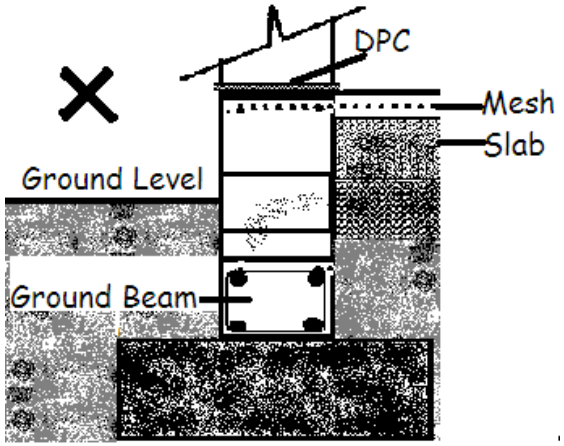
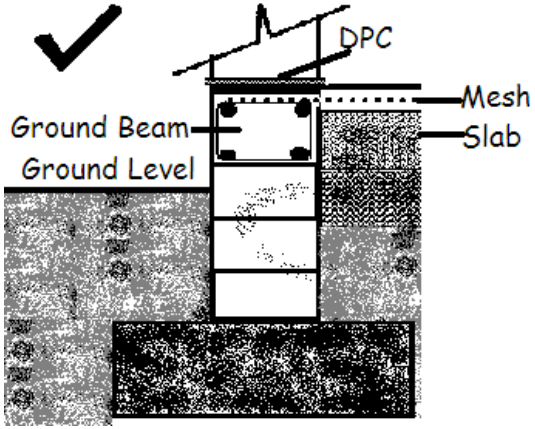
2.7 The Ground Beam

The purpose of the ground beam is to provide horizontal reinforcement so as to hold the foundation as one unit on which the superstructure is supported.

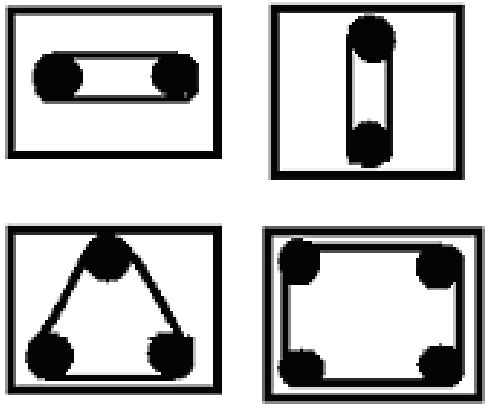
The ground beam therefore ensures strong stability of the structure as it holds the foundation as one unit, which must move together once, subjected to horizontal and vertical forces.

The ground beam is normally constructed with 2 or 3 or 4 steel bars of between 10mm to 16 mm thick tied with rings of 6-8 mm width at 250-300 mm spacing.





The ground beam should be on top of the plinth wall and not at the base



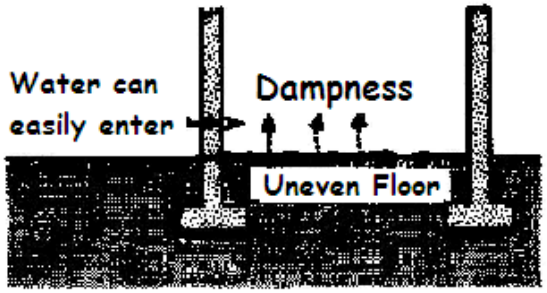
Number of steel bars that could be used in the ground beam

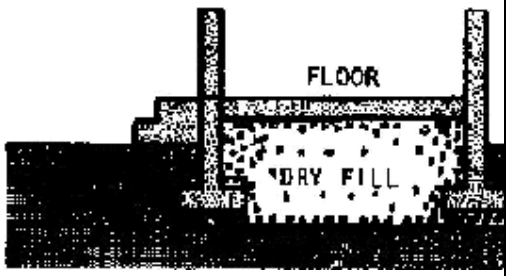
2.8 The Damp Proof Course (DPC)

A damp-proof course is required where ground moisture is a problem.
Avoid using a plastic membrane for a DPC as it introduces a weak link between the wall and the plinth. Use the recommended DPC. The DPC should be placed on the slab 150-200mm above ground level.

2.9 The Floor Slab

Construct floors well above the ground surface: This helps in achieving protection against splashing rain and flood water in predominantly humid climates, and exclusion of windblown dust during dry seasons.

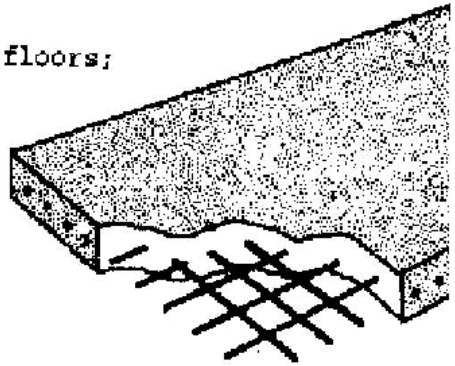


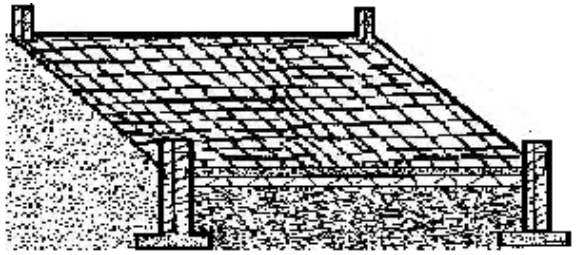


Correct: Raised to prevent Flooding

Non-uniform ground conditions can cause the foundations and/or floors to subside partially, causing serious damage. Hence, in some cases, it is advisable to construct movement or expansion joints between the floor and wall (or foundation).

Introduce wire-mesh in the slab to strengthen the floor and protect it against cracking in event of an earthquake.





The wire mesh is connected to the ground beam to ensure stability.

