C5

Principles of Hazard Resistant Construction

No. of Slides: 46
Time: 45 min

National Disaster Management Authority

NCPDP
National Centre for Peoples'-Action in Disaster Preparedness
Technology for Vulnerability Reduction
Disaster Risk Reduction Platform in CEDAP

People in Centre

GUJARAT INSTITUTE OF DISASTER MANAGEMENT
BUILDING RESILIENCE

Gujarat Institute of Disaster Management

Recollection

Various housing typologies exist in a region.

It is possible to make all of these typologies safe?
Why is it important for different typologies to exist?

We must ensure different typologies continue so that the cultural identity of different communities continue to flourish and skills and knowledge of using different materials evolves in a manner such that it is appropriate to that region and context. These building typologies have evolved over generations, each responding suitably to the local climate. However, they need to be analyzed for their hazard resistance capabilities in the present times.

Response to prevelant hazards is necessary.

How do we decide which hazard to build resistance against?

We must check the local history and the zone in which our region falls to know which hazards we need to increase the resistance of our homes against.

Recollection

Different hazards are prevalent in varying degrees across India.

What are the various **forces that impact houses** during different hazards?

How do we check **quality of materials** during construction?

Why is the quality of materials important for hazard resistance?

Quality of construction and the quality of materials used is critical because the inconsistencies in sizes and techniques, use of weak materials, or badly-made details will prove to be the first to fail during a hazard.

Expected Outcomes

1. To develop understanding on Hazard Resistant Construction technologies and materials to reduce risk and minimise loss of life

2. Contextualising the vulnerability in local construction

Effects that impact the performance of Houses against different hazards

Earthquake: Inertia, shaking, twisting

Flood: Thrust force, erosion, submergence, splashing

Cyclone: Uplifting, suction, pressure, rainfall

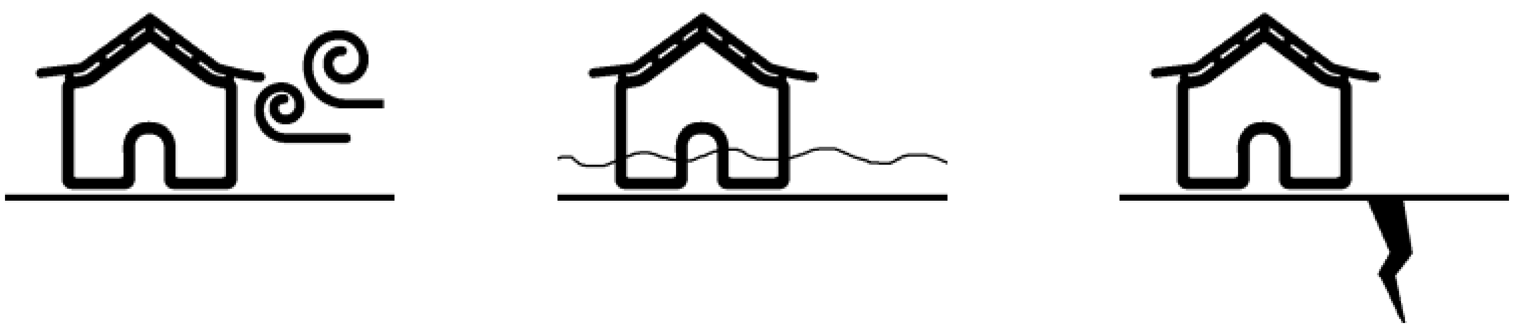
Tsunami: Impact of tidal wave

Landslide: Impact of mass of earth, sliding

Principles of Hazard Resistant Construction

If any of the above effects impacts our houses during a hazard:

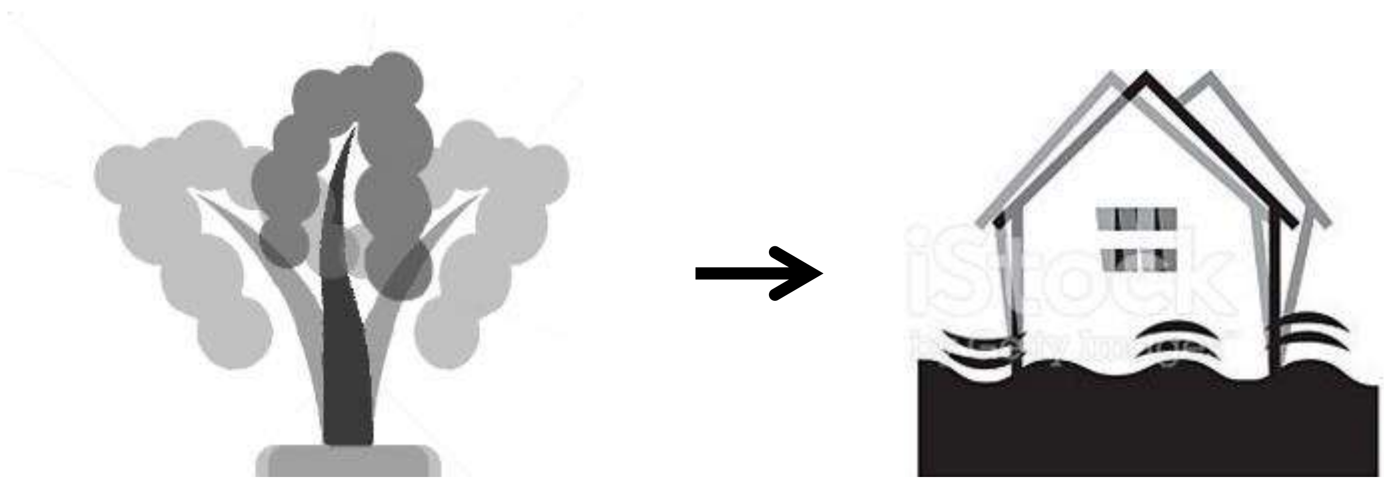
1. **A house must be able to retain it's original shape or come back to its original shape.**



Principles of Hazard Resistant Construction

If any of the above effects impacts our houses during a hazard:

