : 10
2. Limestone : 10
3. Granite : 1
4. Trap : 6
5. Shale : 10
6. Gneiss : 1
7. Slate : 1
8. Quartzite : 3

Seasoning: The stone should be well seasoned.

Weathering: The resistance of stone against the wear and tear due to natural agencies should be high.

Workability: Stone should be workable so that cutting, dressing and bringing it out in the required shape and size may not be uneconomical.

Fire Resistance: Stones should be free from calcium corbonate, oxides of iron, and minerals having different coefficients of thermal expansion. Igneous rock show marked disintegration principally because of quartz which disintegrates into small particles at a temperature of about 575 o

C. Limestone, however, can withstand a little higher temperature; i.e. up to 800 o C after which they disintegrate.

1.3 DRESSING OF STONE

Dressing of stone is a process of providing a proper shape, size and smooth finish to the rough-surfaced broken stone which is collected from a quarry.

This process is done by either hand tools or machinery. Hand tools are used as a pickaxe, chisel etc. Stone dressing process is required more technical skilled labours and fair understanding of drawing, materials and specifications.

With respect to the place of work, dressing can be divided into two types,namely,quarry dressing and site dressing.

Stages in the Dressing of Stone

1. **Sizing:** Sizing is the process where we remove the extra portion of a stone by hand tools like hammer, chisel etc. It's done to give a stone to a proper shape.
2. **Shaping:** Shaping is the process where we remove the sharp sides of a stone block.
3. **Planning:** Planning is the advanced type of dressing where the stone is cleaned of all kind of irregularity.
4. **Finishing:** Finishing of stone is the process of rubbing of the stone surface by silicon carbide.
5. **Polishing:** It is the last stage if dressing and polishing are done only on marble, limestone and granite.

Different Finishes of Stones

Various types of finishes are available for dressing of stones. Use of each finish depends upon the type of work and the variety of finishes are as follows:

- Axed finish
- Boasted finish
- Combed finish
- Circular finish
- Chisel-draughted margins
- Molded finish
- Furrowed finish
- Plain finish
- Polished finish
- Hammer dressed finish
- Rubbed finish

- Reticulated finish
- Punched finish
- Tooled finish
- Scrabbling finish
- Vermiculated finish
- Sunk finish
- Quarry faced finish

Axed Finish of Stones

Axe is used to get the required surface of hard stones like granite etc. This finish is called as axed finish.

Boasted Finish of Stones

Boasted finish is also called as droved finish. This type of finish contains intermittent parallel lines which are horizontal or vertical or inclined. This finish is obtained by a tool called boaster which have an edge of width about 60 mm.

Combed Finish of Stones

Combed finish is suitable for soft stones. Steel comb of sharp teeth is dragged on the surface of soft stone. This is done in all directions of stone surface. This is also called as dragged finish.

Circular Finish of Stones

The surface of stone is made into rounded shape. Circular finished stones are mainly used for columns.

Chisel-Drafted Margins for Stones

Chisel drafted margins are provided on stones which represents uniform joints in stone masonry.

These margins may be pitched or square or chamfered. This is done by using chisel.

Molded Finish for Stones

Using machines or tools, stone surfaces are molded into desired shapes which also provide good appearance to the work.

Furrowed Finish for Stones

Furrowed finish has beautiful appearance in which sides are sunk up to 20mm width and the middle portion is projected by 15mm. 10 mm grooves are made on the projected portion. This is used to make the quoins prominent.

Plain Finish for Stones

In case of plain finish, the surface of stone is made very smooth using saw or chisel.

Polished Finish for Stones

Polished finish is provided for marbles, granites etc. which are mostly used as floor tiles. Polishing can be done by hand or machines.

Hammer Dressed Finish for Stones

Hammer dressed finish is adopted to stones which does not contain sharp edges or corners. These types of stones are well suitable for masonry works. Waller's hammer is used for finishing. Hammer dressing contains square or rectangular shaped marks.

Rubbed Finish for Stones

Rubbed finish is achieved by rubbing the surface of stone with another hard surface or with suitable machine. The rubbing is fastened by using water and sand.

Reticulated Finish for Stones

Reticulated finish is a special type of finish in which a margin of 20 mm wide is marked on the sides of surface and irregular sinking type finish is made in the middle area. For that sinks also margin of 10 mm wide with 5 mm depth is provided. Finally, dots are marked in the sunk surface using pointing tool.

