C10

Hazard Resistant Features of Walls and Openings

No. of Slides: 58
Time: 45 min

National Disaster Management Authority

People in Centre

Gujarat Institute of Disaster Management

Expected Outcomes

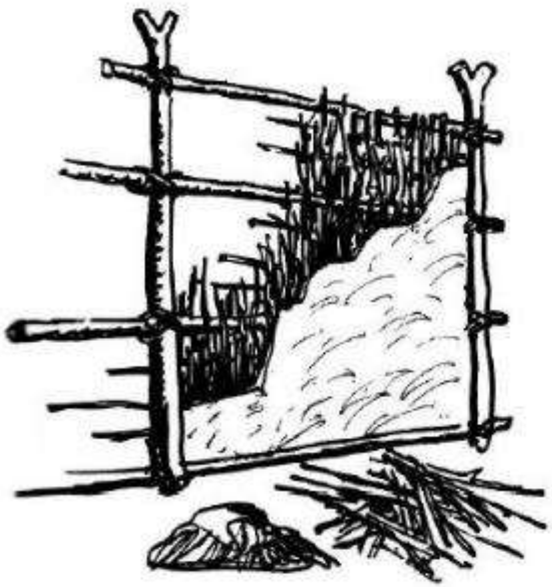
1. Participants are aware of various damages inflicted upon load bearing and in-fill walls during different hazards.

2. They know construction methods of mitigating impact of hazards on walls (principles and design limits).

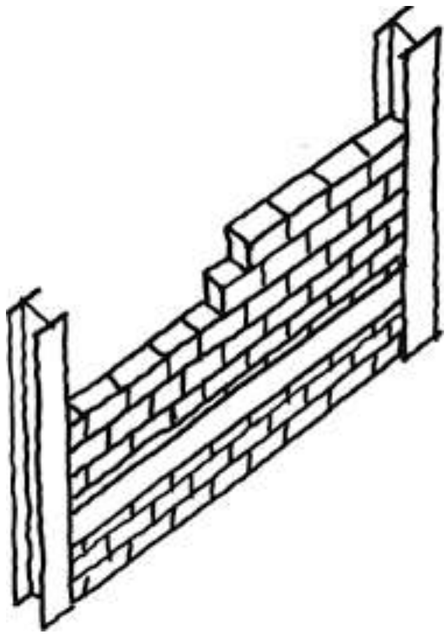
3. They are aware of safety features and measures for increasing resilience of walls during hazards through construction details (masonry bonds, corner junctions, vertical reinforcements etc.).

Types of Walls

1. Infill Walls: When the load of the roof is transferred to the ground by columns and beams, the walls take only their self-weight. Such walls are known as infill walls.

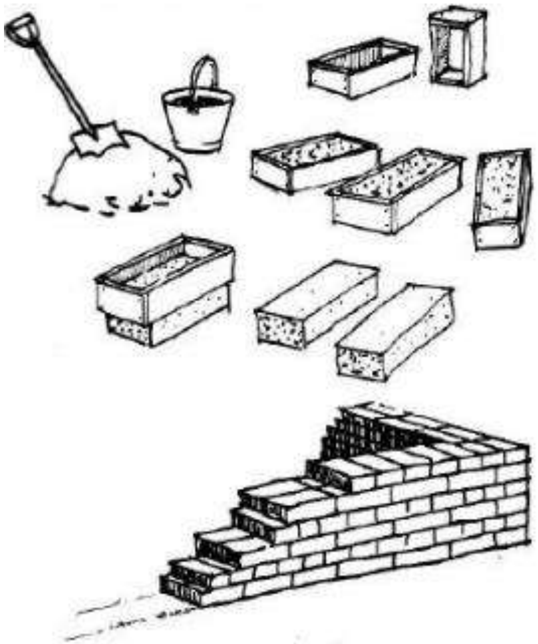


Wattle and daub

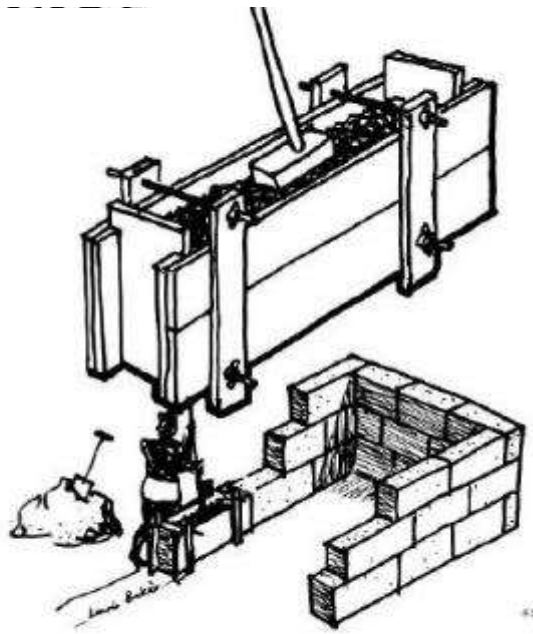


Brick Infill Wall

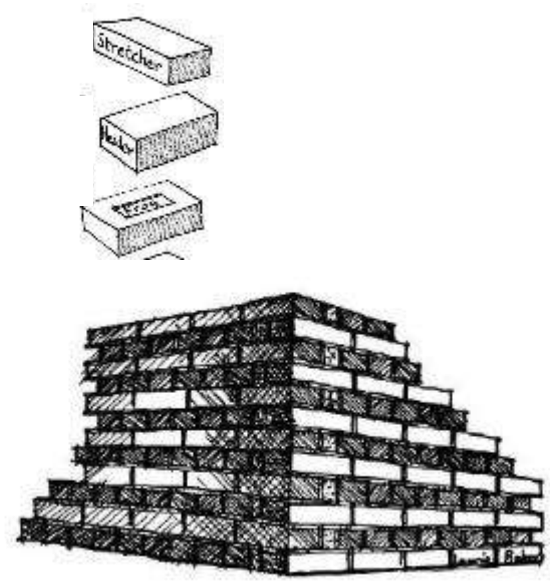
2. Load Bearing Walls: Walls which transfer the load of the roof or floor above to the ground are known as Load Bearing Walls.



Adobe bricks



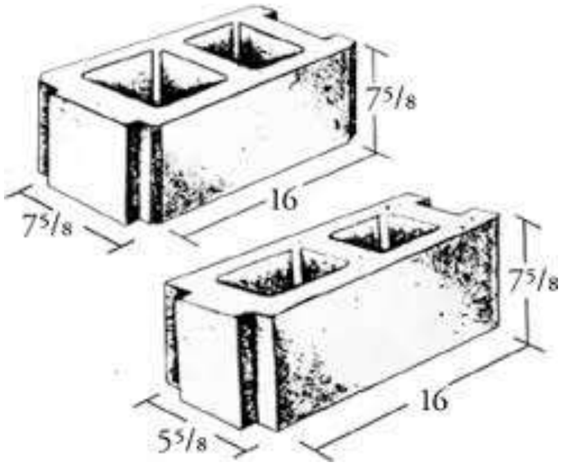
Rammed Earth



Fired bricks

Load Bearing Walls: Load bearing walls with different materials

Hollow Concrete Blocks

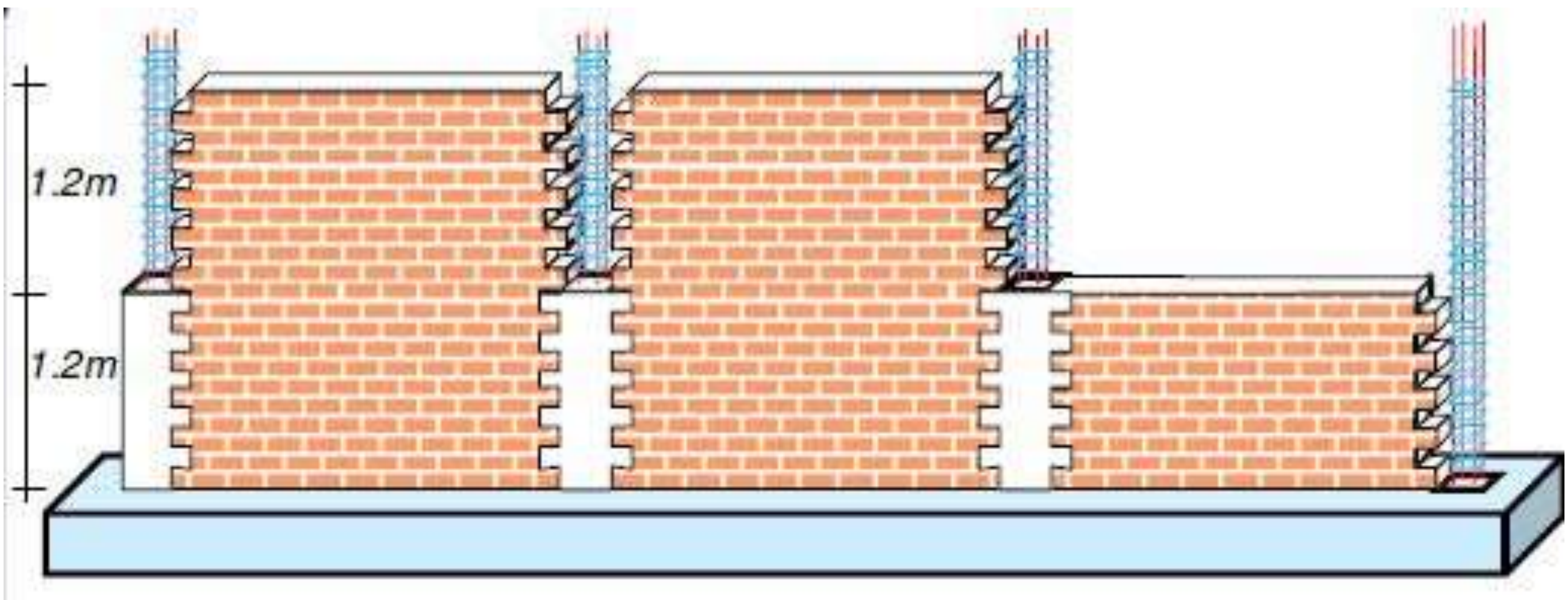


Uncoursed Random Rubble Stone

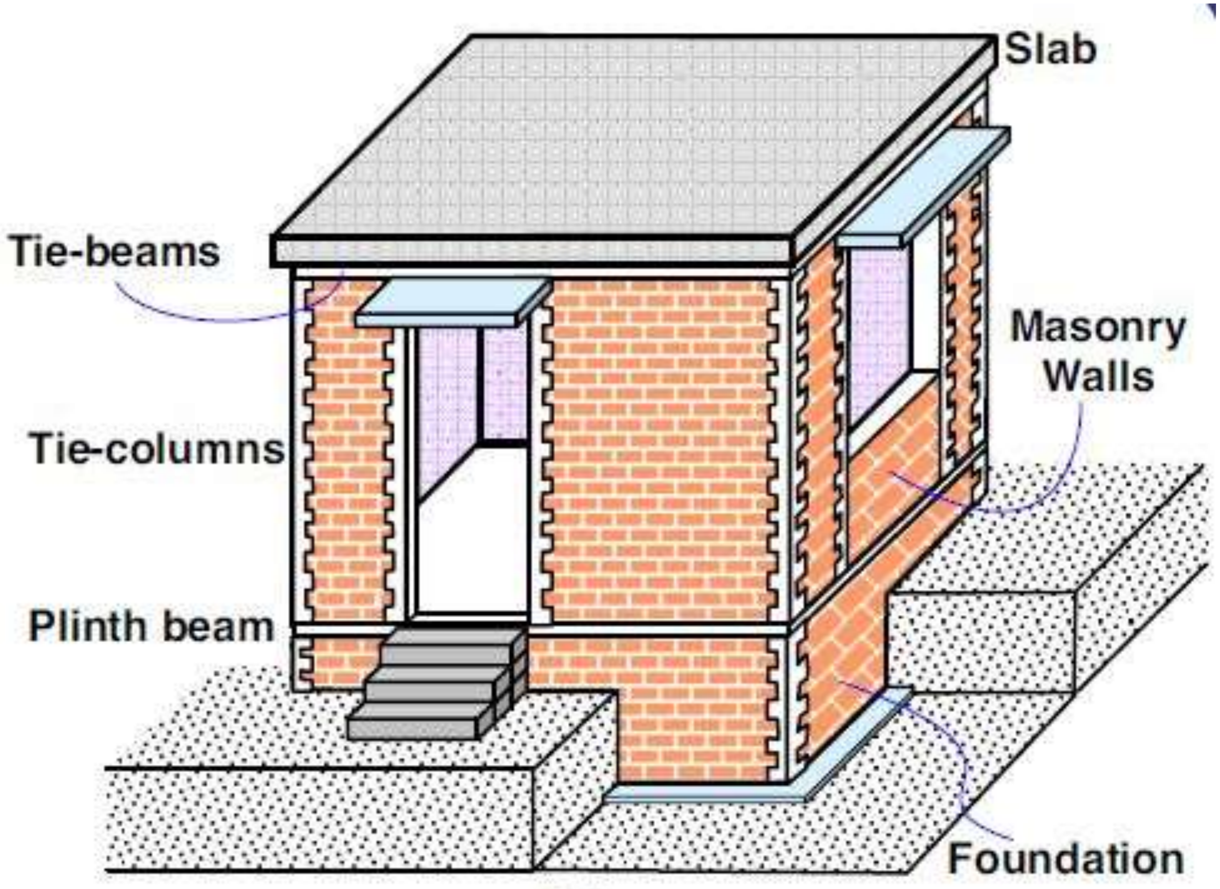
Random Rubble Stone

Ashlar Stone

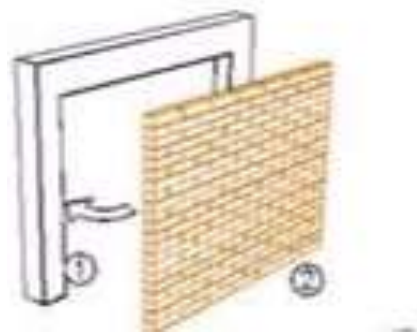
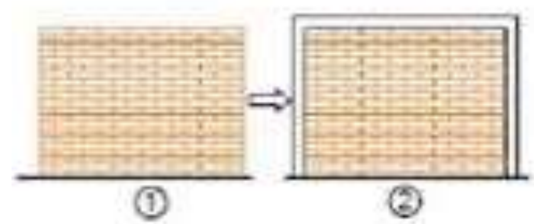
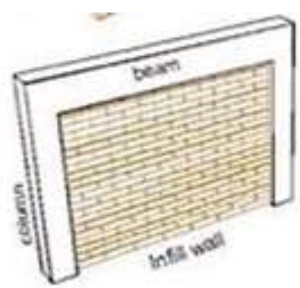
3. Confined Masonry Walls: The load is taken by the masonry walls as well as the RC elements. Further, the RC elements confine the units at corners and junctions, strengthening the structure against lateral forces.

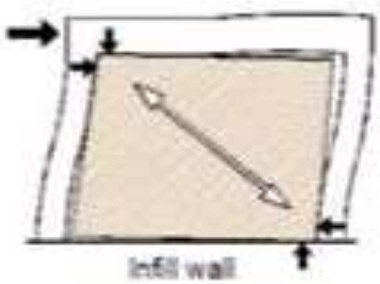
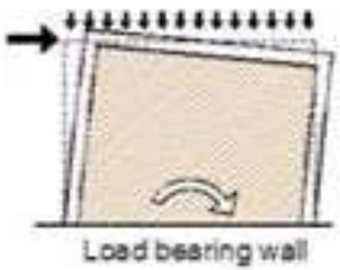


The RC corners as well as the brick masonry is constructed together and integrated well with each other.