2.10 The Wall Brick/Block work

The main functions of walls are:

- exclusion of heat or cold, rain, wind, dust, noise, and other undesirable climatic and environmental elements;
- regulation of indoor climate (temperature, moisture, air movement);
- privacy;
- security against human and animal intrusion; and
- support of ceiling and roof structure (though not the case in frame constructions with infill walls).

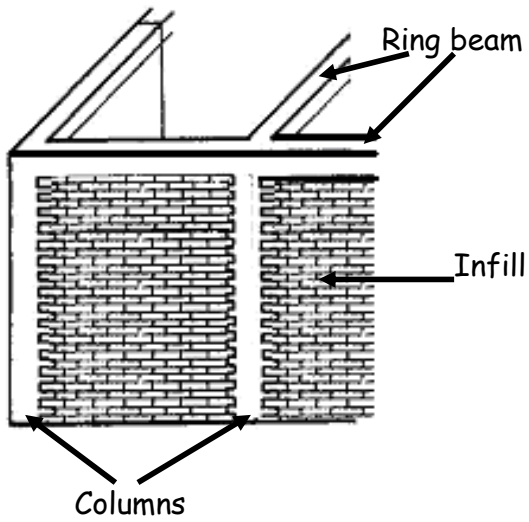
2.10.1 Types of Walls

Good quality masonry depends on:

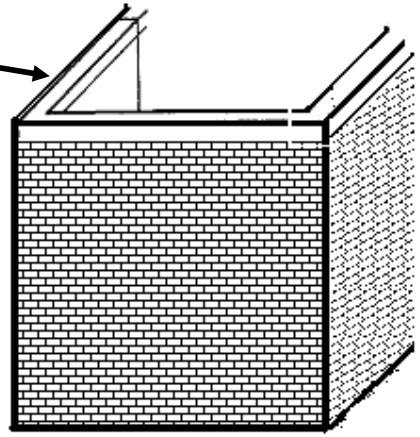
- the quality of blocks/bricks;
- the quality of mortar;
- the quality of bonding pattern;
- the compatibility between the block/brick, the bonding pattern and the mortar and
- the workmanship.

There are principally two ways of building a wall:

- massive or load-bearing wall construction;
- skeleton or frame construction with non-load-bearing walls.



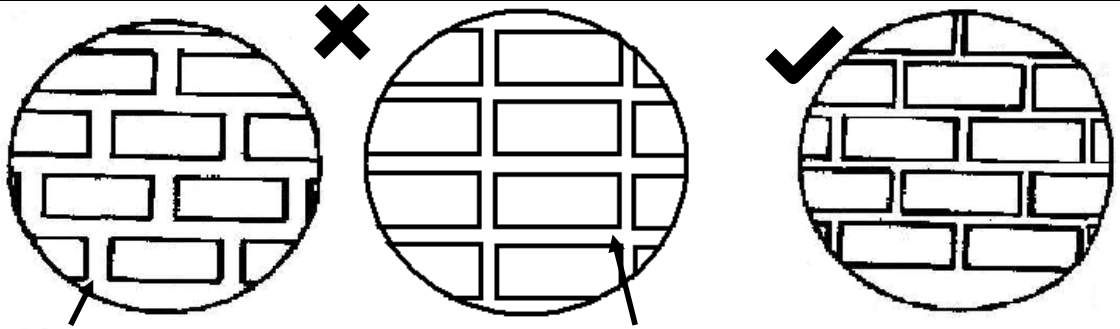
Skeleton or frame construction



Load bearing wall

2.10.2 The Mortar

- Use the right quality of mortar;
- The vertical joints should be totally filled; and
- The horizontal joints should be 12.5 – 15 mm thick
- Avoid superimposing vertical joints above each other (straight joints).

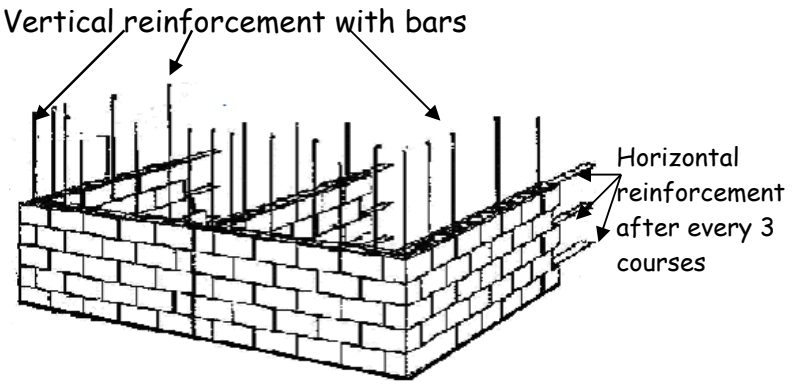


2.10.3 Building Reinforced Block /Brick wall

- Starter bars coming out of the foundation will tie the wall to the foundation
- Lay blocks so that those starter bars come out through block pockets;
- Use vertical reinforcement bars of minimum diameter of 10mm at 800mm centers;
- As more courses are laid more lengths of steel should be added to overlap for at least 300mm with starter bars;
- Pockets of blocks containing reinforcement are filled with concrete;
- Use a 1 : 3 mortar to form joints of width between 12mm to 16mm
- Vertical bars should be put at all junctions and window and door openings and
- Block walls should be constructed in running bond rather than stacked bond (laying horizontal courses after course).