Punched Finish for Stones

Punched finish is obtained by punching the stone using a machine which depresses the surface of stone and creates hollows and ridges on it.

Tooled Finish for Stones

It is a classic finish which consists parallel continuous marks. The marks may be either horizontal or vertical or inclined. The marking is done by chisel.

Scrabbling Finish for Stones

The irregular projections on stone surface are removed using scrabbling hammer and the resultant rough surface finish is called as scrabbling finish.

Vermiculated Finish for Stones

This is similar to reticulated finish except that the sinking in this case is more curved and is like worm eaten appearance.

Sunk Finish for Stones

Sunk finish is achieved by depressing the original surface into wide groves, marks, inclined surfaces etc.

Quarry Faced Finish for Stones

Quarry faced finished stones are stones which have smooth surface and do not require any dressing. These types of stones are sometimes directly available from quarrying. These are also called as self-faced stones or rock faced stones.

1.4 CHARACTERISTICS OF DIFFERENT TYPES OF STONES AND THEIR USES

1) Basalt and trap:

Classification: Igneous

Qualities: Hard and tough; difficult to work. It's sp. gr. is 3 and compressive strength varies from 1530 to 1890 kg / cm2 •

Uses: Road metal. for rubble masonry, foundation work, etc.

2) Chalk:

Classification: Sedimentary

Qualities: Pure white limestone, soft and easy to form a powder.

Uses: In preparing glazier's putty, as colouring material in manufacture of portland cement

3) Gneiss:

Classification: Metamorphic

Qualities: Splits into thin slabs: easy to work. Its sp. gr. is 2.69 and compressive strength is 2100 kg/cm2 •

Uses : Street paving, rough stone masonry work, etc.

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4) Granite:

Classification: Igneous

Qualities: Hard, durable and available in different colours. Highly resistant to natural force, can take a nice polish. Its sp. gr. varies from 2·G to ‘2·7 and compressive strength varies from 770 to 1300 kg /cm2.

Uses: Steps, sills, facing work, walls, bridge piers, columns, road metal, ballast, etc. It is unsuitable for carving.

5) Kankar:

Classification: Sedimentary.

Qualities: Impure limestone.

Uses: Road metal. manufacture of hydraulic lime, etc.

6) Laterite:

Classification: Metamorphic.

Qualities: Porous and spongy structure, easily quarriedd in a block, contain high percentage of oxide of iron; available in a different colour. Its compressive strength varies from 18 to 32 kg/cm2 •

Uses: Building stone. road metal, rough stone masonry work. etc.

7) Limestone:

Classification: Sedimentary.

Qualities: Consists of carbonate of lime, easy to work. It’s sp. gr. varies from 2.00 to 2.75 and compressive strength is 550 kg/cm2.

Uses Floors, steps, walls. road metal, manufacture of lime in blast furnaces, etc.

8) Marble:

Classification: Metamorphic.

Qualities: Can take a good polish and is available in different colours. Its sp. gr. is 2.65 and compressive strength is 720 kg/cm2 •

Uses: Flooring, facing work, columns, steps, ornamental work, etc. It can take a nice polish. It can easily be sawn and carved.

9) Murum:

Classification: Metamorphic

Qualities: Decomposed laterite', deep brown or red in colour.

Uses: Blindage for metal roads, for fancy paths and garden walls.

10) Quartzite:

Classification: Metamorphic

Qualities: Hard. brittle, crystalline and compact; difficult to work and dress.

Uses: Retaining walls, road metal, concrete aggregate, pitching, rubble masonry, facing of buildings, etc.

11) Sandstone:

Classification: Sedimentary

Qualities: Consists of quartz and other minerals, easy to work and dress and available in different colours. Its sp. gr. varies from 2.65 to 2.95 and compressive strength is 650 kg/cm2.

Uses: Steps, facing work, columns. flooring, walls, road metal, ornamental carving, etc.

12) Slate:

Classification: Metamorphic

Qualities: Black colour and splits, long natural bedding plane,non-absorbent. Its sp. gr. is 2.89 and compressive strength varies from 770 to 2110 kg/cm2.

Uses: Roofing work, sills. dampproof courses, etc.