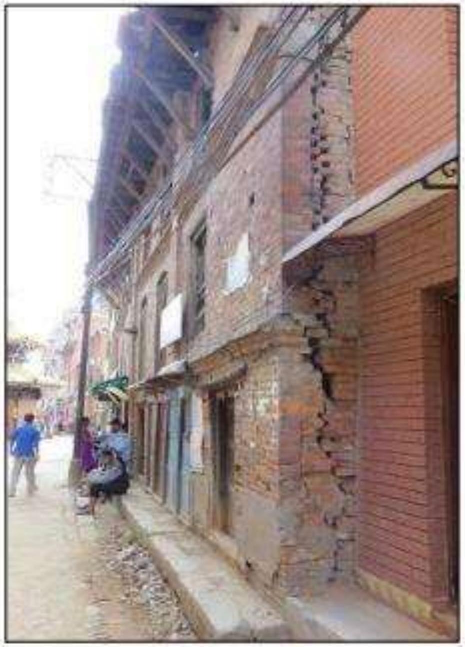
Difference between Confined Masonry and RC Frames with Infill Walls

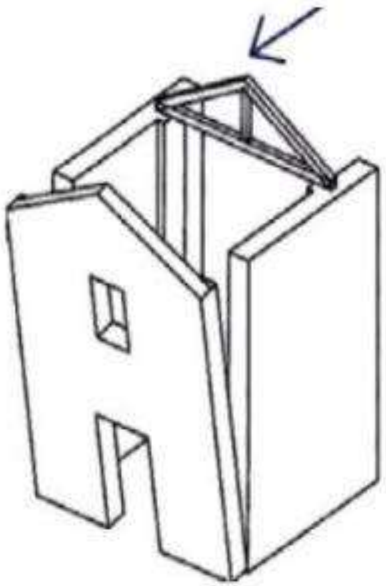
	RC Frame and Infill	Confined Masonry
Construction Sequence	First RC frame is made, later the brick infill wall is made. 	First the brick wall is made and later the confining RC elements are added. 
Size of Elements	The beam and column of the RC frame are relatively larger. 	The confined vertical and horizontal members are relatively smaller. 

	RC Frame and Infill	Confined Masonry
Behaviour during Lateral In-place effects	RC Frame is designed to take the vertical as well as lateral loads while the brick infill walls act as struts. 	The brick wall and the confining elements together act as one element to take the vertical and horizontal loads. 

Typical Damage to Walls

1. Corners separation

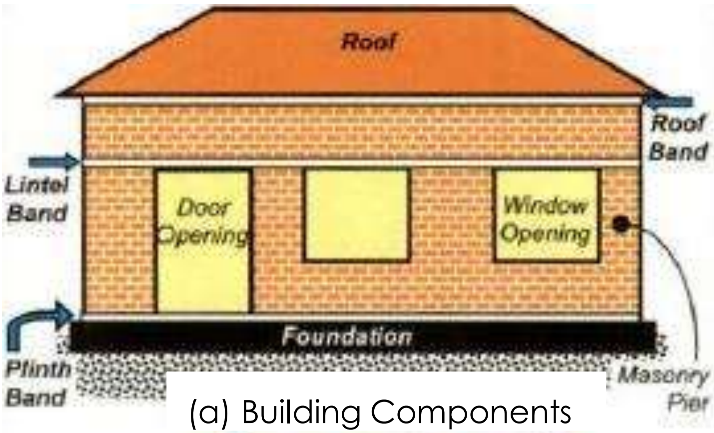




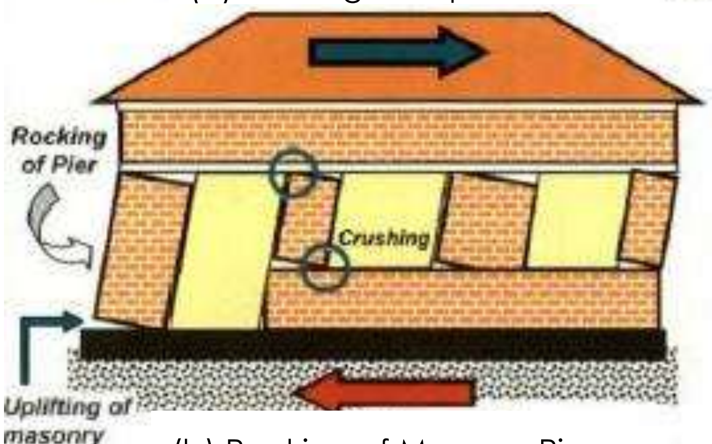
Separation of adjoining walls

2. Diagonal Cracks around openings

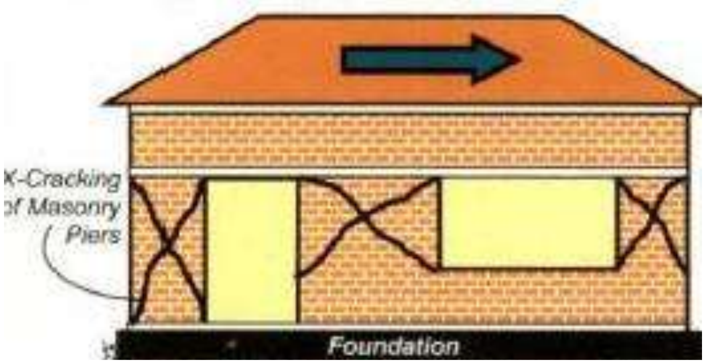
3. Cracking of Masonry piers



(a) Building Components



(b) Rocking of Masonry Piers

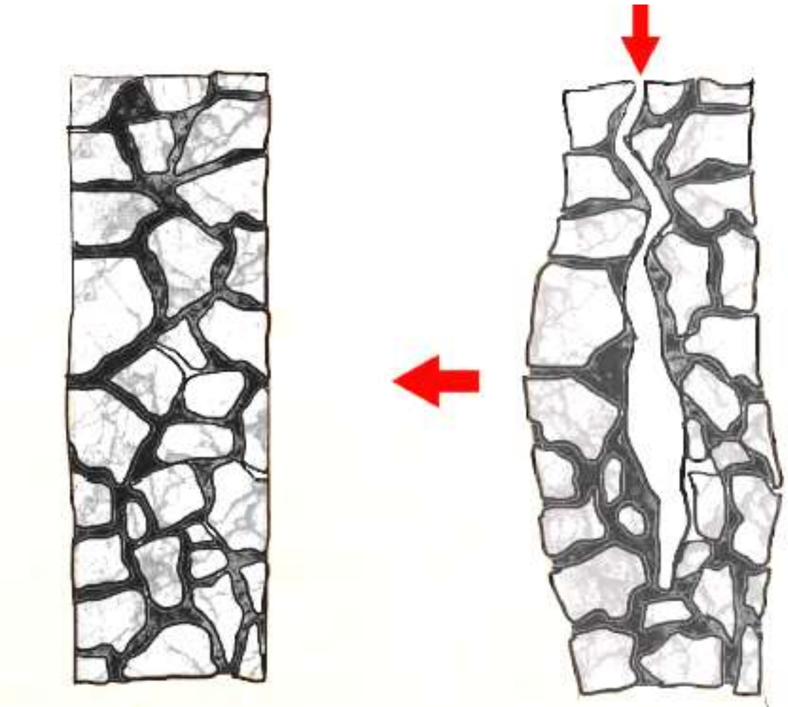


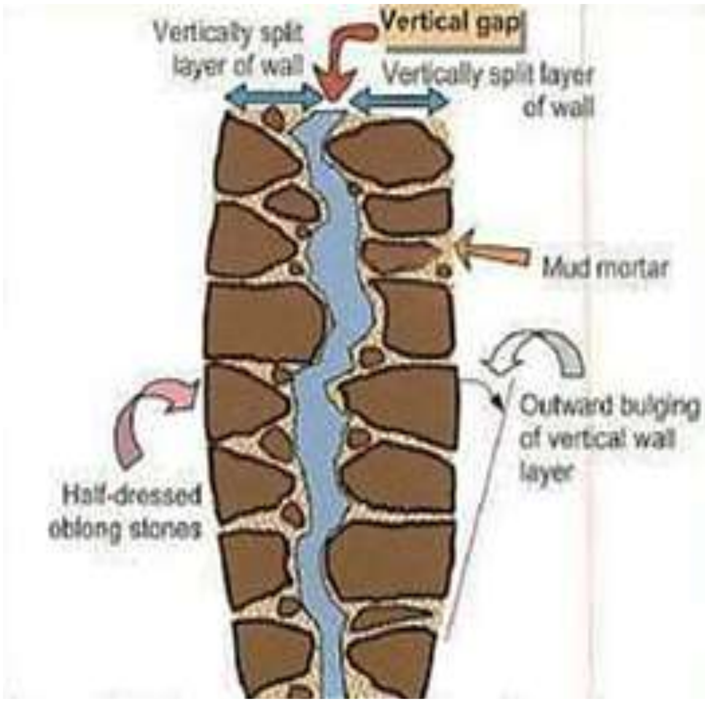
(c) X-Cracking of Masonry Piers

Earthquake response of a hipped roof masonry building - no vertical reinforcement is provided in walls.

4. Delamination of Internal and External Surfaces

Bulging and Splitting of Stone Wall: If there are not enough through stones to bind two faces of the walls together, the wall behaves as two separate walls.





Schematic diagram of the wall section of a traditional stone house- thick walls without stones that go across split into 2 vertical layers.

5. Out of Plane Failure: As long walls behave differently at different points along their length during vibrations, long walls are vulnerable.

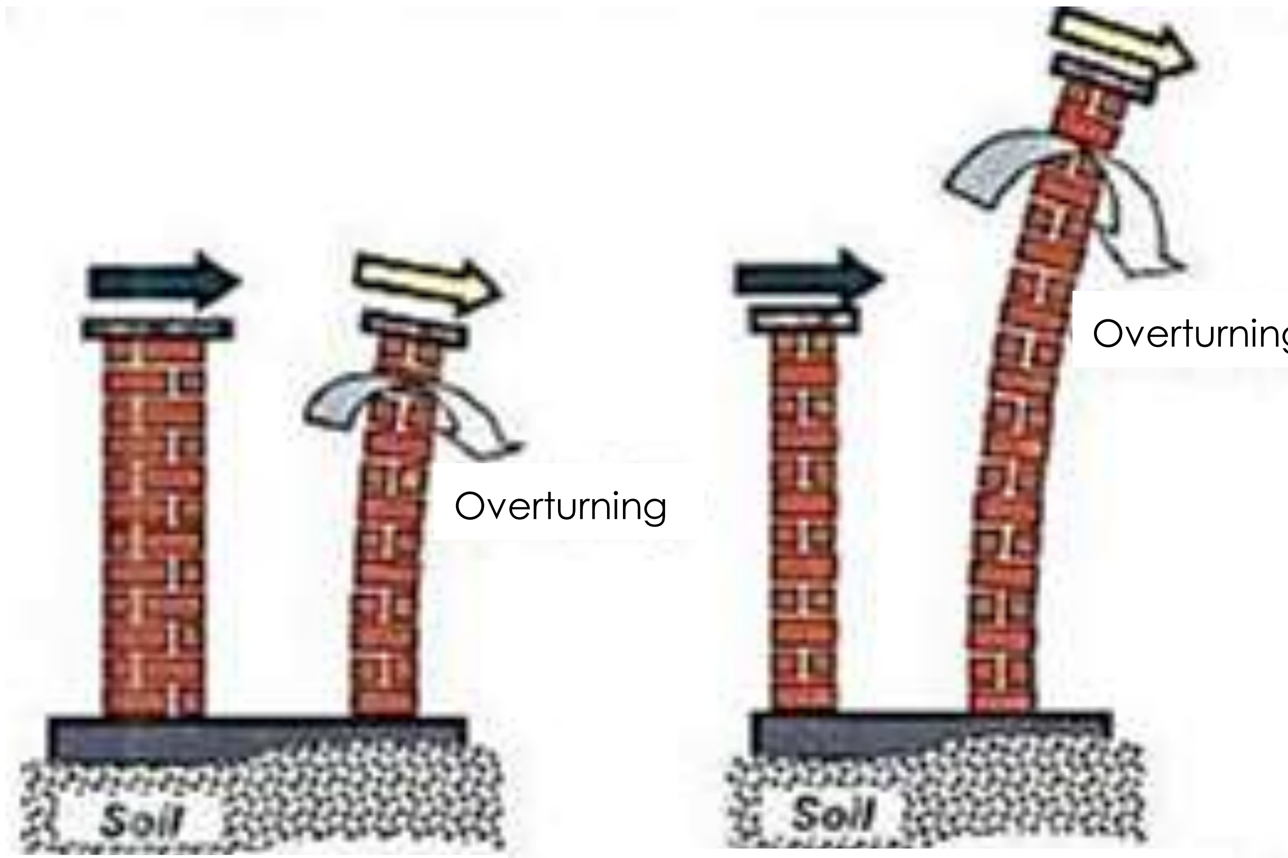
6. Column damage during earthquakes (Short column effect)

If the infill wall is not of full height of a storey, it adds to the stiffness of the column over a part of the height of the column. Since stiffness means resistance to deformation, portion with walls resists the earthquake forces, while the remaining part of the column is exposed to larger amount of lateral forces. If such part is not designed to resist these loads, it can suffer significant damage during an earthquake.