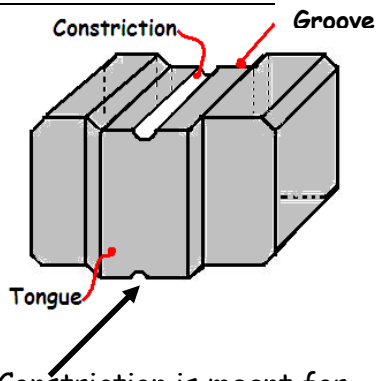
Walls should be reinforced both vertically and horizontally to increase their stability:

- Horizontal reinforcement should be provided no more than 3 courses apart.
- Use hoop iron strips, or round bars of 6-8 mm thick, or barbed wires embedded in mortar for horizontal reinforcement

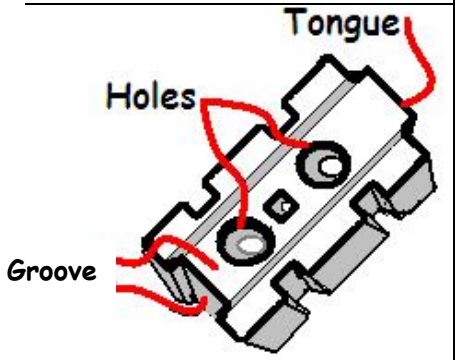


2.10.4 Interlocking Block Walls

Walls without mortar can be built with interlocking blocks pressed in special moulds and normally stabilized with cement or lime. Several systems have been developed. The blocks have grooves and tongues for both horizontal and vertical interlocking. Blocks can be stacked without mortar and in case of any seismic shocks; they will normally be displaced or lifted up but fall back to their position. Improvements have been made to provide for reinforced columns at the corners and horizontal reinforcement using round bars of 6-8 mm thick embedded in a mortar to interconnect with columns after every three courses.

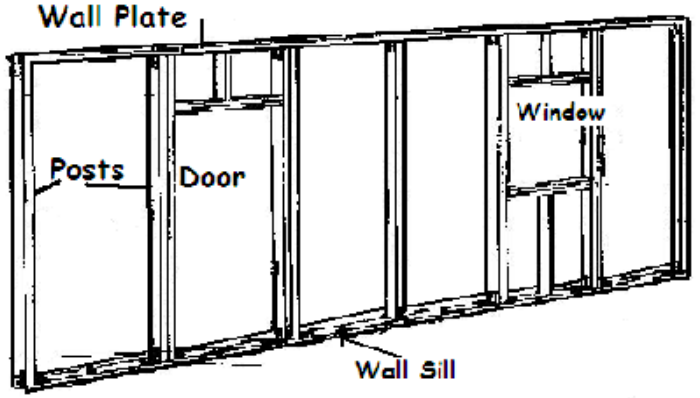


Constriction is meant for horizontal reinforcement



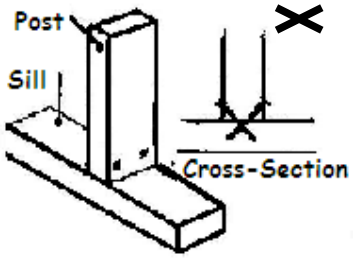
2.10.5 Wooden Walls

- The timber posts or uprights should be fixed to the sill which is bolted to the foundation wall (plinth);
- Metal Straps should be used to improve the resistance of timber houses to earthquakes;
- The wall plate must be fastened and strapped to the top of uprights;
- Use double posts at the door and window openings;

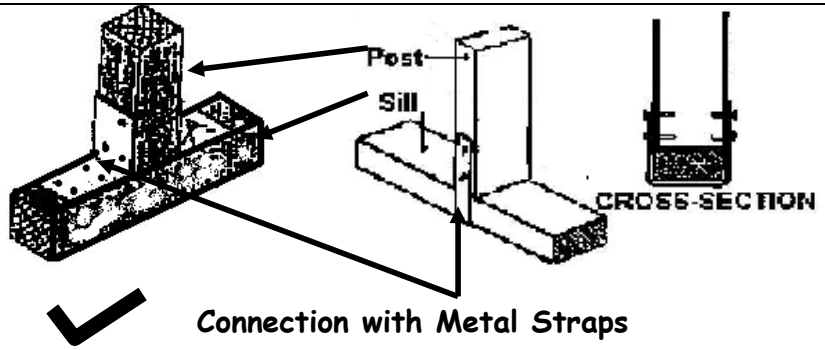


2.10.6 Connection for Timber Walls

The walls must be securely tied to the foundation to prevent the building from total destruction or collapse in event of earthquake shaking. They can be tied with the following connections:



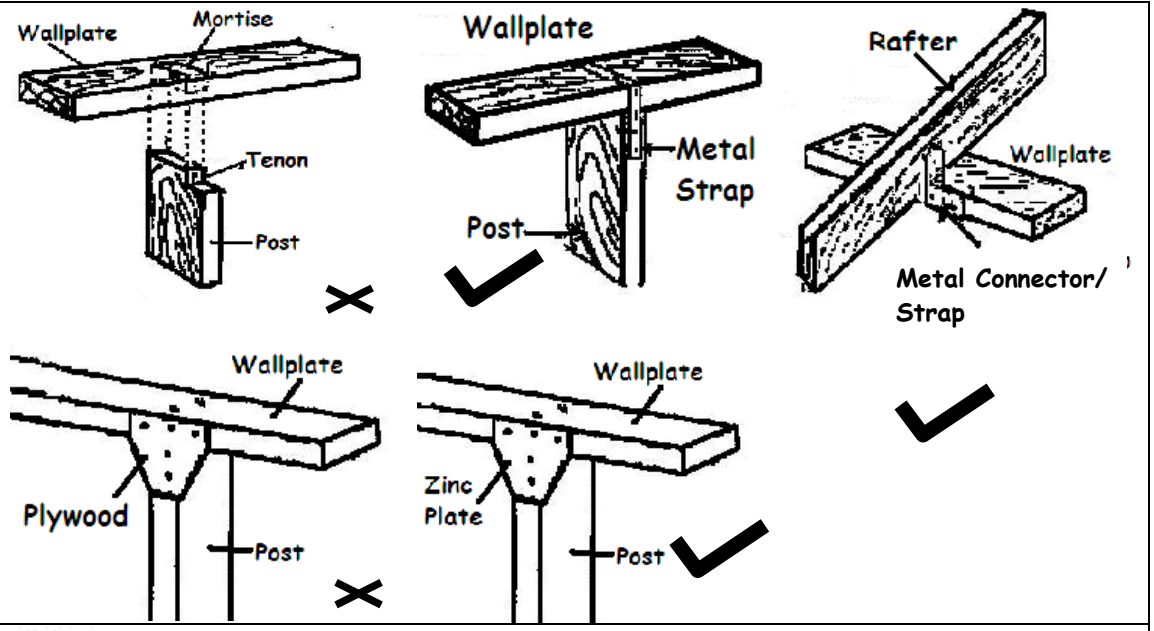
Connection with Nails; this is not strong enough.