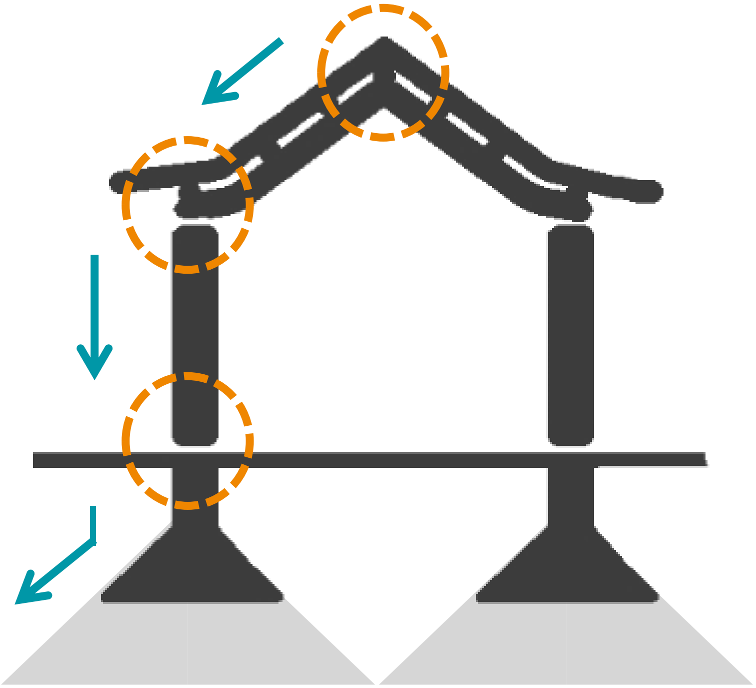
2. **All the main elements of a house must be able to sway back and forth during an earthquake, or any other hazard, withstand the stresses and other effects with some damage, but without collapse.**



Principles of Hazard Resistant Construction

If any of the above effects impacts our houses during a hazard:

3. **Every junction and connection must be so constructed to be capable of transfering the inertia forces through them to the ground.**



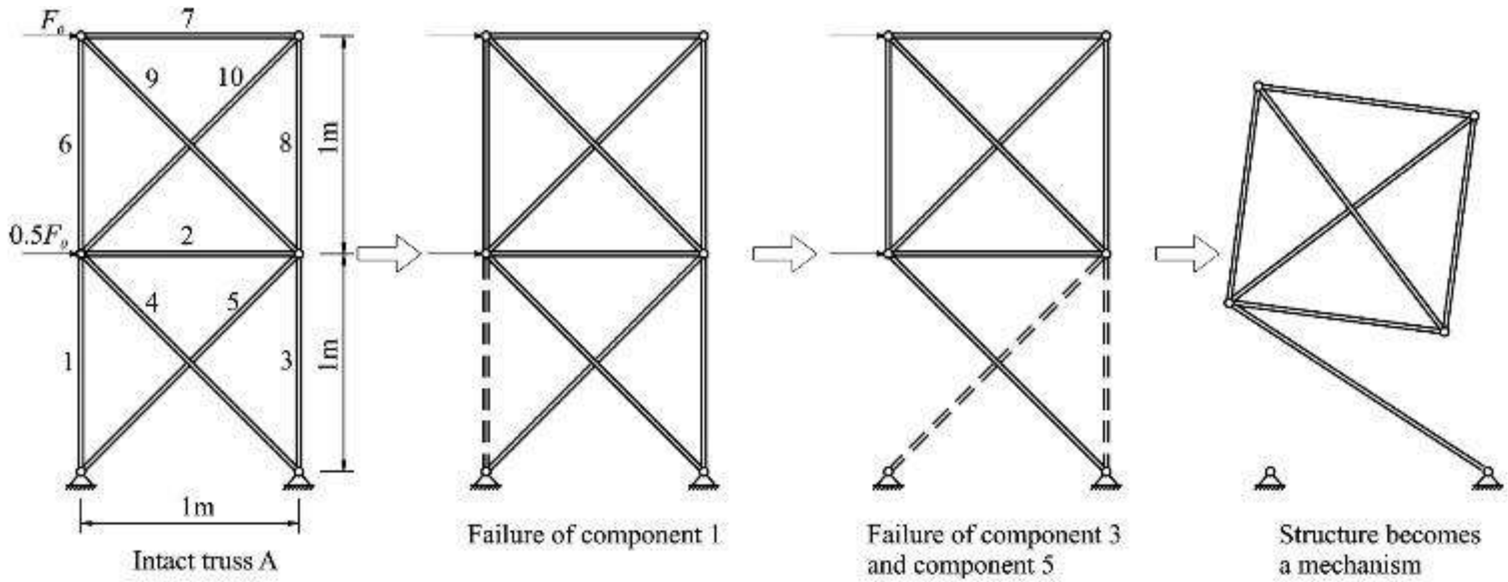
Principles of Hazard Resistant Construction:

If any of the above effects impacts our houses during a hazard:

4. Alternate load path design:

If one element weakens along the load path, the house must be capable of transferring the load through an alternate path to avoid collapse.

Alternate load path design



In usual condition, part of the load travels from 7 to 6 to 1 to ground. In case of failure of element 1, the load is then transferred to elements 2 and 4, hence choosing alternate paths 7 to 6 to 4, 7 to 6 to 2 to 3 and 7 to 6 to 2 to 5, thus preventing a collapse of the house.

Design Principles

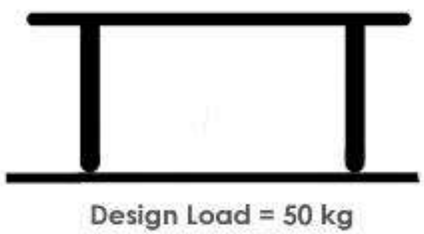
The principles that help a house resist the effects imposed on it are:

1. Structural Robustness,
2. Structural Integrity,
3. Elasticity,
4. Ductility,
5. Bracing, and
6. Design of elements of the house to protect from wind and water.

1. Structural Robustness

Robustness is the ability of a **house** to withstand events (like fire, explosions, impact or the consequences of human error), without being damaged to an extent disproportionate to the original cause.