Masonry column cracking

Principles of Hazard Resistant Walls

1. A thick wall is more stable than a thin wall.
   A wall of short height is more stable than a tall wall.

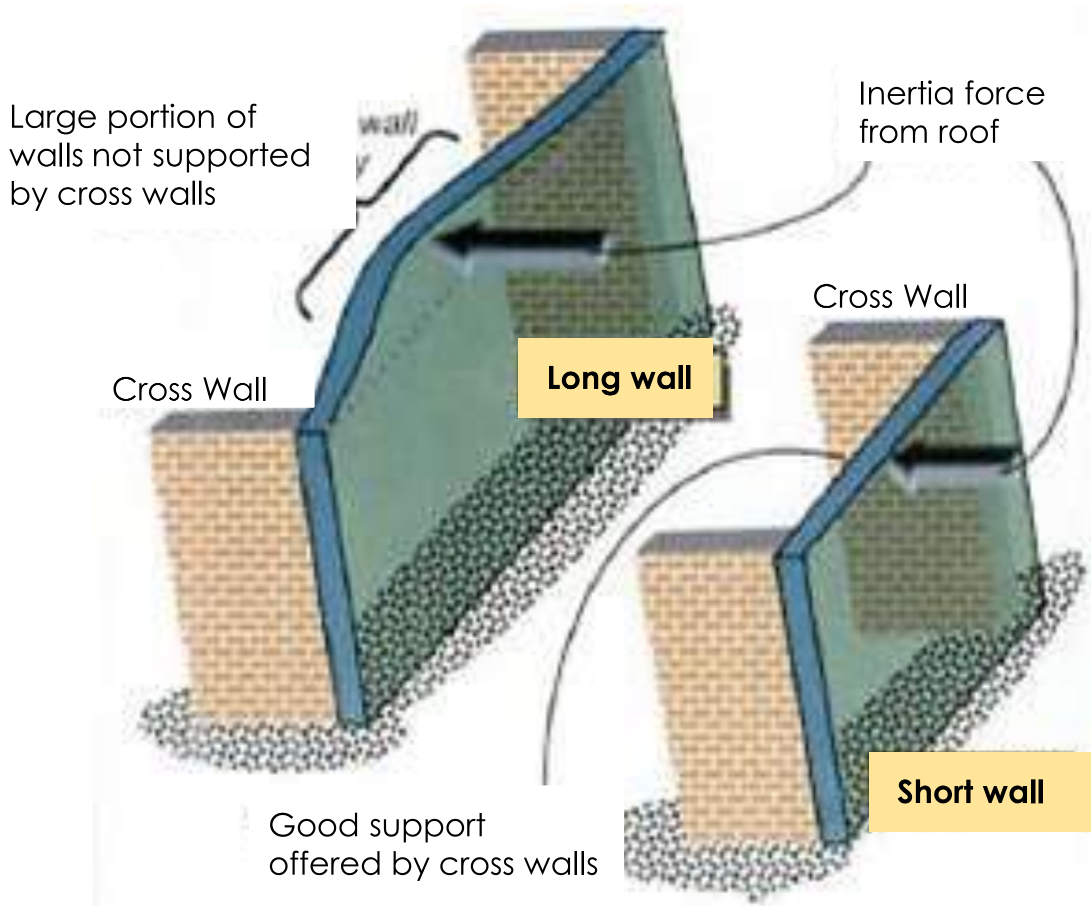


Thick Wall (1½ brick)
Versus
Thin Wall (1 brick)

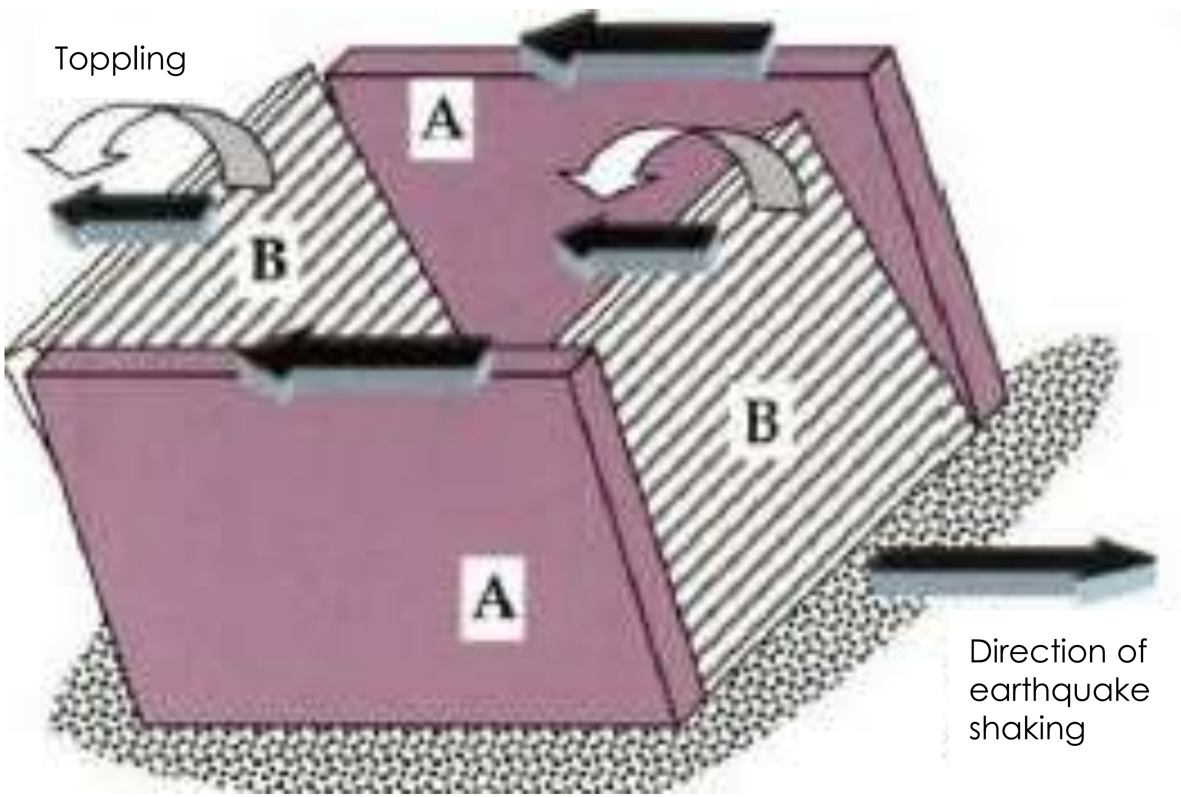
Short Wall (1 brick)
Versus
Tall Wall (1 brick)

2. A short wall is more stable than a long wall

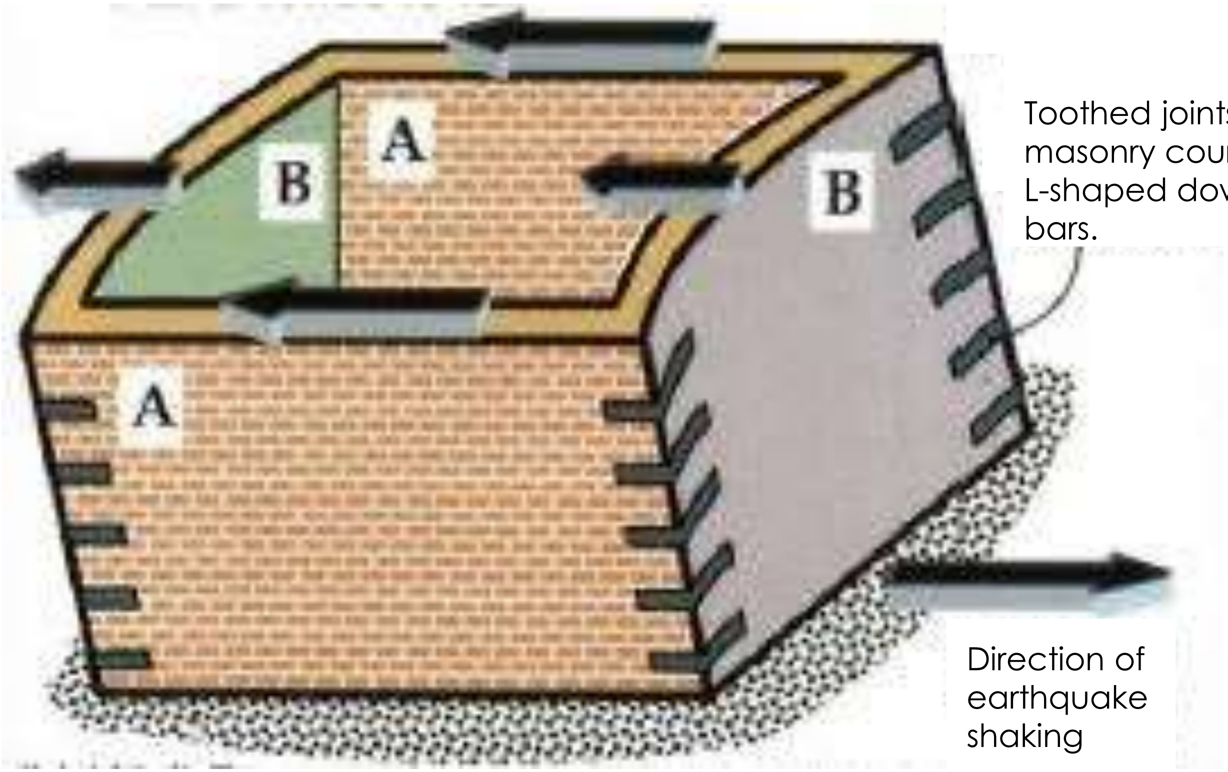
Walls longer than 7m length needs to be suported by cross walls or pillasters.



3. When an earthquake strikes, walls perpendicular to the direction of the earthquake are subjected to stronger force. Here, given the direction of the earthquake, walls in B tends to fail.



By connecting adjacent walls properly, **box action** ensures that the entire structure moves together and the loads are transferred from the weaker walls to the stronger walls with respect to the direction of the shaking.



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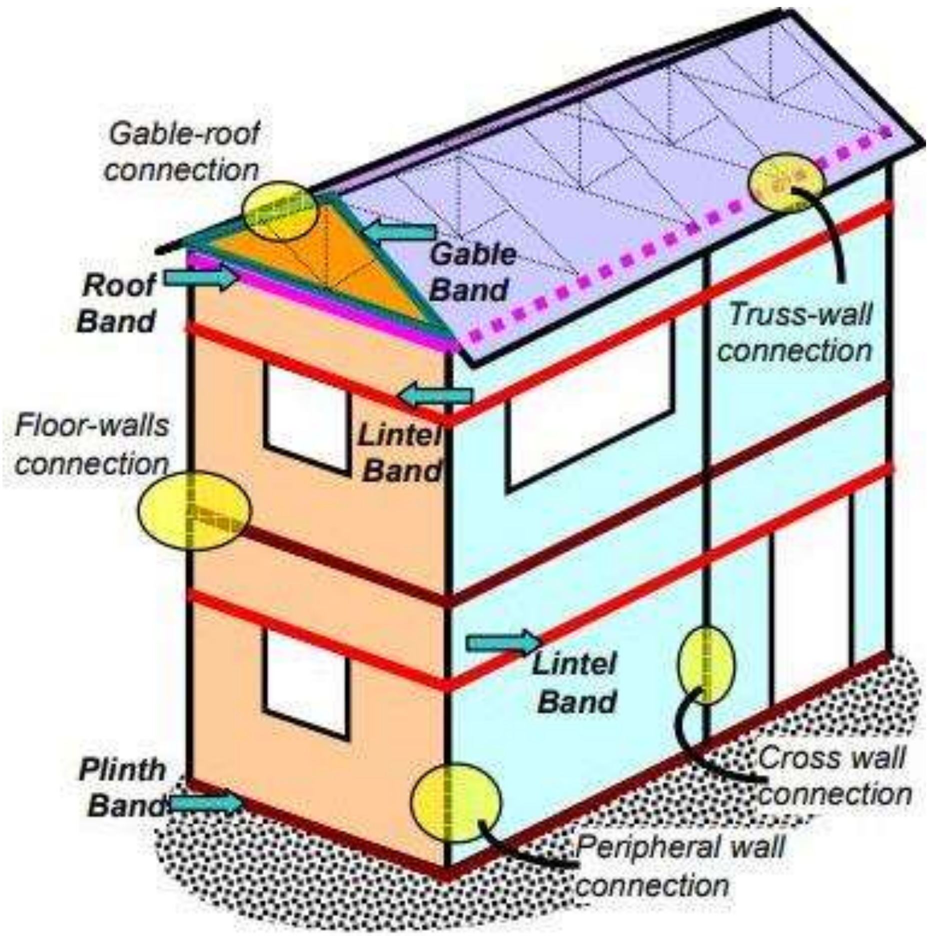
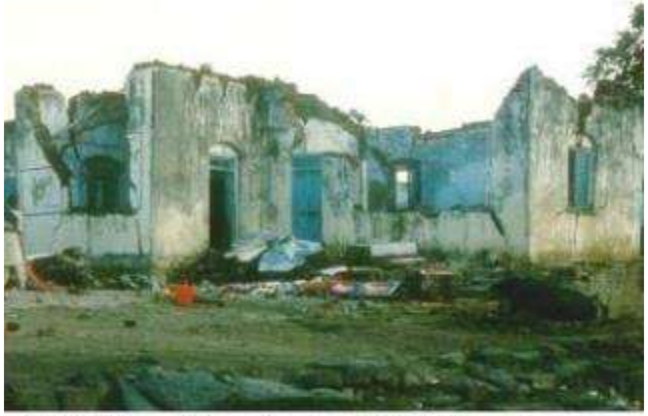
4. Houses with horizontal bands are better

Types of bands in a building





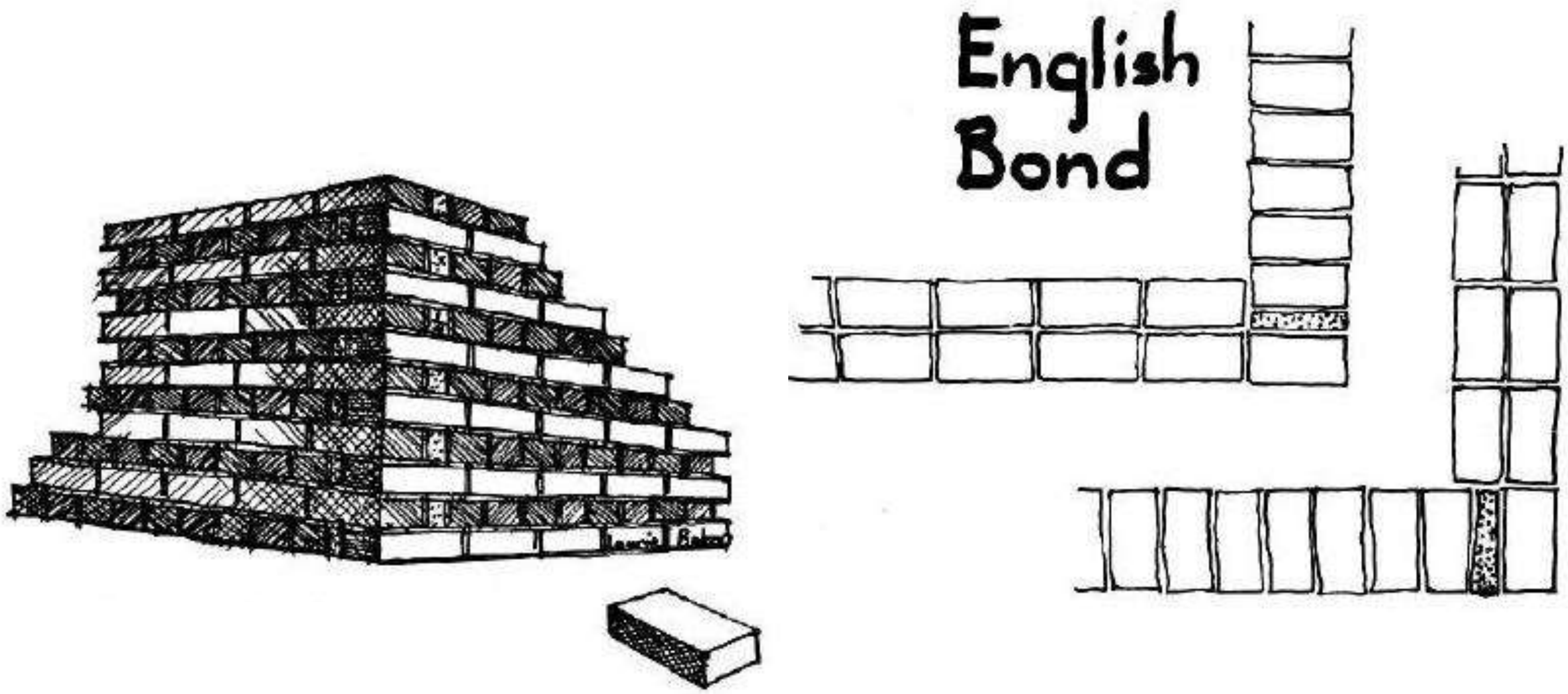
(a) Building with no horizontal lintel band: collapse of roof and walls

(b) A building with horizontal lintel band in Killari village: no damage

Details of Hazard Resistant Walls

1. Masonry Bonds: English Bond

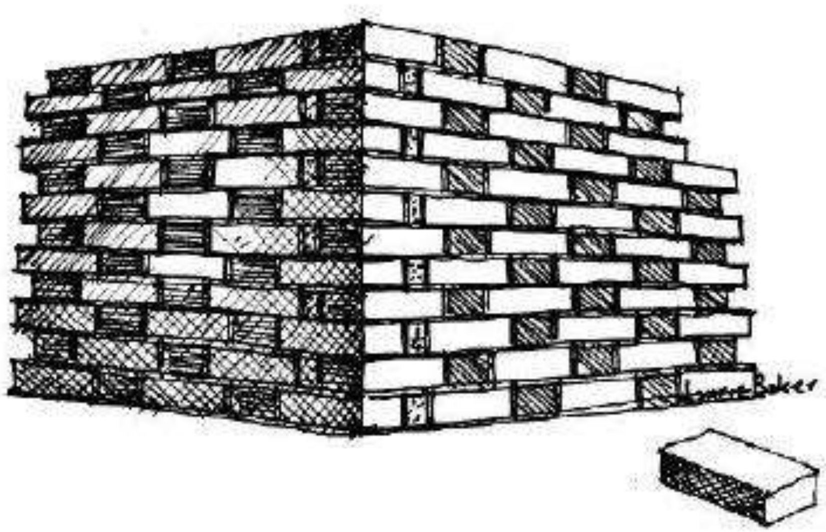
Avoid vertical joints by ensuring that proper bond is maintained.

