# outline

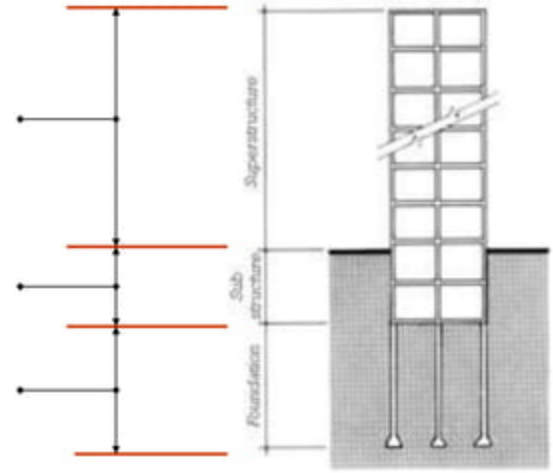
- Introduction
- Purpose of foundation
- Importance of foundation in building construction
- Foundation requirements
- Load and settlement of foundation
- Factors affecting foundation design
- Underpinning
- Types of foundations
  - Shallow foundations
  - Deep foundation
- Seismic base isolation
- Construction process of foundation
- Water proofing and drainage

# Major Building Parts

Superstructure

Substructure

Foundation

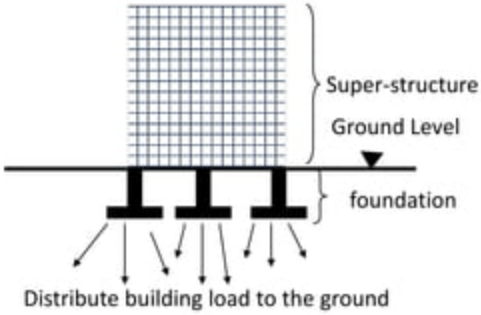


# Introduction

- *"The foundation of a building is that part of walls, piers and columns in direct contact with the ground and* ***transmitting loads to the ground****."*
- Every building needs a foundation of some kind.
- Because of the variety of soil, rock, and water conditions that are encountered below the surface of the ground and the unique demands that buildings make upon their foundations, foundation design is a highly specialized field combining aspects of geotechnical and civil engineering.

# Purpose of foundation

- To distribute the load of the structure over a large bearing area so as to bring the intensity of load within the safe bearing capacity of soil.
- To load the bearing surface at a uniform rate to avoid differential settlement.
- To prevent the lateral movement of supporting material.
- To attain a level and firm bed for building operations.
- To increase the stability of the structure as a whole.




- The size and depth of a foundation is determined by the **structure and size of a building** it supports and the **nature and bearing capacity of the ground** supporting it.

# The importance of foundations in building constructions

- Buildings are built for a purpose: schools for education, offices for work, theatres for culture. Each is constructed for a specific purpose behind with a specific provision of foundation.
- to be aesthetically pleasing as well as to fulfill the purpose for which it was created.
- Foundations do not typically contribute to the architectural aesthetics of a building. Yet, without suitable foundations, a building will not function effectively, will be unsafe and its architectural merits will rapidly fade.

# Requirements of foundation

- Structural stability
- Not impairing function of the building
- Durability
- Economy

# Factors affecting design of foundation

- Soil types and ground water table conditions.
- Structural requirements and foundations.
- Construction requirements .
- Site condition and environmental factor.
- Economy etc.

# Types of foundation

- There are two basic types of foundations
  1. Shallow foundation
  2. Deep foundation

- Shallow foundation
  - The foundation provided immediately below the lowest part of the structure near the ground level, transferring load directly to the supporting soil, is known as shallow foundation.
  - Shallow foundation is provided when stable soil with adequate bearing capacity occur near to the ground level.
  - Requirements
    - Suitable soil bearing capacity
    - Undisturbed soil or engineered fill

# 1) Types of Shallow foundation

a) Spread footing or open trench foundation

b) Grillage foundation

c) Raft foundation

d) Stepped foundation

e) Inverted arch foundation

f) mat foundation

g)Rubble trench foundation

# Spread footing

- A spread footing foundation, which is typical in residential building, has a wider bottom portion than the load-bearing foundation walls it supports. This wider part "spreads" the weight of the structure over more area for greater stability.
- The design and layout of spread footings is controlled by several factors, foremost of which is the weight (load) of the structure it will support.
- These foundations are common in residential construction that includes a basement, and in many commercial structures. But for high rise buildings they are not sufficient.
- A spread footing which changes elevation in several places in a series of vertical "steps" in order to follow the contours of a sloping site or accommodate changes in soil strata, is termed a **stepped footing**.

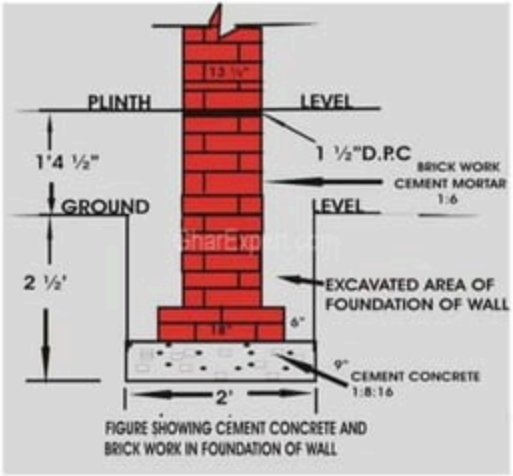
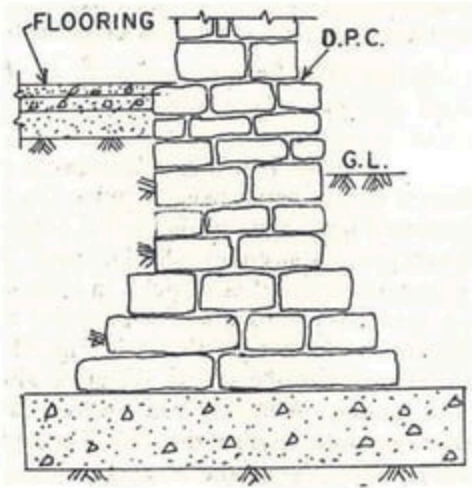


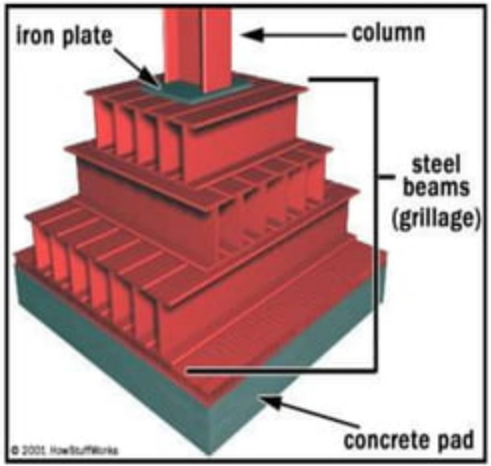
FIGURE SHOWING CEMENT CONCRETE AND BRICK WORK IN FOUNDATION OF WALL

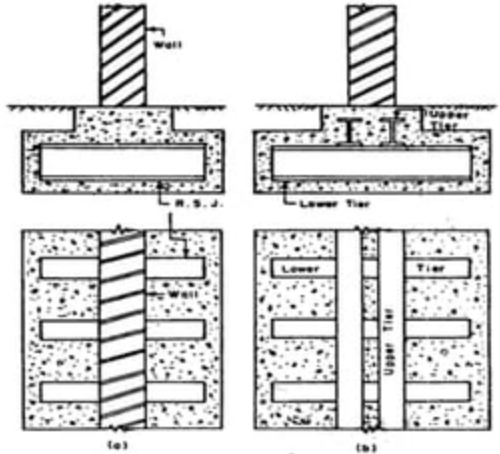


Spread footing in stone masonry

# Grillage foundation

- A type of foundation often used at the base of a column. It consists of one, two or more tiers of steel beams superimposed on a layer of concrete, adjacent tiers being placed at right angles to each other, while all tiers are encased in concrete.
- This is dependable foundation and is used in those place where the load of the structure is pretty and bearing capacity of soil comparatively poor.
- The grillage foundation helps in distributing the load over a wider area of subsoil.
- The grillage foundation helps in avoiding deep excavations as the necessary base area is provided for the load of transmission.
- This type of foundation generally used for heavy structure columns piers and steel stanchions etc.

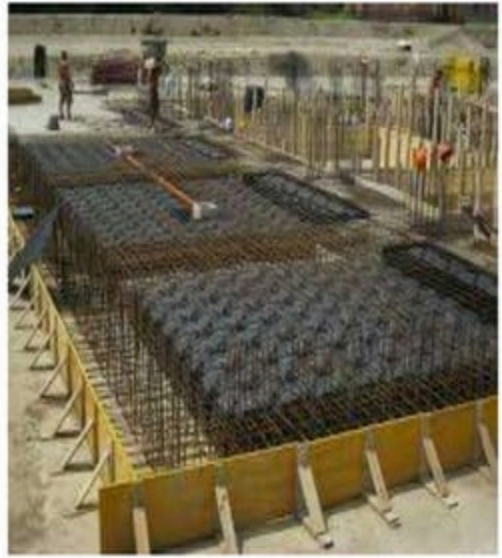



Grillage foundation

# Raft foundation

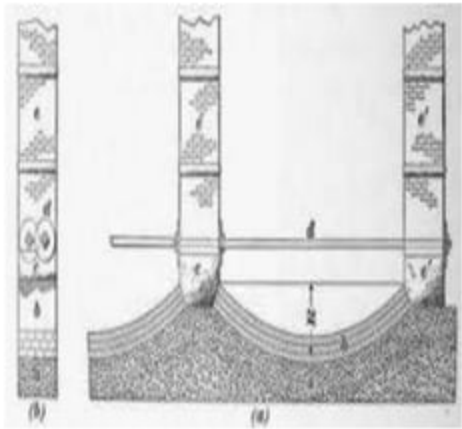
- Raft foundation is a thick concrete slab reinforced with steel which covers the entire contact area of the structure like a thick floor.
- The reinforcing bars runs normal to each other in both top and bottom layers of steel reinforcement.
- Sometimes inverted main beams and secondary beams are used to carry column loads that require thicker foundation slab considering economy of the structure.
- Used generally for higher loads and prevention of excessive settlements.

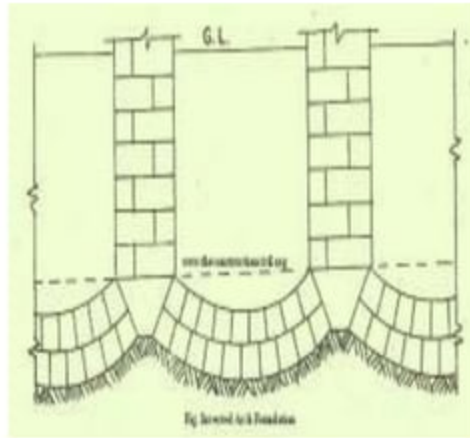


**Raft foundation**

# Inverted arch foundation

- Provided for multi storyed buildings in old times.
- However, with the advent of reinforced cement concrete construction practice, **inverted arch footing** is rarely done these days.
- One of the drawbacks in this type of construction is that the end piles have to be specially strengthened by buttresses to avoid the arch thrust tending to rapture the pier junction.
- However, the advantage of inverted arch construction is that in soft soils the depth of foundation is greatly reduced.






Inverted arch foundation

# Stepped foundation

- A foundation constructed in a series of steps that approximate the slope of the bearing stratum.
- The purpose is to avoid horizontal force vectors that might cause sliding.
- Generally provided in hilly areas.
- It is a special form of strip foundation.

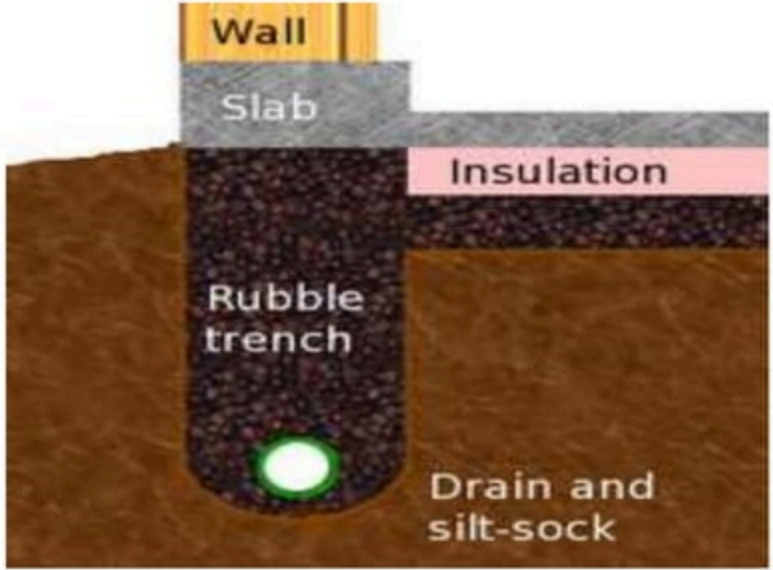
**Stepped footing**

# Mat / slab foundation

- Mat-slab foundations, also called on-grade mat foundations for expansive soils, are used to distribute heavy column and wall loads across the entire building area, to lower the contact pressure compared to conventional spread footings.
- Mat-slab foundations can be constructed near the ground surface, or at the bottom of basements.
- In high-rise buildings, mat-slab foundations can be several meters thick, with extensive reinforcing to ensure relatively uniform load transfer.

# Rubble trench foundation

- is a type of foundation that uses loose stone or rubble to minimize the use of concrete and improve drainage.
- It is considered more environmentally friendly than other types of foundation because cement manufacturing requires the use of enormous amounts of energy.
- However, some soil environments (such as particularly expansive or poor load-bearing (< 1 ton/sf) soils) are not suitable for this kind of foundation.


Wall
Slab
Insulation
Rubble trench
Drain and silt-sock

# 2) Deep foundation

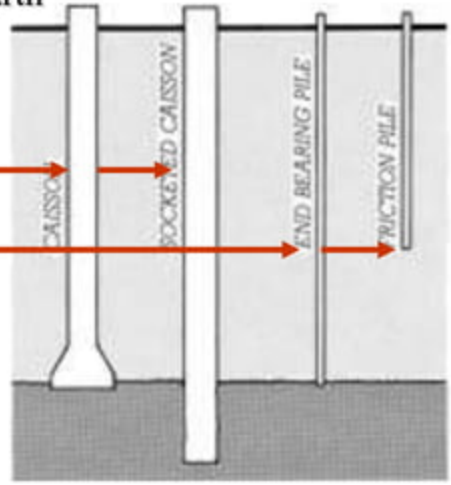
# Deep Foundations -

## *Purpose*

transfer building loads deep into the earth

Basic types

- Drilled (& poured)
- Driven



# Caisson Installation Sequence

- Hole drilled with a large drill rig
- Casing installed (typically)
- Bell or Tip enlargement (optional)
- Bottom inspected and tested
- Reinforced
- Concrete placement (& casing removal)


D 7

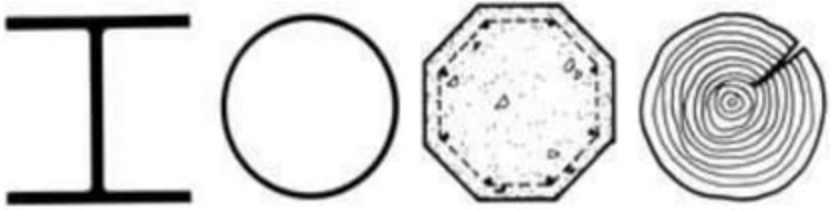
# Driven Piles

Two basic types of Piles

- **End bearing pile** - point loading
- **Friction pile** - load transferred by friction resistance between the pile and the earth

# Pile material

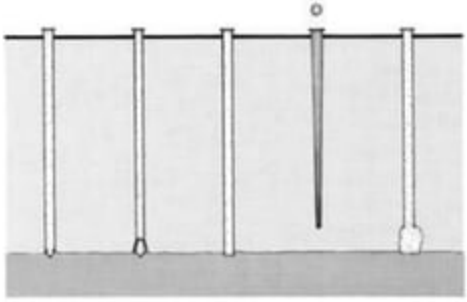
- Steel; H- piles, Steel pipe
- Concrete; Site cast or Precast
- Wood; Timber
- Composite



# Precast Concrete Plies

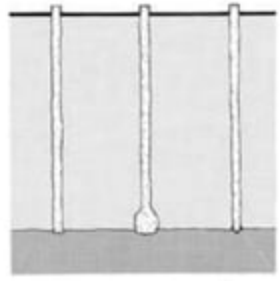
# Site Cast Concrete Piles

Cased Piles




CASED PILES

Uncased Piles




UNCASED PILES

# Factors affecting choice of foundation

- The type of construction.
- The magnitude of load.
- Drainage conditions.
- Feasibility in terms of available skilled labors and cost.
- The type and bearing capacity of soil.
- The seismic hazard and vulnerability of site to earthquake.

# Construction of foundation

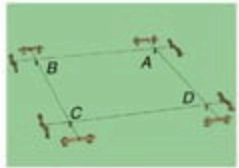
- Construction of foundation  consists upon the following activities
  - Site preparation
  - Site layout
  - Excavation
  - Pour footing
  - Pour slab on grade
  - Pour concrete foundation walls

# Site Preparation

- Remove trees and any debris
- Remove top soil (4-6” below surface)

## Site Layout

- Define the boundaries by using chalk powder.
- Layout building perimeter, Establish building corners & building perimeter.
- Use surveying instruments




## Excavation

- Excavate foundation along line created.
- Excavate remainder of soil inside perimeter
  - *(Don't excavate inside soil if slab on grade)*
- If deep foundation, taper edges to prevent collapse
- If soil unstable, or very deep - use shoring

## Pour Footings

- Construct formwork (if required)
- Install reinforcement (rebar) for footing.
- Pour concrete footings
- Smooth / finish surface

## Pour Slab on Grade

- Install gravel base (to keep water off of slab)
- Install moisture barrier (to keep water off of slab)
- Install reinforcement (welded wire fabric)
- Pour concrete slab
- Finish slab surface

## Pour Concrete Foundation Walls

- Construct formwork (include sleeves / doors / windows)
- Install reinforcement into formwork
- Pour concrete foundation wall
- Install anchor bolts into semi-cured concrete

## Pour Concrete Foundation Walls

- Allow concrete to cure adequately (7-10 days)
- Strip forms
- Apply waterproofing
- Backfill

# Protecting foundation against moisture

# Waterproofing

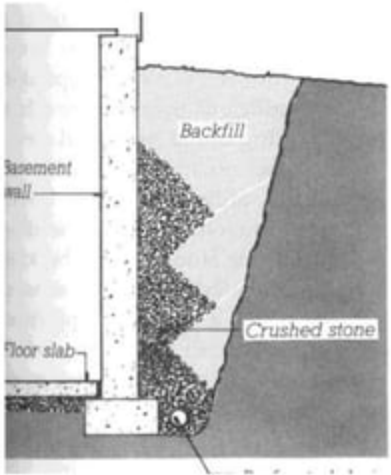
- Structures Below Ground subject to penetration of ground water
- More extreme, if below $H_2O$ table
- Two basic approaches to Waterproofing
  - Waterproof Membranes, or
  - Drainage
  - Generally - both used in tandem

# Waterproofing Membranes

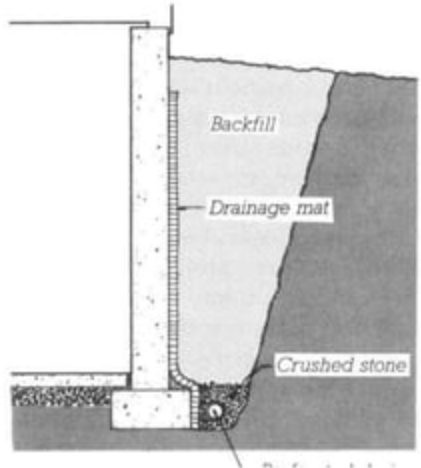
- Materials
  - Liquid or Sheet (Plastic, asphaltic, synthetic rubber)
  - Coatings (asphaltic)
  - Cementitious Plasters & admixtures
  - Bentonite clay
- Protecting boards or panels
  - Protection Board
  - Waterstop
    - » Unit of Measure - SF, in (thickness)

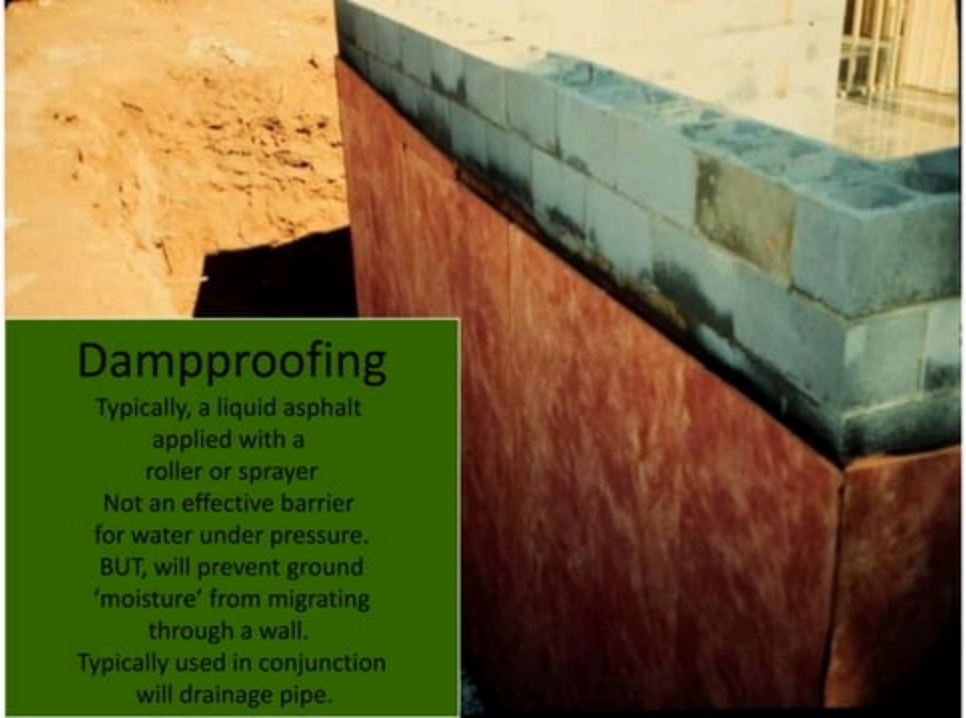
# Drainage Methods

Stone & Perforated Pipe




Drainage Mat & Perforated Pipe





# Dampproofing

Typically, a liquid asphalt
applied with a
roller or sprayer
Not an effective barrier
for water under pressure.
BUT, will prevent ground
'moisture' from migrating
through a wall.
Typically used in conjunction
will drainage pipe.