Example of robustness,



Design Load > Total External Load

Deformed but not broken. ***Hence, more robust.***

Deformed beyond control, leading to total collapse. ***Hence, less robust.***

Design Load < Total External Load

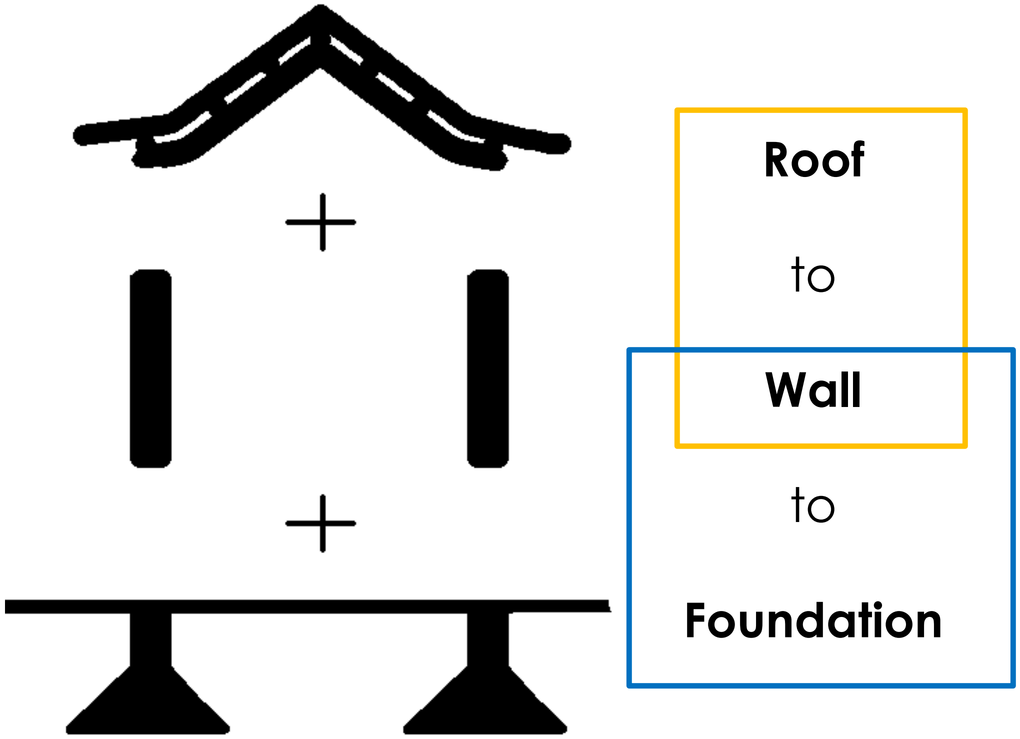
How to achieve Structural Robustness?

Design Loads need to be considered with respect to the location and the severity of hazards in that region.

1. Good quality of materials
2. Good workmanship and construction techniques
3. Hazard Resistant design (Architectural and Structural)

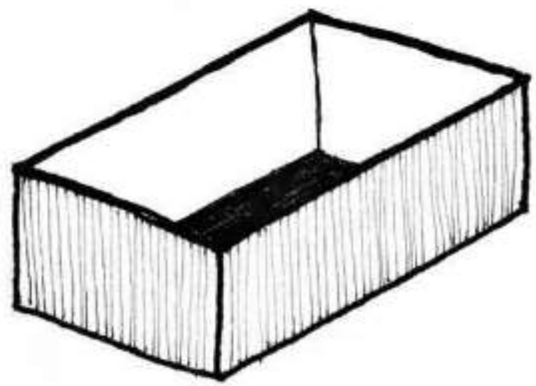
2. Integrity

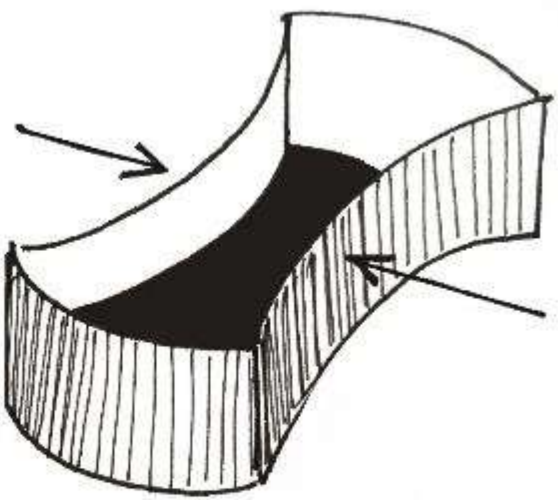
All elements of the house must be tied well to each other.

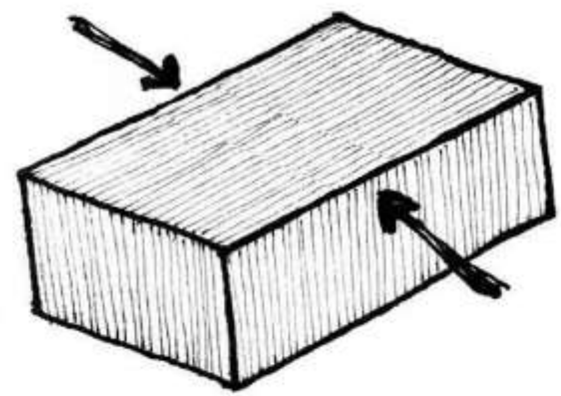


Box Action (Load Bearing Construction)

Imagine a cardboard box. When we apply a horizontal force on it, the entire box deforms. Does it make a difference, if the box is open or closed?