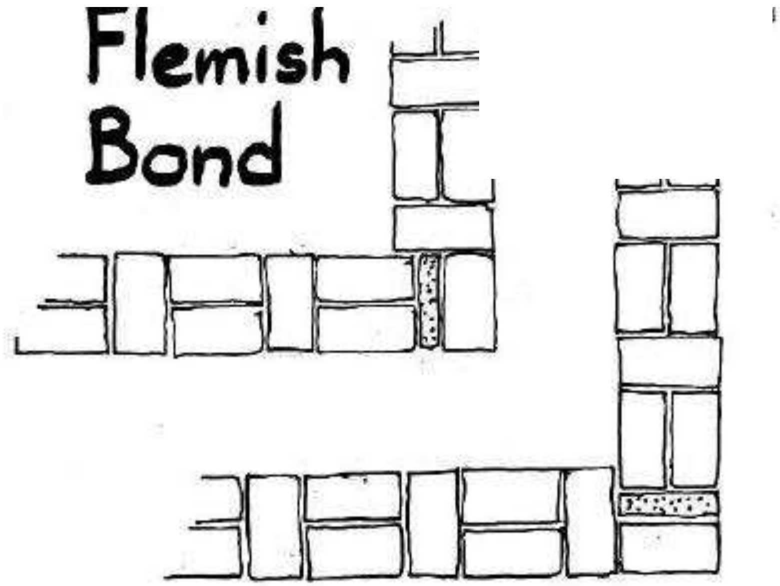


(Baker, Laurie, 1988, Brick Work)

1. **Masonry Bonds: Flemish Bond**

One must avoid vertical joints by ensuring that proper bond is maintained.





(Baker, Laurie, 1988, Brick Work)

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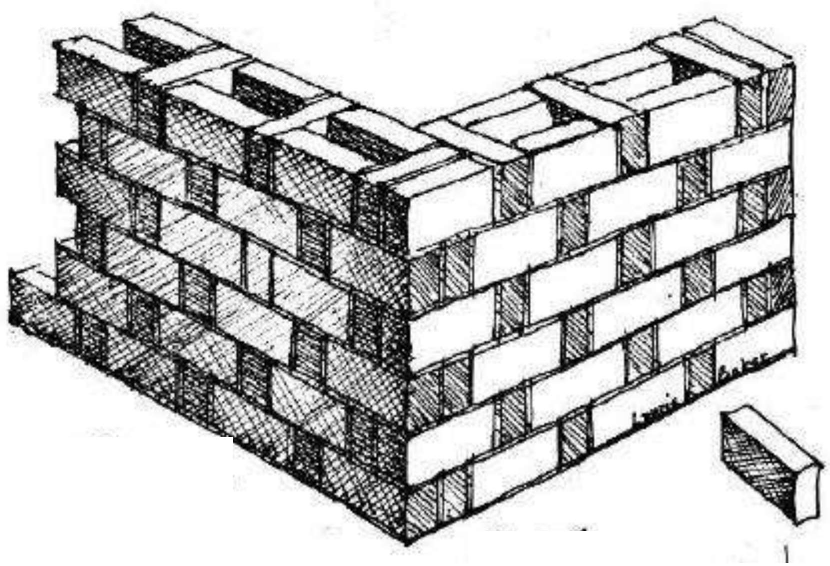
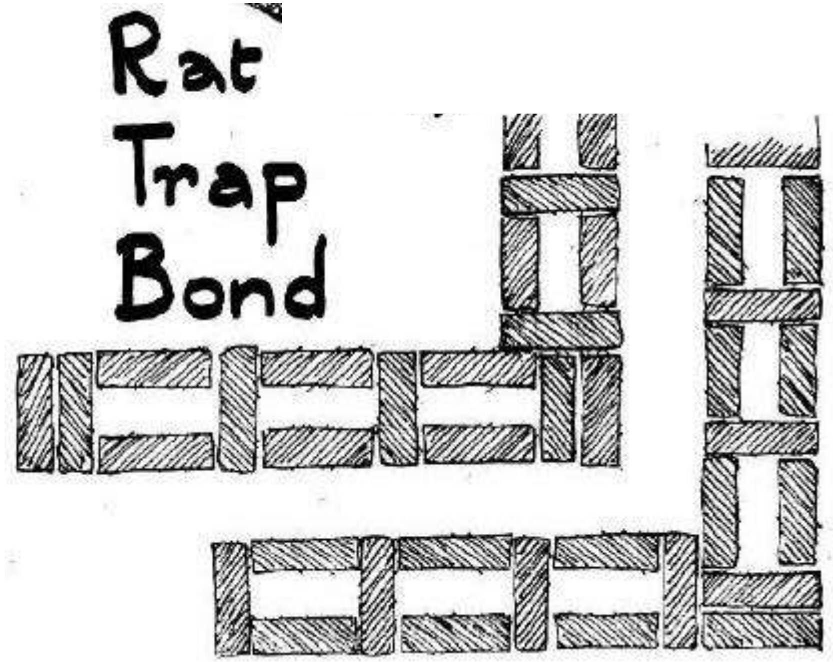
1. Masonry Bonds: Rat Trap Bond

One must avoid vertical joints by ensuring that proper bond is maintained.

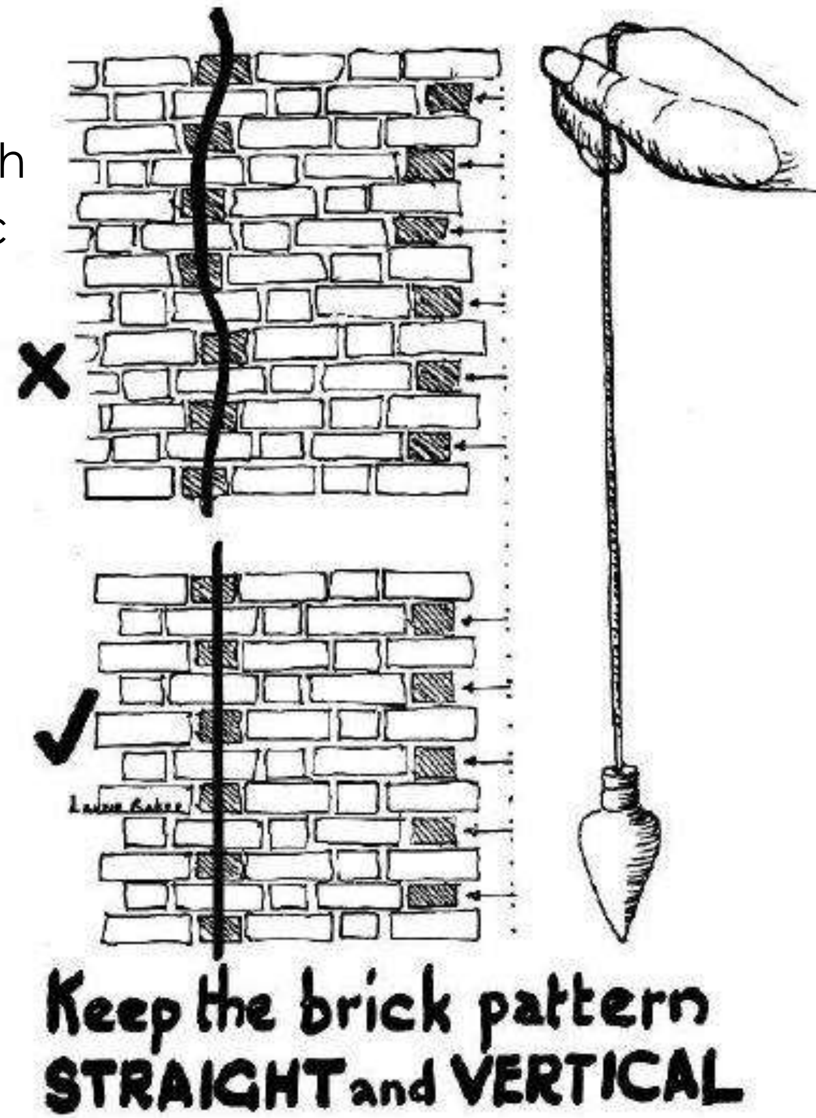




(Baker, Laurie, 1988, Brick Work)

Importance of Staggering Joints

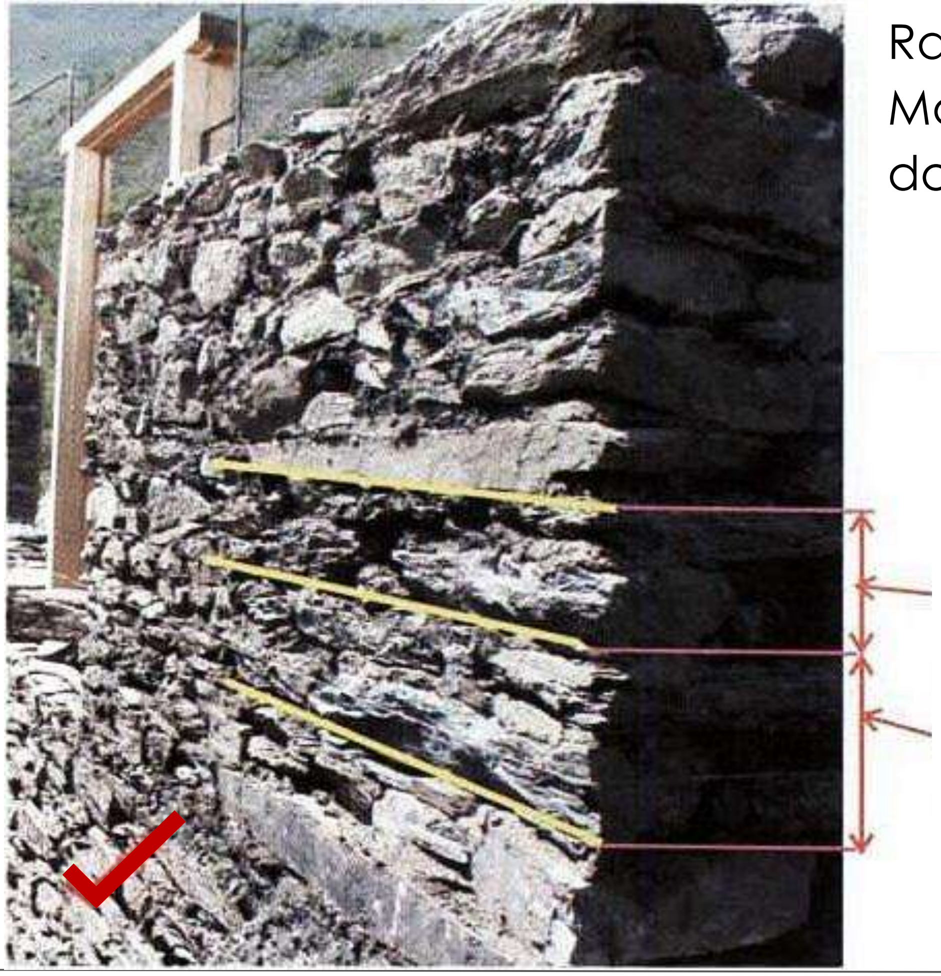
Joints in a wall should be staggered such that the wall behaves as one monolithic unit. Otherwise, during the effects of a hazard, the wall may behave as separate parts and split where the joints are not staggered.



(Baker, Laurie, 1988, Brick Work)

2. Random Rubble Masonry

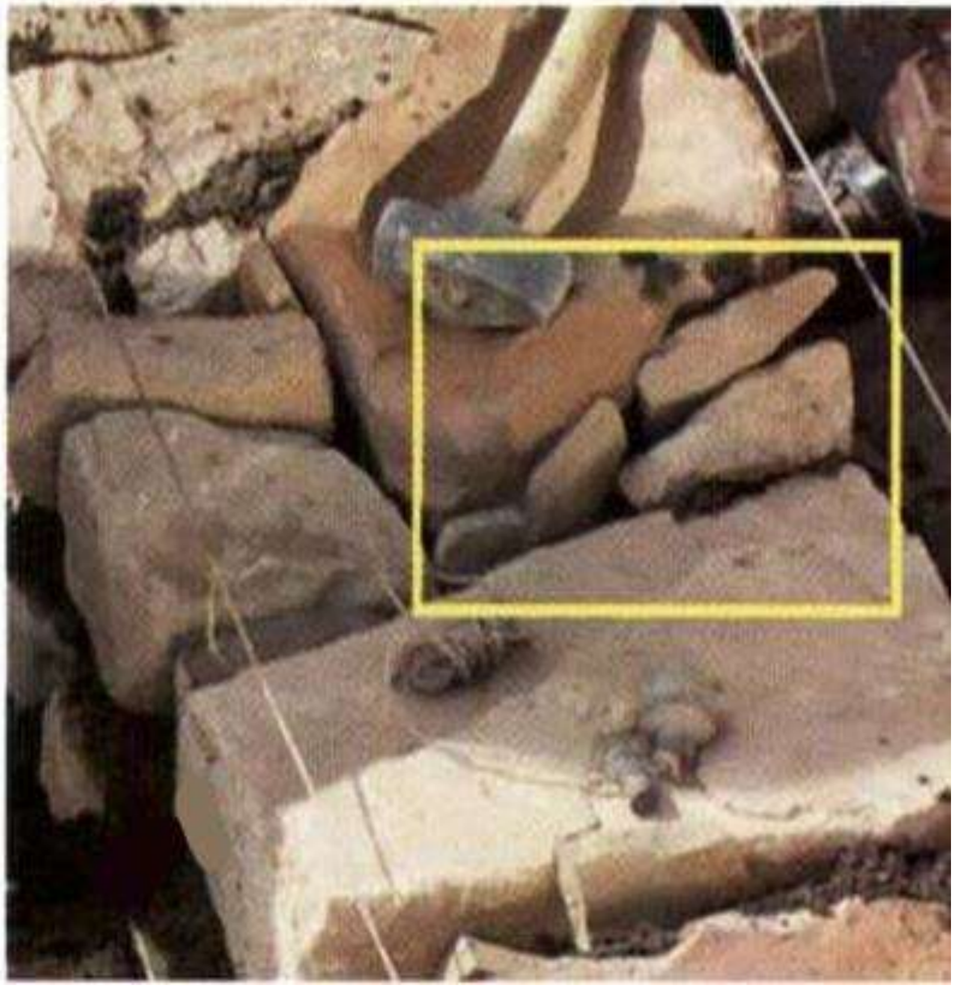
At regular intervals, the random rubble masonry should be brought to leveled course.