Connection with Metal Straps

Connection of Wall Plate and Posts, and the rafters and wall plate should be made using metal connectors of gauge 20. This ensures strong resistance against seismic forces.

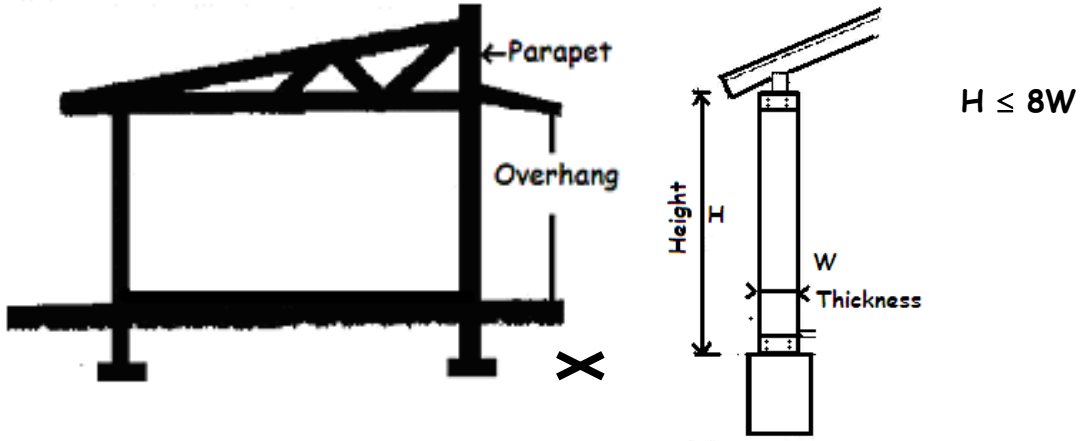
The conventional solutions e.g. mortise & tenon joint with glue and dowel pins or use of plywood are not strong enough to resist seismic shocks.



The walls should not be too thin. As a general principle the wall height should not be more than eight times its width.

Parapet walls should be avoided or else they should be braced with columns and tie beams.

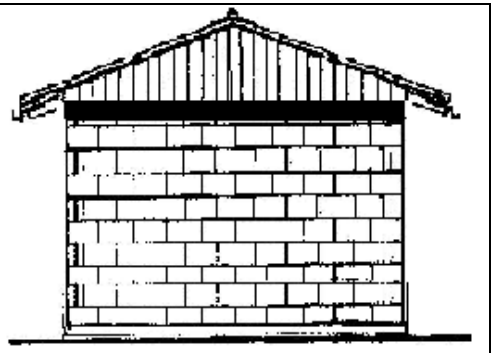
Long cantilevered overhangs should also be avoided.



Gable walls are very weak against vertical forces. They should therefore be discouraged. This problem can be overcome by:

- Using hipped roof;
- Using light materials such as timber, iron sheets to cover up the gable end

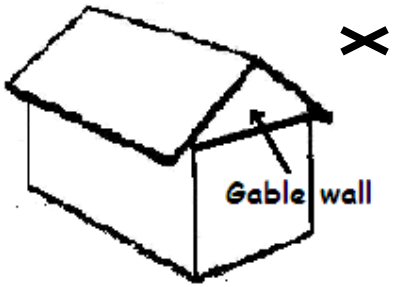
Hipped Roof



Use timber pieces at gable end

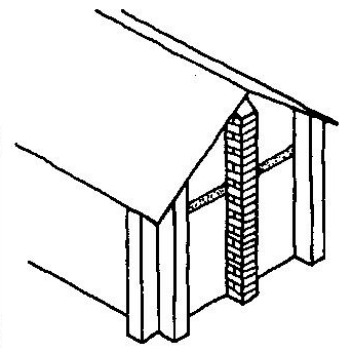
- Stabilize with a buttress (2); and
- Stabilize with reinforced concrete elements (3).

1



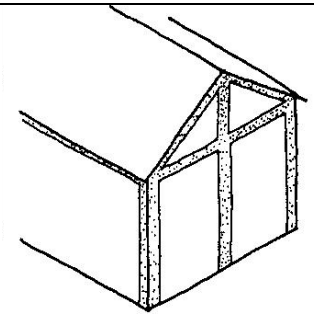
Unsafe

2



Stabilize with buttresses

3

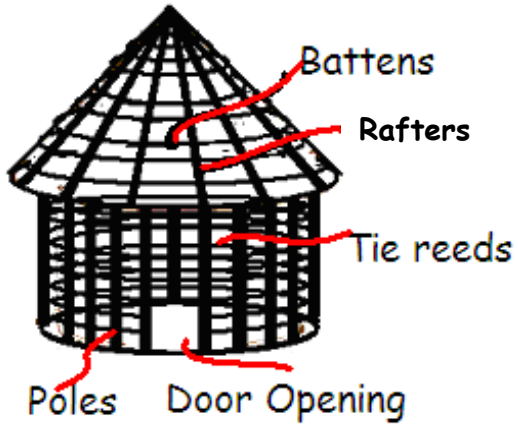


Use concrete columns & tie beams

2.10.6 Walls of Traditional Mud & Wattle Houses (Huts)

The mud and wattle wall system consists of vertical and horizontal elements made of timber or bush poles forming a double grid which is filled with mud. This is the most flexible system as it is basically a timber grid structure with flexible interconnected joints and earth infill.

The structure contains interconnected structural elements that adequately resist seismic forces in both vertical and horizontal directions.