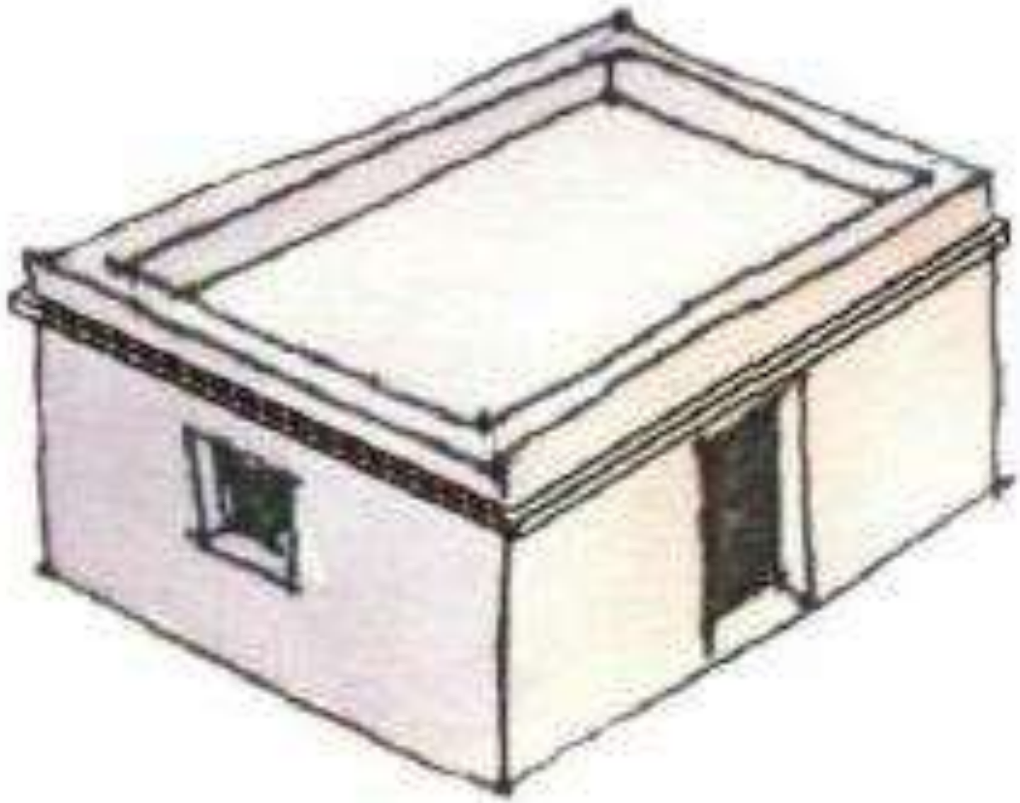






Box Action (Load Bearing Construction)

A house is like a cardboard box. If its walls, roof and foundation are tied together well, it will not fall apart or deform, even if shaken by an earthquake or forced by a cyclone.



Box Action (Load Bearing Construction)

When a horizontal force is applied to a masonry house, some walls will be in the direction of the force and others perpendicular to it. Walls in the direction of the force are stronger, and those perpendicular to the force are weaker.

Weaker walls will transfer their loads to the walls in the stronger direction and **this load transfer happens at corners, through bands and through the roof.**

If a house acts like a box, it has a better chance of transferring the loads more easily to the ground, and therefore sustains less damage.

Bands

Have you noticed that the top of a bucket has a thick ring around it? Why is this so?

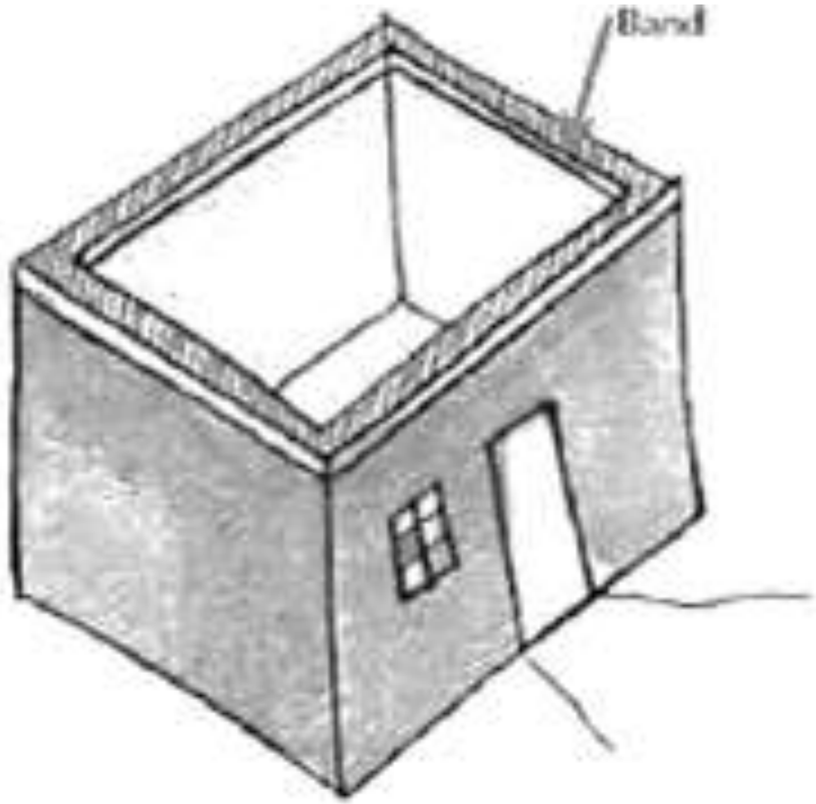
Bands

The bucket without a rim behaves similarly to a plastic glass without a rim. It deforms with the slightest of pressure on it's edges.

In houses, the bands in walls are like the rim of a bucket and the rim on the plastic glass. They keep the building together to ensure that it acts as one box.