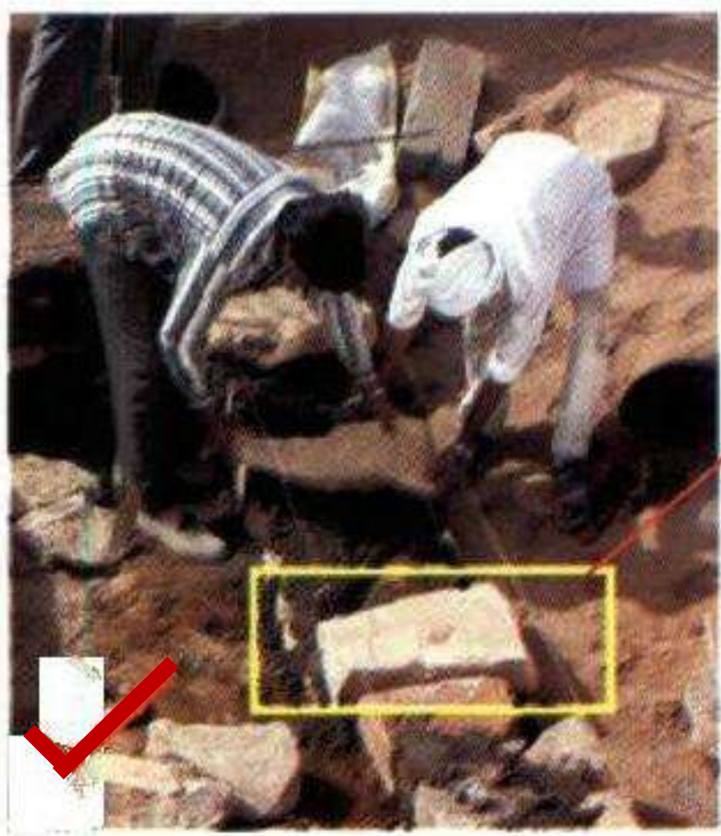
Random Rubble Masonry must be done in courses

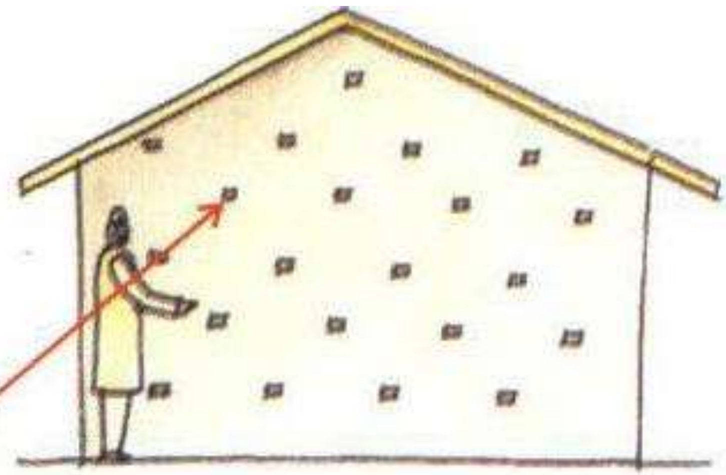
Max. Course height = 600 mm

All voids must be filled completely with smaller stones of different sized stones and minimum possible mortar.



Placing Through Stones in a Stone Wall: Through stones are used to hold the layers of the wall together to prevent splitting.

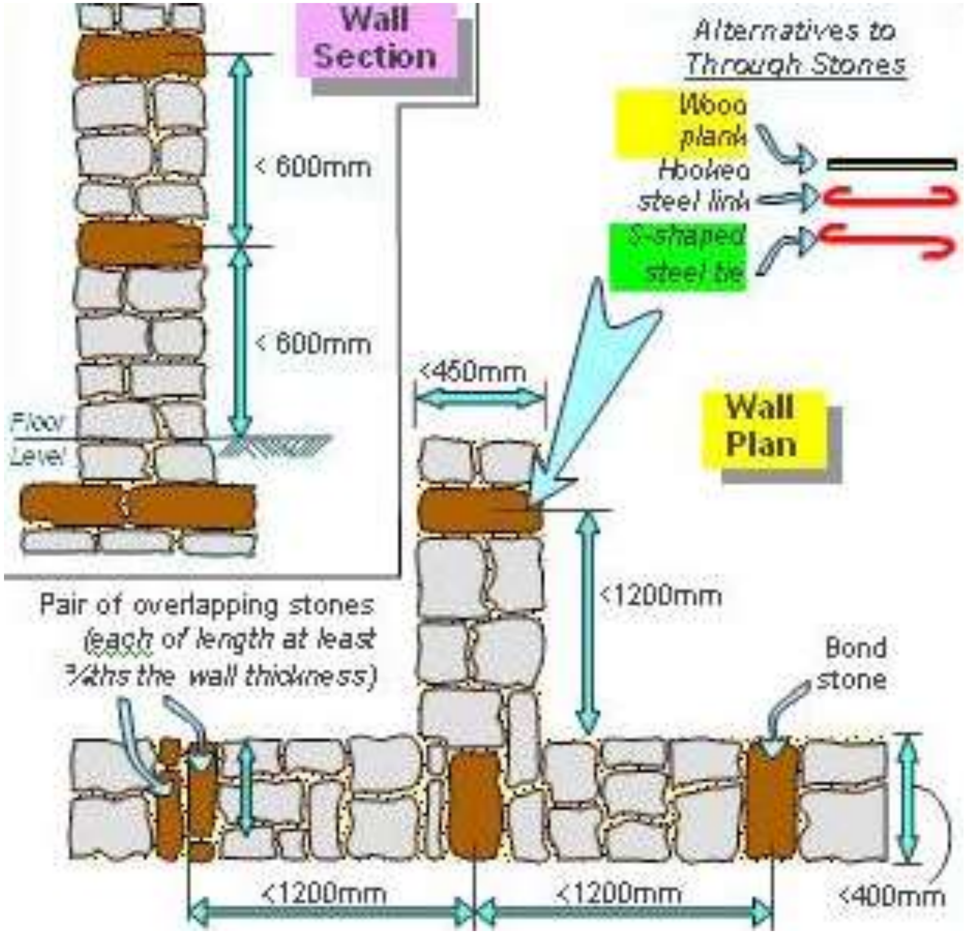




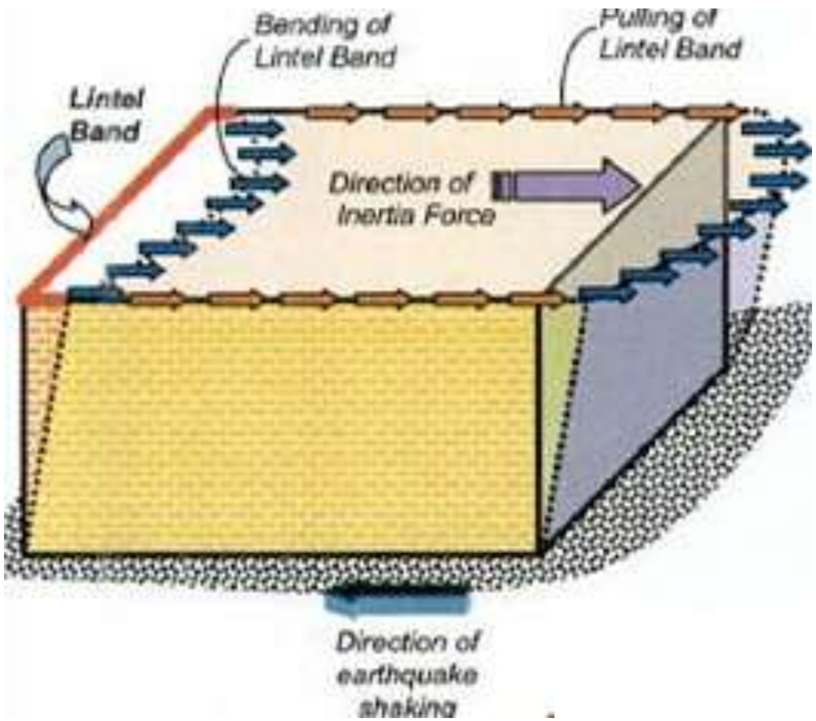
Provide at least one “through stone” at every 1200 mm horizontal distance in the masonry and at every 600 mm height in staggered manner.

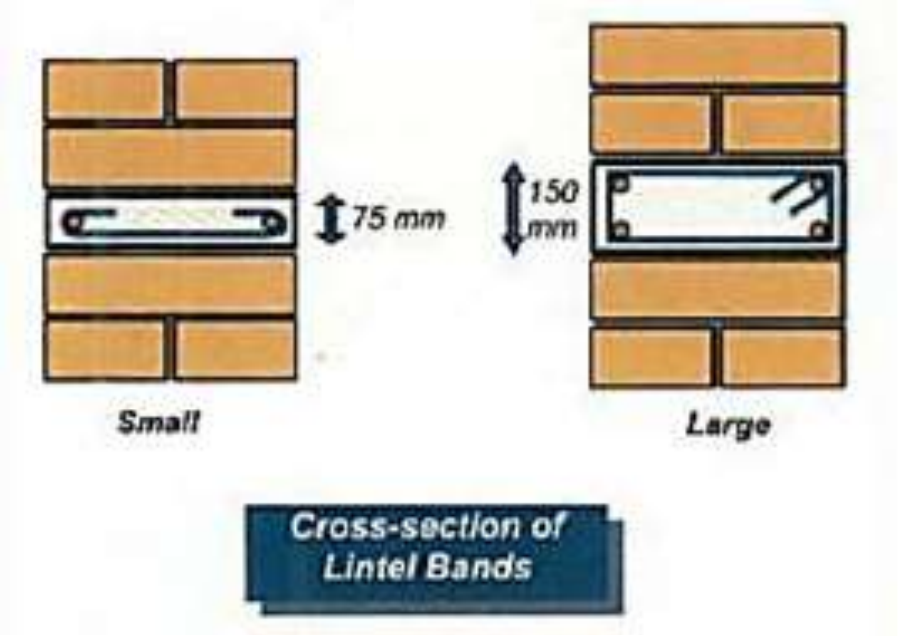
Placing Through Stones in a Stone Wall

1. Minimum Distance until a through stone is required: **At a distance of every 1200 mm for a 400 mm thick wall and at height of 600 mm.**
2. They must be staggered as much as possible across the wall.
3. If appropriate through stone is not available, concrete block of required length, may be cast in-situ to create such stone.



3. Horizontal bands in a structure are important to ensure that the entire building behaves as one structure.





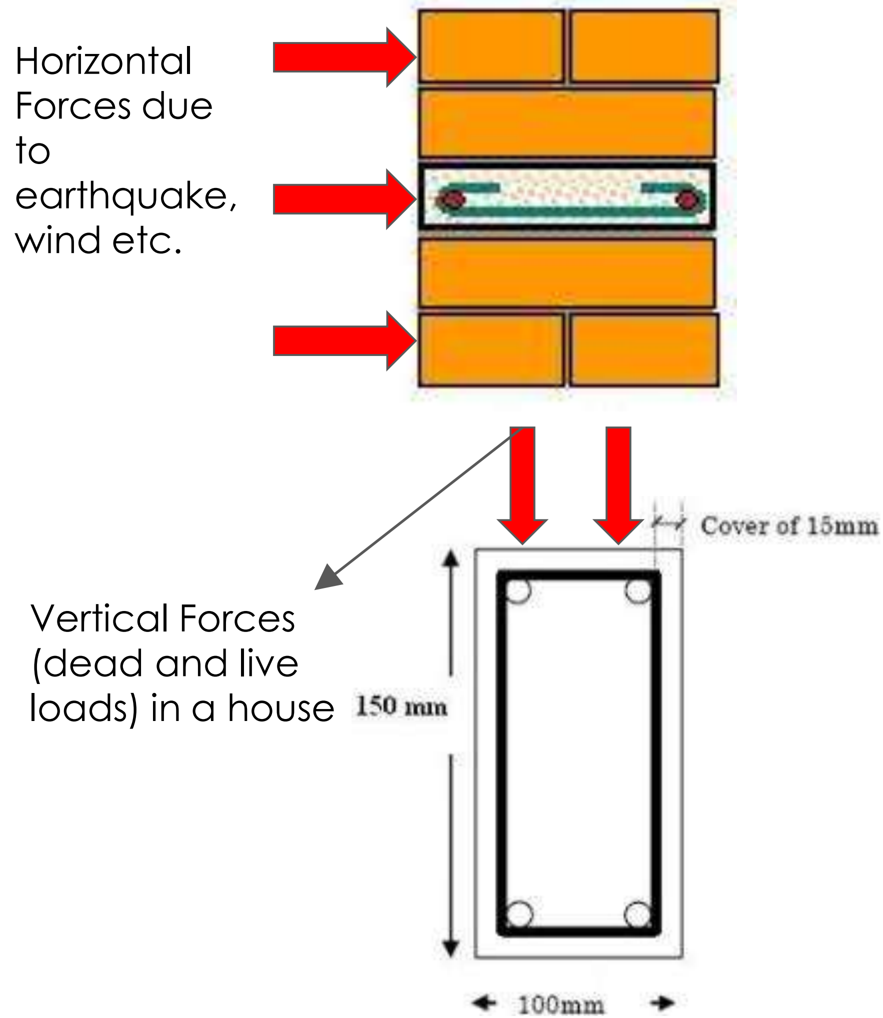
Bending and pulling in lintel bands
Bands must be capable of resisting these.

Difference between a Band and a Beam:

A horizontal band ties together all walls of a house, and therefore, helps transfer the **horizontal** loads between weak and strong walls depending on the direction of the forces.

A beam is meant to take the **vertical** load of the roof or other storeys, which it transfers to the walls or columns beneath it.