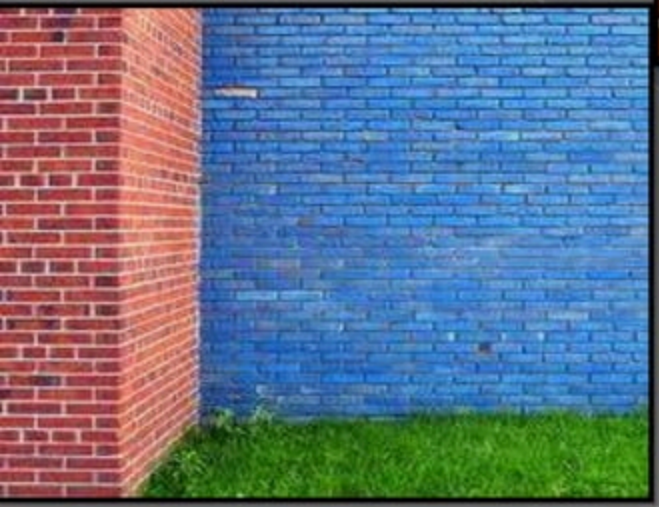
# Underpinning

- **underpinning** is the process of strengthening the foundation of an existing building or other structure. Underpinning may be necessary for a variety of reasons:
- The original foundation is simply not strong or stable enough.
- The usage of the structure has changed.
- The properties of the soil supporting the foundation may have changed (possibly through subsidence) or were mischaracterized during design.
- The construction of nearby structures necessitates the excavation of soil supporting existing foundations.
- To increase the depth or load capacity of existing foundations to support the addition of another storey to the building (above or below grade).
- It is more economical, due to land price or otherwise, to work on the present structure's foundation than to build a new one.
- Earthquake, flood, drought or other natural causes have caused the structure to move, thereby requiring stabilisation of foundation soils and/or footings.
- Underpinning may be accomplished by extending the foundation in depth or in breadth so it either rests on a more supportive soil stratum or distributes its load across a greater area. Use of micropiles and jet grouting are common methods in underpinning

# Introduction

- A Vertical load-bearing member.
- Wall fulfills the function of privacy, security and protection against natural factors.

It supports roof and ceilings.



The main purpose of the wall is to divide the space of the building.

# Types of Walls

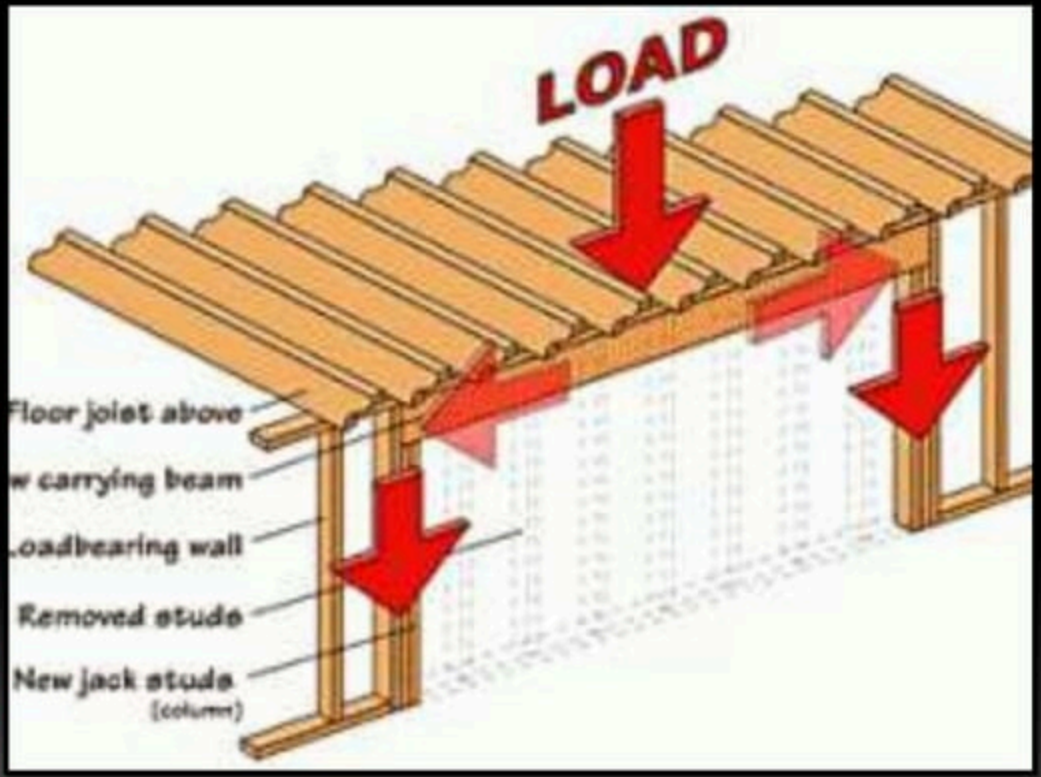
Load Bearing Walls

Non-load bearing walls

# Load bearing walls

- They are meant to carry super imposed loads in addition to their own weight.
- The materials most often used to construct load-bearing walls in large buildings are concrete, block, or brick.

# LOAD BEARING WALL



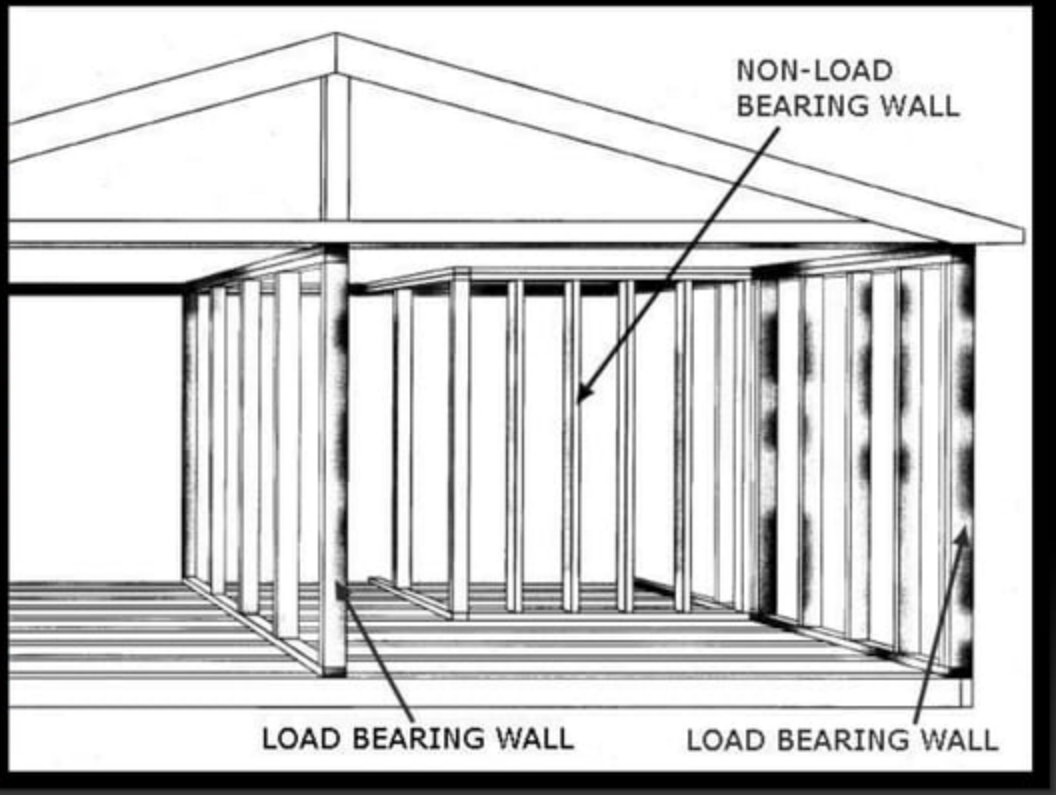
# Load-bearing Walls

- Load-bearing walls always run perpendicular to the ceiling joists of your home.
- All exterior walls are load bearing; interior walls that are aligned above support beams are also lead bearing.

# Non-load bearing Walls

- They carry their own load only.
- The main purpose of these walls is to divide walls or serve as partition walls.
- They run perpendicular to the floors and ceiling.

# NON LOAD BEARING WALLS.



# Other category of walls

Cavity walls

Partition walls.

# Cavity walls

- A cavity wall has two separate walls constructed with a gap in between the two walls .
- The two leaves of cavity walls can be of equal thickness if it is non load bearing wall.

# Characteristics

The cavity is normally between 5 cm to 10 cm.

Cavity walls give good sound property.

It gives better thermal insulation.

# Characteristics

Cavity walls are constructed to prevent the transmission of dampness to the inner walls.

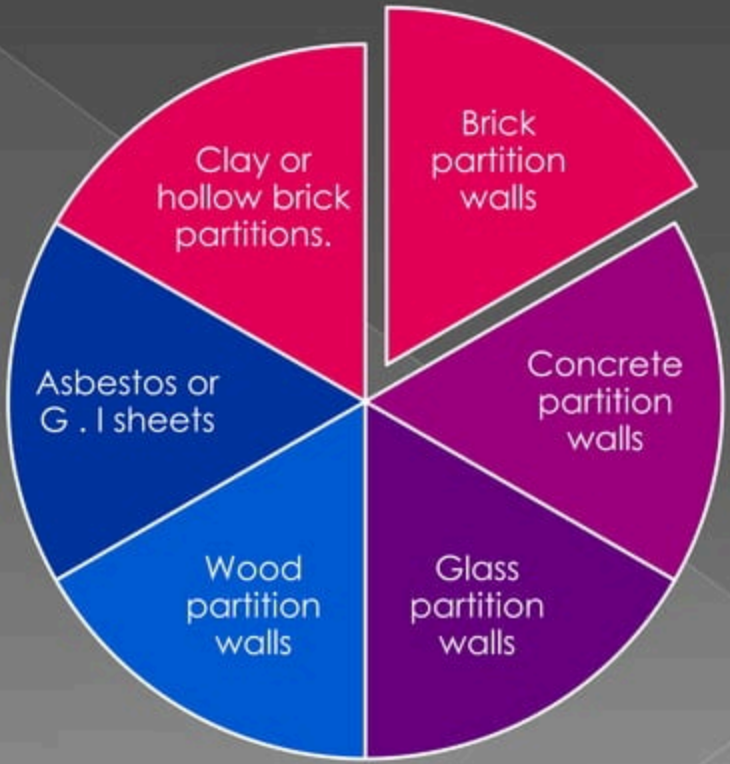
It prevents moisture.

They prove to be economical.

# Partition Walls

- Divide the space into parts
- Non load bearing walls
- Foldable, collapsible or fixed
- Privacy

# Types of partition walls



# Brick partition wall

**Plain brick partition**

- This type of partition are cheapest as well as considered strong and fire resistant .

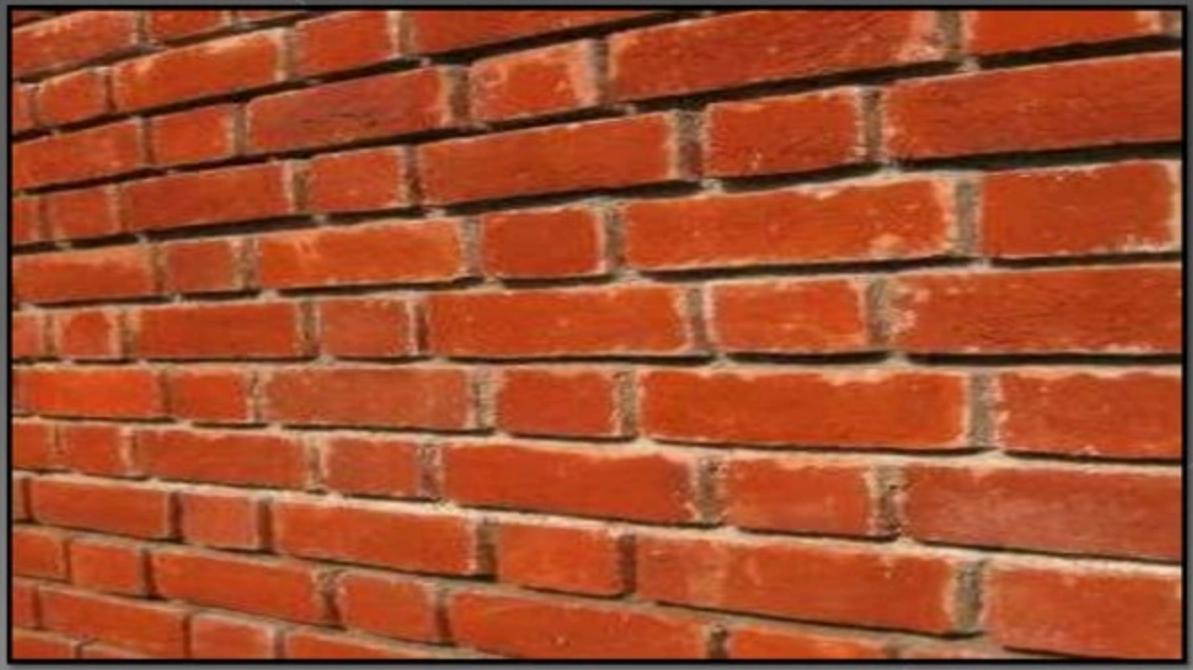
**Reinforced brick partition**

- Bricks are reinforced with iron strops or steel bars.

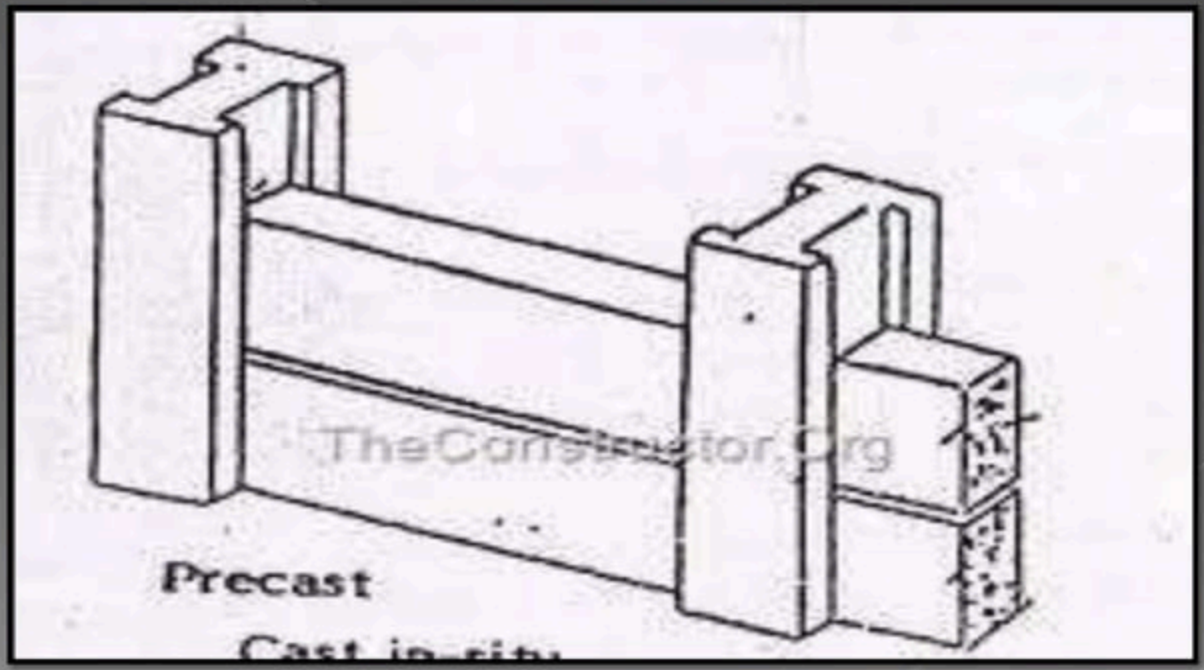
**Brick nogging partition**

- It consists of brick work within the frame work of wooden members namely studs (vertical members)and nogging pieces (horizontal member).

# Plain brick



# Reinforced brick partition



# Brick nogging partition

# Concrete partition

Can be plain or reinforced.

It may be cast in site or built from panels or blocks precast in advance.

This partition are rigid and stable along both vertical and horizontal directions.

# Concrete partition

# Glass partition

- These may be made from sheet glass or hollow glass bricks.
- Sheets of glass are fixed in the framework of wooden members dividing the entire area into a number of panels.

- Glass block adds to the architectural beauty and also provide good day light.
- They  are soundproof and fire proof.
- Needs care and mainteance.

# Glass partition

# Wood partition

- This type of partition walls consists of a wooden framework either supported on the floor below or by side walls.
- Such partitions are not fire-resistant and the timber forming the partition is likely to decay or be eaten away by white ants.
- The major advantage of using this partition is light in weigth though costlier.

# Wood partition

# Asbestos sheet

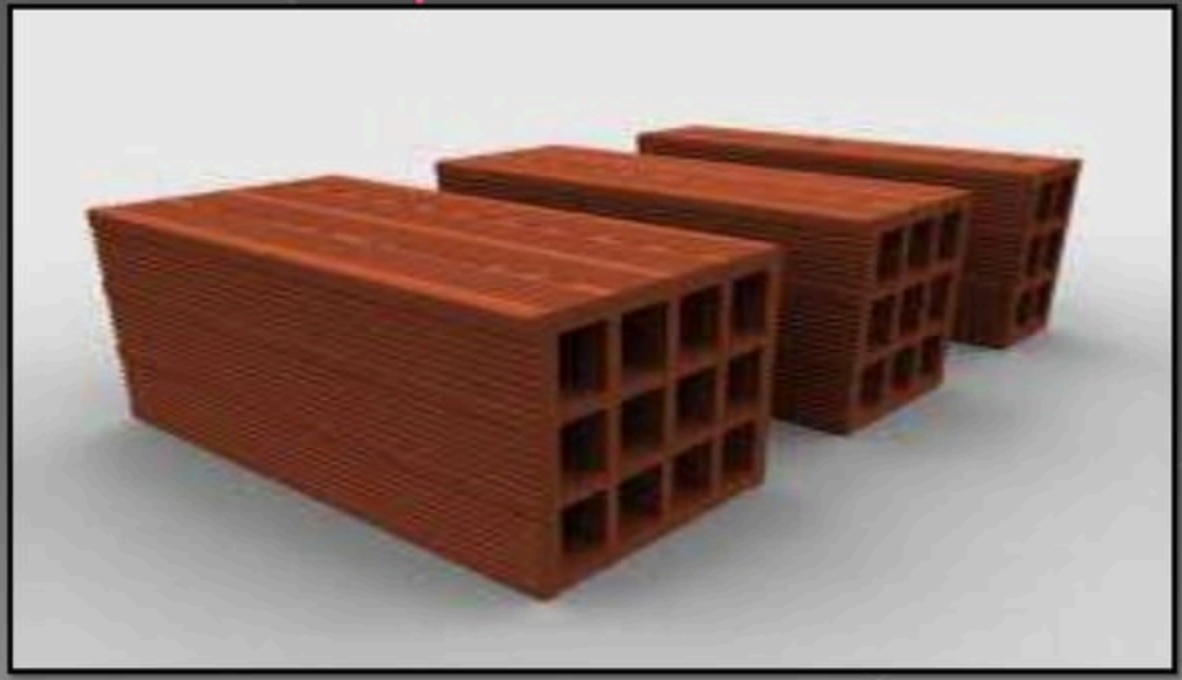
- Wooden frame is used to fix the this sheets for the partition.
- They are lighter in weight , thin and cheaper.
- To make it more strong ,specially manufactured asbestos slabs are used.
- Fire-resistant and makes it have good heat and sound insulation properties.

# Asbestos sheet

# Clay or hollow bricks partition

- They are made from clay , terra-cotta or concrete.
- They are light in weight , rigid ,strong , economical and good insulation.
- They are available in variety of sizes.