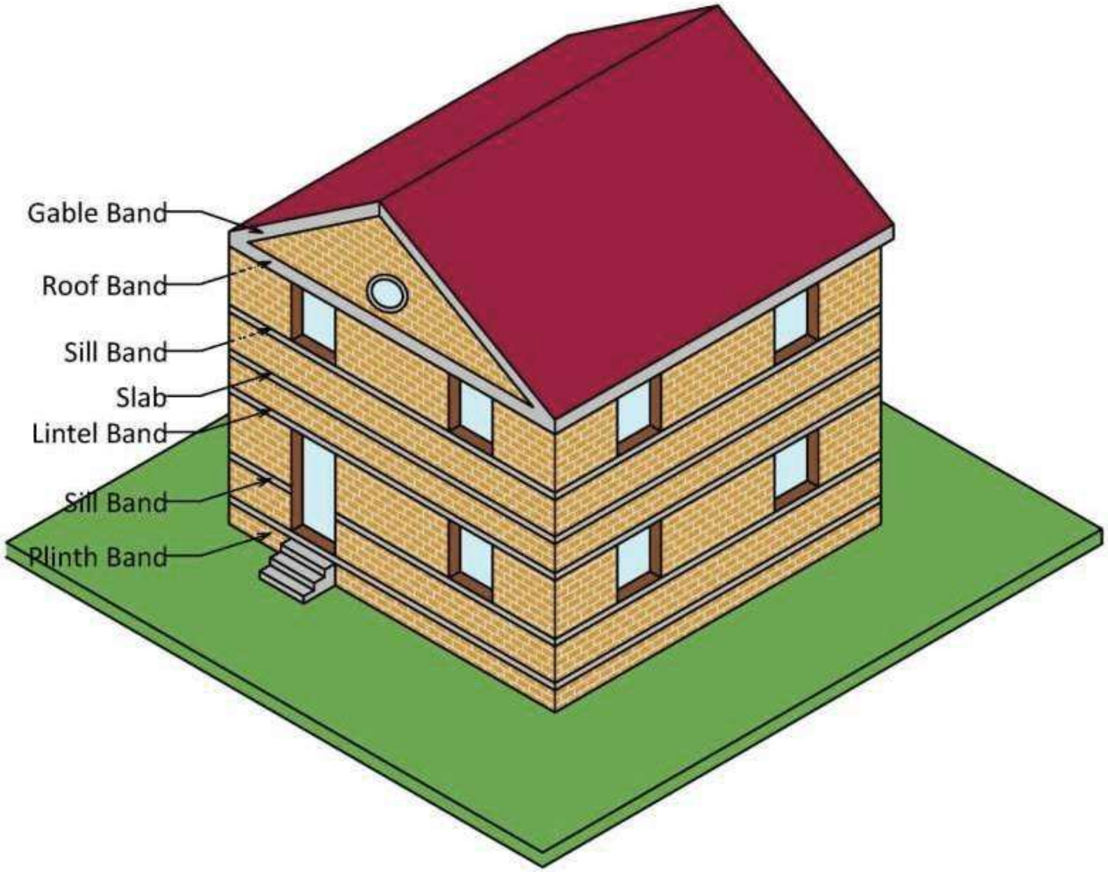
Bands

Bands are added to houses to ensure that the walls stay together, and transfer the loads from one wall to the adjoining perpendicular wall, so the loads can be transferred to the ground more evenly.



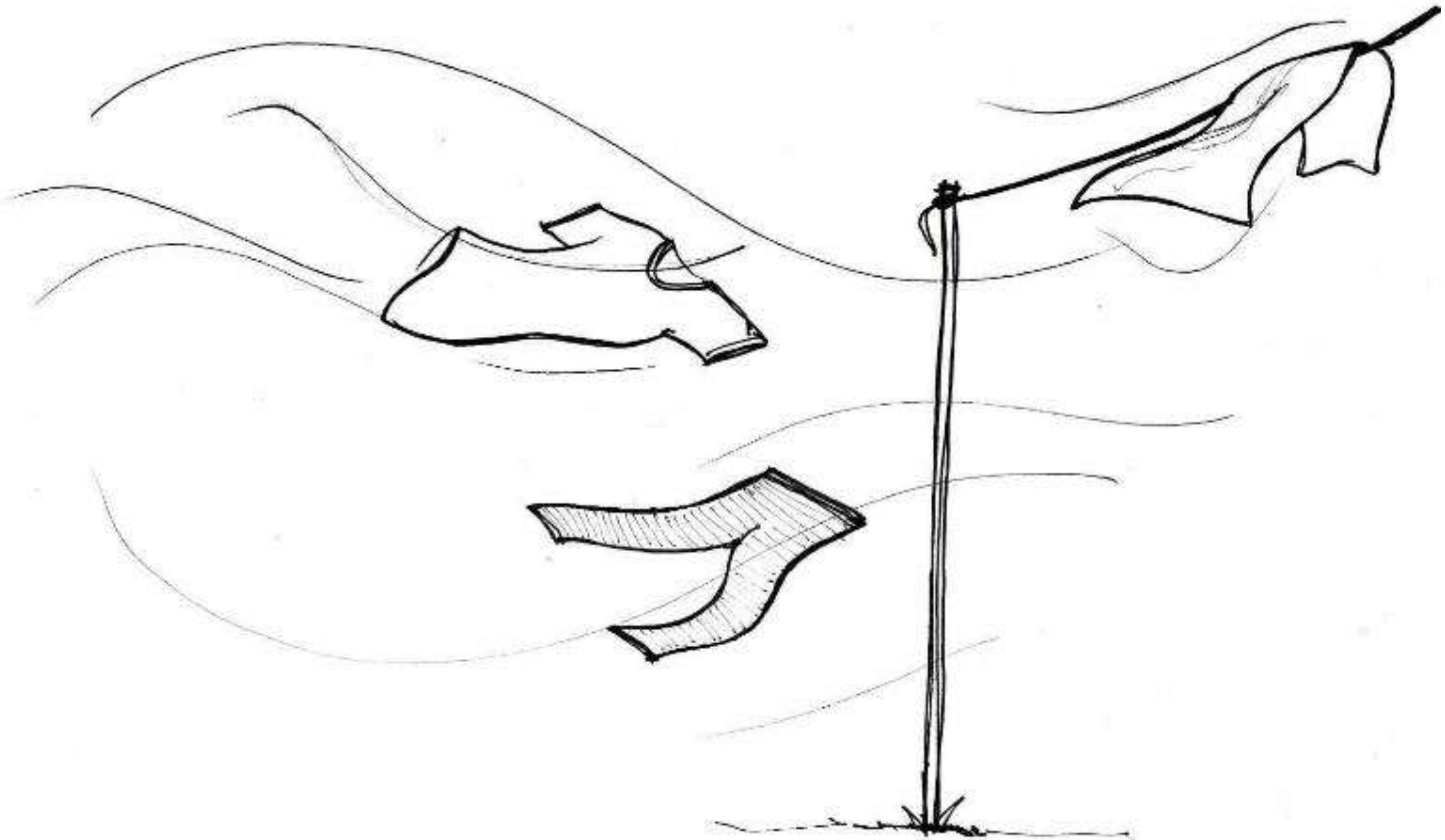
Bands

Here is an example of a house, where bands tie it all together.