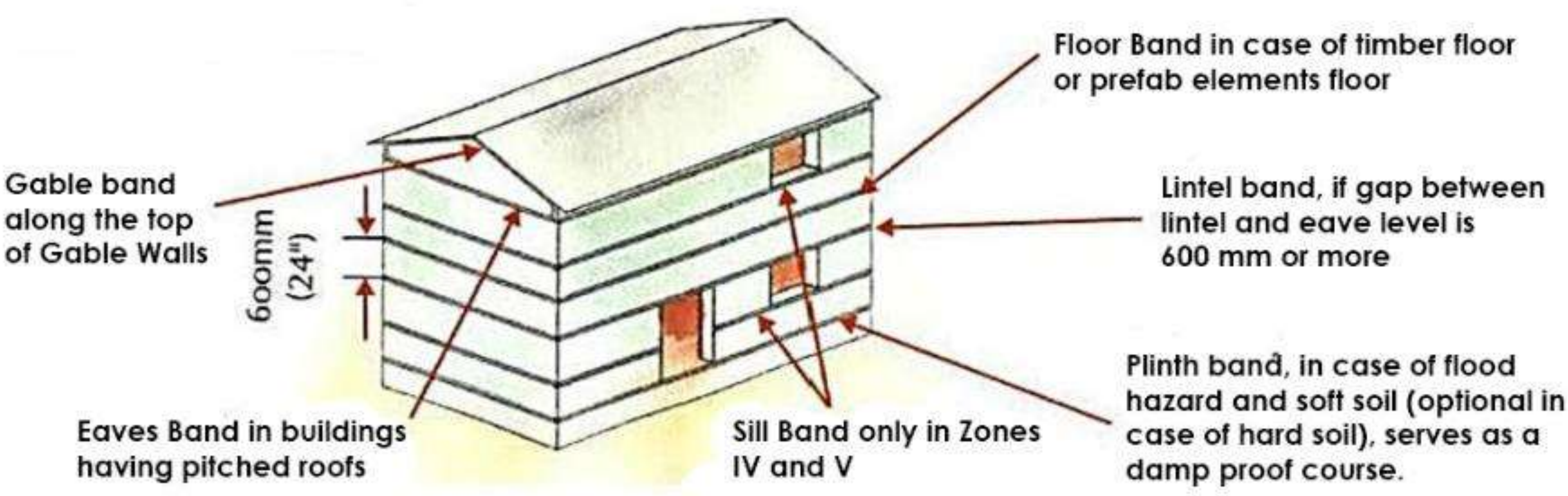
Seismic Band



Structural Beam

Requirement of Bands in different Seismic Zones?

1. Bands are Important to Strengthen Masonry Walls
2. All other bands are required in Seismic Zones IV and V.
3. Sill Band can be avoided in Seismic Zones II and III.



4. Details of Sill Band, Lintel Band and Eave Band

These Bands are to be made in the same way as the Plinth Band (C8). Things to be kept in mind are:

1. In an RC band, the longitudinal bars must be raised from the brick and 25mm inside from the face of the wall.

2. The junctions and overlaps will have 450 mm of overlap of the longitudinal bar, which will then be tied together.

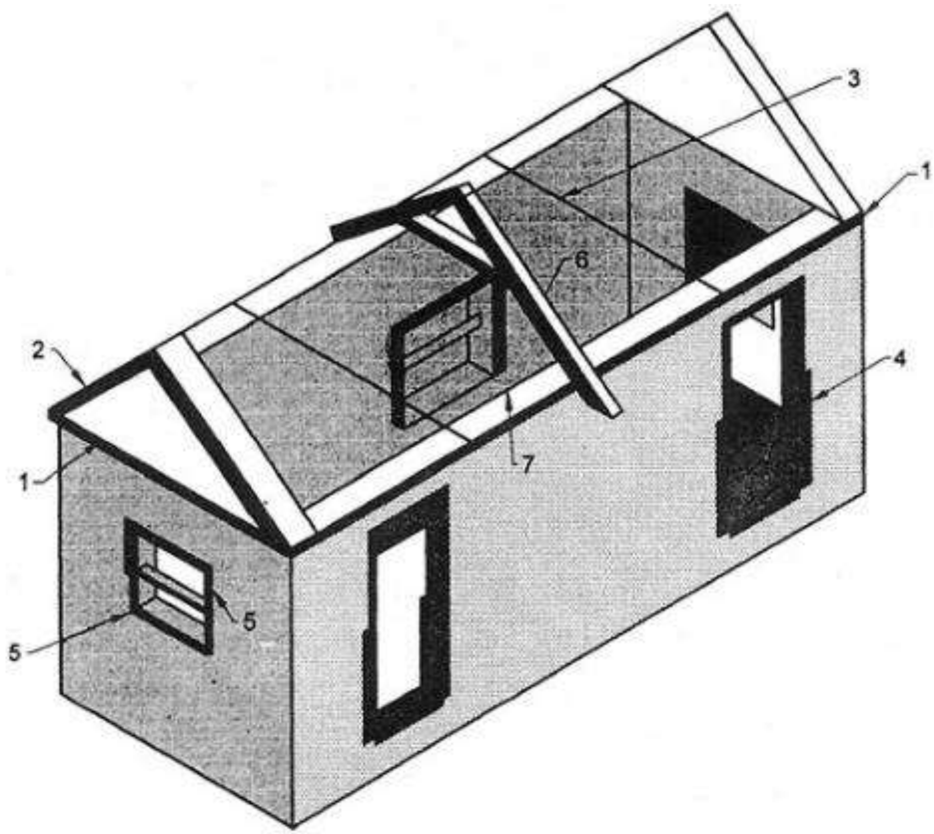
3. The ends of the cross ties should be bent inwards across the band.

4. Bands can also be made with other materials, like bamboo ladder and timber ladder.

5. The junctions must be secured so that they transfer the loads evenly.

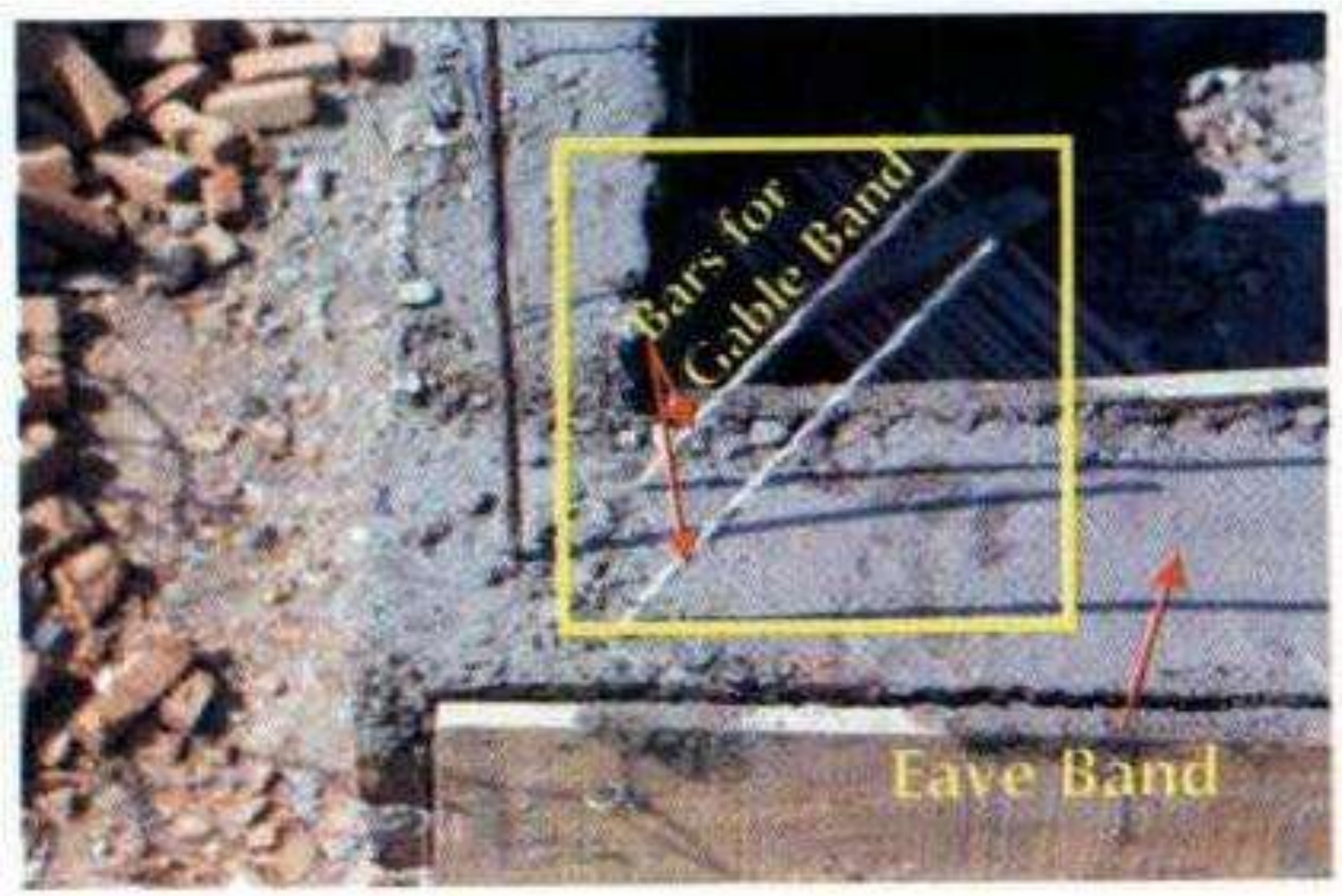
4.1. Connection of Eaves and Gable Band

The junction between the Eaves and Gable Bands must be secured to ensure box action.



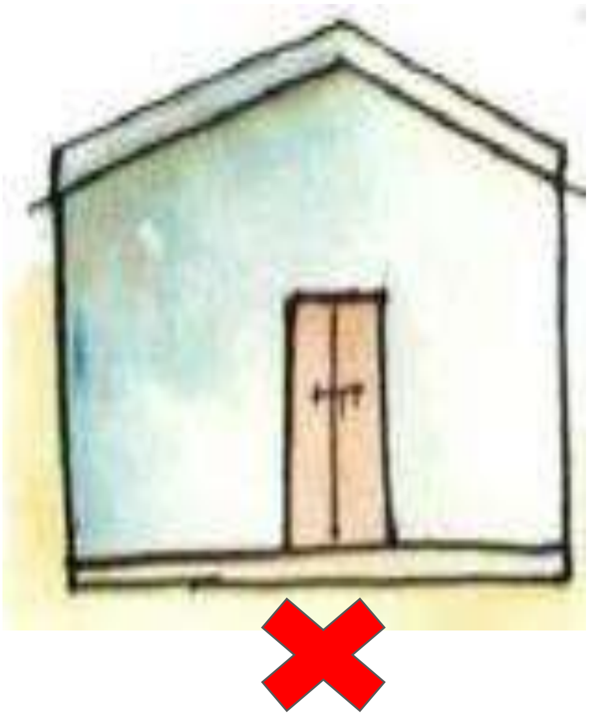
1 Seismic belt above opening and below roof at eave level
2 Seismic belt on gable wall
3 Tie at belt level
4 Door
5 Window
6 Rafter with collartie
7 Tying of rafter with band

Provide two bars of same size in the Eaves Band and bent at the angle of the gable band. These will be overlapped with the bars in the Gable Band, which will make a secure junction to ensure the loads transfer evenly.

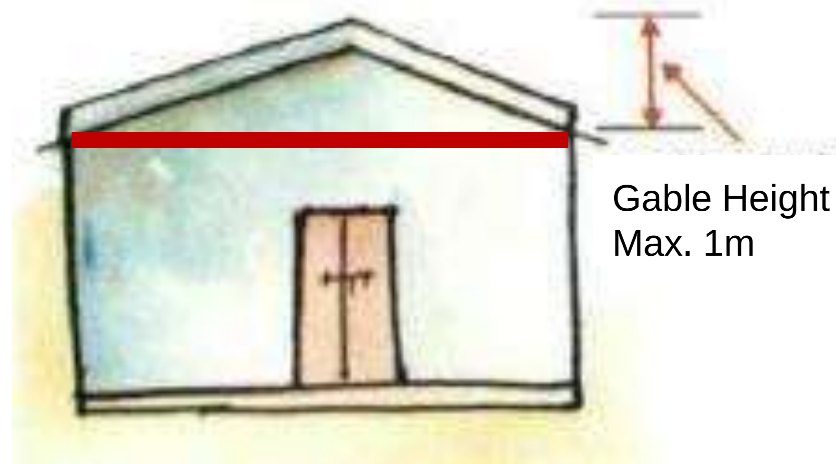


4.2. Gable Wall and Gable Beam

The height of the gable band should be not more than 1m above the Eave Band. The Eave Band and the Gable Band must both be provided.

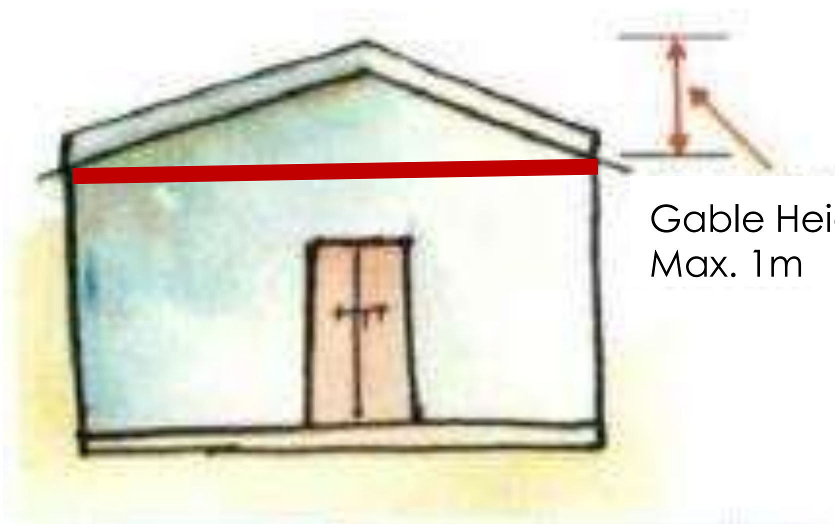


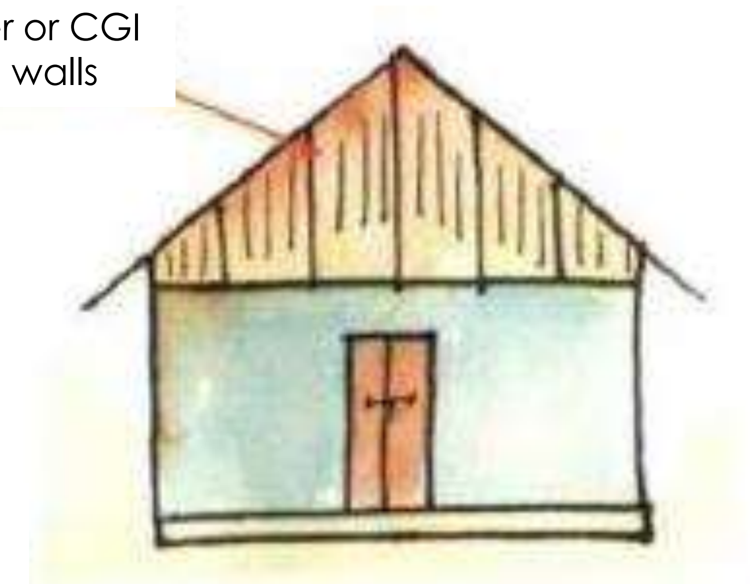
No Eaves Band



Eaves Band provided

If Gable Wall is taller than 1 m, it is better to build it with light materials, like CGI sheet, wattle & daub or timber planks.





4.3. Anchoring of Roof to Walls

Anchor the ridge beam of a sloping roof and the intermediate beams of the roof to the Gable Band, so that the entire house behaves like a box.