# Hollow brick partition



# Wall Finishes

Plaster

Wood walls

Sand

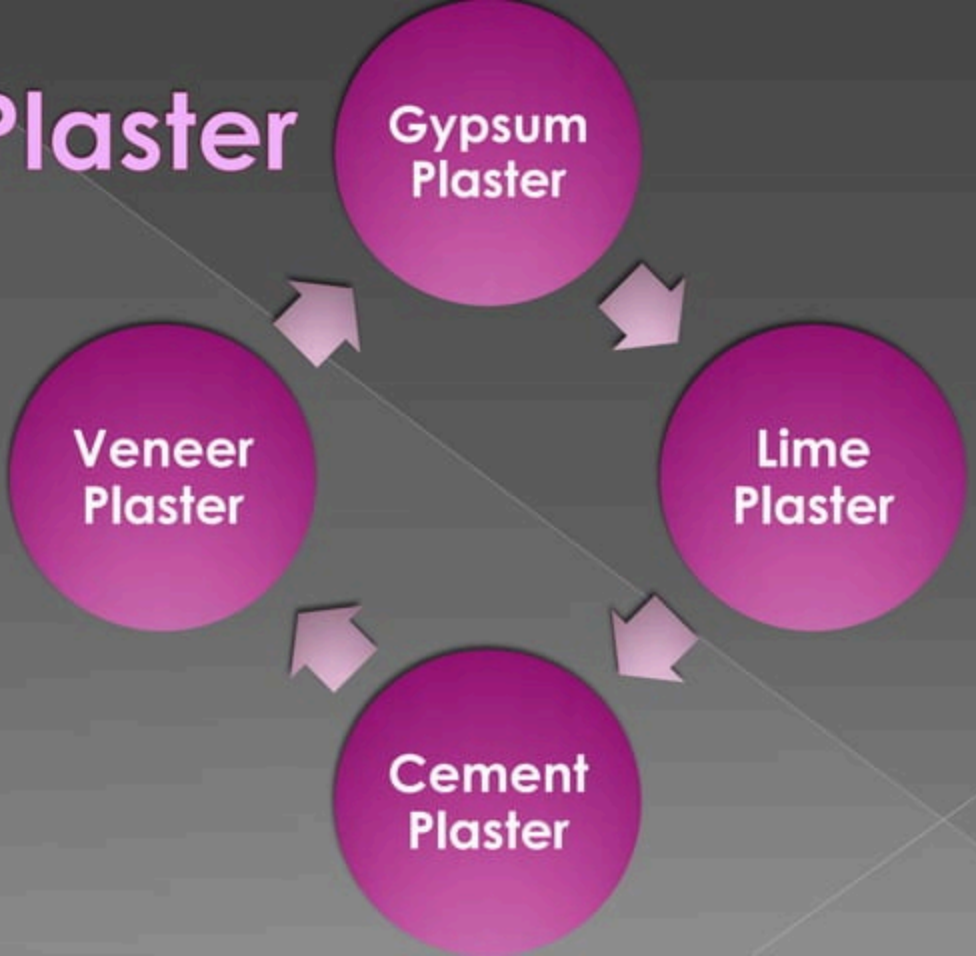
White washing

Stone facing

Skirting

Metal Wall covers

# Plaster


Gypsum Plaster
Lime Plaster
Cement Plaster
Veneer Plaster

# Gypsum Plaster

# Veneer Plaster

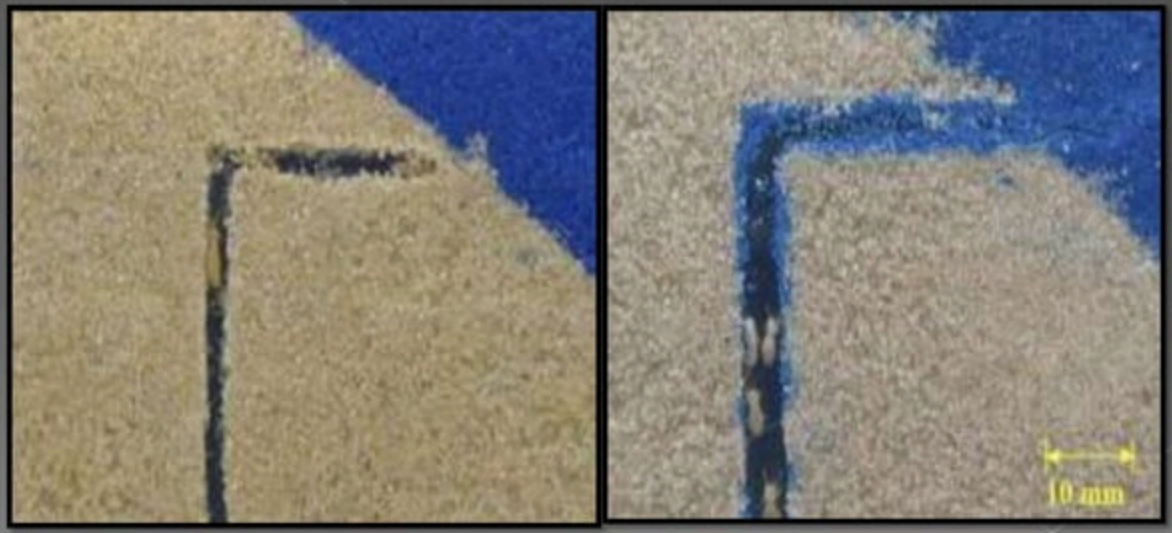
# Lime Plaster

# Cement Plaster

# Sand effect

- Sand is mixed with fevicol and applied on the wall.
- Sand are available in different colors like orange, blue, brown, etc.
- It gives the desired look, dull or smooth. It is not affected by fire.
- It is very expensive and it cannot be easily removed.

# Sand Effect



# Stone Facing

**Limestone**

- Is available in a variety of colours. It is mostly used on exterior walls.

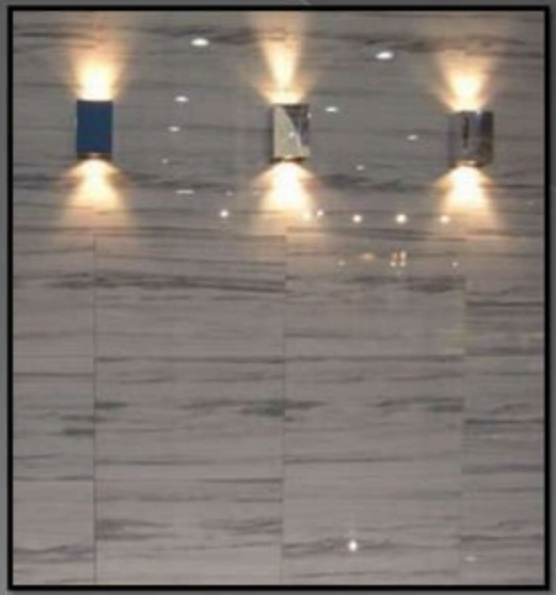
**Sandstone**

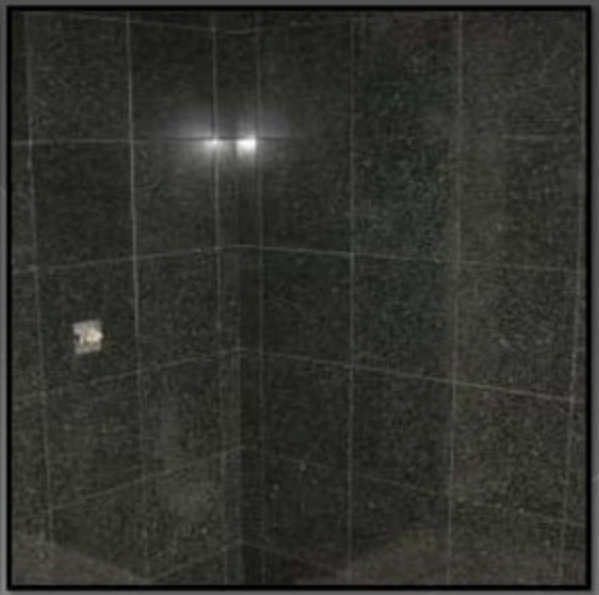
- It is natural concrete of sand grains. It looks and feels sandy.

**Slate**

- A sedimentary rock that splits easily into thin sheets with smooth surfaces; it gives good interior flooring or outdoor paving.

# Stone facing

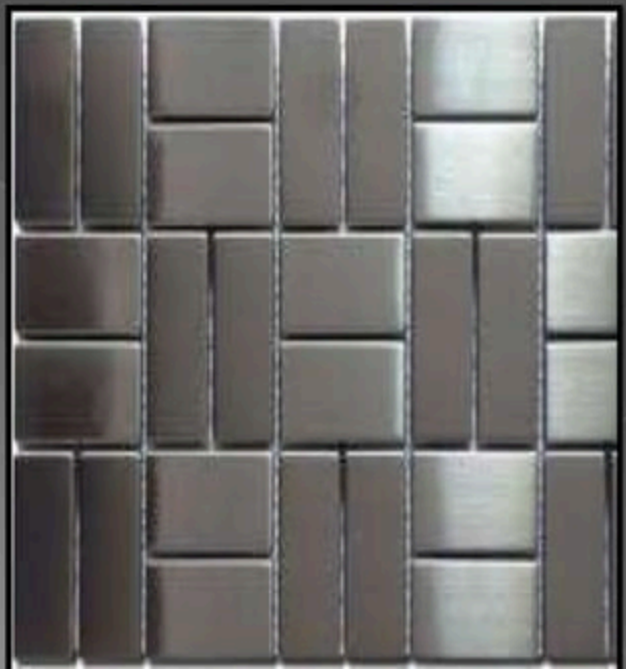




# Metal Wall covers

- Metals are mostly used for their decorative and hygienic qualities.
- Metals such as copper and aluminium are decorative.
- Stainless steel in the form of tiles can be used in kitchens where they present a durable, easily cleaned hygienic surface in areas where splashing is likely

# Metal wall covers



# Skirting

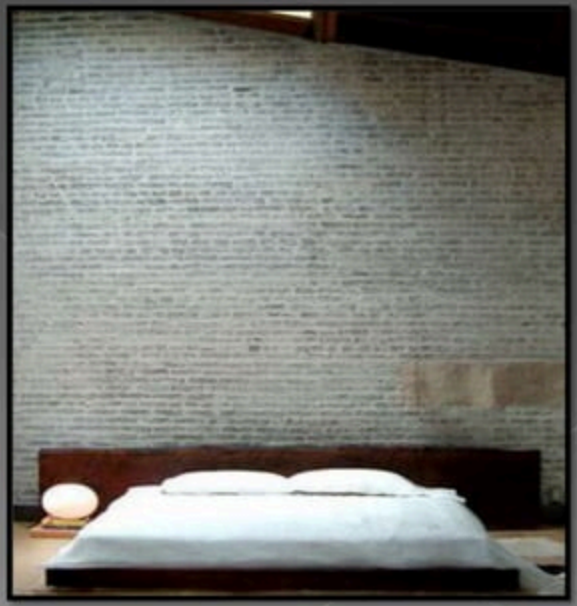
- It is a board/tile covering the lowest part of an interior wall.
- Its purpose is to cover the joint between the wall surface and the floor.
- It covers the uneven edge of flooring next to the wall; protects the wall from kicks, abrasion, and furniture; and can serve as a decorative moulding.

# Skirting

# White washing

- White wash is made from pure fat lime (white stone lime) or shell lime.
- White wash may be applied in specific number of coat until the surface presents a smooth and uniform finish.

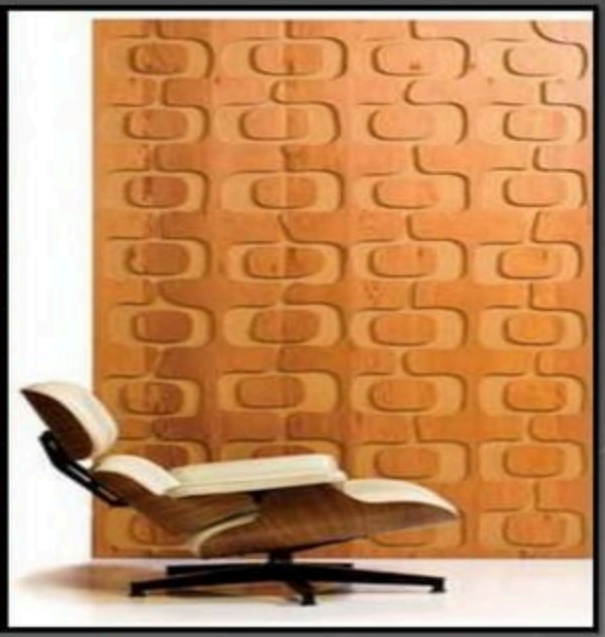
# White washing



# Wood Walls

- The major disadvantage of wood wall is that it does not provide proper insulation and makes a lot of noise but on the other hand it has an advantage as it does not need any type of painting or plaster.

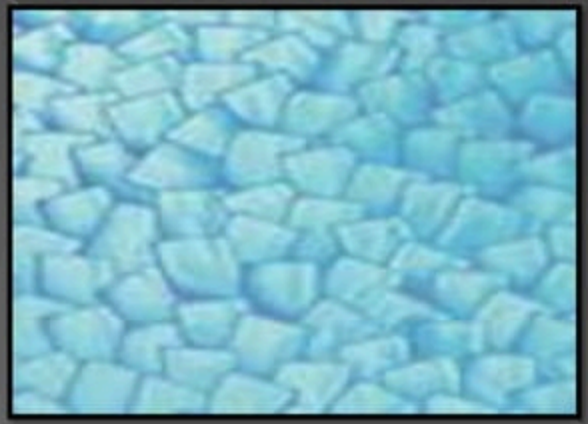
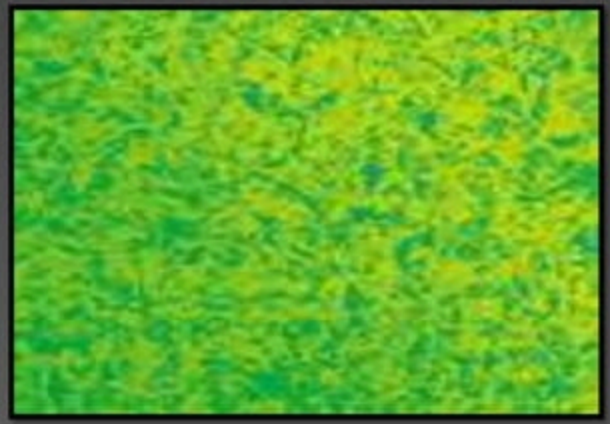
# Wood walls



# Paints

- Paint is the simplest finish to apply to walls.
- Paint is applied on timber, metal, brick or other material in the form of a liquid which on drying forms a thin cover on the painted surface.
- The most important function of the paint is to provide protection or decoration.

# Paints

# Wall Papers

- Wall papers are available in a variety of colors and design.
- They are preferred in bedrooms, living rooms or drawing rooms.
- The wall papers are just struck on the plastered surface with the help of an adhesive.




# Materials of Insulation

- **Fiberglass:-** It is low cost and has good insulating values. It is available in batts, blankets and loose.
- **Mineral wool:-** most often called rock wool. Its insulating qualities are good.
- **Cellulose:-** this is an inexpensive insulation made of recycled materials most notably newspapers.

# Materials used for insulation

- **Mica**:- this product is made from the mineral mica. The insulating qualities are only fair.
- **Silver wool**:- It consists of wood slivers retardant. The most common wood appears to be cedar that is resistant to rot and pests. The insulating qualities are quite good.

# Wall soundproofing products

- Wall panels are available which are sound absorbing panels that mount directly to the walls or ceilings. They are designed to increase speech intelligibility by reducing reverberation and echoes.

# Acoustical treatment

- An 'isolated' stud wall is build incorporating resilient bars, acoustic mineral wool and sound proofing mats , in front of the existing wall.
- Sound proofing mats are also available which dramatically reduce the airborne noise transmission of standard lightweight structures.
- Mineral fiberboard is a common substrate used with fabrics, wood or acoustical tile to control the acoustics within the room.

- Acoustical plaster, used to finish walls, is made with perlite or vermiculite aggregate that is most often sprayed onto the walls rather than applied by hand.
- Another product that is available in many sound-absorbing materials is a wall panel.
- Many are made from molded mineral fibers and covered in fabric that is attached to a standard wall surface.

## Masonry -

- Masonry may be defined as the construction of building units bonded together with mortar.

- The building units commonly know as masonry units may be Stones, bricks or precast blocks of concrete.

## Masonry Classification –

Masonry can be classified into three categories -

- Brick Masonry
- Stone Masonry
- Hollow block concrete masonry

# Brick Masonry –

- Brick Masonry is made of Brick units bonded together with mortar.
- Mortar is a mixture of Sand, cement or lime and water in suitable proportion.

- **Types of Bricks –**
  - Modular bricks
  - Traditional or Convectional bricks
    - The dimensions of traditional bricks varies from 20 to 25 cm in length, 10 to 13 cm in width and 7.5 cm to 10 cm in height.
    - The commonly adopted size of brick 23 cm × 11.4 cm × 7.5 cm

- Indian standard recommended the bricks of uniform size known as Modular bricks.
- The actual size modular bricks is 190 mm × 90 mm × 90 mm (i.e. 19cm × 9cm × 9cm)
- With mortar thickness, size of such bricks becomes 200 mm × 100 mm × 100 mm. (i.e. 20 cm × 10 cm × 10 cm) and it is known as the nominal size of the modular bricks.

- **Common Terms used in Brick Masonry -**

- **Stretcher –**

  This is the brick laid with its length parallel to face or front or direction of wall.

- **Header –**

  This is brick laid with its width parallel to the face or front or direction of wall.

- **Course –**

  A course is a horizontal layer of brick in a wall.

- **Header Course –**

  It is a course of brickwork in which all the bricks are laid as headers.

- **Stretcher Course –**

  It is a course of brickwork in which all the bricks are laid as stretchers.

- **Frog –**

  A small depression created purposely on one side of brick to form a key for holding the holding the mortar.

- **Face –**

  The surface of wall exposed to the weather is called as face.

- **Back –**

  The Inner surface of a wall which is not exposed to weather is called as back.

- **Joint –**

  It is junction of two or more bricks or stones in a wall construction.

- **Facing –**

  The material used in the face of the wall is known as facing.

- **Backing –**

  The material used in the back of the wall is known as backing.

- **Hearting –**

  The portion of a wall between facing and backing is known as Hearting.

- **Arrises –**

  The edges formed by the intersection of plane surfaces of brick are termed as arrises. In good quality bricks they are straight and sharp.

- **Bed –**

  The bottom surface of the brick when it is laid flat is termed as bed.

- **Lap –**

  It is  defined as the horizontal distance between the vertical joints in successive courses.

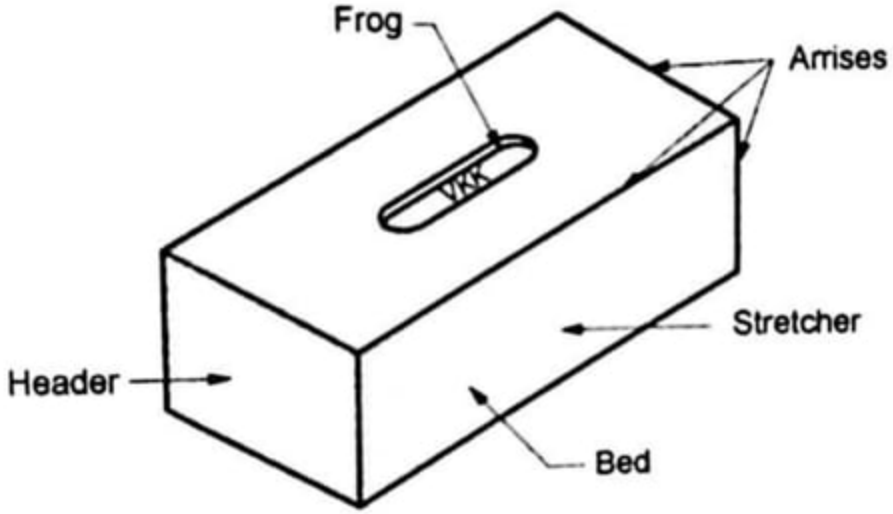



**Fig. 6.3.1 : Brick with various component part**

good.

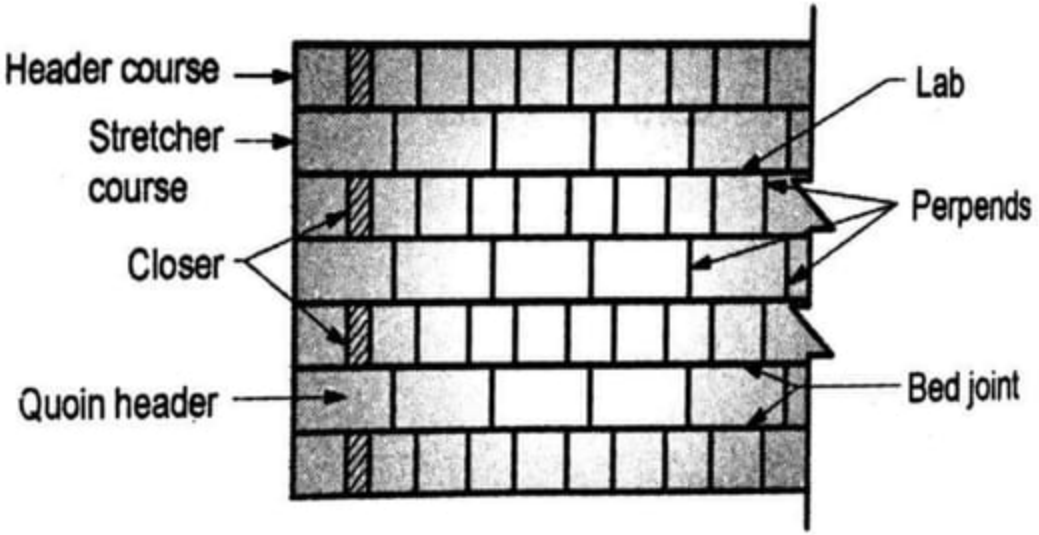



**Fig. 6.3.6 : Brick wall with various terms**

- **Perpends –**

  It is defined as the vertical joints in each course of masonry work. For a good bond, the perpends in alternate courses should be vertically one above the other.

- **Bond –**

  The method of arranging the bricks in courses so that the individual units are tied together is called bond.

- **Closer –** A piece of brick which is used to close up the bond at the end of brick courses is known as a closer

It helps in preventing the joint of successive courses to come in vertical line.

- **Types of closers –**

  **1) King Closer**

  **2) Queen Closer**

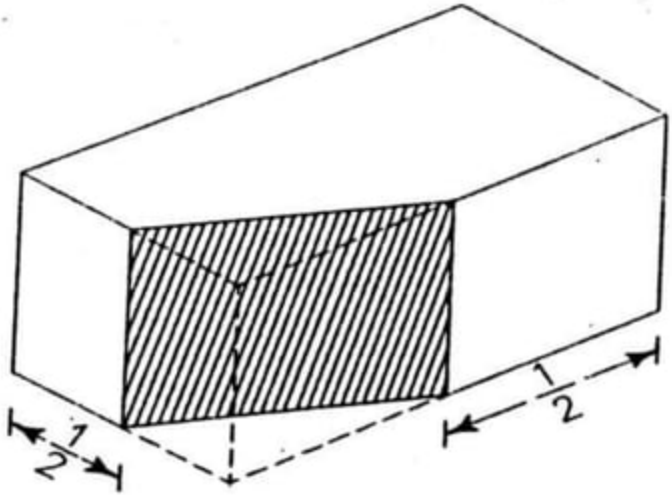
  **3) Mitred Closer**

  **4) Bevelled Closer**

1) King closer –

   This is obtained by cutting a piece of brick in triangular in shape between the center of header and stretcher.