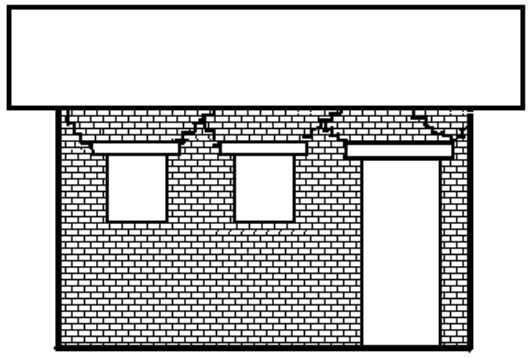
Poles should therefore be preserved against termites and rains by:

- Smoking (partial burning of the surface)
- Application of ash in the foundation/base
- Covering of the base of poles with polythene paper
- Application of used oil onto the surface of the poles and
- Embedding of poles in cement-sand mortar base.

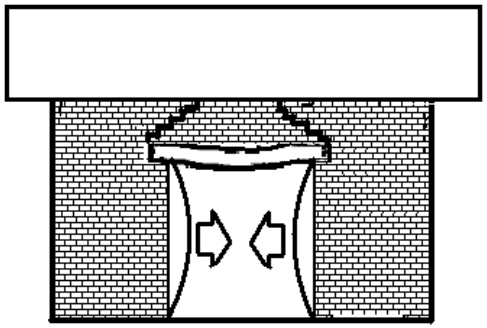
2.11 The Openings

Openings within the walls destabilize the wall system. In an earthquake, diagonal cracks often occur, starting from the window edges particularly when:

- There are no lintels
- The lintels are too short (there is insufficient overhang)
- Opening is very wide
- The lintels are not rigid enough to support the load above

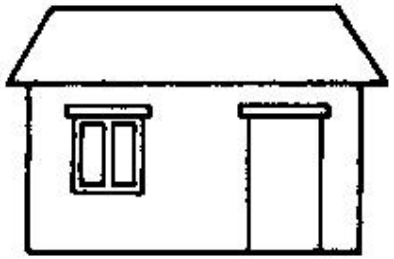


Cracks resulting from lintel weaknesses

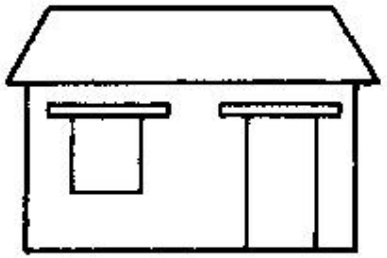


The lintel is not rigid while the opening is too wide

Lintels should penetrate into the wall for at least 40 cm in order to achieve a good bond. They should be 1.5 times the width of the window.
To ensure maximum stability, use a ring beam to support the entire roof structure as one unit.

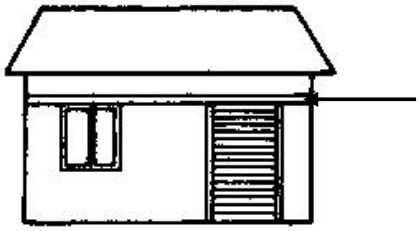


Dangerous



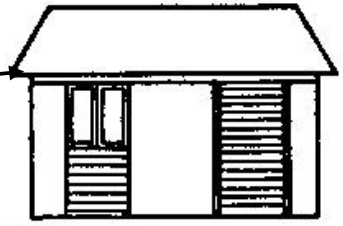
Acceptable

These openings should be well planned so that their sides correspond to the ends of formwork sections, their height is in line with the top of the last layer, and the ring beam substitutes the lintel.



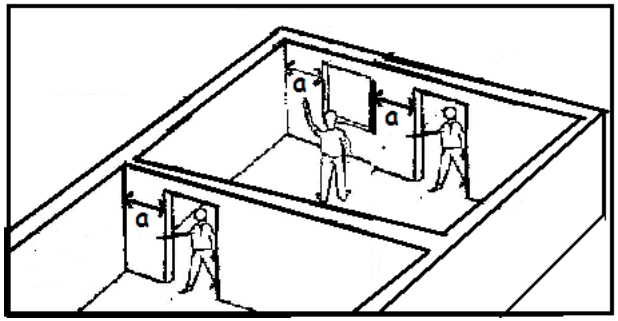
Better

Ring beam

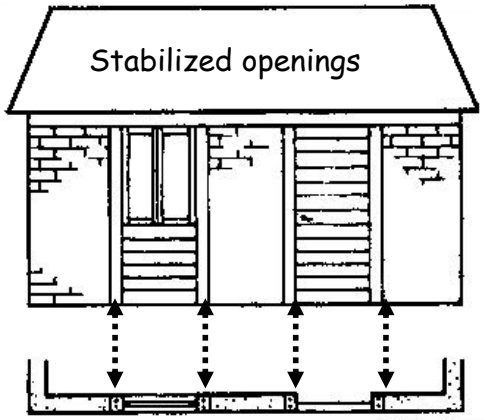


Best

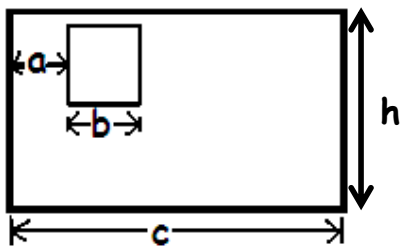
- Openings should be as small as possible but adequate, located not less than 100cm from corners or other openings;
- Large sized glass panes should be avoided.
- There should be vertical reinforcement on the openings from the foundation to the roof.



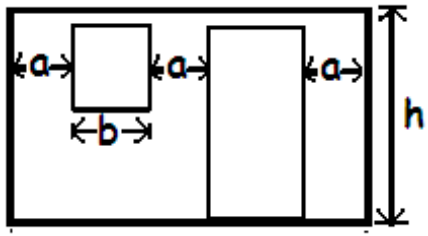
a ≥ 100cm



- The length of the windows (b) should not be more than 1.2 metres and not more than 1/3 of the length of the wall (c);
- The length of walls (a) between openings must be at least 1/3 of their height (h) and not less than 1 metre.