Step1

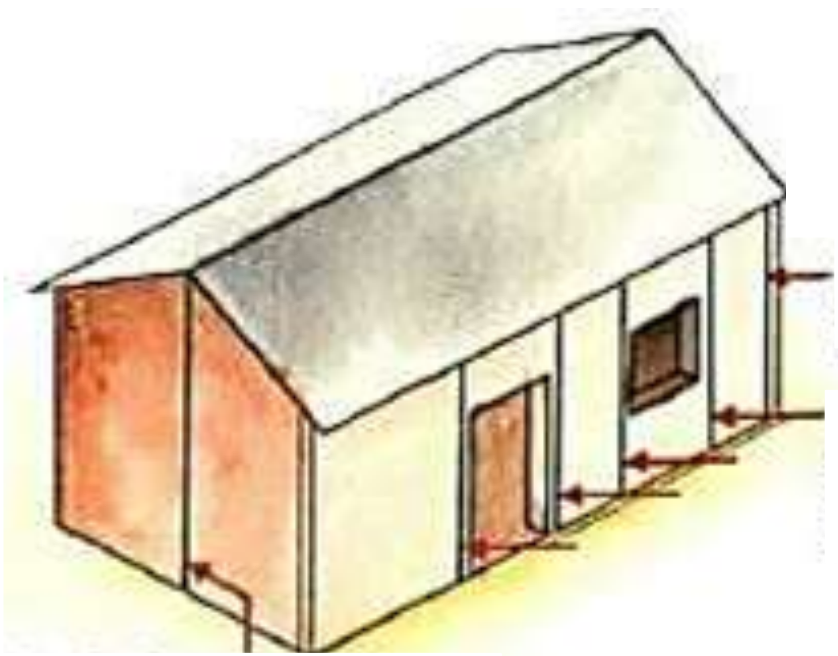
Install a 12mm diameter 250 mm long bolt with a 100X100x5 mm MS plate welded at it's bottom in the band, where the ridge beam or rafter sits on the Gable Band.

Step 2

When the concrete of the band is poured and becomes hard, the ridge beam with a through hole can be attached over the bolt and then anchored down using a washer and a nut.

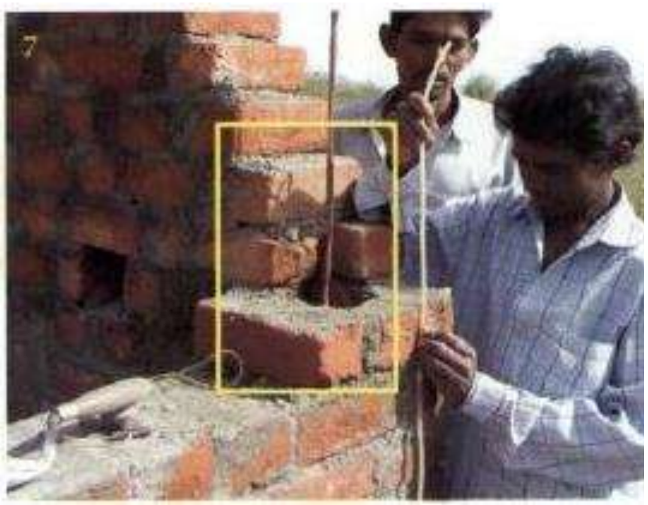
5. Vertical Reinforcement

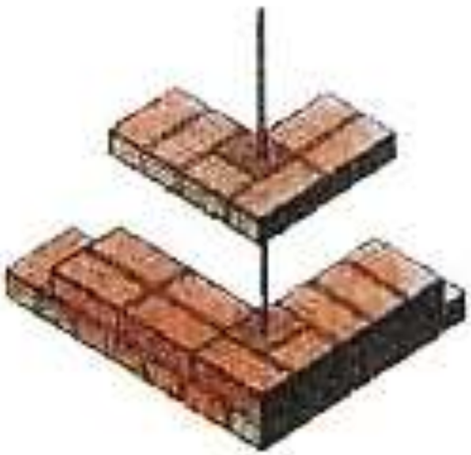
Vertical reinforcement is important to aid the transfer of stresses directly to the ground, especially at critical points, like corners and around openings.

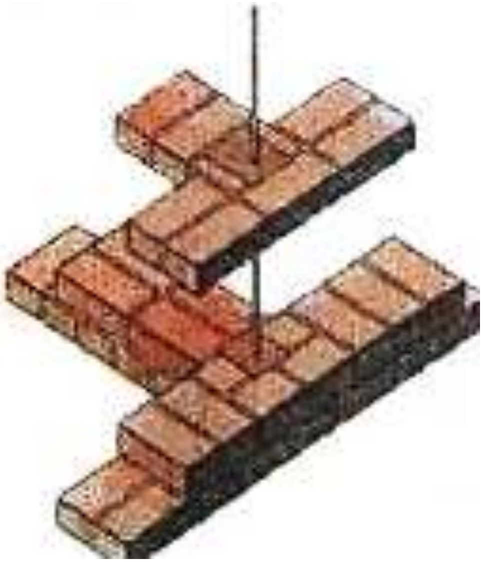


5.1. Vertical Reinforcement in Brick walls

The brick bonds are arranged in such a way that a cavity is created at the centre of the L or T junction around the reinforcement bar. The cavity is later filled with micro concrete in 450 mm lifts. The details of brick bonding with cavity for vertical reinforcement are given in C9. The reinforcement bar must be anchored at the foundation.

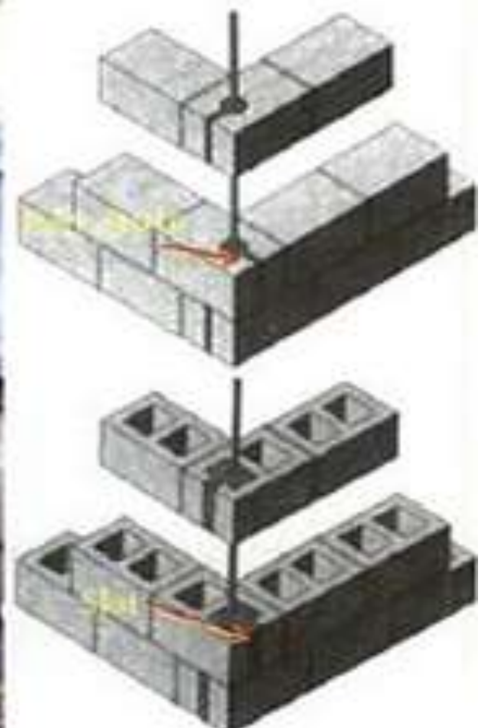




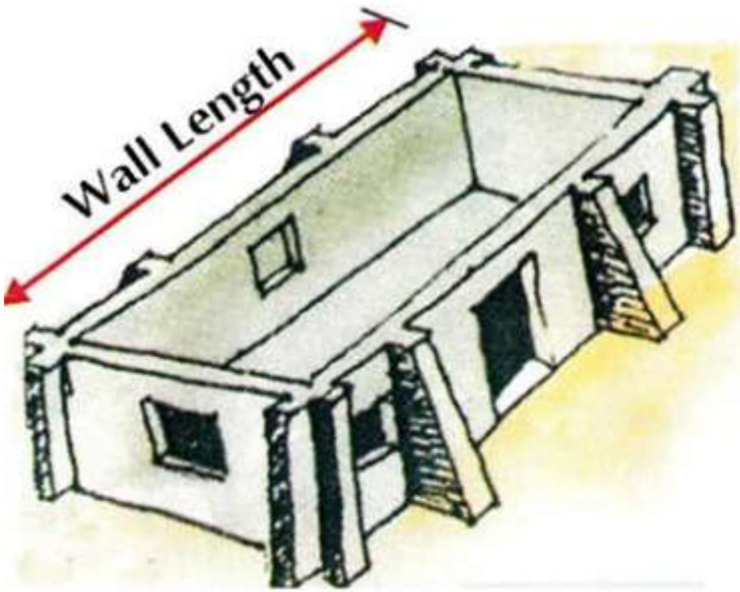


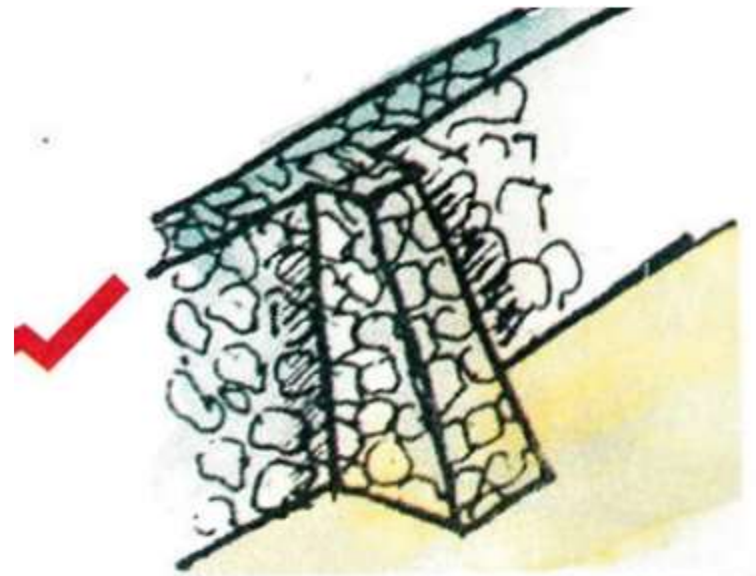
5.2. Vertical Reinforcement in Concrete blocks

While using concrete blocks, use solid blocks which have a key hole or hollow blocks with a slot keep the reinforcement bar in the centre of the cavity. This cavity can then be filled with micro concrete.



6. How to strengthen slender and long Walls





In long walls (more than 7m), buttresses must be provided.

7. Load Bearing Non-Masonry Walls

Earthen walls are just as brittle as other masonry walls, and need to be protected from moisture in the air.

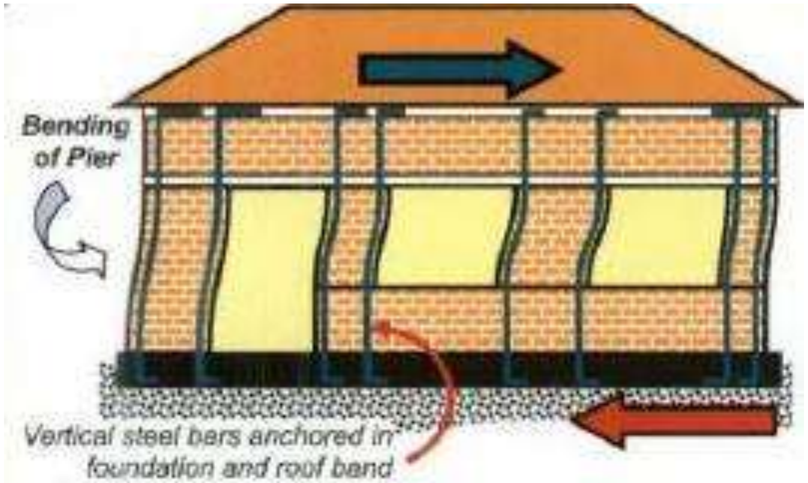
7. Load Bearing Non-Masonry Walls

1. They need vertical reinforcement as well as bands to be strong and hazard resistant.

2. Their behaviour is similar to masonry walls, except when there is a lot of moisture in the atmosphere. Earthen walls, if not stabilised, lose strength in such a situation and may fail.

8. Openings in Masonry Walls

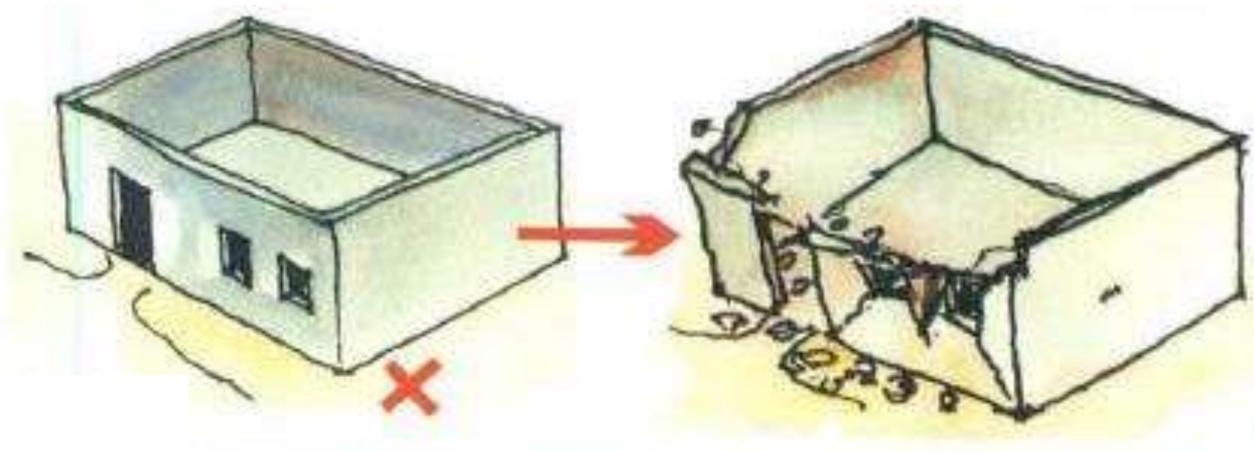
The vertical reinforcement bars allow the entire house to act as one and bend accordingly, rather than shake as separate elements and cause more damage.

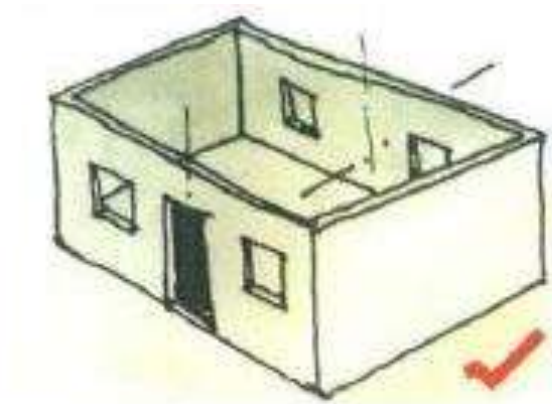


Vertical reinforcement bars cause bending of masonry piers instead of rocking.

Vertical reinforcement bars in masonry walls; wall behaviour is modified.

i) Asymmetric openings cause uneven stresses on wall and can cause more damage.

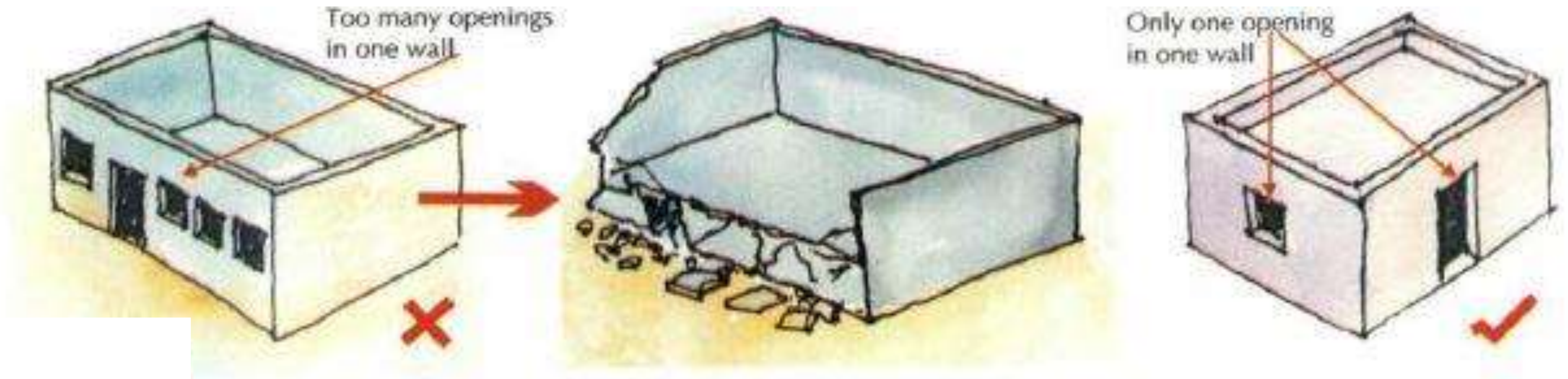




House with asymmetrically arranged wall openings can suffer more damage. For symmetry place identical openings in opposite walls.