- **King closer Diagram -**



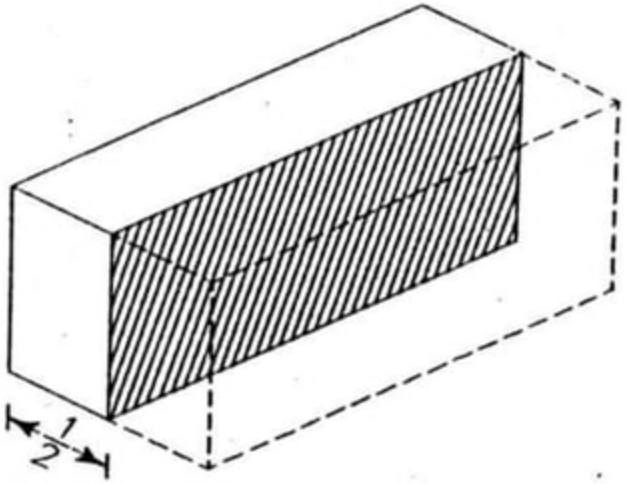

King closer

FIG. 4-4

## 2) Queen closer –

Queen closer is obtained by cutting a brick length wise into two pieces.

necessary

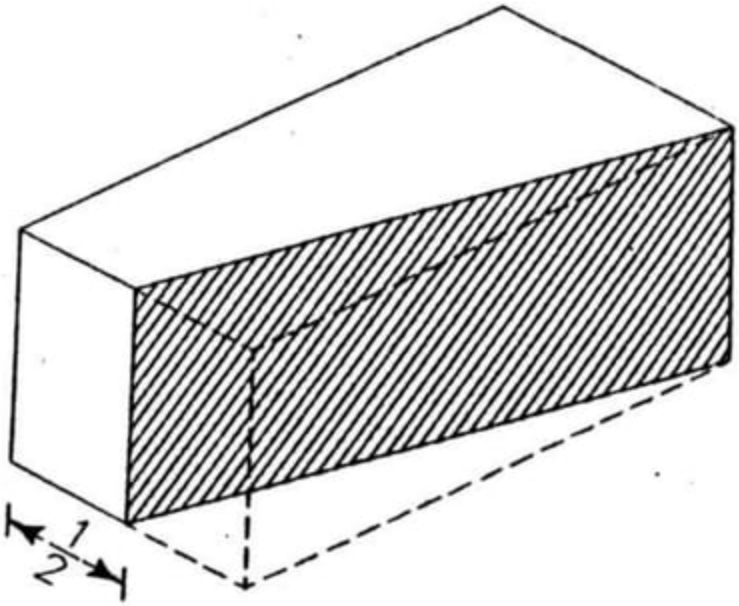



Queen closer

FIG. 4-3

**3) Bevelled closer –**

When a triangular portion of a brick is cut through its half width and to a full length, then remaining portion after cutting is called as bevelled closer.

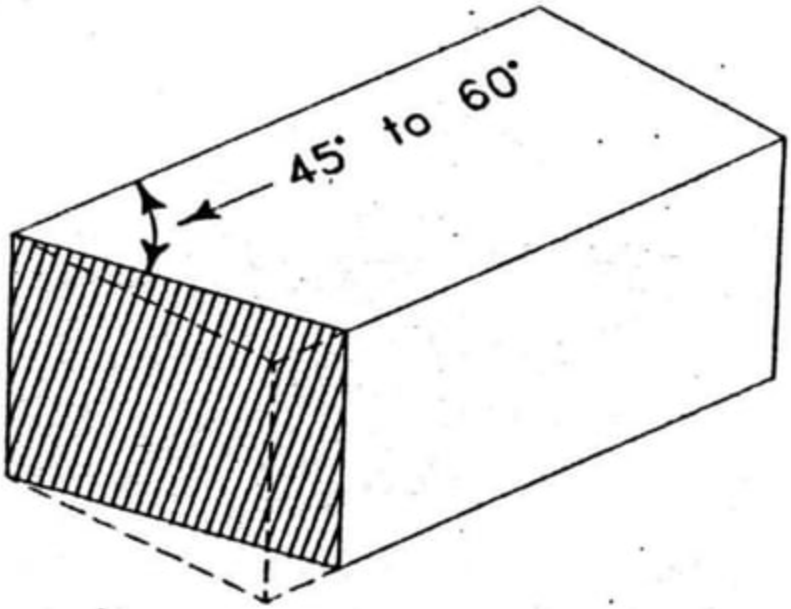



Bevelled closer

FIG 4-5

**4) Mitred closer –**

When a triangular portion of a brick is cut through its width and making an angle of $45^{o}$ to $60^{0}$ with the length of the brick, the remaining portion after cutting as called as Mitred closer.




Mitred closer

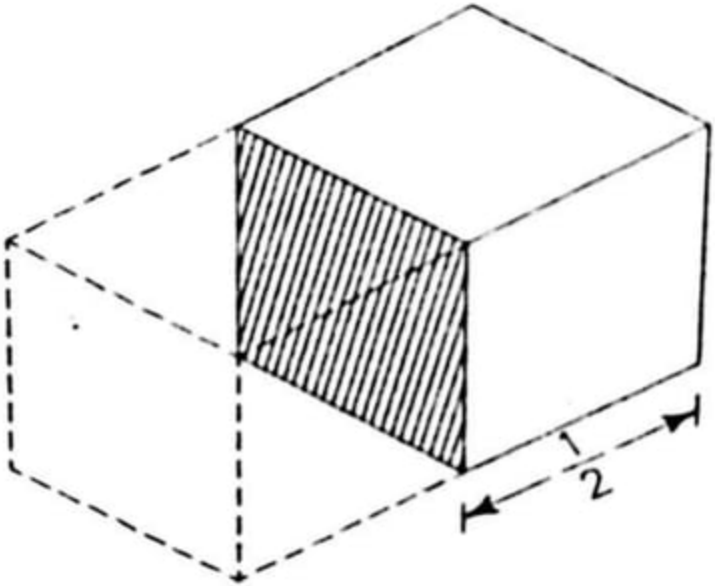
FIG. 4-6

- **Bat-**

A portion of brick cut across the width is known as bat

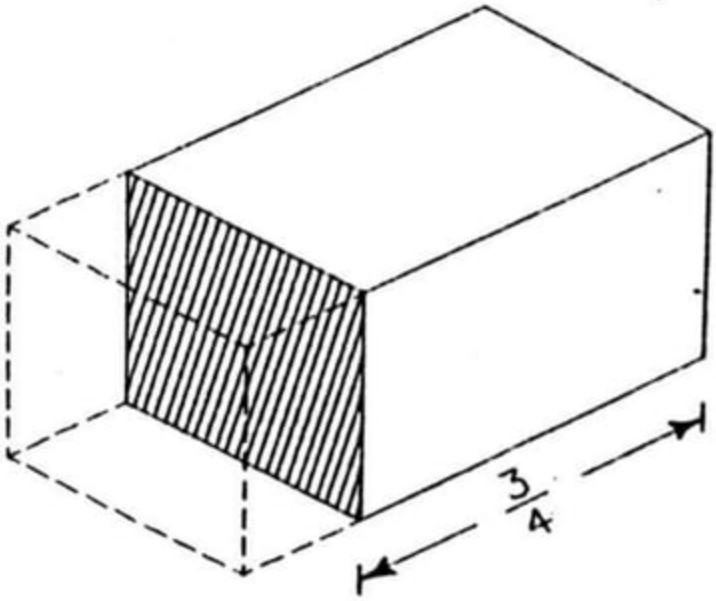
There are different types of bats, namely

Half bat, three-quarter bat and bevelled bat.




Half bat

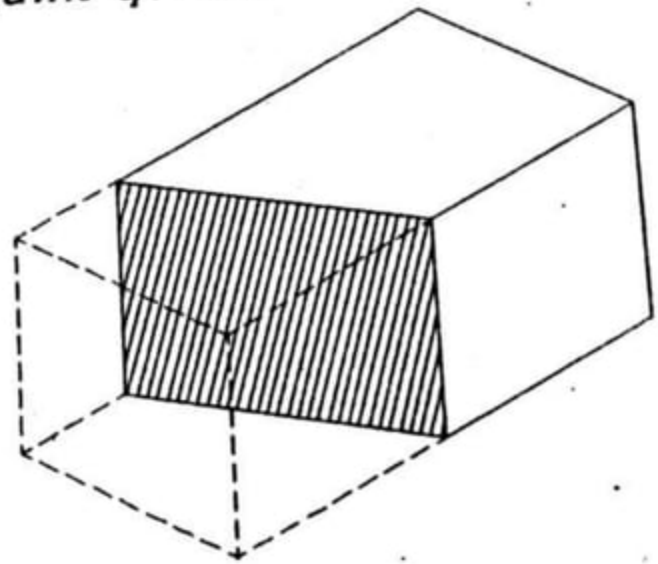
FIG. 4-7




Three-quarter bat

FIG. 4-8

a *squint quoin*.

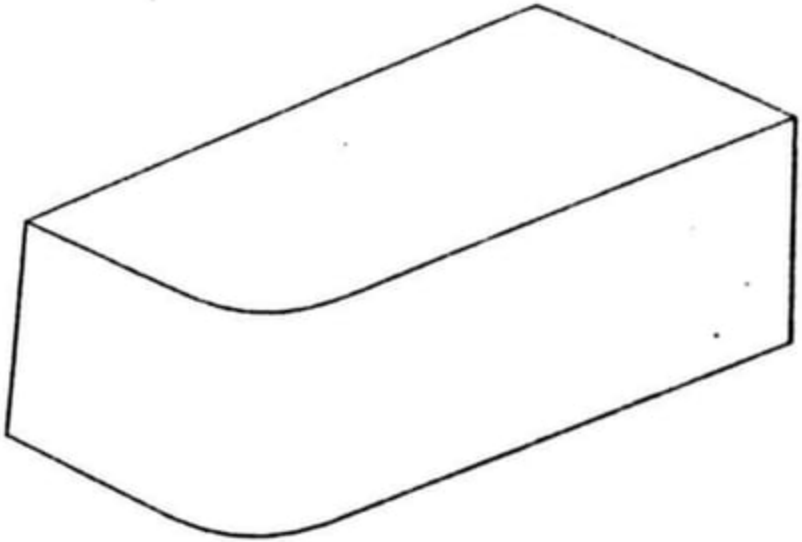


Bevelled bat

FIG. 4-9

- **Bullnose –**

  The bricks with one edge rounded is known as single bullnose and the bricks with two edge rounded are known as double bullnose.



Bullnose

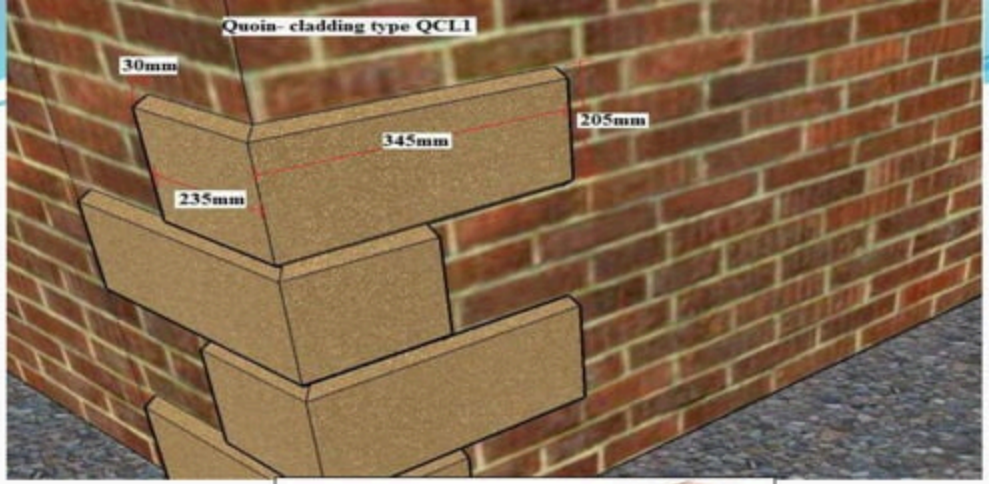
FIG. 4-10

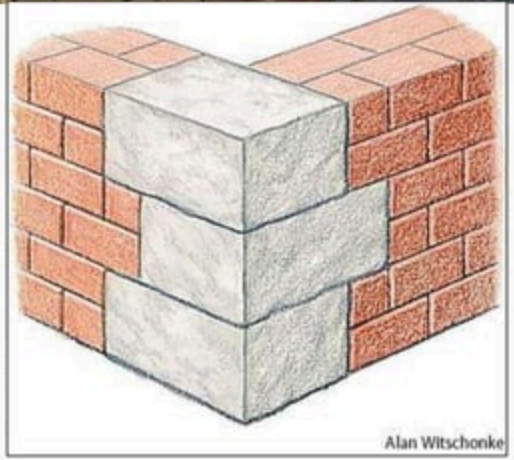
- **Quoin**

  A corner or the external angle on the face side of a wall is known as quoin.

- **Quoin Header -**

  It is the brick used at the corner of two walls meeting at 90 degree.


Quoin- cladding type QCL1
30mm
345mm
205mm
235mm


Alan Witschonke

- **Requirement of good brickwork –**

1) A good brick masonry should utilize bricks which are hard, well burnt and tough with uniform colour, shape and size.
2) The bricks should be compact, homogeneous, free from holes and cracks.
3) A good brickwork should have maximum compressive strength and durability.
4) A good brick work should have maximum resistance to weathering.

5) A good brickwork should be fire resistant.

6) When brick dropped from a height of about 1 meter on another brick, it should not break.

7) When brick struck with hammer, it should give a good metallic sound.

8) Brick should have uniform size generally 19×9×9 cm. Normally 500 numbers of bricks are required for 1 cu.m. of brick work masonry work.

- **Bond in brickwork –**
- Brick masonry consist of bricks built to form walls. In order to hold the bricks in position and to improve the appearance of the wall.
- The bricks are held together to act as a single unit by arranging them in such a specific manner, that they rest over each other and break the continuity of the vertical joints.
- The overlapping arrangement of bricks in order to tie them together in a mass of brick work is known as bonding.

- Bond is also introduced for its pleasing appearance or to make decorative patterns.

**Types of Bonds –**

- Stretcher bond
- Header bond
- English bond
- Flemish bond

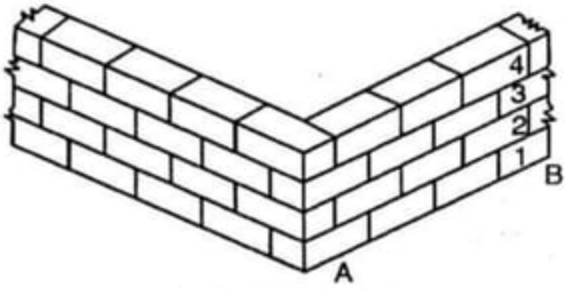
- **Stretcher bond –**

In this type of bond all the bricks are laid with their lengths In the direction of the wall.

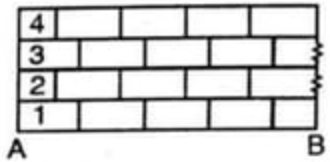
This pattern is used only for walls having thickness of the half brick i.e. 9 cm

e. g. Walls in case of framed structure construction

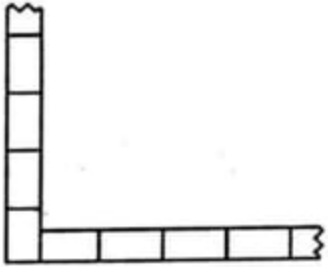
ND




(a) Isometric view

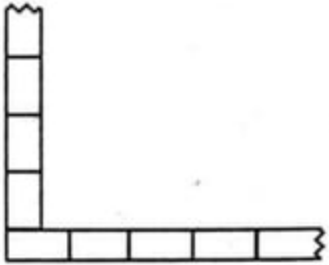



(b) Elevation



2, 4, 6 - - - courses

(c) Plan



1, 3, 5 - - - courses

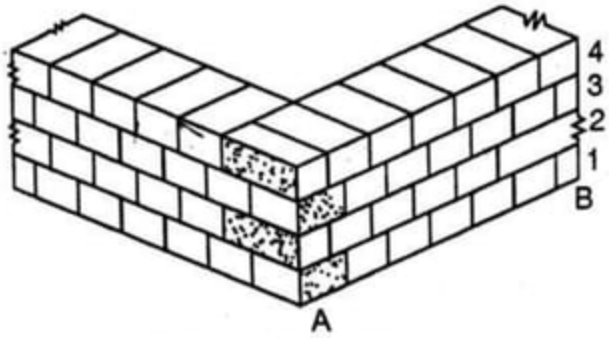
(d) Plan

FIG. 6.4. STRETCHER BOND.

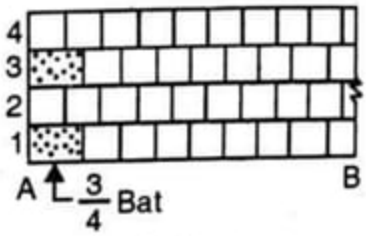
## Stretcher Bond

## Header bond –

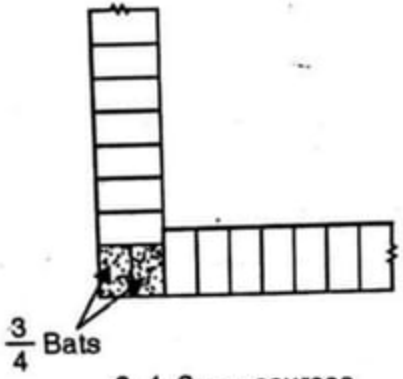
- In this type of bond, all bricks are arranged in header course.
- This type of arrangement is suitable for walls which are one brick thick.
- This is suitable for walls of lightly loaded load bearing structure.
- The bond being formed by three-quarter bat at the quoin is generally used.




(a) Isometric view

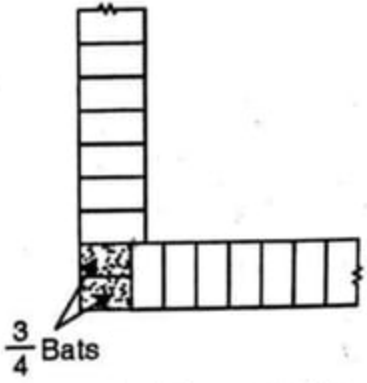



(b) Elevation




2, 4, 6 - - - courses

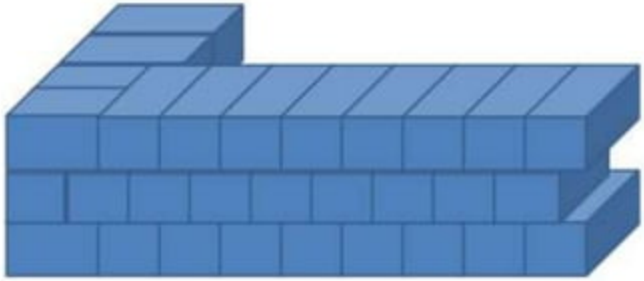
(c) Plan




1, 3, 6 - - - courses

(d) Plan

# Header Bond



## English Bond –

- This is most common and popular bond is used for wall thickness ranging 20 cm and above.
- This type of bond has alternate courses of header and stretchers.
- A queen closer must be provided after the quoin header. A Header course should never start with a queen closer.
- Continuous vertical joints should not be allowed.

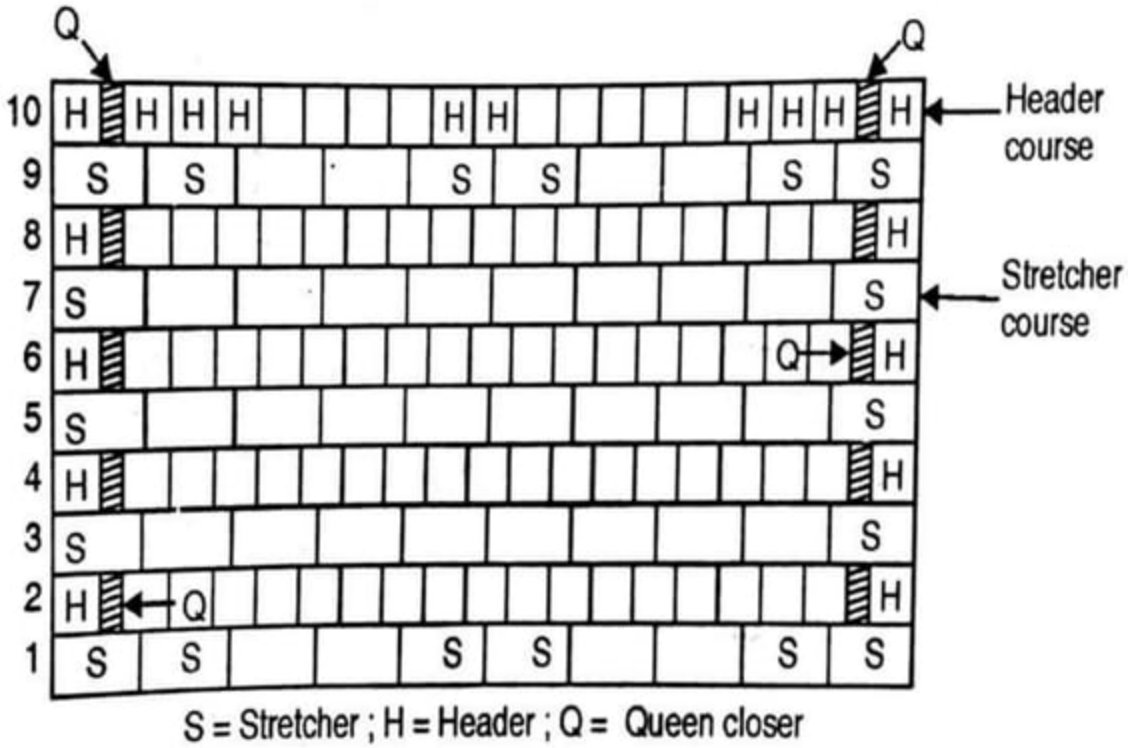
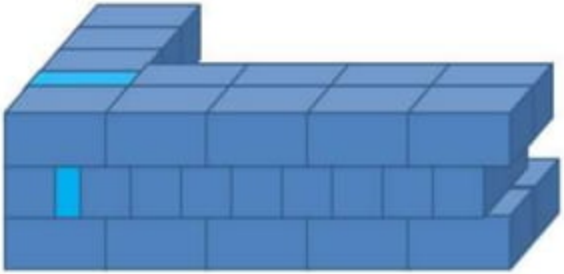



FIG. 6.6. ENGLISH BOND.

# English Bond



## Flemish Bond –

- In this arrangement of bonding brickwork each course consists of alternate header and stretchers.
- Every alternate course starts with a header at the corner.
- Following diagram shows 1 brick thick wall.