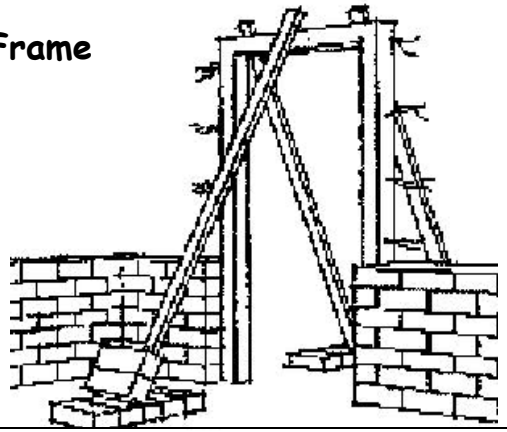
a ≥ h/3 ≥ 100cm; b ≤ c/3 ≤ 120cm

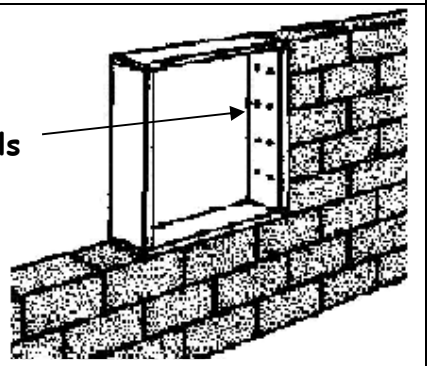


a ≥ h/3 ≥ 100cm;
b ≤ h/2 ≤ 120cm

- It is advisable to insert the window and door frames within the masonry formwork and attach anchors, so that the frames are rigidly fixed to the wall.
- If burglar-proof is to be used in the windows, they should be openable for easy exit in case of emergency.

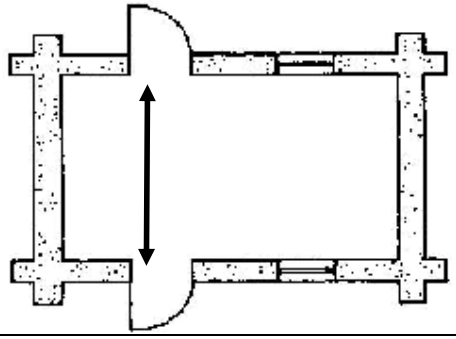
Door Frame

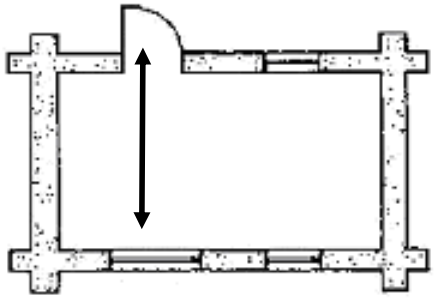




Window frame

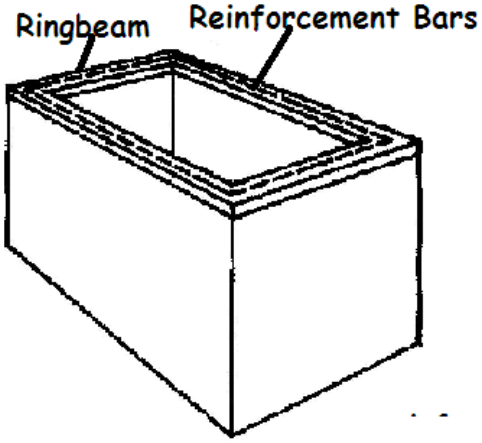
Doors must be opened towards the outside. Opposite the entrance door there should be a large window or another door, which acts as emergency exit.

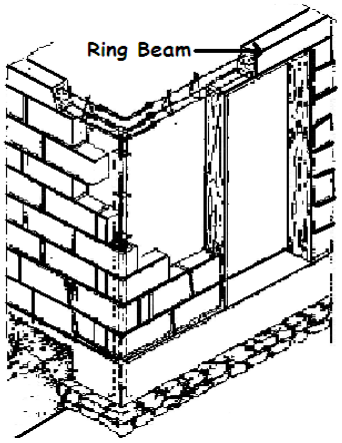




2.12 The Ring Beam

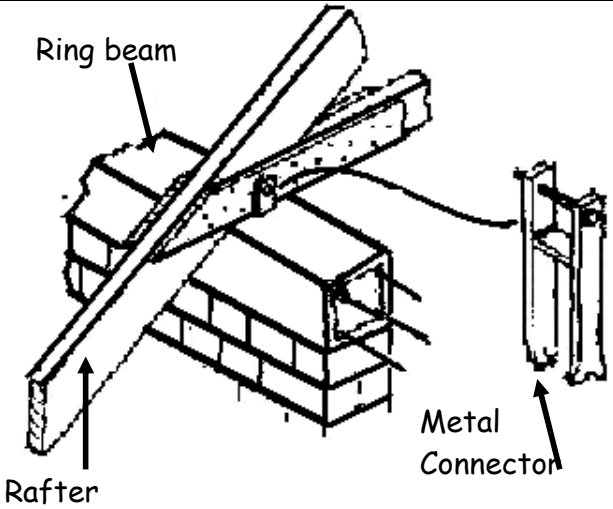
This is a continuous collar or tie at the top of the wall that provides a solid base on which wall plates or rafters can be anchored. In earthquake prone areas, the ring beam should be supplemented by columns, forming a framed structure to ensure stability of the structure. Such structures are usually made of reinforced concrete.