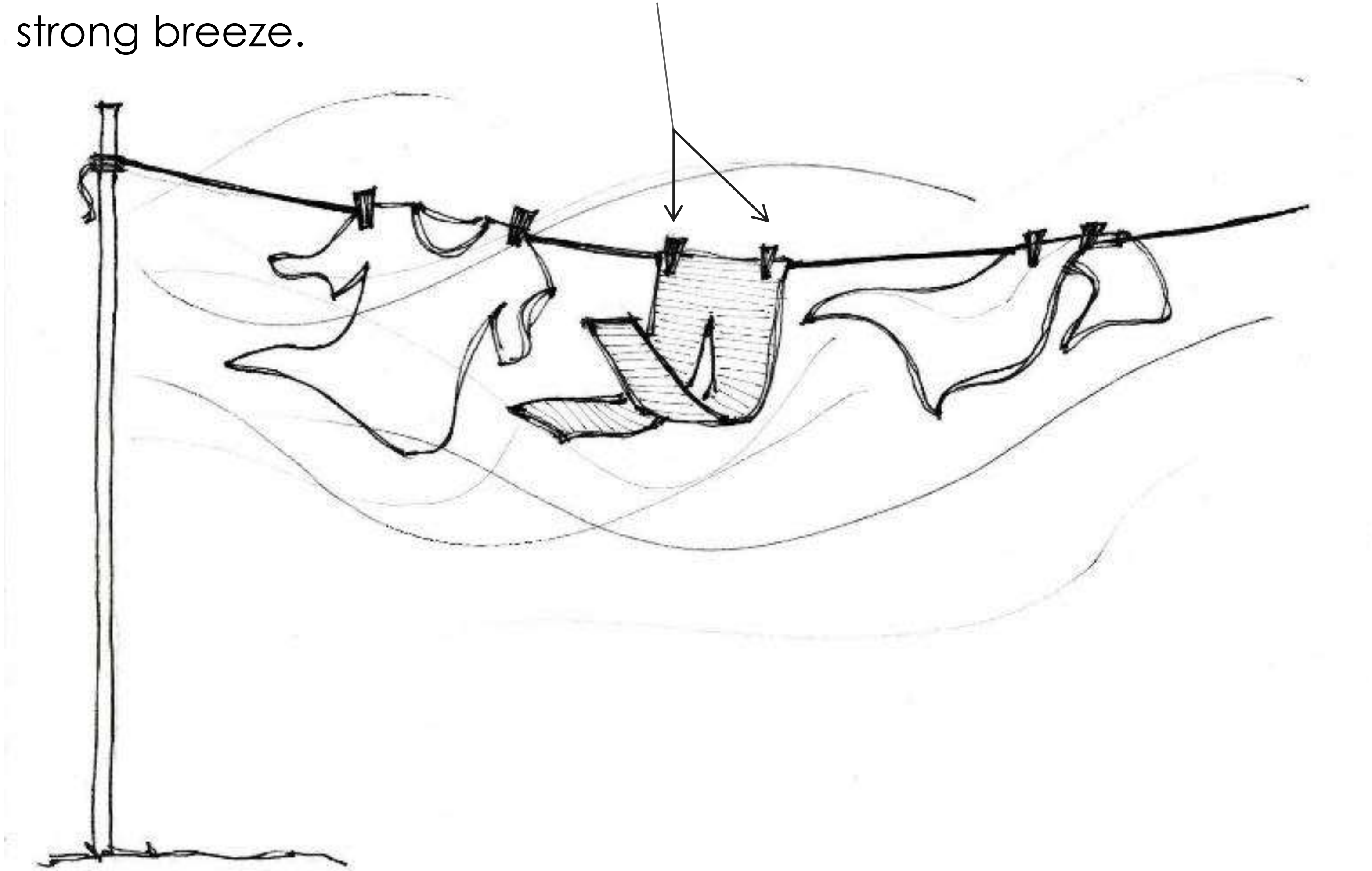
Anchoring

Clothes hanging on a clothesline fly off in strong breeze.



Anchoring

Clothes need to be anchored using clips to ensure they do not fly off in strong breeze.



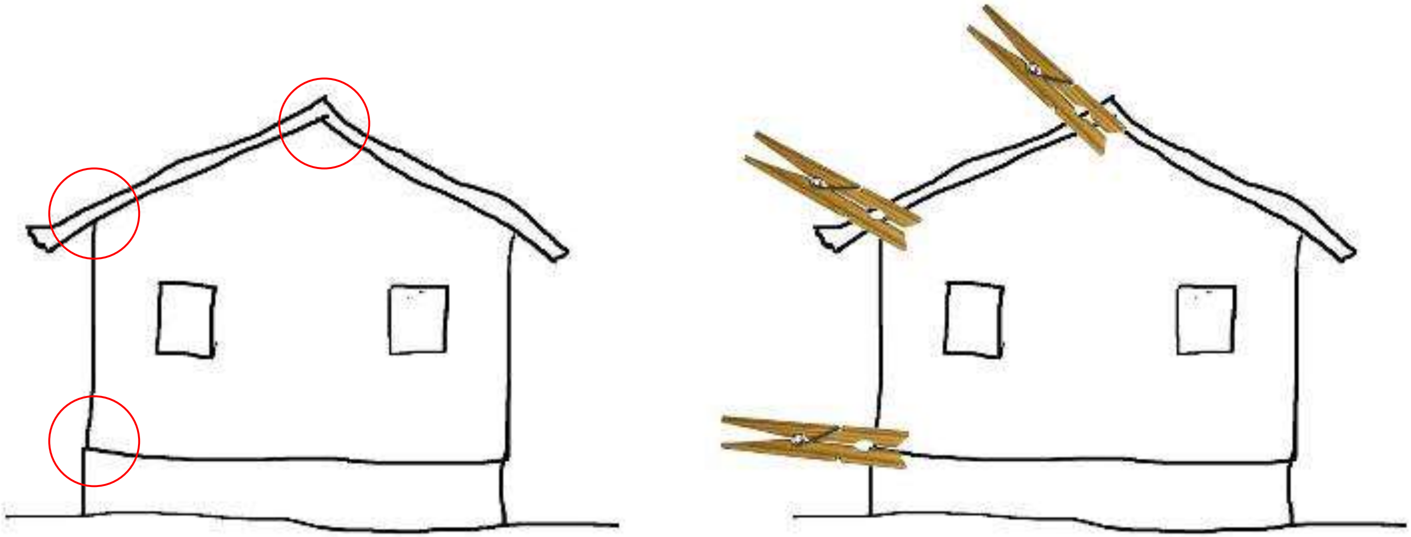
Anchoring

Similarly, when a strong wind blows, the roof may be uplifted and may be pulled away along with any other element of the house which is loosely attached.