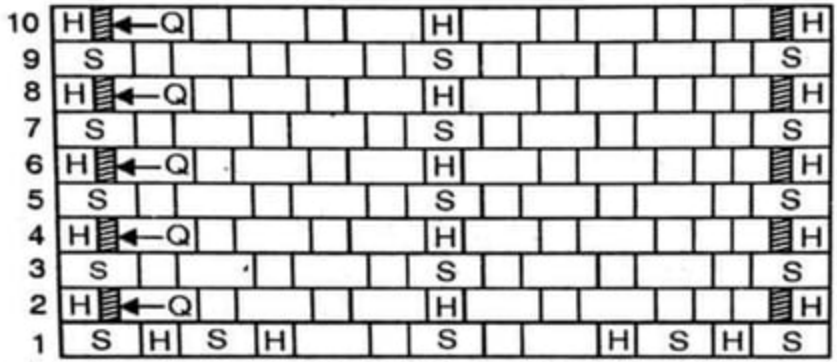
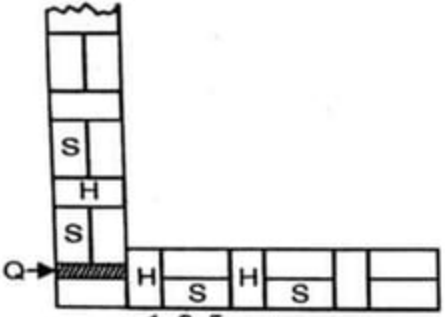
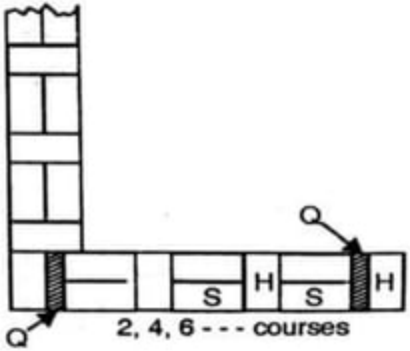


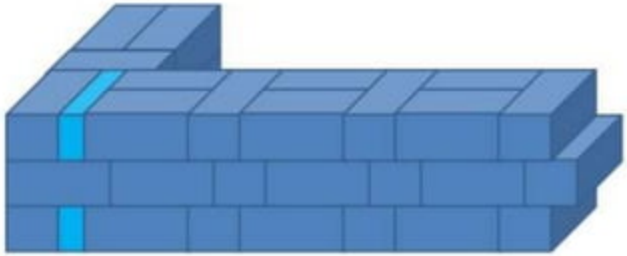

FIG. 6.9. DOUBLE FLEMISH BOND (ELEVATION).

ʻation of flemish bond, for all the wall thicknesses. Fig.6.10



## Flemish Bond



## Comparison between English and Flemish bond –

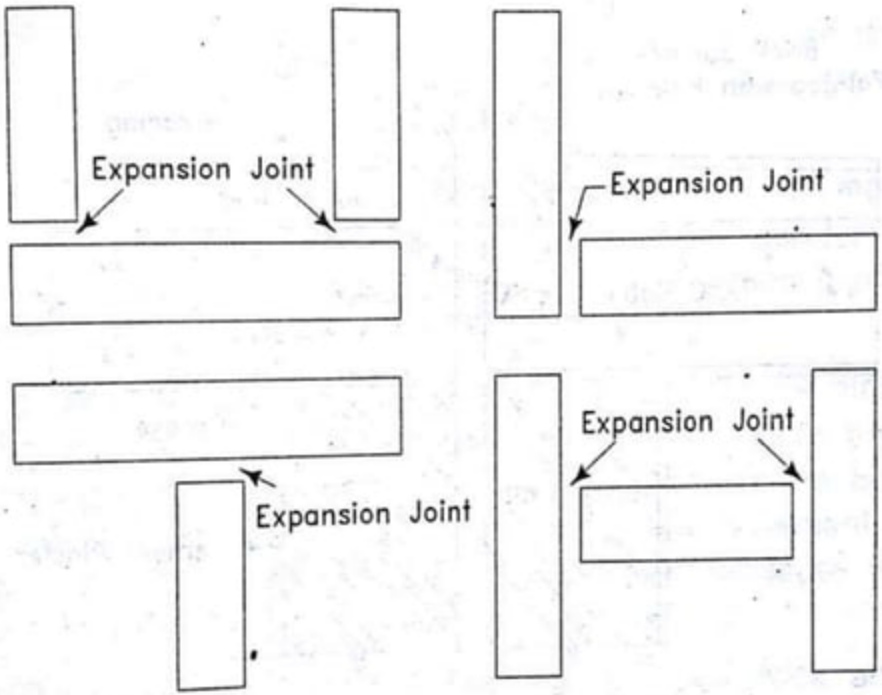
| English Bond | Flemish Bond |
|---|---|
| More compact and stronger for wall having thickness more than 1½ brick. | Less stronger and compact than English Bond. |
| Less Pleasing appearance as compared to Flemish bond | Appearance more attractive and pleasing. |
| More cost as compared to Flemish Bond | Slightly economical as a number of bricks bats can used. |
| No strict supervision and skill required for construction of this bond | Require good workmanship and careful supervision. |

- **Requirement of good brick masonry –**
- A good brick masonry should utilise bricks which are Sound, hard, well burnt and tough with uniform colour, shape and size.
- The bricks should be compact, homogeneous, free from holes, cracks.
- These bricks should be properly soaked in water for at least two hours before use.
- The bricks should be laid on their beds with the frogs pointing upwards.
- The brick course should be laid truly horizontal.

- The height of brick masonry construction in a day should not exceed 1.5 m
- Finished brickwork is cured for a period 1 to 2 weeks.

- **Expansion Joints in brick masonry their purpose and Procedure-**
- The provision of horizontal and vertical expansion joints in wall helps in reducing the cracks to a considerable extent.
- Vertical movements are absorbed by horizontal expansion joint.
- Whereas horizontal movements are absorbed by vertical expansion joints.
- When the wall of brick masonry is more than 15 m expansion joints are must.

- In case of brick masonry the expansion joints are usually provided in long walls at offsets or junction and near corners.
- The sealant to be used for expansion joints may be produced from Natural or cellular rubber, bitumen, Plastics, coconut pith. etc.
- The depth of sealant should not be more than one half of the width of joints and not less than 4mm




Locations of expansion joint

FIG. 4-42

coconut pith, etc.

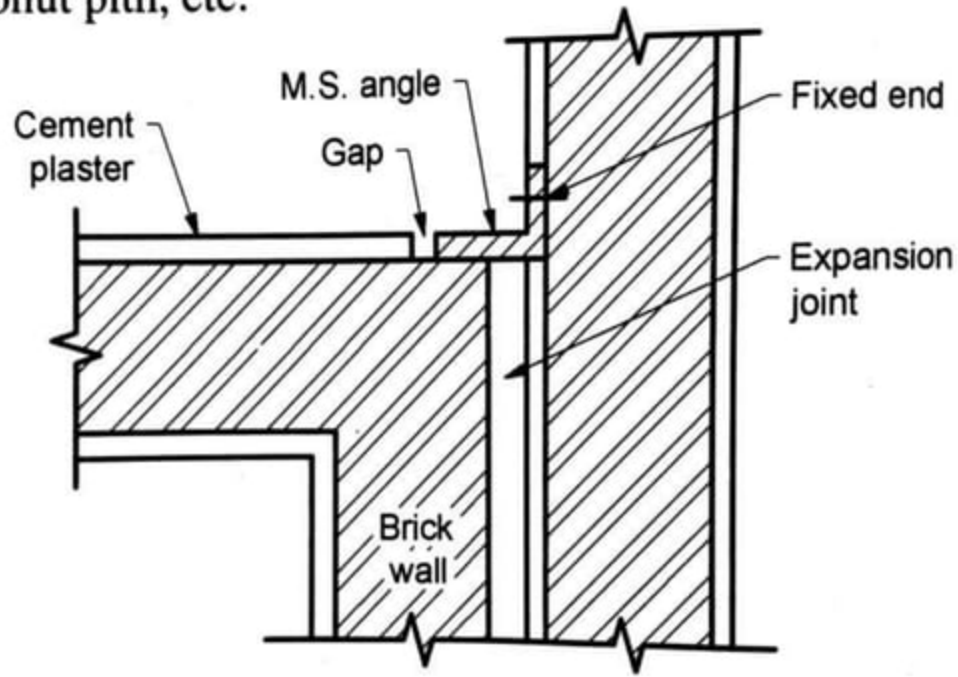



**Fig. 6.10.1 : Expansion joint at corner of walls**

- **Precaution in brick masonry –**
- Brick should be as per the specifications.
- Bricks should be soaked in the water before using them into the masonry work.
- Use of brick bats should not be more.
- Frogs should be on the top surface.
- The bricks should be neatly and properly laid on mortar.
- The brick masonry work should be done in proper bond.

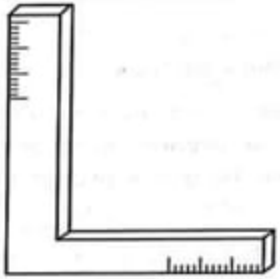
- The brick work should be perfectly in level.
- The mortar used should be as per specification and fresh.
- Hold fasts for door should be properly inserted into the masonry work.
- After completion of brickwork, a proper curing at least seven days should be done to the masonry work for getting required strength.

- **Tools and plants used in brick Masonry –**

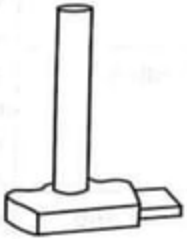
## 3.14 TOOLS AND PLANTS USED IN BRICK MASONRY

Following are the tools required in brick masonry construction :

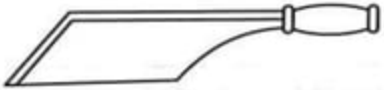
Trowel



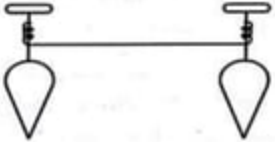
Mason's square (Gunya)



Hammer

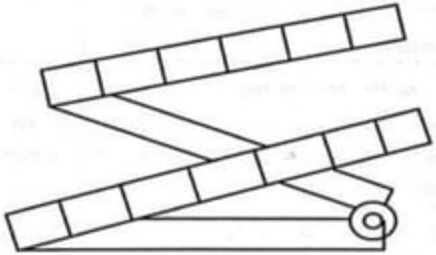


Brick axe



Line and pins

Spirit level



Two-foot four-fold rule

Fig. 3.42

- **Stone Masonry –**

  When stones are used as the building units , we have stone masonry.

- **Through stone –**
  - In stone masonry work, some stones in one piece or in two piece at regular interval are placed across the walls, such stones are termed as through stones.
  - This stones increase the bonding capacity.
  - A through stone is also called as stone header.

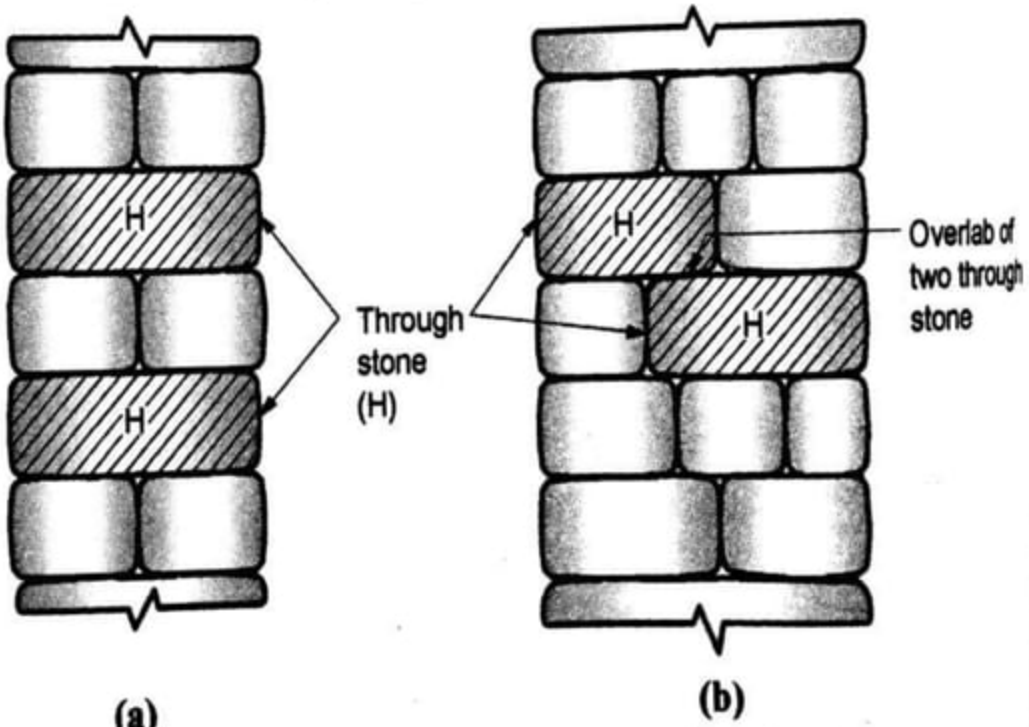



**Fig. 5.4.1 : Through stone or stone header**

- **Corner stone –**

  It is the block of stone used at the corner of two walls meeting at $90^0$

- **Cornice –**

  It is a projecting ornamental course near the top the wall or at the junction of wall and ceiling.

- **Characteristics of a good stone –**
- **Availability-** The stone used for masonry should be easily available from nearby sources.
- **Ease of working –** The stone should permit easy dressing and shaping to facilitate working on it.
- **Appearance –** should be attractive and colour should be uniform
- **Strength -** should be sufficient to carry load.

## Meaning of Dressing of stones –

- It is process in which the stone surface, especially the facing of the stone is prepared to a form fit to be used for any construction work.
- Dressing is carried out either manually with the help of hand hammers, chisels etc.
- Dressing of stones gives the desired shape to stones and improves the appearance of stone surface.

- **Classification of stone masonry –**
  - **Rubble Masonry**
  - **Ashlar masonry**
- **Rubble Masonry –**

According to the degree of dressing-

- Dry rubble masonry
- Uncoursed rubble masonry (U.C.R Masonry)
- Coursed rubble masonry (C.R. Masonry)
- Polygonal rubble masonry

## Dry Rubble Masonry –

- It is most inferior type of masonry in which either dressed or undressed stones are used without using mortar.
- This type of construction is the cheapest and require more skill in construction.
- This may be used for retaining walls, compound wall, pitching on bridge approaches.
- The strength and durability of masonry does not depends upon the quality of materials used but on the workmanship.

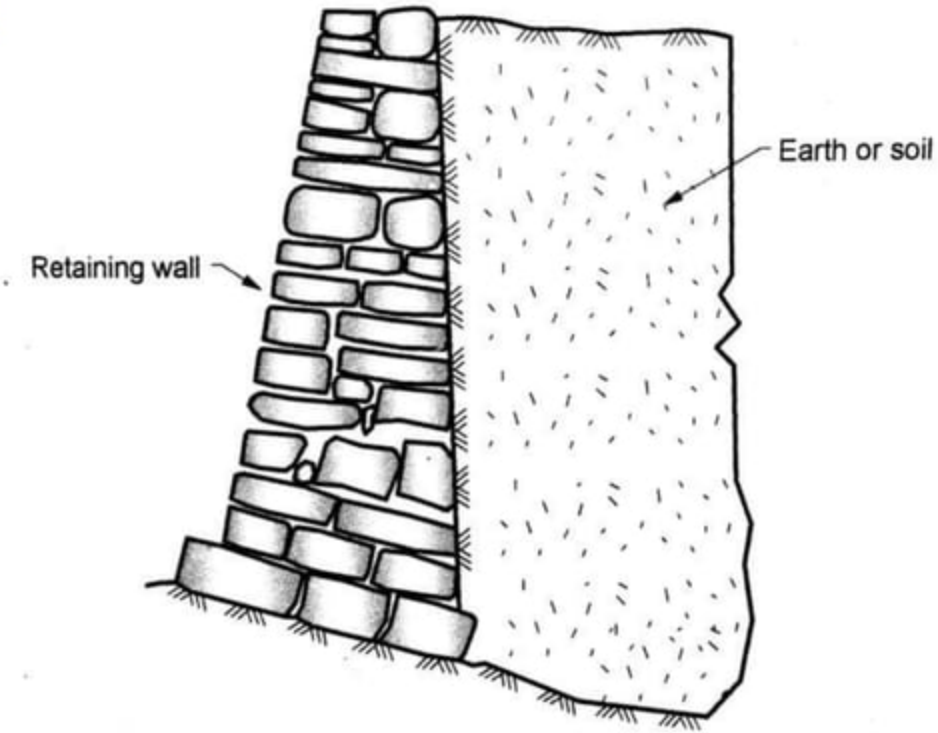
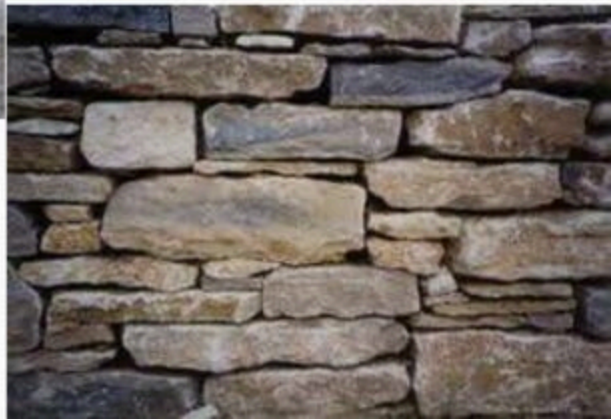



**Fig. 5.8.1 : Dry rubble masonry**

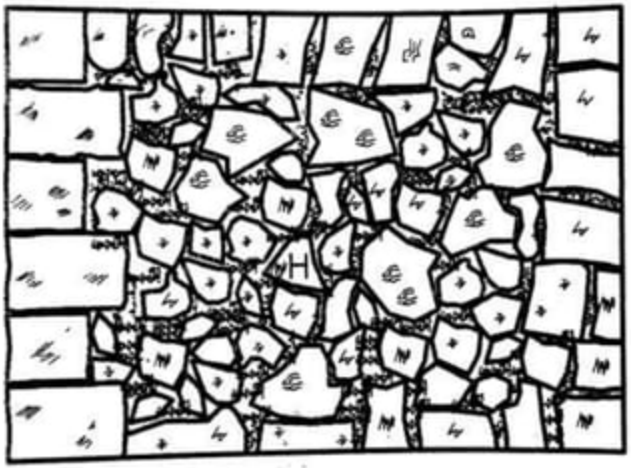
# a) DRY RUBBLE MASONRY



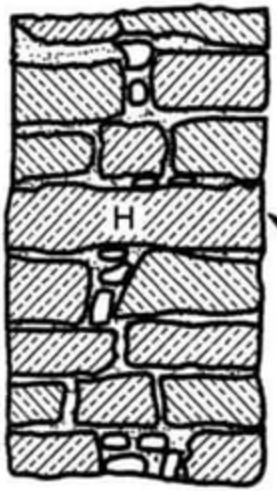
- **Uncoursed rubble masonry ( U.C.R.)or Random rubble masonry –**
- Stones or rubble are used without dressing, shape and size of stones used are of widely different sizes.
- Before laying the stones, all projecting corners are slightly knocked off with a hammer.
- The joints are filled with mortar by steel trowel
- The joints should not exceed 13mm in thickness.

- Large stones are used at corners to increase strength.
- Through stones are also provided at intervals to interlock the portion in between facing and backing.
- This type of masonry have rough appearance.
- This type of masonry is used for constructing the compound wall or boundary wall, plinth wall, retaining walls, etc.

by at least 15 cm should




Elevation




Section

**Fig. 5.8.2 : U.C.R masonry**

## Coursed rubble masonry –

- In type of rubble masonry, the heights of the stones vary from 50mm to 200mm.
- The stones are sorted out before the work.
- The masonry work is then carried out in courses such that the stones in a particular courses are of equal heights.
- This type of masonry is used for the construction of public buildings, Residential buildings etc.

- Joints are about 15mm in thickness.
- In each course, header stones of full course height are placed at certain intervals.
- Care should be taken that joints must break in different courses.

understanding.