2.BRICKS

INTRODUCTION

The bricks are obtained by moulding clay in rectangular blocks of unifrm size and then by drying these blocks .As bricks are of uniform size they can be properly arranged and further, as they are light in weight ,no lifting appliance is required for them.The bricks do not require dressing and the art of laying bricks is so simple that the brickwork can be carried out with the help of unskilled labourers.

Thus,at places where stones are not easily available ,but if there is plenty of clay suitable for manufacture of bricks,the bricks replace stones.

The common brick is one of the oldest building material and it is extensively used at present as a leading material of construction because of its durability ,strength ,reliability,low cost,easy availability,etc.

2.1 BRICK EARTH –ITS COMPOSITION

Following are the constituents of a good brick earth:

(1) Alumina (Al_2O_3):

It is the chief constituent of a good brick earth. A content of about 20% to 30% is necessary to form the brick earth of a good quality. It imparts plasticity to the earth so it helps in the moulding of the brick earth.
If alumina is present in excess with inadequate quantity of sand then the raw bricks shrink and warp during drying, on burning they become too hard. So it is important to have an optimum content of alumina.

(2) Silica (SiO_2):

It exists in the brick earth either free or combined. As free sand it is mechanically mixed with clay and in combined form it exists in chemical composition with alumina. A good brick earth should contain about 50% to 60% of silica.

The presence of this constituent prevents the shrinkage, cracking and warping of raw bricks. It thus imparts uniform shape to the bricks. The durability of bricks depends upon proper composition of silica in brick earth. The excess of silica destroys the cohesion b/w particles and brick become brittle.

(3) Lime($CaCO_3$):

A small quantity of lime not more than 5% is desirable in good brick earth. It should be present in very fine state, because even small particles of size of a pin-head can result in the flaking of the brick.
The lime prevents shrinkage of the raw bricks, sand alone is infusible, but it slightly fuses at kiln temperature in presence of lime. Fused sand acts as a hard cementing material for brick particles.

The excess of lime causes brick to melt and therefore its shape is lost. The lumps of lime turns into quick lime (CaO) after burning and this free lime can later react with water to form slaked lime. This process is called slaking it may result in splitting of the brick into pieces.

(4) Oxide of Iron (Fe_2O_3):

Iron oxide performs two functions, first it helps in fusing of the sand like lime and second it provides the red color to the bricks. It is kept below 5 to 6% because excess of it may result in the dark blue or black color of brick.

(5) Magnesia:

It is used to provide a yellow tint to the bricks. Its content is only about 1% or less.

2.2 BRICK MAKING

In the process of manufacturing bricks, the following four distinct operations are involved:

(1) Preparation of clay

(2) Moulding

(3) Drying

(4) Burning.

2.2.1 PREPARATION OF BRICK EARTH

The clay for bricks is prepared in the following order:

(i) Un-soiling

(ii) Digging

(iii) Cleaning

(iv) Weathering

(v) Blending

(vi) Tempering

(i) Un-Soiling:

The top layer of soil, about 200 mm in depth, is taken out and thrown away. The clay in top soil is full of impurities and hence it is to be rejected for the purpose of preparing bricks.

(ii) Digging:

The clay is then dug out from the ground. It is spread on the levelled ground, just a little deeper than the general level of ground. The height of heaps of clay is about 600 mm to 1200 mm.

(iii) Cleaning:

The clay, as obtained in the process of digging, should be cleaned of stones, pebbles, vegetable matter, etc. If these particles are in excess, the clay is to be washed and screened. Such a process naturally will prove to be troublesome and expensive. The lumps of clay should be converted into powder form in the earth crushing roller.

(iv) Weathering:

The clay is then exposed to atmosphere for softening or mellowing. The period of exposure varies from few weeks to full season. For a large project, the clay is dug out just before the monsoon and it is allowed to weather throughout the monsoon.