If we keep a coaster on a glass and shake the glass, the coaster may fall off, unless it is properly anchored. Similarly, when there is a strong wind force acting on a side of the house, it may cause elements that are not anchored properly to fly off.

Anchoring

To ensure the entire house is well anchored, the joinery between plinth and walls, between adjoining walls, walls and roof, and between different roof elements must be secured safely to ensure that they do not get damaged during an earthquake or a cyclone.



3. Elasticity

It is the property of a material to be able to come back to it's original shape.

a) Materials, like **timber, bamboo and steel,** are more elastic than materials, like brick, concrete blocks and earthen materials.

b) Homes made of elastic materials may be able to come back to original positions more easily.

c) For practical purposes, these cannot be the only materials used in the building and therefore it becomes important to design buildings well to ensure that elastic materials are at the right place and in the right quantity.

d) Also materials that are elastic, but which break suddenly when their limit of elasticity is crossed, need to be used carefully in construction.

A house should be able to come back to it’s original position after a hazard.

Think about a tree. Typically it stands firmly on the ground. When the harsh winds put horizontal pressure on a tree, it moves with the wind. It is flexible enough to not break and bend with the wind. When the wind stops blowing it returns to its original position.

4. Ductility

It is the ability of a material to deform under stress instead of breaking.

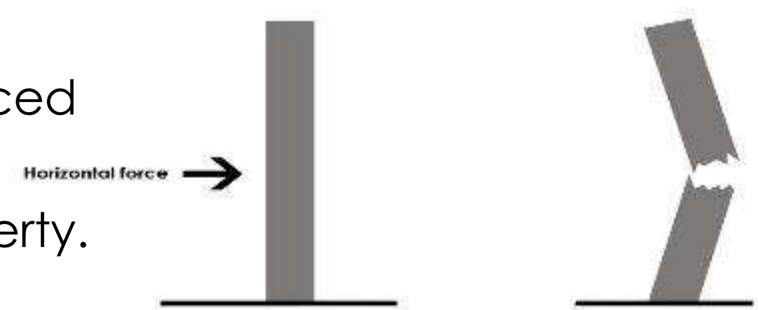
Let's compare this chalk and a steel pin. What would happen, if I apply a (horizontal) force on the chalk and on the steel pin?

The chalk would break into two or more pieces, while the steel pin would bend. This property of materials (like steel) to bend with damage but without breaking is called **ductility.**

4. Ductility

1. This property helps houses, which need to be reinforced to not break suddenly during a hazard.

2. When a horizontal force is applied to a column that typically takes vertical forces, the brittle material may break first. In case of a typical column, it is the concrete.
   If a column in a house has not reinforced appropriately, it may immediately break and cause loss of life and property.



3. On the other hand, an appropriately reinforced column, will first fail due to reinforcement (usually steel) and so will bend and deform, but it will not break suddenly. Steel has the ability to stretch large amounts before it breaks. This will give enough warning to escape or repair the building.

Caution: Over reinforcement should be avoided, since concrete will fail first in such case.

Are these materials Ductile or Brittle?

Ductile

Bamboo

Wood

Steel bars

Plastic pipe

Brittle

Stone

Concrete

4. Ductility

Here is a RC roof under-construction, reinforced with steel bars.

Does it mean that putting more steel reinforcement is good?

Over-reinforced beam

When the longitudinal reinforcement is more and transverse reinforcement is less, then the concrete fails first. It results in sudden collapse of the beam.

Under-reinforced beam

When the longitudinal reinforcement is less and transverse reinforcement is more, the reinforcement fails first. Due to ductility of steel, the collapse is gradual.