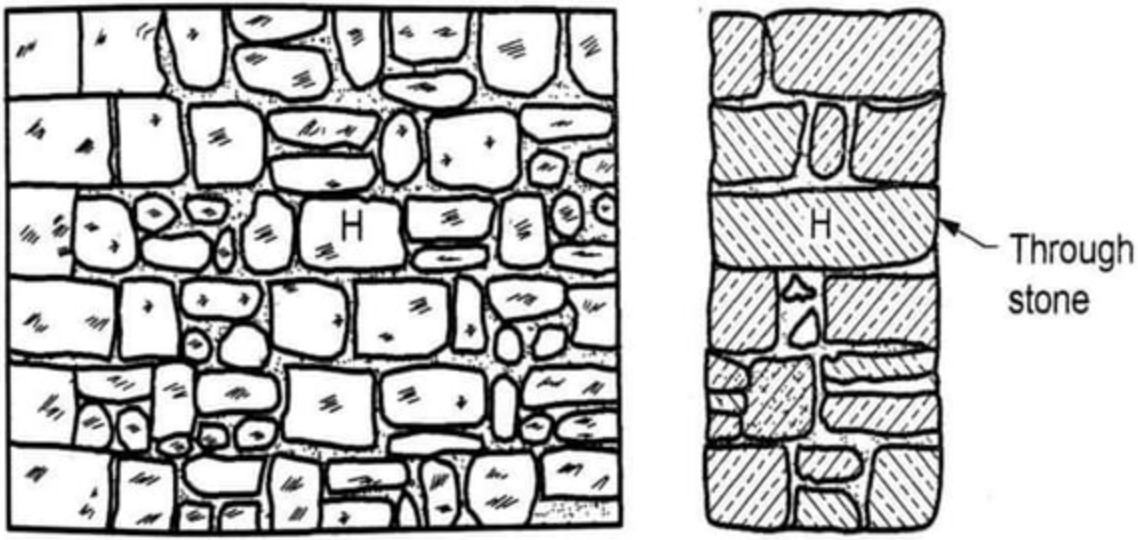
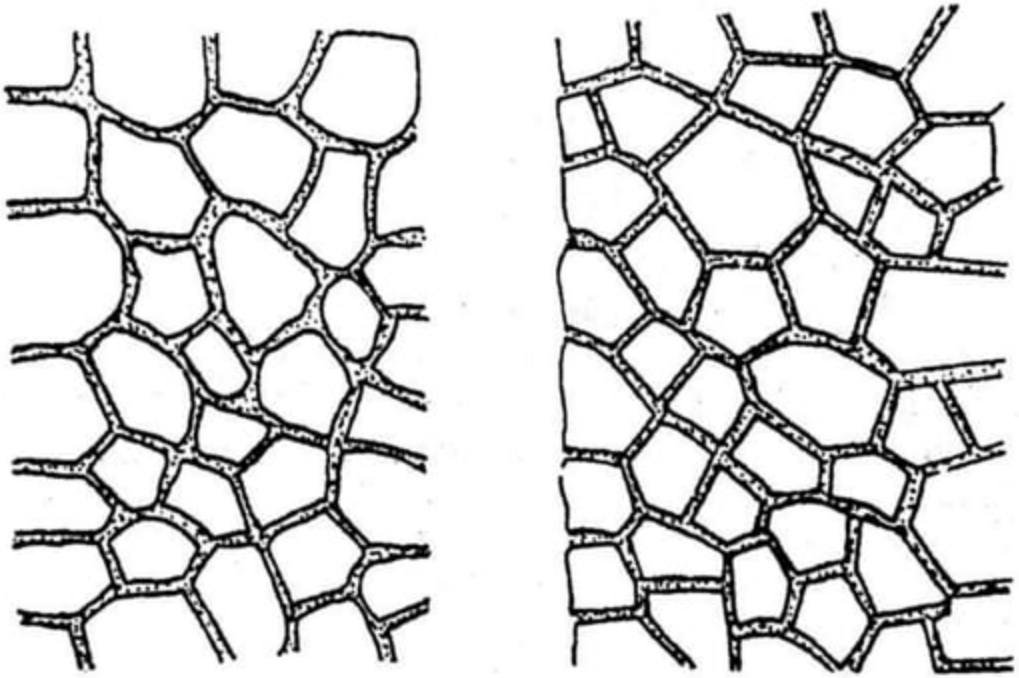



**Fig. 5.8.3 : Coursed rubble masonry**

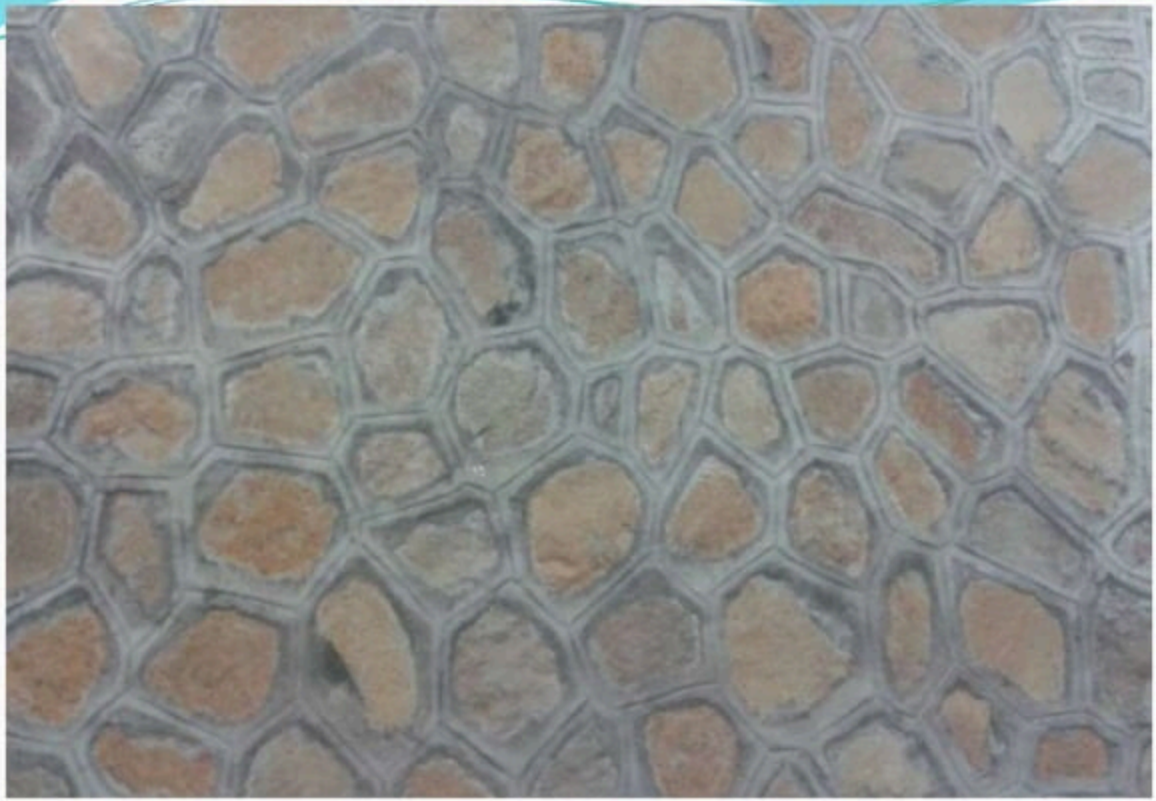
- **Polygonal rubble masonry –**
- In this type rubble masonry, the stones are hammer dressed and the stones selected for the face work are dressed in an irregular polygonal shape.
- Thus, the face joints are seen running in an irregular fashion in all direction.
- The more skill is required in the construction of this type of masonry.
- As the stones are of irregular shape, it is difficult to adjust them with regard to stability.



(a) Rough picked

(b) Close picked

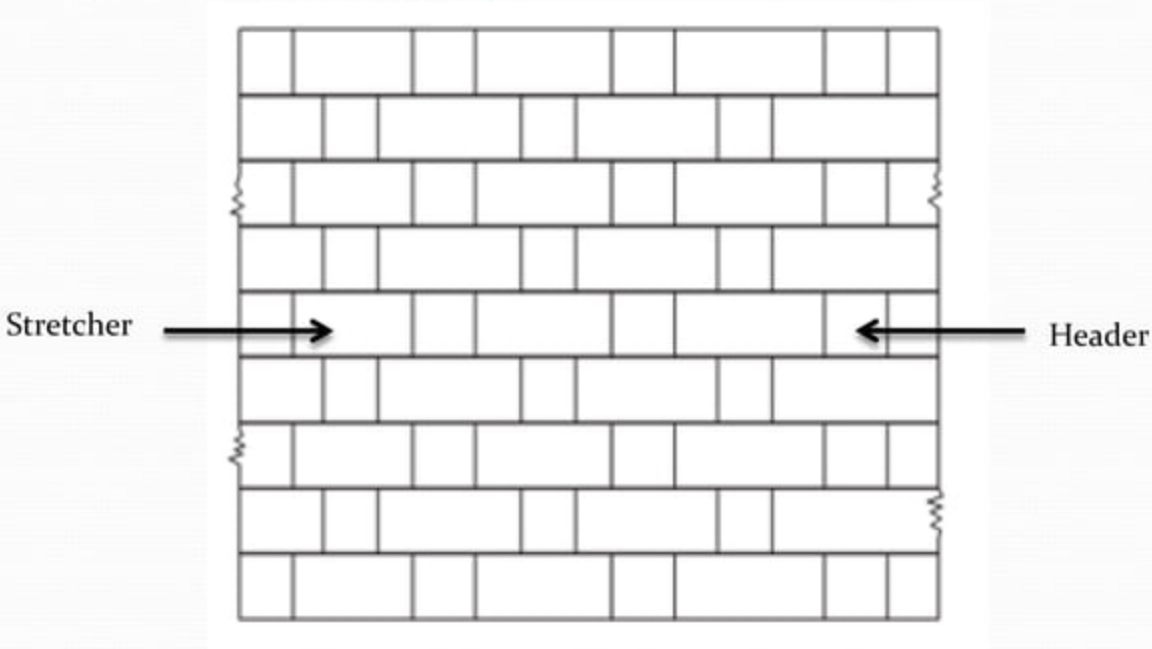
FIG. 5.19. POLYGONAL RUBBLE MASONRY.



- **Ashlar Masonry –**
- Ashlar masonry is the type of masonry in which well dressed stones having sharp and straight edges and smooth faces are used i.e. square and rectangular blocks of stones are used.
- This type of masonry is expensive and required highly skilled labour.
  - Ashlar fine masonry
  - Ashlar chamfered masonry
  - Ashlar rock quarry faced
  - Ashlar facing
  - Ashlar rough tooled

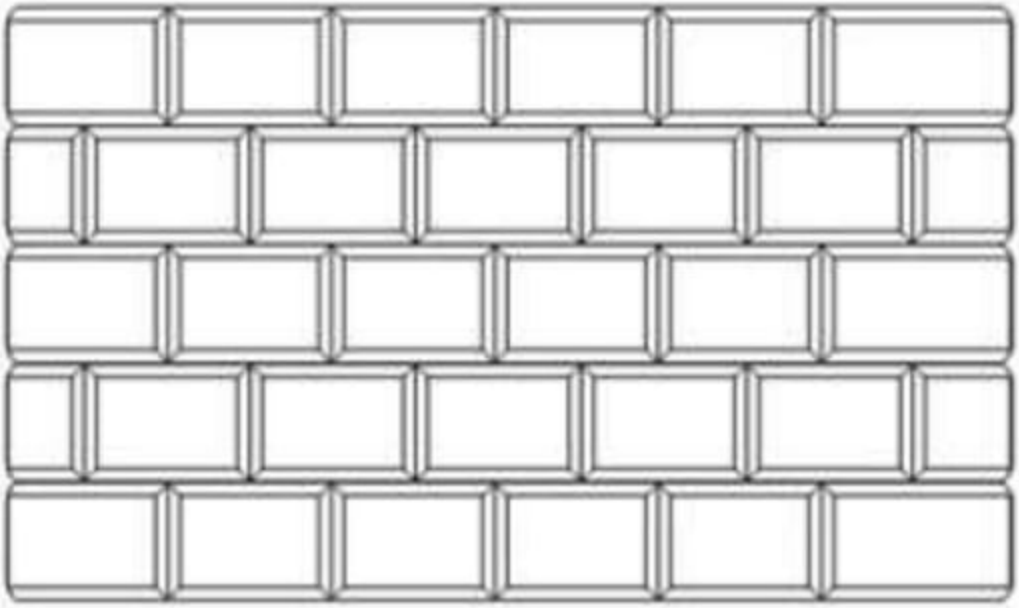
- **Ashlar fine Masonry –**
- In this type of ashlar masonry, the beds, sides and faces are finely chisel-dressed.
- The stones are arranged in proper bond.
- Thickness of the mortar joints does not exceed 3 mm.
- This type of construction gives perfectly smooth appearance.
- But it is costly in construction.

# a) ASHLAR FINE



- **Ashlar chamfered masonry –**
- This type of masonry is very much similar to that of ashlar fine with the difference that edges of the stones are bevelled off at an angle of $45^0$ for a depth of about 25mm.
- The joint are thin and faces of the stones are smooth.

# b) ASHLAR CHAMFERED



(b) Ashlar chamfered

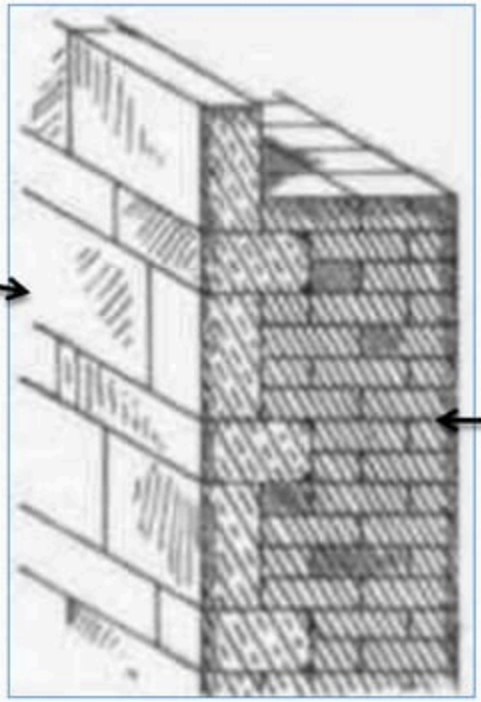
# b) ASHLAR CHAMFERED

- **Ashlar rock quarry faced –**
- In this type of masonry the edges of stones are made straight and sharp so as to have thin mortar joints, but the faces are left in a condition as obtained from quarry.
- This means the faces of stones will have natural rock like appearance.
- The advantage in this method is that it increases the architectural appearance.
- And reduces the cost of dressing.

# b) ASHLAR ROCK QUARRY FACED

- **Ashlar facing masonry-**
- Ashlar is the best grade of masonry and it is very expensive.
- Therefore to achieve economy as well as appearance of ashlar masonry only the exposed faces of wall are constructed of ashlar masonry whereas the backing of the wall is in brick masonry.
- The minimum height of course is 20 cm and the width of each stone is about 1.5times its height.

# c) ASHLAR FACING



- **Mortar –**

  The workable paste prepared by mixing a binding material such as cement, lime etc., fine aggregate (i.e. sand) and water in suitable proportion is called Mortar.

- **Types of mortar -**
  - Cement mortar
  - Lime mortar
  - Gauged mortar or composite mortar or lime cement mortar

- **Cement mortar –**
  - The paste prepared by mixing cement, sand and water in suitable proportion is called as cement mortar.
  - The general proportion for stone masonry are 1 : 2 to 1 : 8 i.e. 1 part of cement and 2-8 part of sand.
  - Cement mortar must be used within half an hour after mixing.

- **Lime Mortar –**
  - The paste prepared by mixing lime, sand and water in suitable proportion is called as lime mortar.
  - The general proportions for stone masonry are 1 : 5 to 1 : 6 i.e. 1 part of lime to 5 – 6 parts of clean sand.

- **Composite mortar or cement lime mortar or gauged mortar –**

- The paste prepared by mixing cement with lime in suitable proportion in addition with water is called as composite mortar.
- Composite mortar should be used within two hours.
- Usual proportion for stone masonry are 1 part of cement, 3 parts of lime, 2 to 12 parts of sand.

- **Tools and plants used for stone Masonry –**

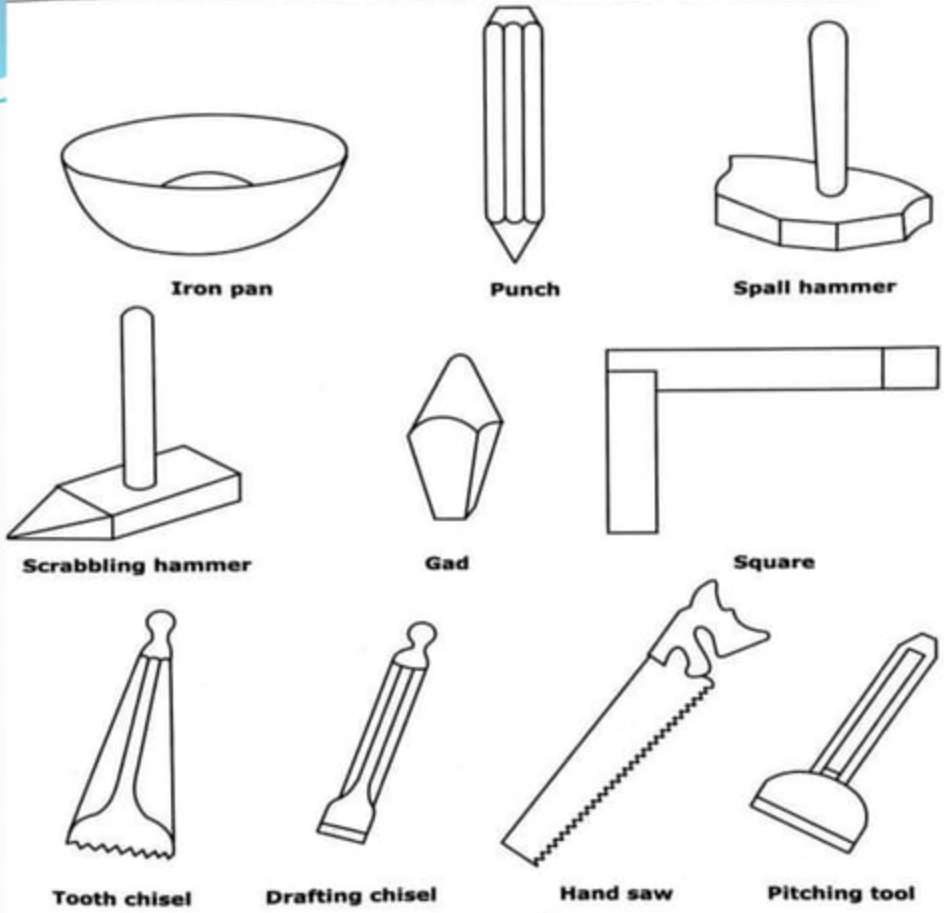
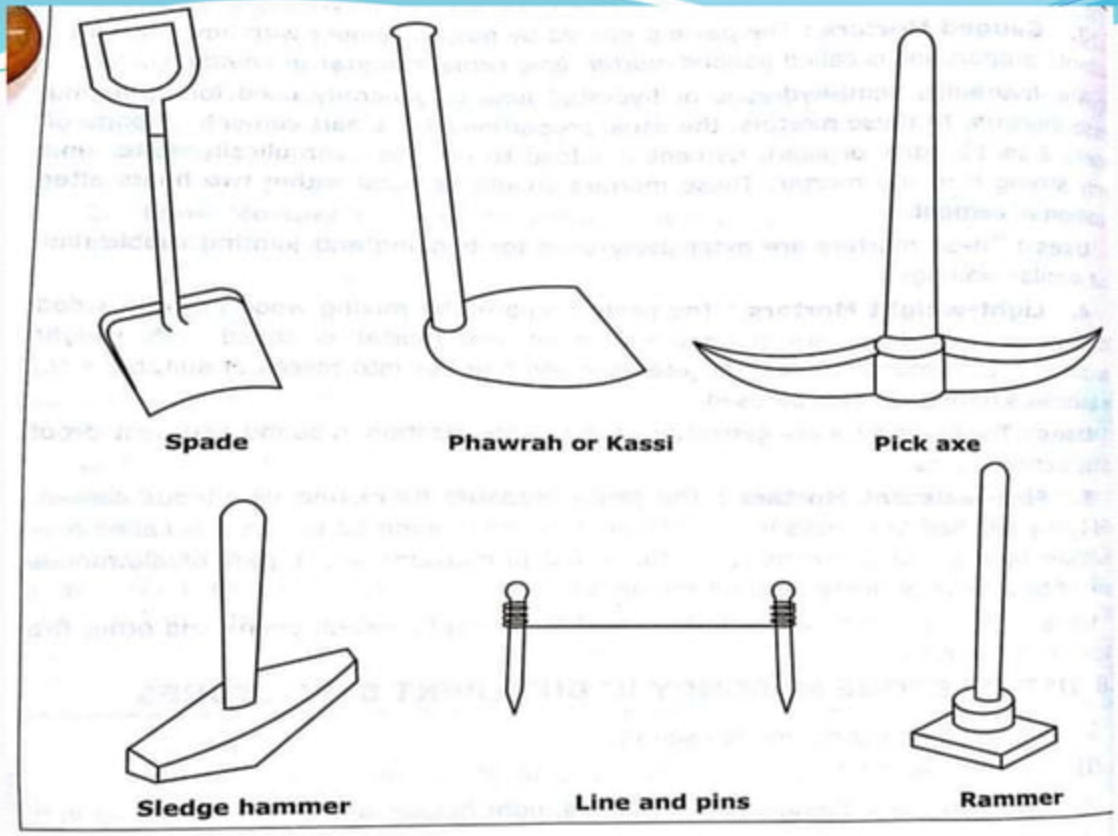

Iron pan
Punch
Spall hammer
Scrabbling hammer
Gad
Square
Tooth chisel
Drafting chisel
Hand saw
Pitching tool

Fig. 3.17


Spade
Phawrah or Kassi
Pick axe
Sledge hammer
Line and pins
Rammer

# TOOLS AND PLANTS USED IN STONE MASONRY

# TOOLS AND PLANTS USED IN STONE MASONRY

# TOOLS AND PLANTS USED IN STONE MASONRY

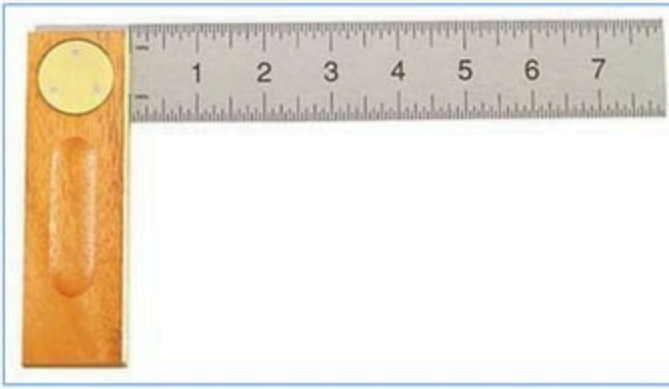
Hand Saw

# TOOLS AND PLANTS USED IN STONE MASONRY

Gad

Tooth Chisel

Square



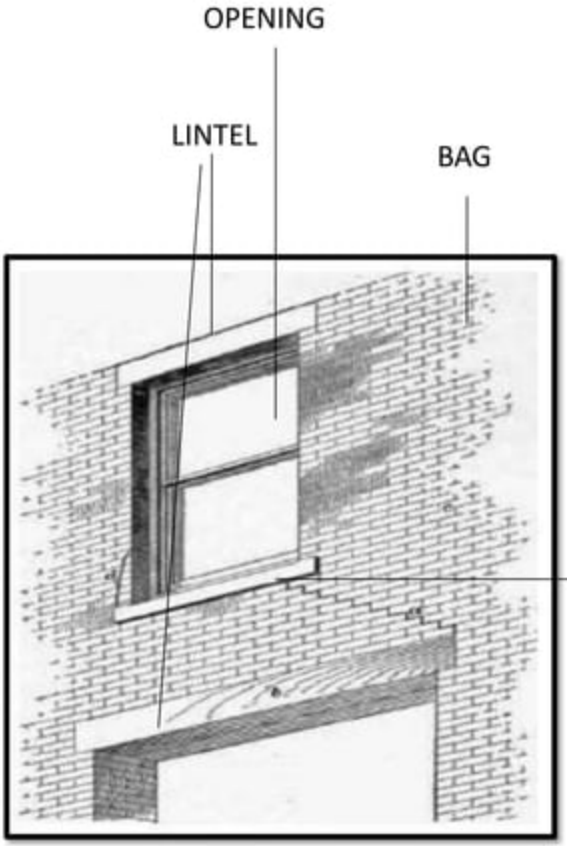
# What is Lintel?