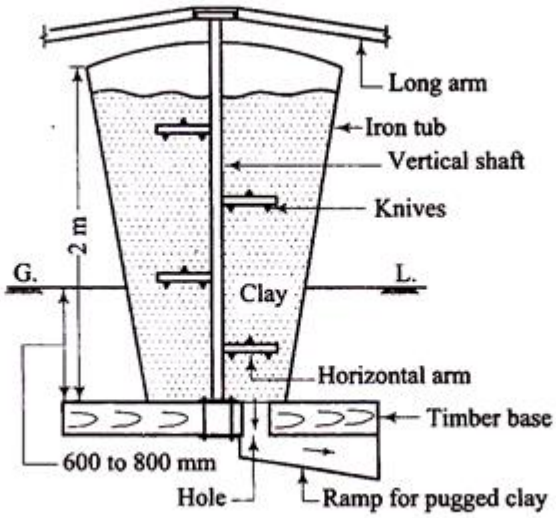
(v) Blending:

The clay is made loose and any ingredient to be added to it is spread out at its top. The blending indicates intimate or harmonious mixing. It is carried out by taking small portion of clay every time and by turning it up and down in vertical direction. The blending makes clay fit for the next stage of tempering.

(vi) Tempering:

In the process of tempering, the clay is brought to a proper degree of hardness and it is made fit for the next operation of moulding. The water in required quantity is added to clay and the whole mass is kneaded or pressed under the feet of men or cattle. The tempering should be done exhaustively to obtain homogeneous mass of clay of uniform character.

For manufacturing good bricks on a large scale, the tempering is usually done in a pug mill. A typical pug mill capable of tempering sufficient earth for a daily output of about 15000 to 20000 bricks is shown in fig. 4-1. The process of grinding clay with water and making it plastic is known as the pugging.



Pug mill
FIG. 4-1

A pug mill consists of a conical iron tub with cover at its top. It is fixed on a timber base which is made by fixing two wooden planks at right angles to each other. The bottom of tub is covered except for the hole to take out pugged earth. The diameter of pug mill at bottom is about 800 mm and that at top is about one metre.

The provision is made in top cover to place clay inside the pug mill. A vertical shaft with horizontal arms is provided at the centre of iron tub. The small wedge-shaped knives of steel are fixed on horizontal arms.

The long arms are fixed at the top of vertical shaft to attach a pair of bullocks. The ramp is provided to collect the pugged clay. The height of pug mill is about 2 m. Its depth below ground is about 600 mm to 800 mm to lessen the rise of the barrow run and to throw out the tempered clay conveniently.

In the beginning, the hole for pugged clay is closed and clay with water is placed in pug mill from the top. When the vertical shaft is rotated or turned by a pair of bullocks, the clay is thoroughly mixed up by the actions of horizontal arms and knives and a homogeneous mass is formed.

The rotation of vertical shaft can also be achieved by using steam, diesel or electric power. When clay has been sufficiently pugged, the hole at the bottom of tub is opened out and the pugged earth is taken out from ramp by barrow i.e., a small cart with two wheels for the next operation of moulding. The pug mill is then kept moving and feeding of clay from top and taking out of pugged clay from bottom are done simultaneously.

If tempering is properly carried out, the good brick earth can then be rolled without breaking in small threads of 3 mm diameter.

2.2.2 Moulding:

The clay which is prepared as above is then sent for the next operation of moulding.

Following are the two ways of moulding:

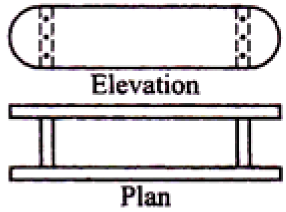
(i) Hand moulding

(ii) Machine moulding.

(i) Hand Moulding:

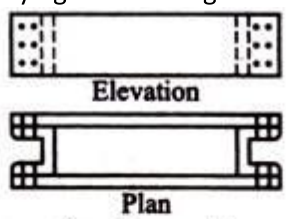
In hand moulding, the bricks are moulded by hand i.e., manually. It is adopted where manpower is cheap and is readily available for the manufacturing process of bricks on a small scale. The moulds are rectangular boxes which are open at top and bottom. They may be of wood or steel.

A typical wooden mould is shown in fig. 4-2. It should be prepared from well-seasoned wood. The longer sides are kept slightly projecting to serve as handles. The strips of brass or steel are sometimes fixed on the edges of wooden moulds to make them more durable.



Wooden mould
FIG. 4-2

A typical steel mould is shown in fig. 4-3. It is prepared from the combination of steel plates and channels. It may even be prepared from steel angles and plates. The thickness of steel mould is generally 6 mm. They are used for manufacturing bricks on a large scale. The steel moulds are more durable than wooden moulds and they turn out bricks of uniform size. The bricks shrink during drying and burning.