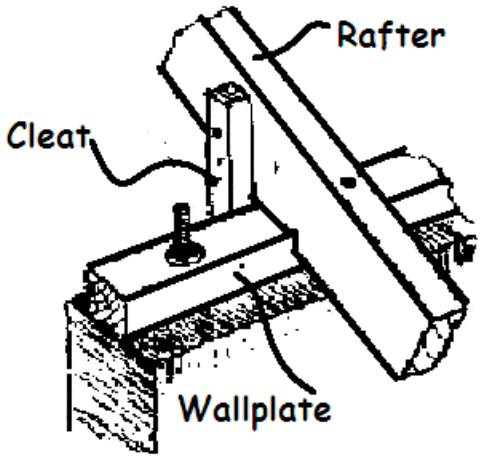


2.13 The Wall Plate

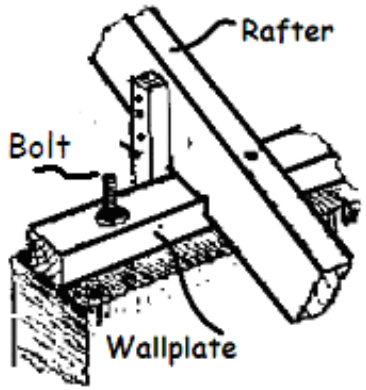
The wall plate is the one through which the roof structure is anchored to the ring beam. Usually a timber board of 4"x3" is tied to the ring beam or the last course of bricks on the wall to serve as wall-plate. Wooden cleats of 1.5" x 2.5" can be used to connect the rafter to the wallplate. It is also possible to embed metal connectors or within the ring beam through which rafters and purlin can be bolted onto the ring beam

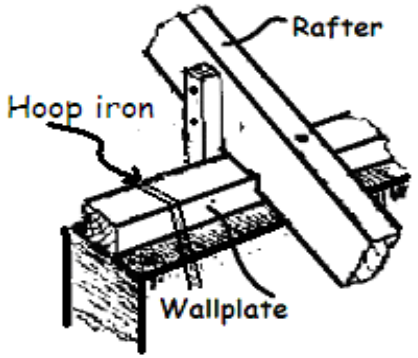


Wall Plate Joint



The wall plates must be bolted onto the ring beam or tied to the wall using hoop iron. The hoop iron should be positioned at least 60 cm below the wall plate.





2.14 The Roof

Roofs are very important as they provide a cover over the rest of the structure. It is the part primarily responsible both for indoor comfort and for damage suffered during earthquakes and hurricanes. A well-designed durable roof can compensate for a great number of problems that may arise in other parts of the building.
In earthquake prone areas, the roof should be as light as possible; either monolithic with high tensile strength or of strong, flexible members, firmly tied to the supporting structure.

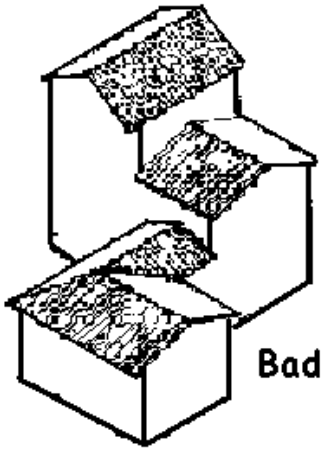
They should be designed in compact symmetrical shapes with spans as small as possible. They must be securely fixed on the ring beam or building frame.

Alternatively, roofs can be fixed to independent supports, structurally separated from the walls, which in the event of failure would not cause the roof to collapse. Appendages such as parapets, chimneys, water tanks, should be very securely fixed to avoid their being shaken off, or be omitted altogether.

Roofs should be simple, symmetrical, regular & light.

Avoid complex roof designs that are asymmetric as they are easily affected by the torsional forces.

Avoid overhang roofs or canopies. If they are desired they should be separated from the main roof structure.



Bad

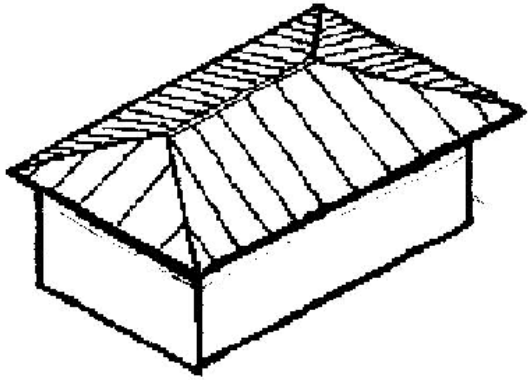
Good

2.14.1 Types of Roofs

Roofs can be categorized in the following types:

- Hipped
- Double pitch } Sloped Roofs
- Mono pitch
- Conical
- Vault
- Dome shaped & } Curved
- Flat Roofs

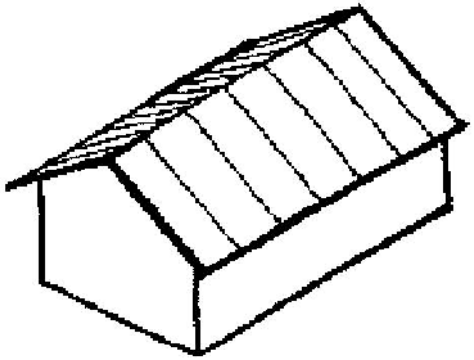
Roofs can also be constructed in various roofing materials, depending on people's tastes, culture, affordability, etc.



Hipped Roof

For earthquake resistant houses, a pyramidal roof with 4 inclined planes which rest on a horizontal ring beam, is ideal.

- Corrugated Galvanized metal sheets – these are gauged in numbers ranging from 24 to 32. The corrugations make the thin sheets stiff enough to span between two purlins without sagging. Thus large areas can be roofed with a minimum of supporting construction, making the roof light and cheaper.
- Tiles or stone plates are not recommended as they are heavy and usually fall during earthquake shaking.

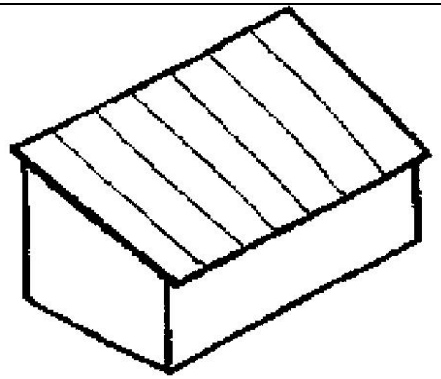


Double pitched or Gable roof

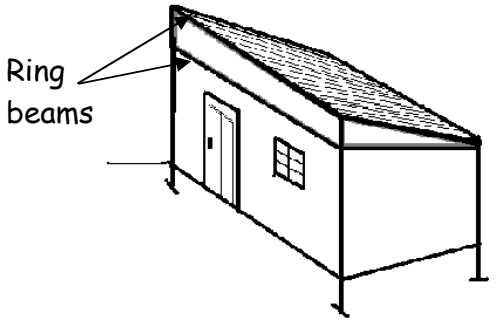
The double pitched roof is the most commonly used roof type. However the gable wall is normally affected during earthquake as it is less stable. It must therefore be stabilized by:

- Buttress or
- Reinforced column and tie beam or
- Use of light material such as timber at the gable end or
- Construct the hipped roof instead.