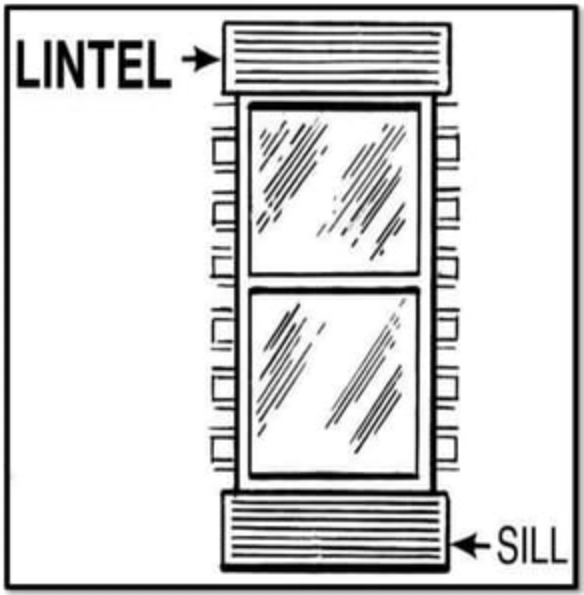
- A lintel is defined as a horizontal structural member which is placed across the opening.
- Hence, the structure remains in the position by the resistance from the support.

# What is an Arch?

- An Arch may be defined as mechanical arrangement of wedge-shaped blocks of stones or bricks mutually supporting each other and supported at the end by piers or abutments.
- An arch is a structure that spans a space and supports structure and weight below it.
- Arches appeared as early as the 2nd millennium BC in Mesopotamian brick architecture and their systematic use started with the Ancient Romans who were the first to apply the technique to a wide range of structures.

LINTEL


OPENING
LINTEL
BAG
SILL


LINTEL
SILL

# Classification of lintel

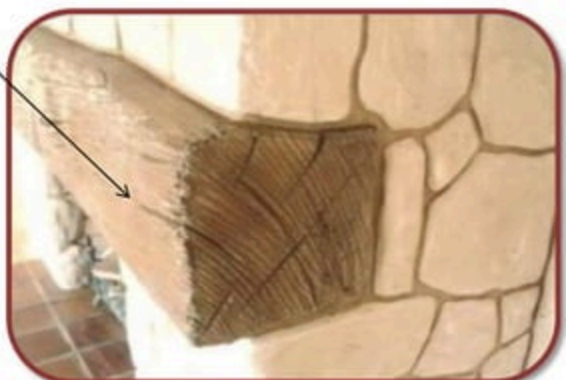
**Lintels are classified into the following types, according to the materials of their construction:**

- Timber lintels
- Stone lintels
- Brick lintels
- Reinforced Brick lintels
- Steel lintels
- Reinforced cement concrete lintels

# Timber lintels

- Easily available in hilly area.
- Relatively costly, structurally weak and valnerable to fire.
- Easily decay, if not properly taken care.

*TIMBER LINTEL*



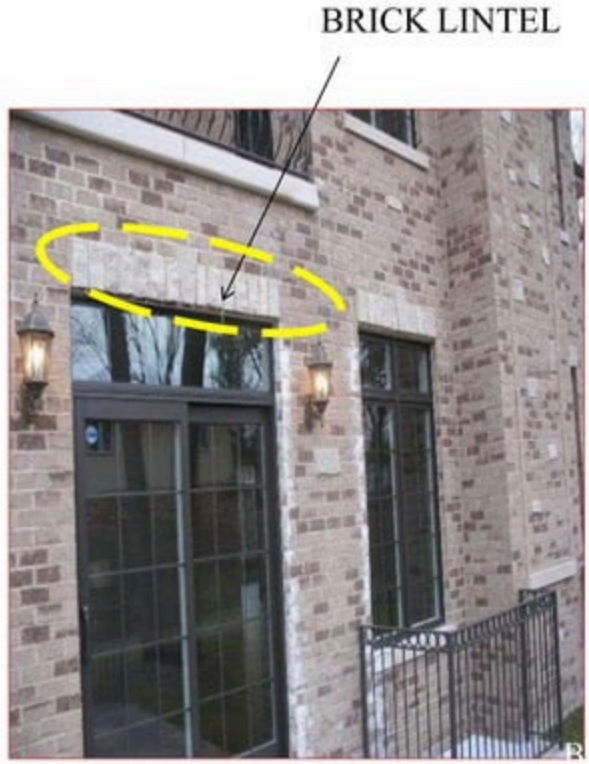
# Stone lintels

- Used , where stones are easily available.
- Consists of a simple stone slab of greater thickness.
- Due to high cost and its inability to with stand the transverse stress load it is not commonly used.

STONE LINTEL

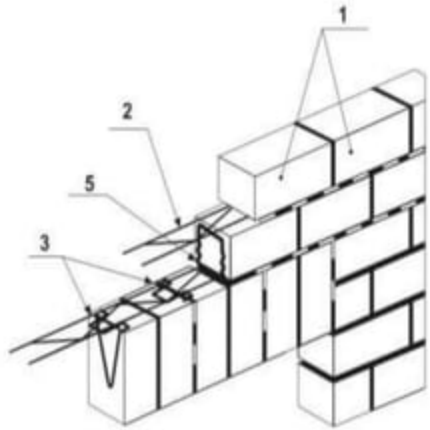
# Brick lintels

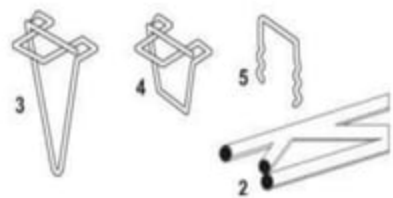
- The brick are hard, well burnt , first class bricks .
- Suitable for small span.
- The bricks having frogs are more suitable.



# Reinforced Brick lintels

- For large spans and heavy loads .
- They are reinforced with mild steel bars.
- Very common due to durability, strength and fire resisting properties.
- Joints are filled with cement concrete.



# Steel lintels

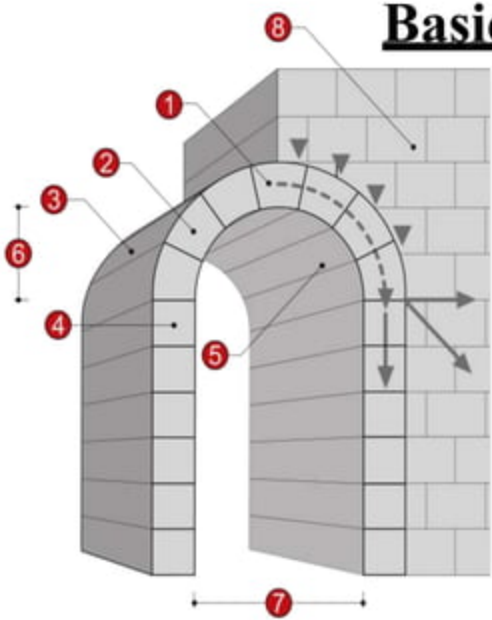
- Provided at large opening and where the super-imposed loads are heavy.
- It consists of rolled steel joists .
- Either used singly or in combination of two or three units.
- Joint with bolts.

# REINFORCED CEMENT CONCRETE LINTEL

- Common in used.
- They may be pre-cast .
- For smaller span, the pre-cast concrete lintels are used.
- Depth of lintel depend on span.

# ARCHES

# Basic concept

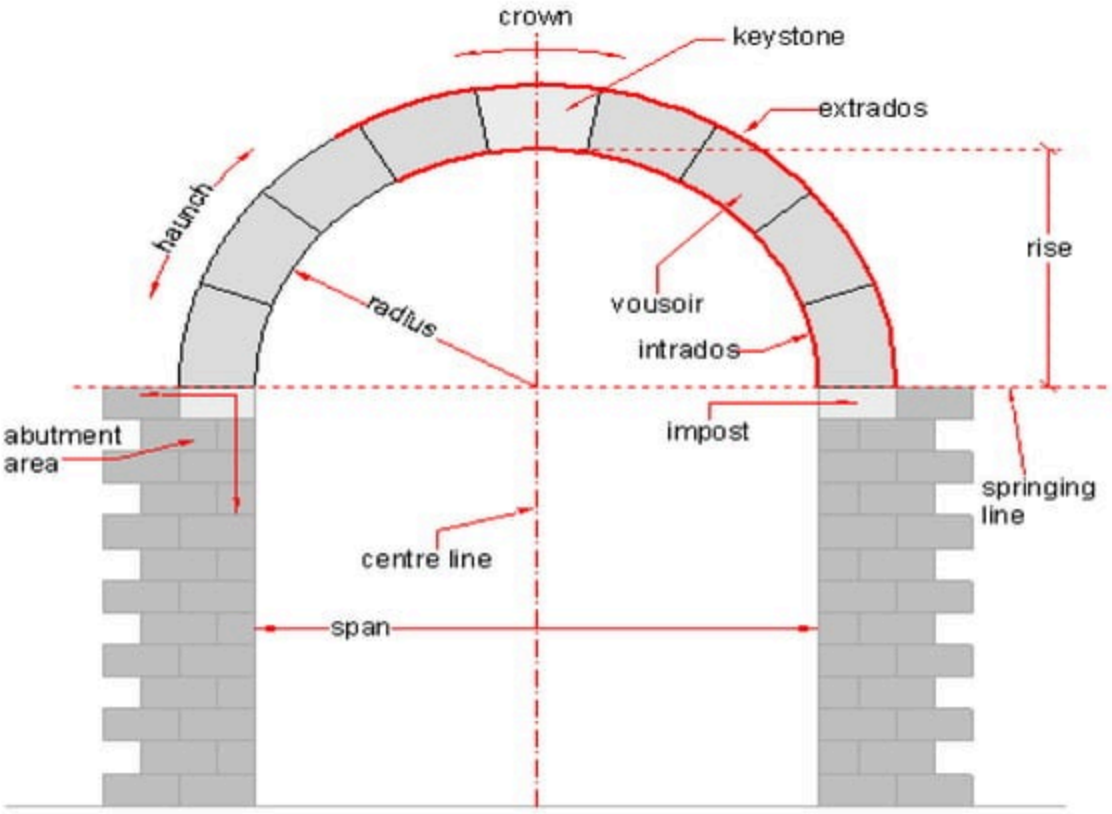



1. Keystone 2. Voussoir 3. Extrados

4. Impost 5. Intrados 6 . Rise

7. Clear span 8. A butment

An arch is a pure compression form. It can span a large area by resolving forces into compressive stresses and, in turn eliminating tensile stresses. This is sometimes referred to as arch action. As the forces in the arch are carried to the ground, the arch will push outward at the base, called thrust. As the rise, or height of the arch decreases, the outward thrust increases. In order to maintain arch action and prevent the arch from collapsing, the thrust needs to be restrained, either with internal ties, or external bracing, such as abutments.


crown
keystone
extrados
haunch
rise
radius
vousoir
intrados
abutment
area
impost
springing
line
centre line
span

# TYPES of ARCHS

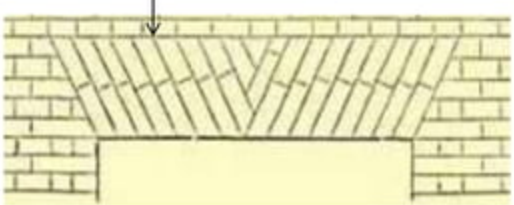
## GEOMETRY BASED ARCHES

1. Flat Arch.
2. Semi-circular Arch.
3. Segmental Arch.
4. Reliving Arch
5. Parabolic Arch.
6. Trefoil Arch.
7. Ogee Arch.
8. Multifoil Arch.
9. Basket handle Arch.

# FLAT or JACK ARCH

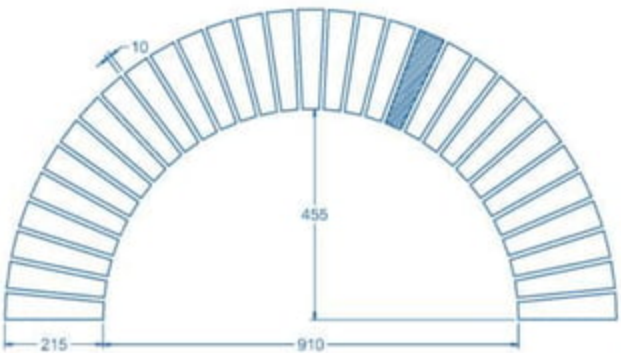
An arch having a horizontal intrados with voissoirs radiating from a centre below, often built with a slight camber to allow settling is called a flat or jack arch.

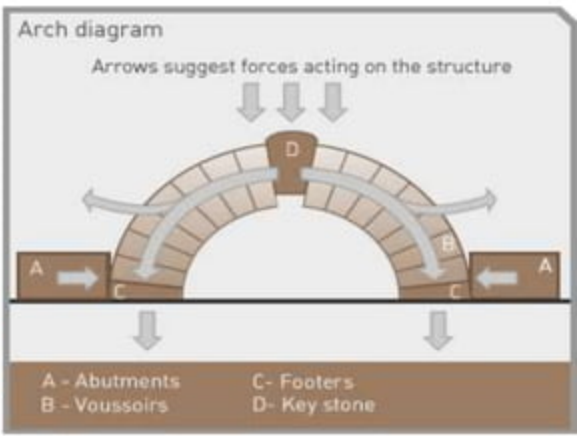
**French arch:** A flat arch with voissoirs inclined to the same angle at each side of the centre. The mortar joints do not, therefore, radiate to a common centre. Not, technically, a proper arch, and of weak form.



# SEMI CIRCULER OR ROMAN ARCH

- **Semi-circular arch** is very simple to construct or design as there is no complex geometry or cutting of bricks. Its semicircular shape with all the bricks facing towards the centre of the arch creates a wonderful view. Two or three rows of bricks are layered to add decorative touch to the beauty of the building.



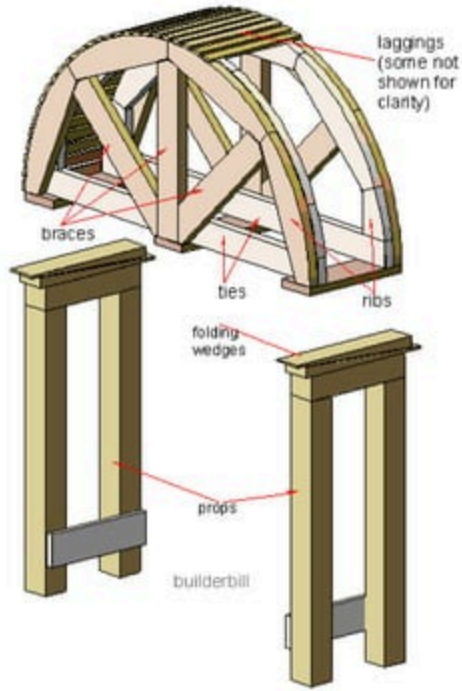



# SEMI CIRCULER OR ROMAN ARCH

- The main parts of an arch centre and they define the curves are the ribs. They are made up of the doubled up curved section. The ties and the braces. These can of course be made out of plywood or rolled steel sections, but timber is still commonly used.

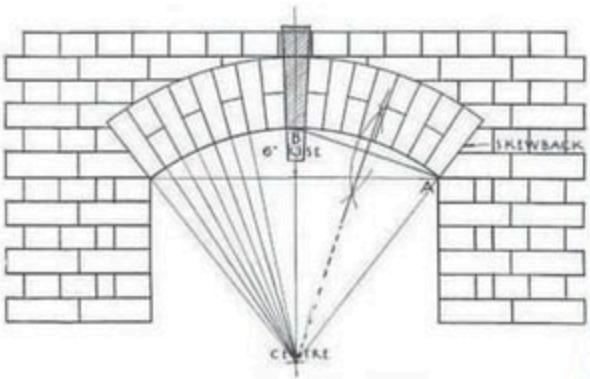
- The ribs are joined together by the lagging and the plates.

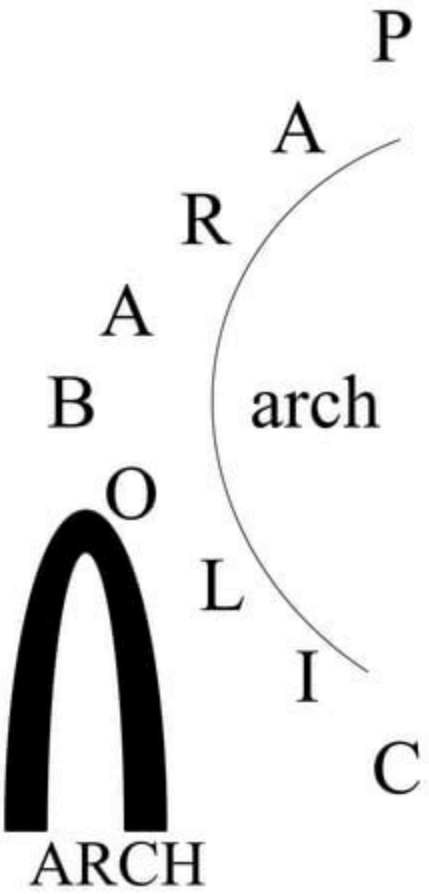
- The number of ribs used in the sketch is only two, and so it is suitable for an arch in a wall. However if more ribs are added, along with more supports then it is easy to see that a barrel vault could be centered.



# SEGMENTAL ARCH

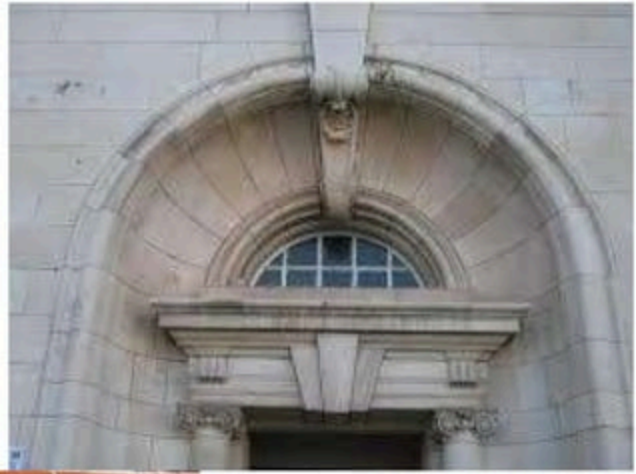
The procedure is similar to that of the semicircular arch, but as the curve is less than a semicircle, the centre will lie below the springing line





P
A
R
A
B
arch
O
L
I
C
ARCH

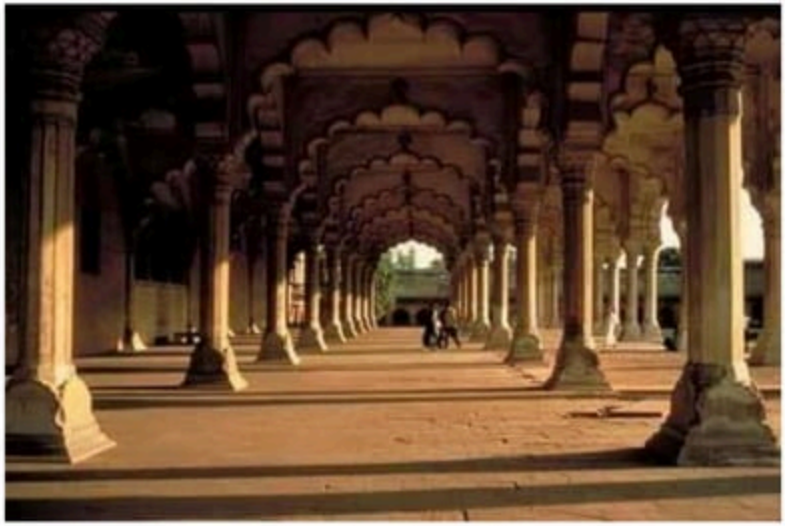
# RELIVING ARCH

An arch built over a lintel to relieve or distribute the weight of the wall above —called also *discharging arch*

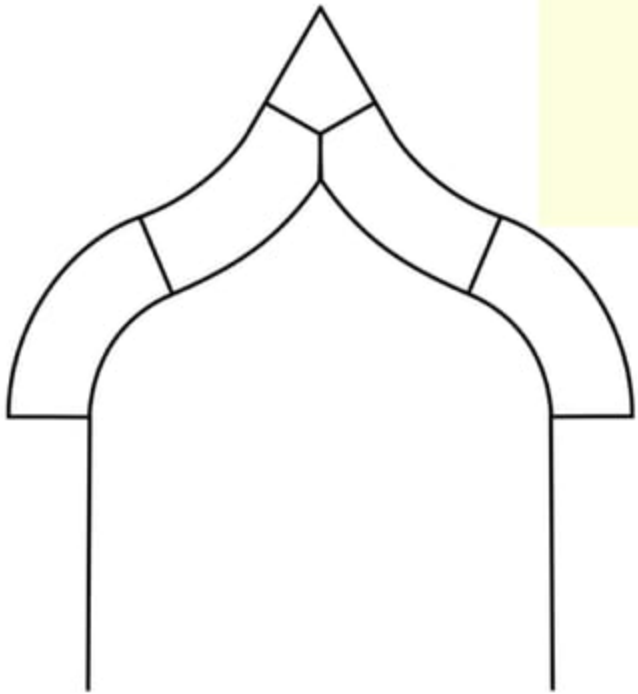


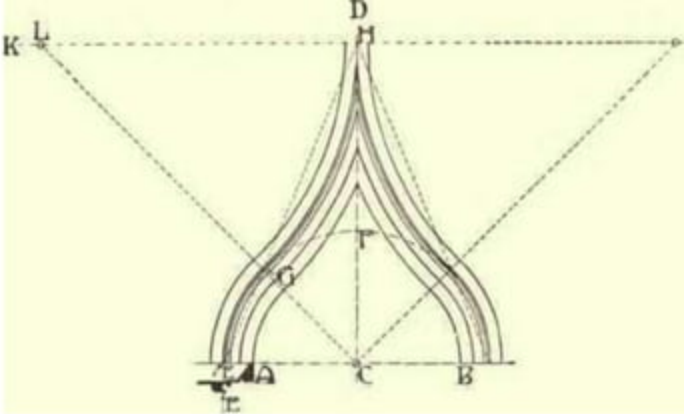
# TREFOIL
## ARCH

# MULTIFOIL
## ARCH



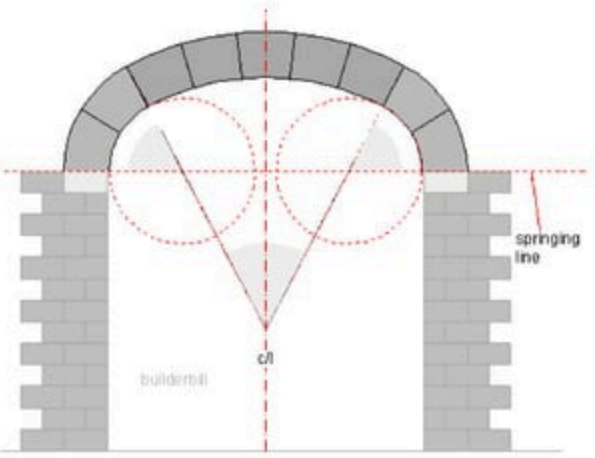
# OGEE ARCH






# BASKET HANDLE ARCH

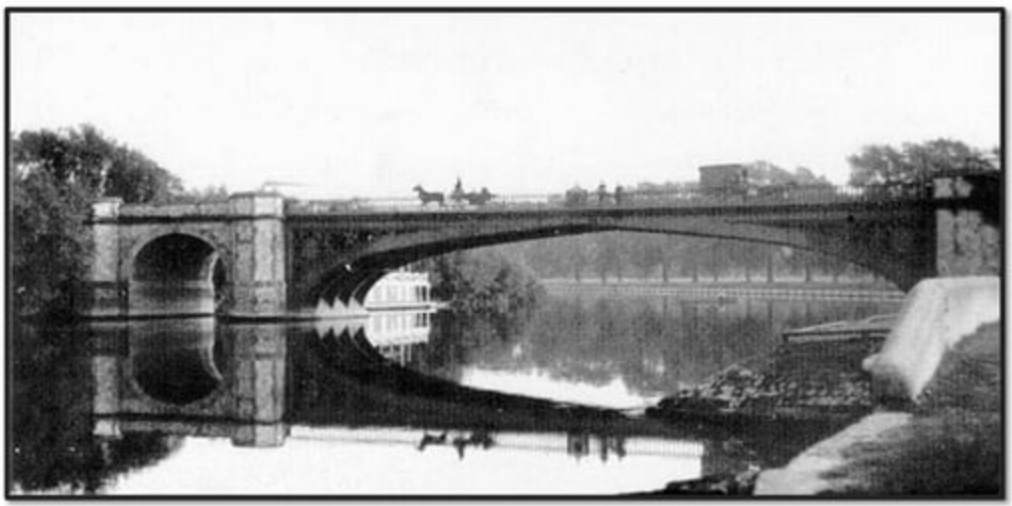
A three-centered arch that is somewhat flattened giving the effect of a false ellipse.