Steel mould
FIG. 4-3

Hence the moulds are to be made larger than the size of Steel mould fully burnt bricks. The moulds are therefore made longer by about 8 to 12 per cent in all directions. The exact percentage of increase in dimensions of mould is determined by actual experiment on clay to be used for preparing bricks.

The bricks prepared by hand moulding are of two types:

(a) Ground-moulded bricks

(b) Table-moulded bricks.

(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 extra or surplus clay is removed either by wooden strike or metal strike or frame with wire. A strike is a piece of wood or metal with a sharp edge. It is to be dipped in water every time.

The mould is then lifted up and raw brick is left on the ground. The mould is dipped in water and it is placed just near the previous brick to prepare another brick. The process is repeated till the ground is covered with raw bricks.

A brick moulder can mould about 750 bricks per day with working period of 8 hours. When such bricks become sufficiently dry, they are carried and placed in the drying sheds.

The bricks prepared by dipping mould in water every time are known as the slop-moulded bricks.

The fine sand or ash may be sprinkled on the inside surface of mould instead of dipping mould in water. Such bricks are known as the sand-moulded bricks and they have sharp and straight edges.

The lower faces of ground moulded bricks are rough and it is not possible to place frog on such bricks. A frog is a mark of depth about 10 mm to 20 mm which is placed on raw brick during moulding.

It serves two purposes:

(1) It indicates the trade name of the manufacturer.

(2) In brickwork, the bricks are laid with frog uppermost. It thus affords a key for mortar when the next brick is placed over it.

The ground-moulded bricks of better quality and with frogs on their surface are made by using a pair of pallet boards and a wooden block. A pallet is a piece of thin wood. The block is bigger than mould and it has a projection of about 6 mm height on its surface.

The dimensions of projection correspond to the internal dimensions of mould. The design of impression or frog is made on this block. This wooden block is also known as the moulding block or stock board.

The mould is placed to fit in the projection of wooden block and clay is then dashed inside the mould. A pallet is placed on the top and the whole thing is then turned upside down. The mould is taken out and another pallet is placed over the raw brick and it is conveyed to the drying sheds.

The bricks are placed to stand on their longer sides in drying sheds and pallet boards are brought back for using them again. As the bricks are laid on edge, they occupy less space and they dry quicker and better.

(b) Table-Moulded Bricks:

The process of moulding these bricks is just similar as above. But here the moulder stands near a table of size about 2 m x 1 m. The clay, mould, water pots, stock board, strikes and pallet boards are placed on this table. The bricks are moulded on the table and sent for the further process of drying. However the efficiency of moulder decreases gradually because of standing at the same place for long duration. The cost of brick moulding also increases when table moulding is adopted.

(ii) Machine Moulding:

The moulding may also be achieved by machines It proves to be economical when bricks in huge quantity are to be manufactured at the same spot in a short time. It is also helpful for moulding hard and strong clay.

These machines are broadly classified in two categories:

(a) Plastic clay machines

(b) Dry clay machines.

(a) Plastic Clay Machines:

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. The arrangement is made in such a way that strips of thickness equal to that of the brick are obtained. As the bricks are cut by wire, they are also known as the wire cut bricks.

(b) 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. Such 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.

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.

2.2.3 Drying:

The damp bricks, if burnt, are likely to be cracked and distorted. Hence the moulded bricks are dried before they are taken for the next operation of burning. For drying, the bricks are laid longitudinally in stacks of width equal to two bricks. A stack consists of eight or ten tiers.

The bricks are laid along and across the stock in alternate layers. All bricks are placed on edge. The bricks should be allowed to dry till they become leather hard or bone-dry with moisture content of about 2 per cent or so.

The important facts to be remembered in connection with the drying of bricks are as follows:

(i) Artificial Drying:

The bricks are generally dried by natural process. But when bricks are to be rapidly dried on a large scale, the 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. Such dryers are heated with the help of special furnaces or by hot flue gases. The tunnel dryers are more economical than hot floor dryers and they may be either periodic or continuous.

In the former case, the bricks are filled, dried and emptied in rotation. In the latter case, the loading of bricks is done at one end and they are taken out at the other end. The temperature is usually less than 120°C and the process of drying of bricks takes about 1 to 3 days depending upon the temperature maintained in the dryer, quality of clay product, etc.