Mono pitched roofs are normally used on very small houses of one or two rooms. One wall is higher than the other and if a ring beam is to be constructed in the normal way, then the wall above the beam will be less stable (parapet). This calls for interconnection of the ring beam on which the roof rests to form an inclined ring beam.



Mono-Pitched Roof

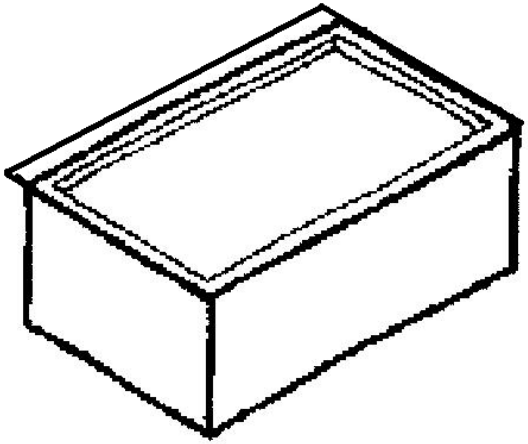


Stabilization through interconnecting the ring beam with the inclined ring beam and vertical reinforcement.

Flat Roof

These can be monolithic slabs, sheets or space frame structures, or simple systems using beams, girders and decking elements of low span capability.

By definition, roofs with inclinations less than 10° to the horizontal are classified as flat roofs. For rainwater run-off at least 2° slope is needed.



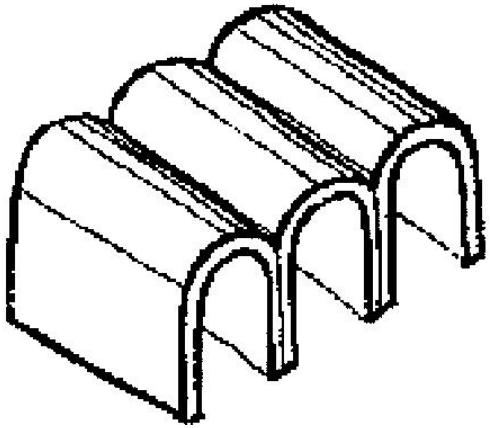
Flat Roof

Flat roofs are most common in predominantly hot arid regions, with low annual precipitation. The roofs provide additional living space (for household activities and sleeping at night) and facilitate vertical extensions of the building.

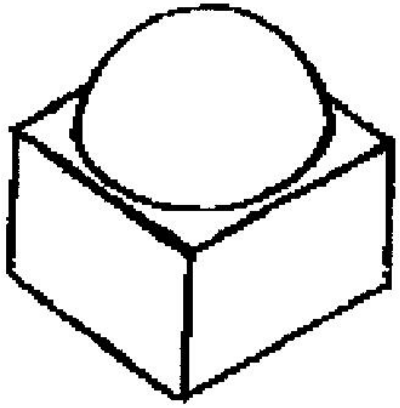
Due to high rainfall in the Western Uganda, flat roofs are less suitable although with concrete reinforcement, they may be able to resist seismic forces.

Curved roofs in form of Vaults and domes are commonly used in hot dry climates.

Masonry vaults and domes are likely to fail during earthquakes and are therefore not recommended.



Vault Roof



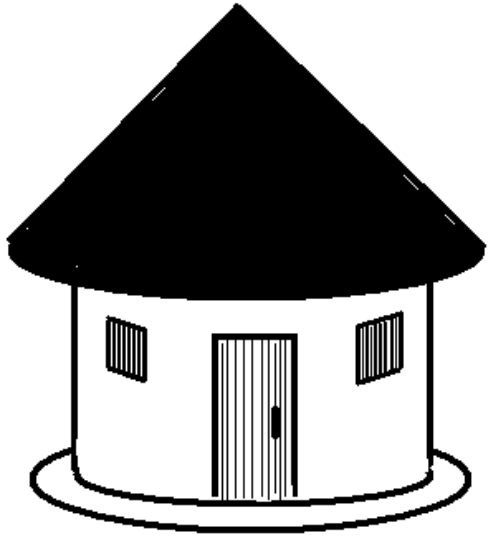
Dome shaped Roof.

The Conical Shaped roof:

This is normally used on traditional circular huts roofed with grass or any other natural fibres such as banana fibres, papyrus etc.

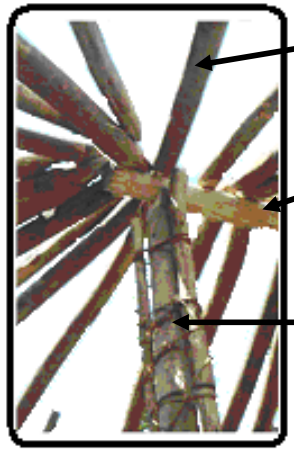
It calls for skilful workmanship to make a leak-proof thatch, which can last longer. The thatched roof should have a minimum pitch of 45° to facilitate fast flow of any rainwater.

Conical roof



- Use only properly dried mature grass layers not less than 10 cm.
- Lay the grass in rows with a minimum lap of 45 cm, and secure by tying with a sisal string or banana fibres around the battens
- Replace after every 2 – 4 rain seasons depending on the length and intensity of the rains, and workmanship.
- Use of a polythene cover underneath the thatch safeguards against leakage.
- Use strong timber members underneath to take the heavy thatch load.

The structure should be capable of supporting up to 40 kg/m^2 which is the weight of the heaviest material –reed. Thatch is placed in horizontal layers approximately 20 cm thick secured by stitching, layer by layer, at approximately half way between cut end and ear. Layers overlap as tiling, so fixings are covered and protected.



The battens are tied or nailed onto the purlins, which are connected from the cross-member to the wall plate.