# CENTERED ARCH

***One Center Arch***

- Segmental, semi circular, flat arches comes under this category.
- Sometime , a perfectly circular arch known as bull's eye arch ,provided for circular window.



# CENTERED ARCH

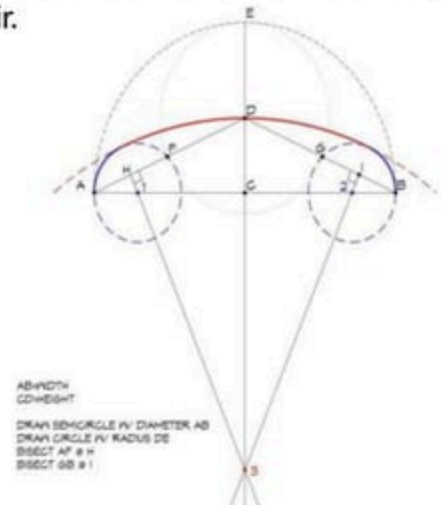
***Two Center Arch***

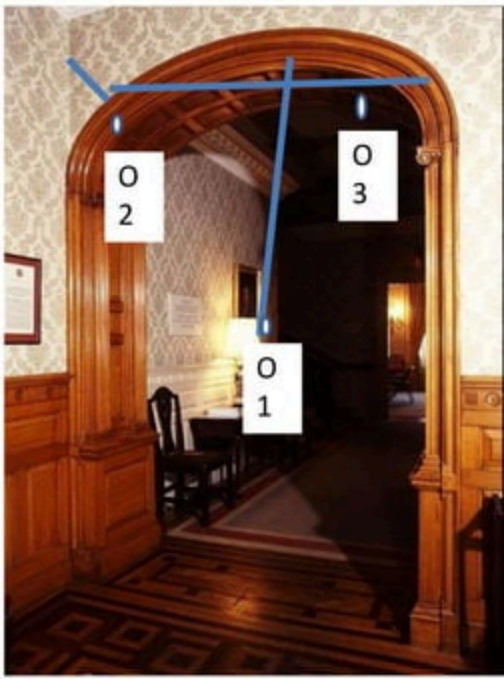
- Pointed, semi-elliptical arches come under this category.

# CENTERED ARCH

***Three Center Arch***

- Elliptical arches come under this category.
- An arch in which the intrados is a Combination of three arcs with one cantered between a symmetrically disposed pair.

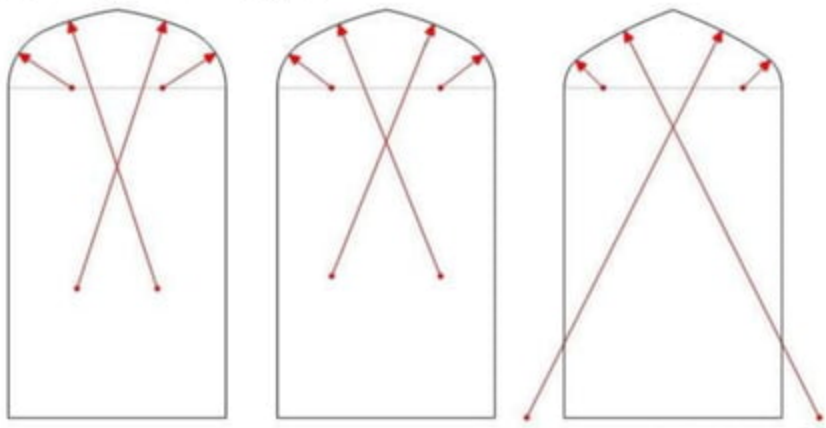


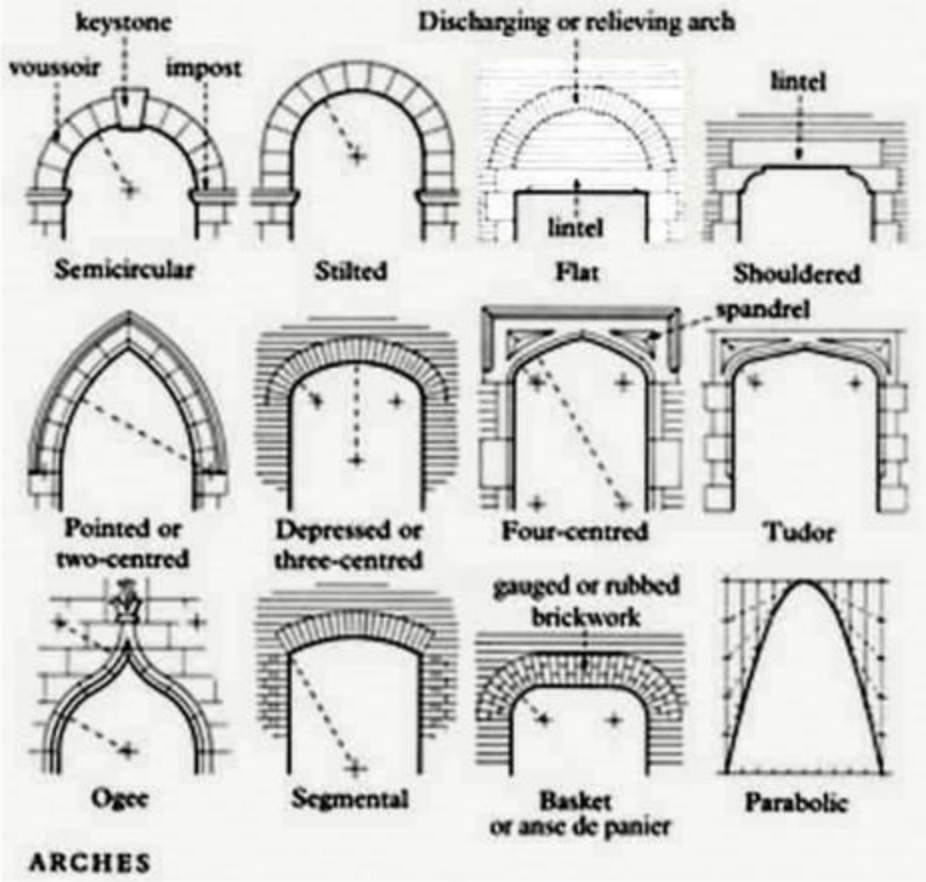
# CENTERED ARCH

***Four Center Arch***

- A **four-centred arch**, also known as a **depressed arch** or **Tudor arch**, is a low, wide type of arch with a pointed apex.
- It is much wider than its height and gives the visual effect of having been flattened under pressure.
- Venetian arch is typical example of this type.



# Types of Arches on Geometry



# Cont..

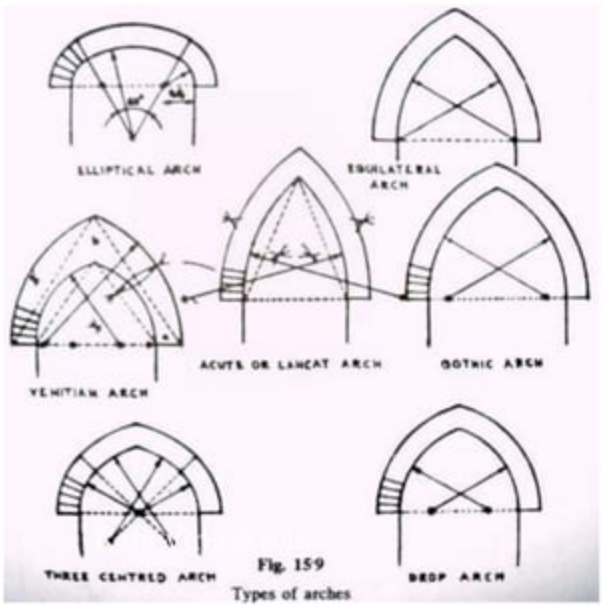
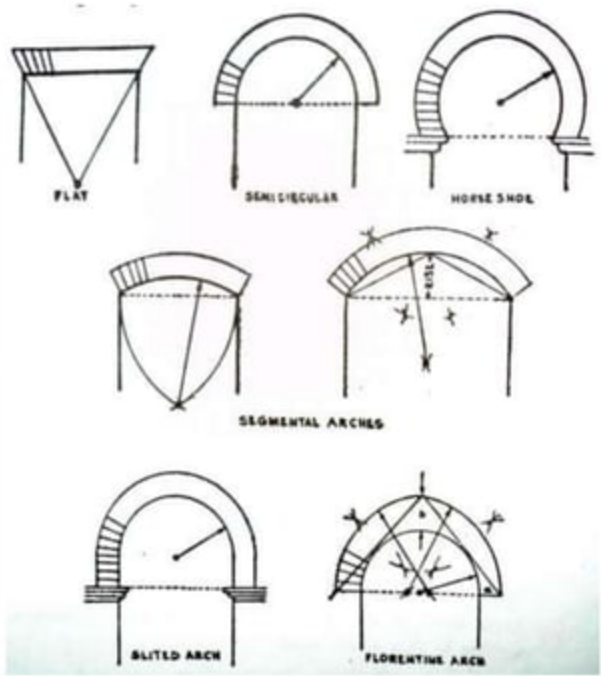
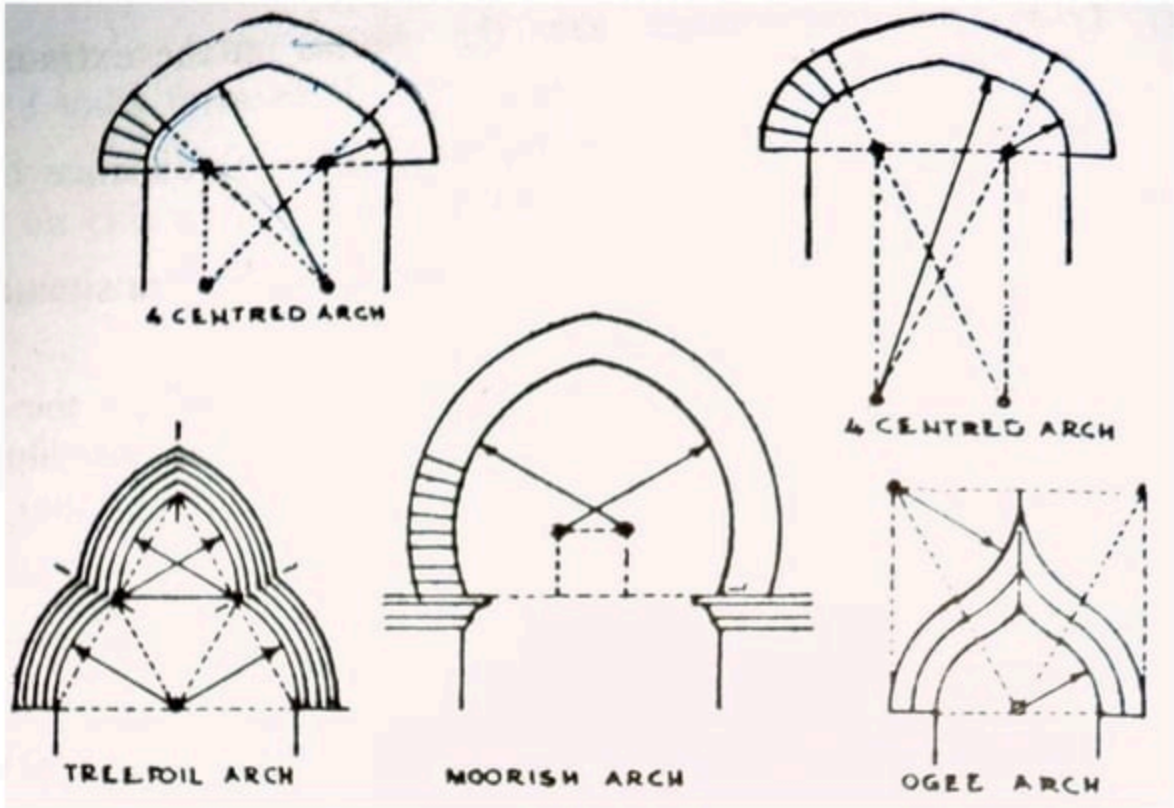



Fig. 159
Types of arches



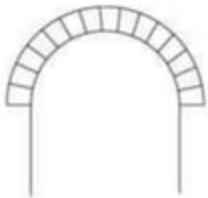
# Cont..


4 CENTRED ARCH
4 CENTRED ARCH
TREFOIL ARCH
MOORISH ARCH
OGEE ARCH

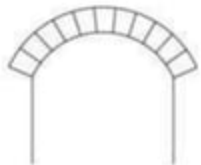
# Cont..



Triangular arch

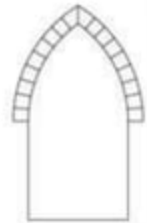


Round arch or Semi-circular arch



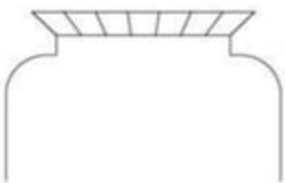
Segmental arch or arch that is less than a semicircle

Unequal round arch or Rampant round arch



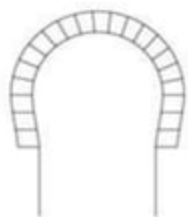
Lancet arch

Equilateral pointed arch

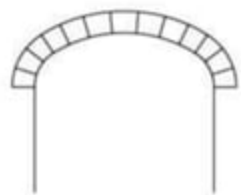


Shouldered flat arch -see also jack arch

Trefoil arch, or Three-foiled cusped arch

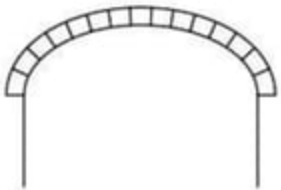


Horseshoe arch



Three-centered arch

# Cont..

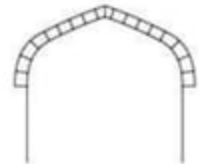


Elliptical arch

Inflexed arch

Ogee arch

Reverse ogee arch



Tudor arch

Parabolic arch

# Types of Arches on Material of Construction

- **BRICK ARCHES**

*Rough brick arches

*Axed brick arches

*Gauged brick arches

- **STONE ARCHES**

*Rubble arches

*Ashlar arches

- **GAUGED ARCHES**

*Precast concrete block arches

*Monolithic concrete arches

# Types of Arches on Material of Construction

Rubble Arch

AshlarArch

Monolithic Concrete Arch

R.C.C Arch

Metal Arch

Wooden Arch

# Rough Brick Arches

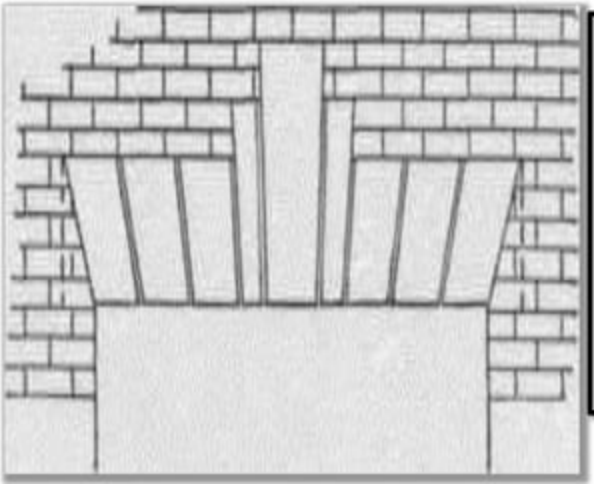
- These arches are built with ordinary bricks, which are not in wedge shape .
- Also known as "RELIEVING ARCHES".
- Made up of rectangular brick that are not cut into wedge shape. Curvature are obtained by mortar.

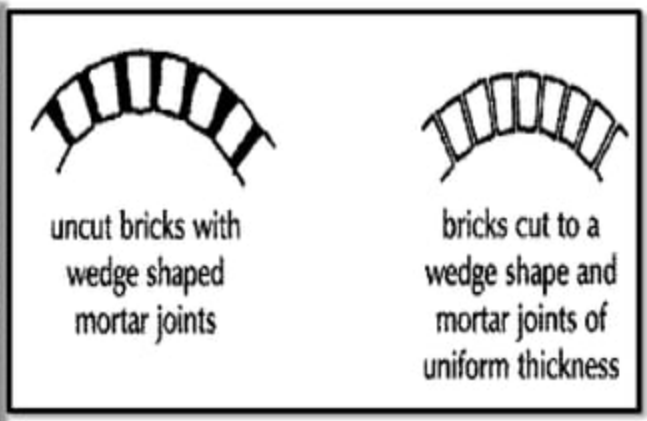
# Axed Brick Arches

- Bricks are cut to wedge-shape.
- Joints of arches are of uniform thickness.
- Not dress finely so it does not give much attractive appearance.

# Gauged Brick Arches

- Accurately prepared to wedge shape.
- Specially shaped bricks known as "RUBBER BRICKS" are used .
- The lime putty is used for binding the blocks.





# Stone Arches

## 1.Rubble Arches

- Made of rubble stones, which are hammer dressed, roughly to the shape and size of voussoirs of the arch and fixed in cement mortar.
- These arches are used for small span upto 1 m.

## Stone Arches

## 2. Ashlar Arches

- Stones are cut to proper shape of voussoirs and are fully dressed, properly joint with cement or lime.
- The voussoirs made of full thickness of the arch.

## GAUGED ARCHES

Precast Concrete Block Arches

- Used for small openings in building.
- The voussoirs, in the form of cement concrete blocks are prepared in special moulds .
- Generally , the concrete blocks are used without reinforcement.

# GAUGED ARCHES

## Monolithic Concrete Arches

- Constructed from cast-in-situ concrete ,either plain or reinforced , depending upon the span and magnitude of loading.
- Quit suitable for larger span (3.0 m).
- The curing is done 2 to 4 weeks.

# FAILURE OF AN ARCH

EVERY ELEMENT OF ARCH REMAINS IN COMPRESSION.

An arches fail due to:-

1)Crushing of the masonry.

2)Sliding of voussoirs.

3)Rotation of some joints about an edge.

4)Uneven settlement of an abutment or pier.

# Crushing of The Masonry

- If the compressive stress exceeds the safe crushing strength of the masonry unit and mortar , the arch will fail in crushing.

- The material should be of adequate strength and size of voussoirs and should be properly designed to bear the thrust transmitted through them.

# Sliding of Voussoirs

To safeguard against sliding of voussoirs past each other due to transverse shear ,the voussoirs of greater height should be provided.

# Rotation of Some Joint About An Edge

- Rotation can be prevented ,if the line of resistance is kept within intrados and extrados.

- Also, the line of thrust should be made to cross the joint away from the edge to prevent the crushing of that edge.

# Uneven Settlement of An Abutment or Pier

- Uneven settlement of abutment ,which causes secondary stresses in arch.
- Hence, the abutment which has ultimately to bear all the load transferred to the arch , should be strong enough.
- Also, the arch should be symmetrical , so that unequal settlements of the two abutment is minimised.

# Construction of Arches

## Critical Factors

1. Curing
2. Quality of Bricks
3. Providing arch - shaped door/window frames
4. Quality of sand for mortar
5. Availability of skilled masons

## Tools Used

1. Trowels
2. Plumb bob
3. Thread
4. Shovel
5. Baskets

# Construction of Arches

**DO'S**

**DON'T'S**

1. Curing shall be done for seven days
2. The mix should be of ratio 1:4
3. Mortar joints should V - shaped with minimum thickness at bottom
4. Mortar should be used within 30 minutes of adding water to the mix
5. Masonry should be always laid from both sides upwards

1. Fine sand should not be used for masonry
2. Arch should not be disturbed while removing the mould