(ii) Circulation of Air:

The bricks in stacks should be arranged in such a way that sufficient air space is left between them for free circulation of air.

(iii) Drying Yard:

For the drying purpose, special drying yards should be prepared. It should be slightly on a higher level and it is desirable to cover it with sand. Such an arrangement would prevent the accumulation of rain water.

(iv) Period for Drying:

The time required by moulded bricks to dry depends on prevailing weather conditions. Usually it takes about 3 to 10 days for bricks to become dry.

(v) Screens:

It is to be seen that bricks are not directly exposed to the wind or sun for drying. Suitable screens, if necessary, may be provided to avoid such situations.

(4) Burning:

This is a very important operation in the manufacture of bricks. It imparts hardness and strength to the bricks and makes them dense and durable. The 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.

When the temperature of dull red heat, about 650°C, is attaired, the organic matter contained in the brick is oxidized and also the water of crystallization is driven away.

The burning of bricks is done either in clamps or in kilns. The clamps are temporary structures and they are adopted to manufacture bricks on a small scale to serve a local demand or a specific purpose. The kilns are permanent structures and they are adopted to manufacture bricks on a large scale.

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:

(1) Intermittent kilns

(2) Continuous kilns.

(1) Intermittent Kilns:

These kilns are intermittent in operation which means that they are loaded, fired, cooled and unloaded. Such kilns may be either rectangular or circular in plan. They may be over-ground or underground.

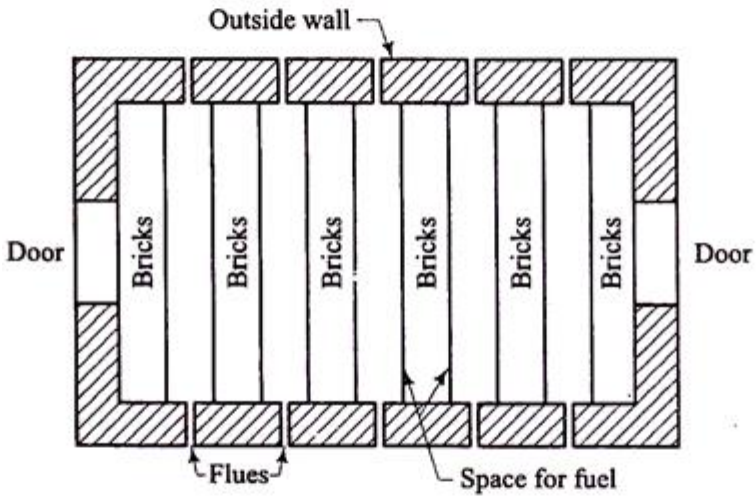
They are classified in two ways:

(i) Intermittent up-draught kilns

(ii) Intermittent down-draught kilns.

(i) Intermittent Up-Draught Kilns:

These kilns are in the form of rectangular structures with thick outside walls. The wide doors are provided at each end for loading and unloading of kilns. The flues are channels or passages which are provided to carry flames or hot gases through the body of kiln. A temporary roof may be installed of any light material. Such roof gives protection to the raw bricks from rain while they are being placed in position. This roof is to be removed when the kiln is fired.



Intermittent kiln
FIG. 4-5

Intermittent Down-Draught Kilns:

These kilns are rectangular or circular in shape. They are provided with permanent walls and closed tight roof. The floor of the kiln has openings which are connected to a common chimney stack through flues. The working of this kiln is more or less similar to the up-draught 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 draught and in doing so, they burn the bricks.

(2) Continuous Kilns:

These kilns are continuous in operation. This means that loading, firing, cooling and unloading are carried out simultaneously in these kilns. There are various types of the continuous kilns.