When possible, place door in the center of the wall with openings placed symmetrically on both sides.

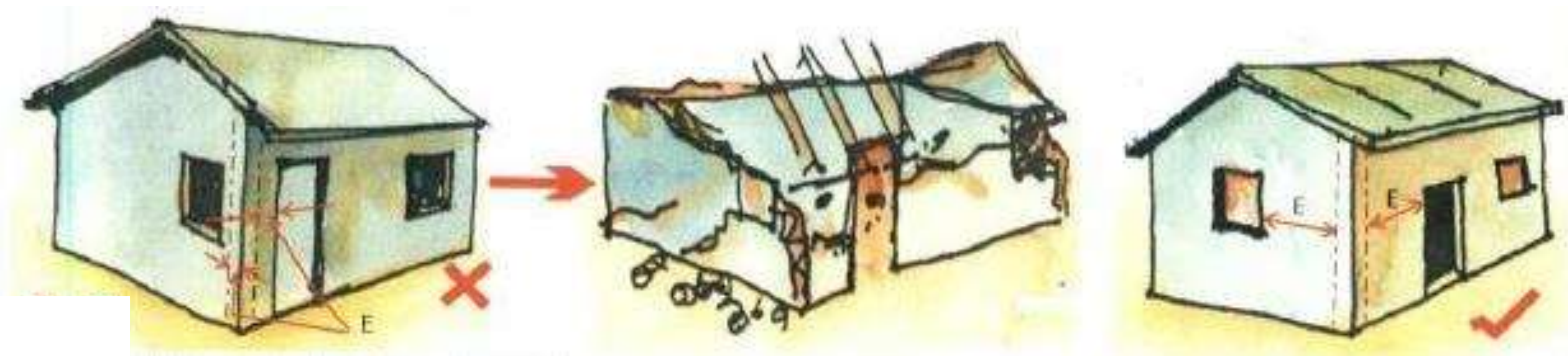
ii) Too many Openings on the same Wall cause Wall to collapse.



Walls with too many door and window openings close to each other could collapse easily. Openings should be restricted to small sizes and few in numbers.

In smaller rooms, provide no more than one opening in each wall.

iii) The Distance between inner edge of the corner and the edge of the opening must be significant.



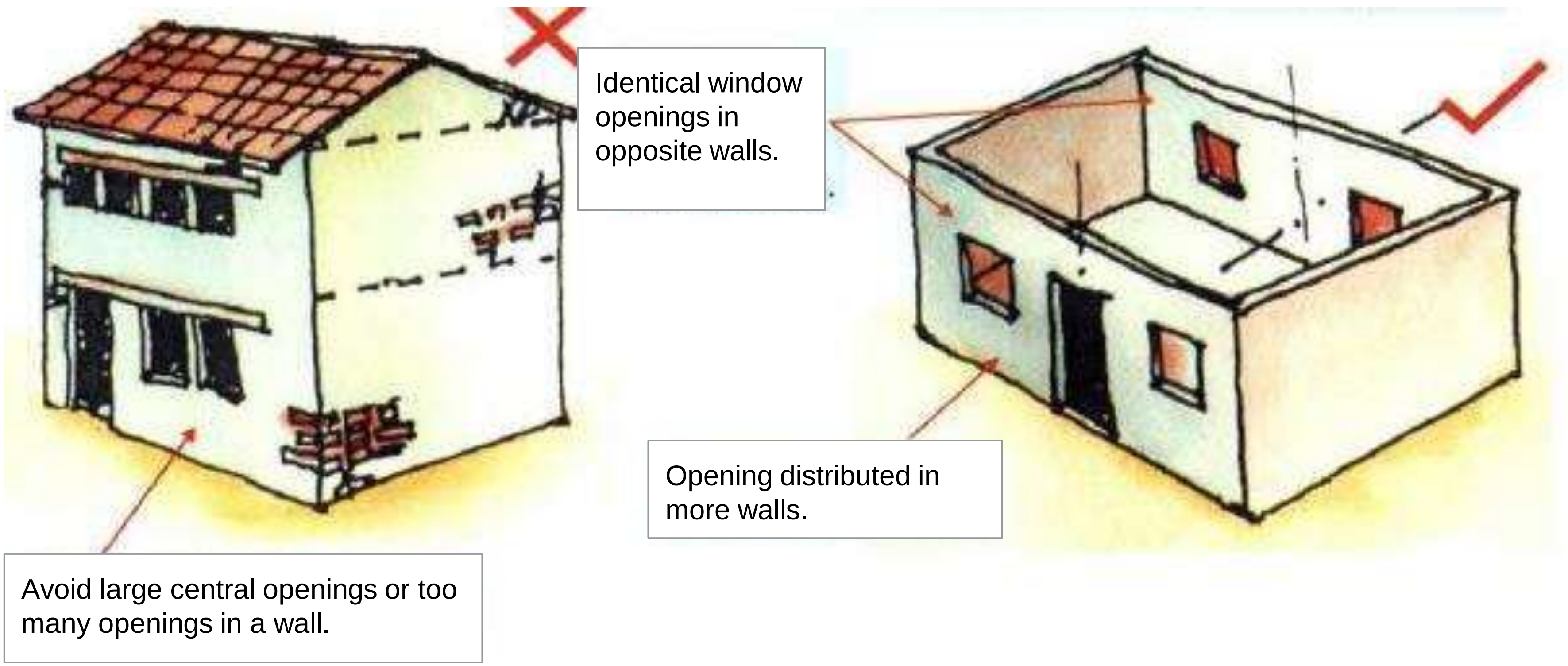
If the gap "E" between inside corner and a door or a window opening in a wall is too small, the wall can get damaged easily.

The gap "E" should be larger for more strength.

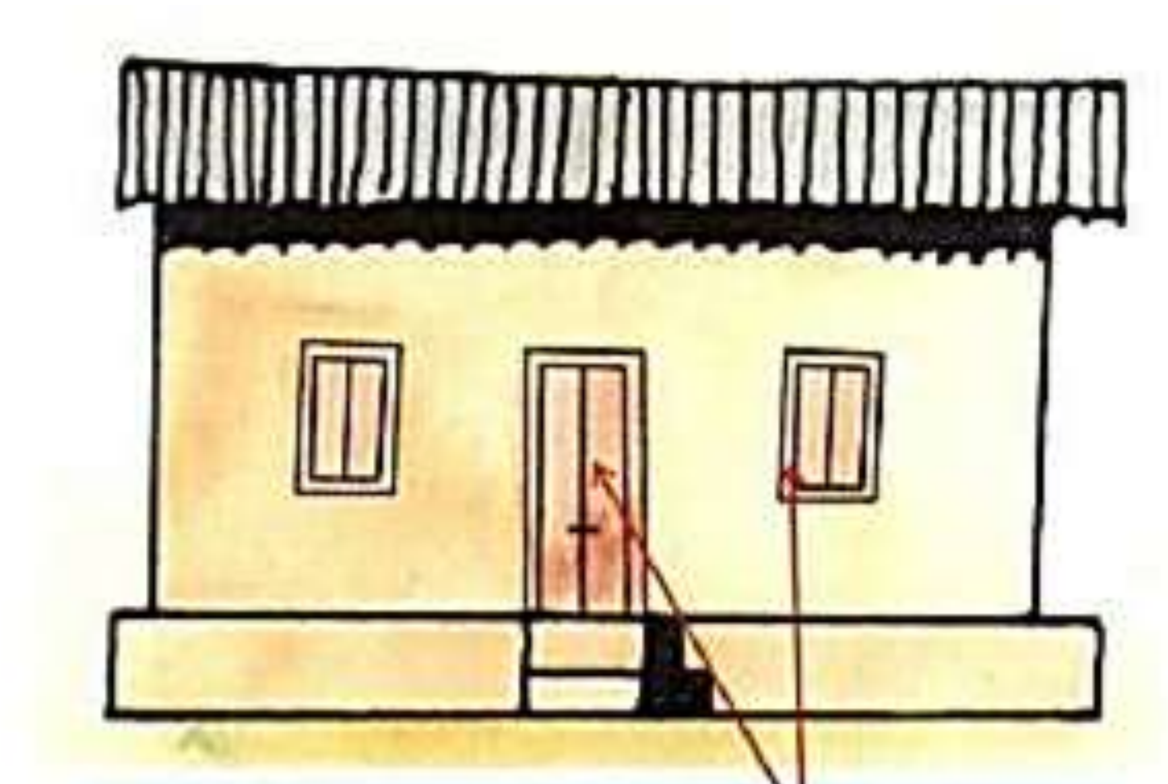
iv) Distance between inner edge of wall and and the edge of the opening should be at least ⅙th of height of wall.

$A \geq H/6$

v) Avoid too many Openings on the same wall

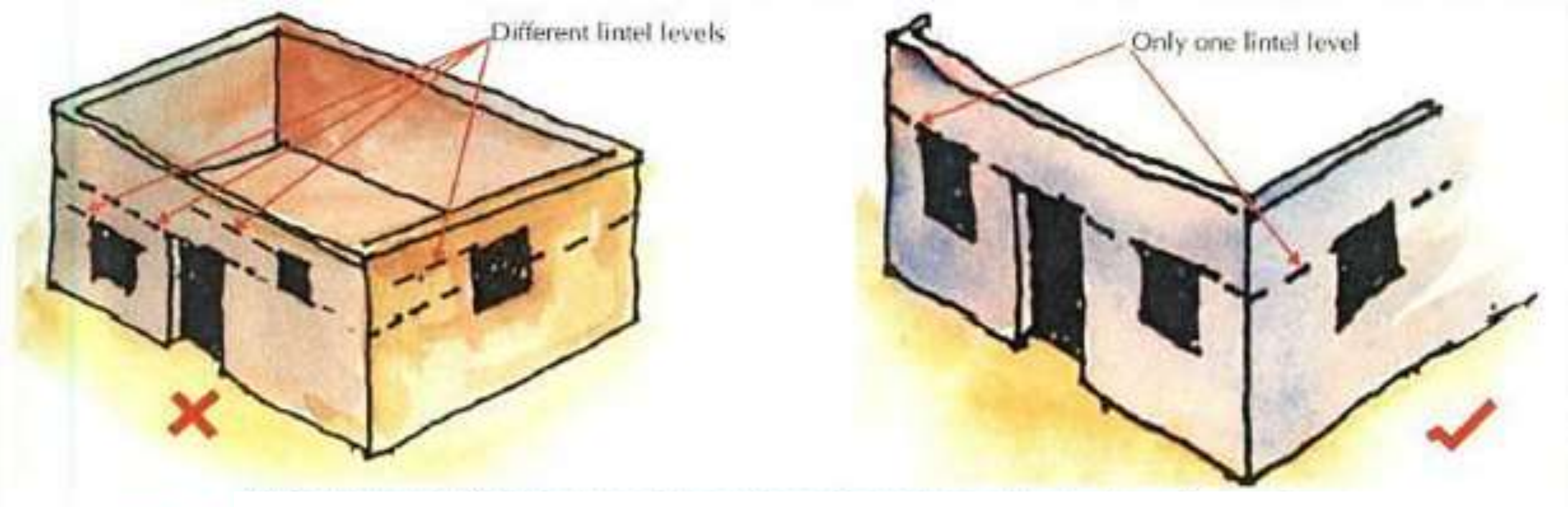


vi) In a cyclone prone area, ensure that all doors and windows can be sealed properly.



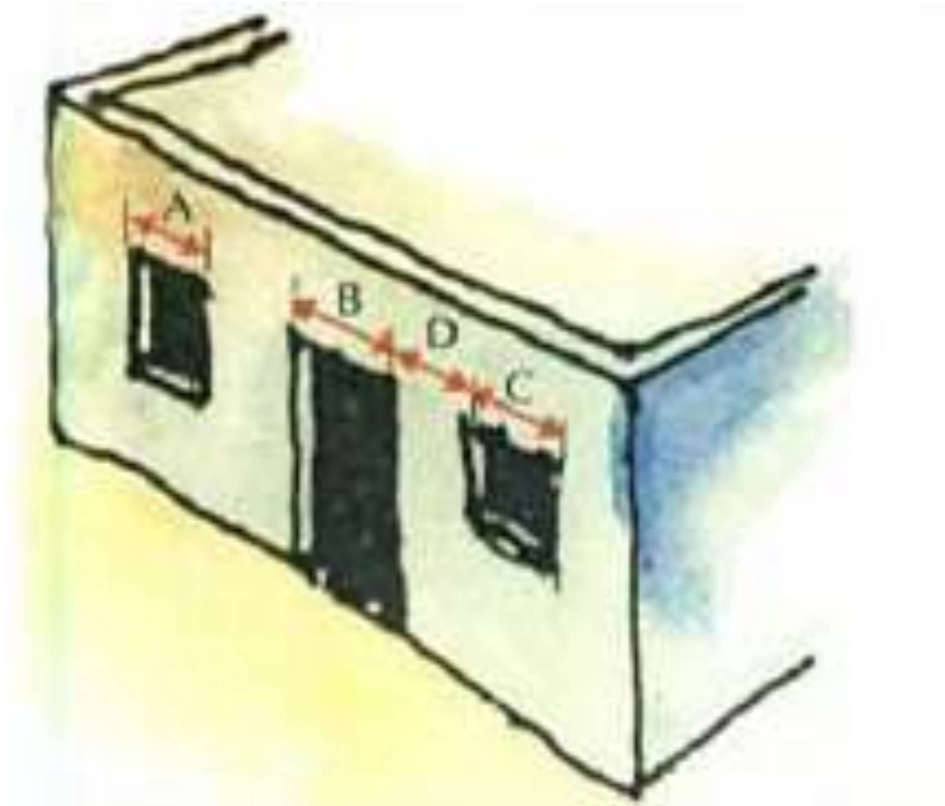
Make all doors and windows such that they can be tightly shut and sealed during cyclone.

vii) The same lintel level should be maintained for all openings. Many different levels and sizes of windows cause stresses to affect the wall in an uneven manner and lead to more damage.



Maintain same lintel level for all openings. Try to keep all windows of same size. Many different sizes and levels make walls unsafe in earthquakes.

viii) A+B+C should be relatively less in comparison to the wall length.



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BUILDING RESILIENCE

Summary

1. Typical damages to walls during various hazards: Failures of corners, diagonal cracking around windows, and splitting of thick walls
2. Basic principles of making walls and openings: We discussed box action, slender vs thick walls, long vs short walls and corner strengthening.
3. Details of makings walls, including vertical reinforcement, different types of bonds, importance of horizontal bands, importance of staggering the joints, through stones, confined masonry and buttressing.
4. Windows and doors play a pivotal role in hazard resistance. The size of the opening, its location with respect to the wall and other openings, all affect the way the wall will behave during a hazard.
5. Openings should be symmetrically placed. They should not be too close to each other. There should be enough wall area between two openings.