Following three varieties of continuous kilns will be discussed:

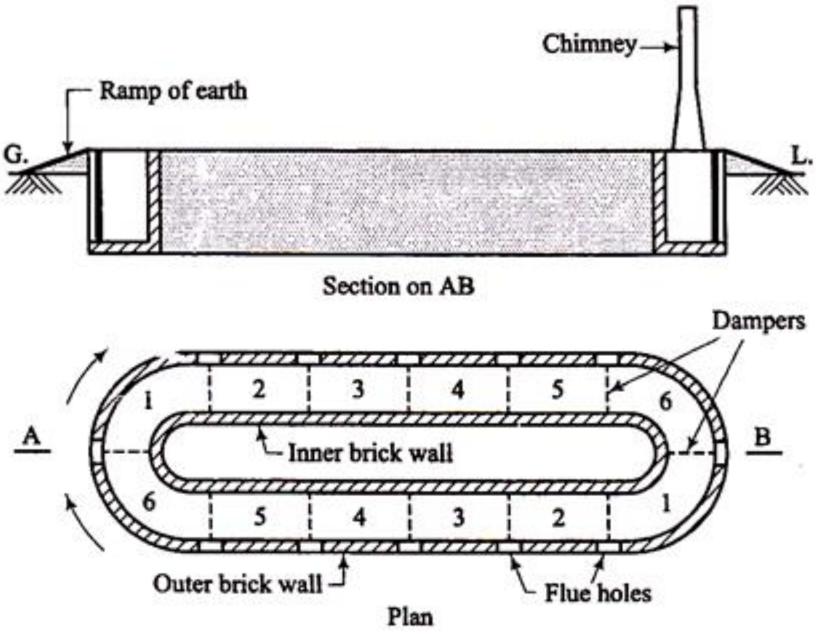
(i) Bull’s trench kiln

(ii) Hoffman’s kiln

(iii) Tunnel kiln.

(i) Bull’s Trench Kiln:

This kiln may be of rectangular, circular or oval shape in plan. Fig. 4-6 shows a typical Bull’s kiln of oval shape in plan.



Bull's trench kiln
FIG. 4-6

As the name suggests, the kiln is constructed in a trench excavated in ground. It may be fully underground or partly projecting above ground.

Fig. 4-6 shows Bull's kiln with two sets of sections. The two pairs of chimneys and two gangs of workers will be required to operate this kiln. A tentative arrangement for different sections may be as shown in table 4-1.

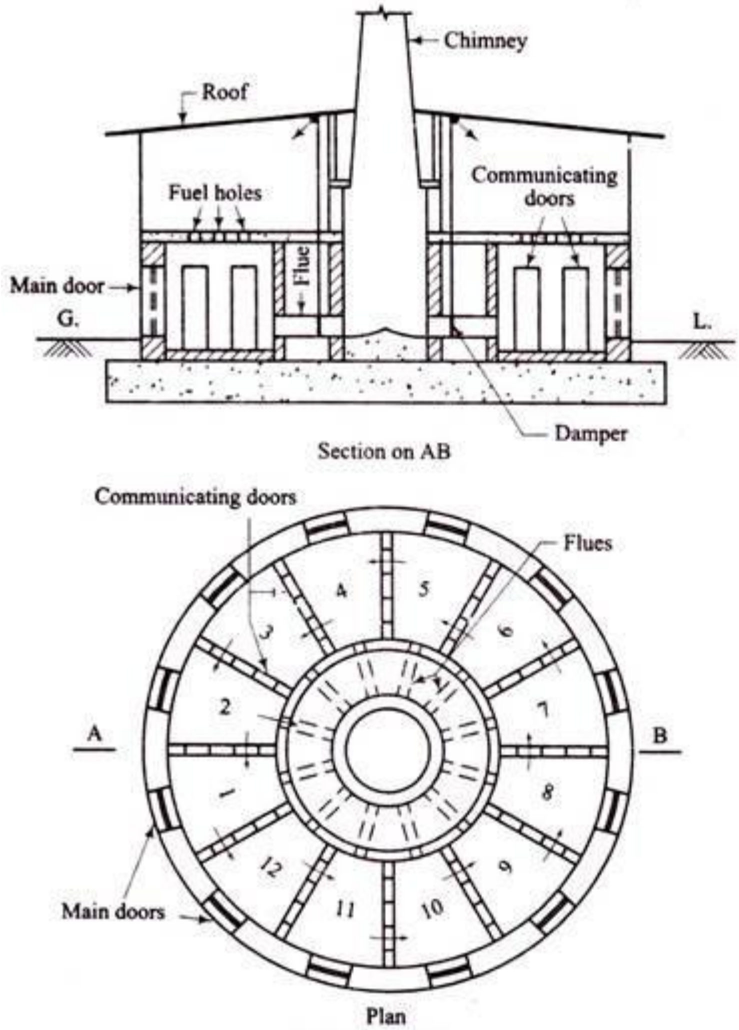
TABLE 4-1

Section	Arrangement
1	Loading
2	Empty
3	Unloading
4	Cooling
5	Burning
6	Heating

(ii) Hoffman's Kiln:

This kiln is constructed over-ground and hence it is sometimes known as the flame kiln. Its shape is circular in plan and it is divided into a number of compartments or chambers. As a permanent roof is provided, the kiln can even function during rainy season.

Fig. 4-7 shows plan and section of the Hoffman's kiln with 12 chambers.



Hoffman's kiln
FIG. 4-7

Each chamber is provided with the following:

(a) A main door for loading and unloading of bricks,

(b) Communicating doors which would act as flues in open condition,

(c) A radial flue connected with a central chimney, and

(d) Fuel holes with covers to drop fuel, which may be in the form of powdered coal, into burning chambers.

The main doors are closed by dry bricks and covered with mud, when required. For communicating doors and radial flues, the dampers are provided to shut or open them. In the normal condition, only one radial flue is connected to the chimney to establish a draught.

In this type of kiln, each chamber performs various functions in succession, namely, loading, drying, burning, cooling and unloading.

As an illustration, 12 chambers shown in fig. 4-7, may be functioning as follows:

Chamber 1 — Loading

Chambers 2 to 5 — Drying and pre-heating

Chambers 6 and 7 — Burning

Chambers 8 to 11 — Cooling

Chamber 12 — Unloading

With the above arrangement, the circulation of the flue gas will be as shown by arrows in fig. 4-7. The cool air enters through chambers 1 and 12 as their main doors are open. After crossing the cooling chambers 8 to 11, it enters the burning section in a heated condition. It then moves to chambers 2 to 5 to dry and pre-heat the raw bricks. The damper of chamber 2 is in open condition and hence it escapes into atmosphere through chimney.

The initial cost of installing this kiln is high, but it possesses the following advantages:

(a) The bricks are burnt uniformly, equally and evenly. Hence the high percentage of good quality bricks can be produced.

(b) It is possible to regulate heat inside the chambers through fuel holes.

(c) The supply of bricks is continuous and regular because of the fact that the top of kiln is closed and it can be made to work during the entire year.

(d) There is considerable saving in fuel due to pre-heating of raw bricks by flue gas. Thus the hot gases are fully utilized in drying and pre-heating the raw bricks.

(e) There is no air pollution in the locality because the exhaust gases do not contain black smoke or coal dust particles.

The capacity of the kiln will depend upon the dimensions of chambers. If each chamber is of about 11 m length, 4.50 m average width and 2.50 m height, it will contain about 25000 bricks. Hence, if it is so arranged that one chamber is unloaded daily, such a kiln will manufacture about 25000 bricks daily or about 8 to 9 million bricks annually. The quantity of coal dust required for burning one lakh of bricks is about 120 to 150 kN.

It may be noted that in case of Bull's trench kiln and Hoffman's kiln, the chambers are zoned in accordance with the brick-processing stages, namely, loading, drying, preheating, burning, cooling and unloading. The source of fire and other zones are moving continuously along the channel of kiln while the bricks in process remain stationary.

Table 4-2 shows the comparison of Bull's trench kiln and Hoffman's kiln with respect to some important items.

TABLE 4-2
COMPARISON BETWEEN BULL'S TRENCH KILN AND HOFFMAN'S KILN

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 round as it is provided with a permanent roof.
3.	Cost of fuel	High as consumption of fuel is more.	Low as consumption of fuel is less.
4.	Drying space	It requires more space for drying of bricks.	It requires less space for drying of bricks.
5.	Initial cost	Low	High
6.	Nature	It is semi-continuous in loose sense.	It is perfectly continuous.
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.

(iii) Tunnel Kiln:

This type of kiln is in the form of tunnel which may be straight, circular or oval in plan. It contains a stationary zone of fire. The raw bricks are placed on trolleys which are then moved from one end to the other end of tunnel.

The raw bricks get dried and pre-heated as they approach zone of fire. In zone of fire, the bricks are burnt to the required degree and they are then pushed forward for cooling. When bricks are sufficiently cooled, they are unloaded.

This kiln proves to be economical when bricks are to be manufactured on a large scale. As temperature is under control, uniform bricks of better quality are produced.