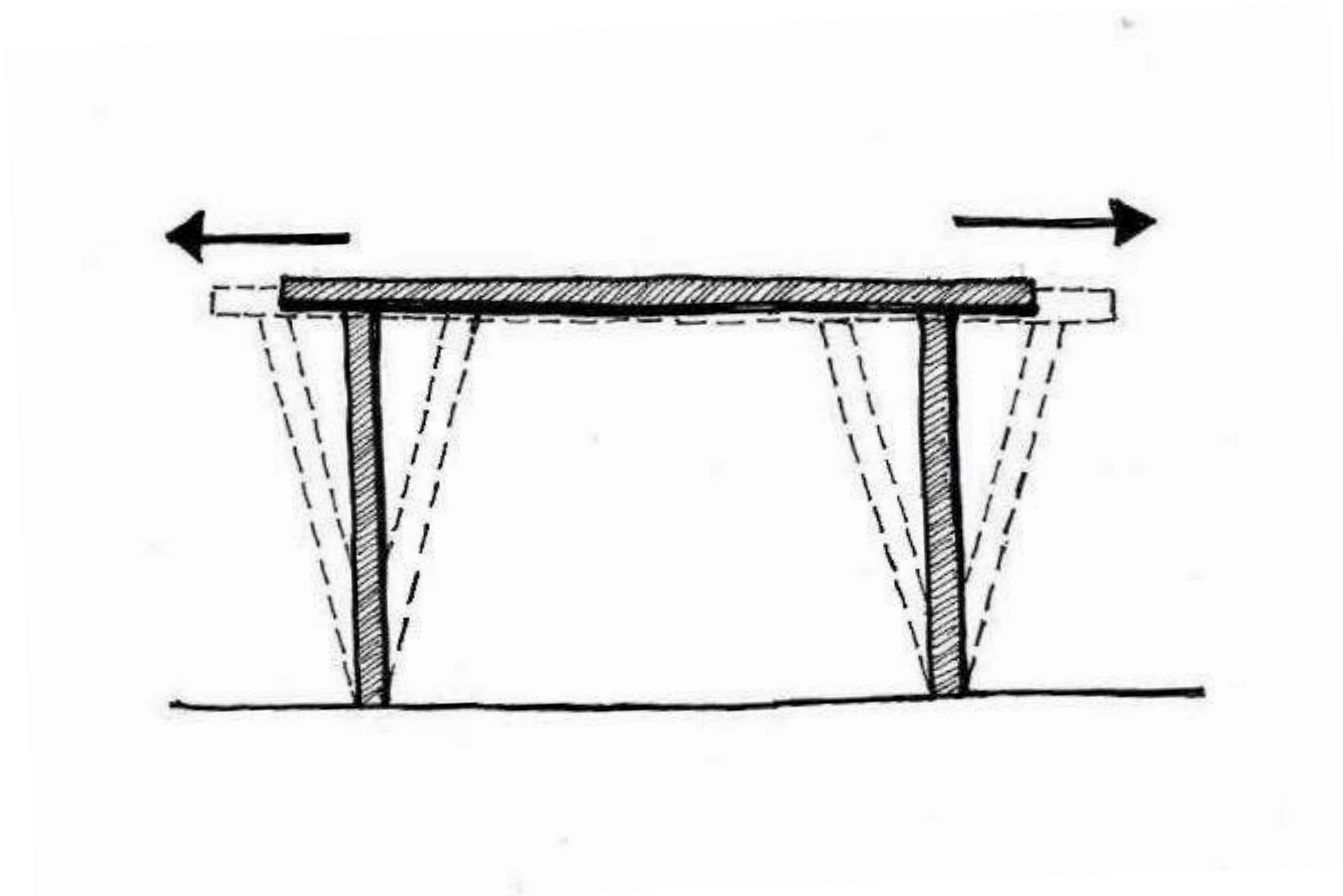
5. Bracing

In-plane deformation for frame construction.

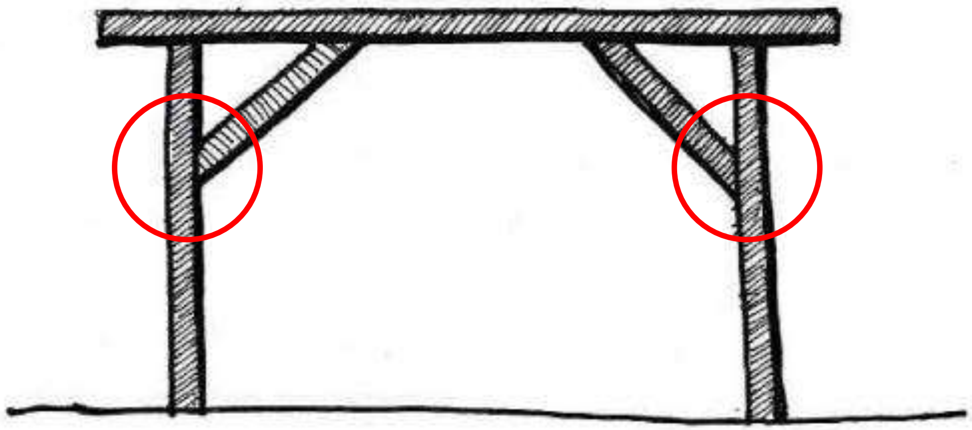
What would happen if a horizontal force is applied to an unbraced frame?

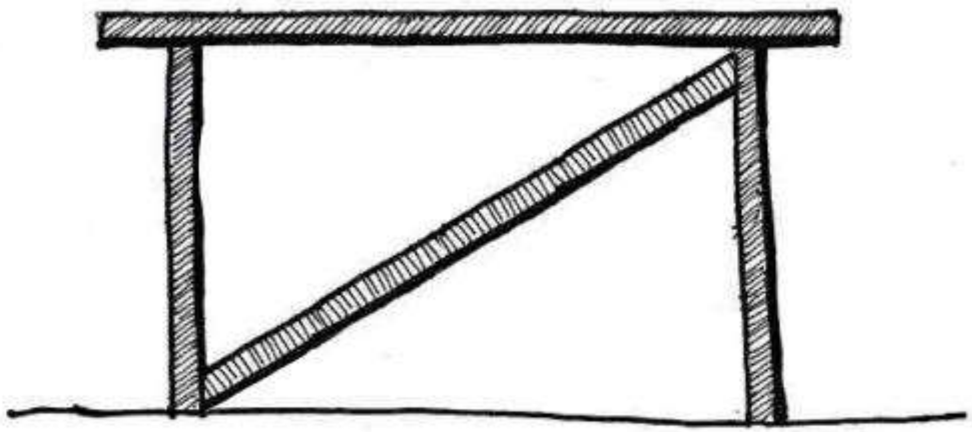
During an earthquake, horizontal forces induced deform unbraced frames. To reduce damage, cross bracings are added to frames.

Imagine a table in your home is not stable and shakes every time you put force on it from one side. How will you stabilize it?



The table can be braced using wooden members to make it stable.





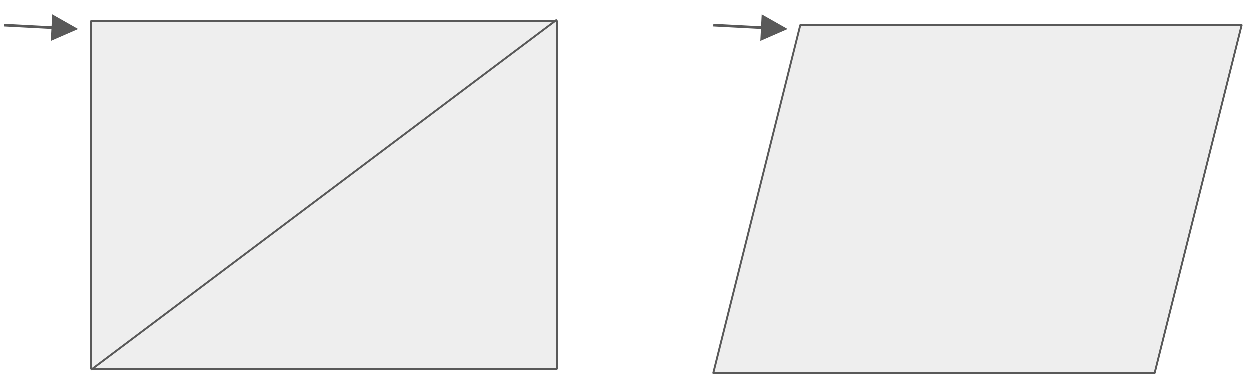
Using the same principle of triangulation, RC frames can be strengthened as shown above.

Bracing: In-plane Deformation of a Frame

Braced frames use **trussing** to resist sideways forces on buildings.

Trussing, or triangulation, is formed by inserting diagonal structural members into rectangular areas of a structural frame.

It helps stabilise the frame against sideways forces from earthquakes and strong winds.



Bracing in frame construction

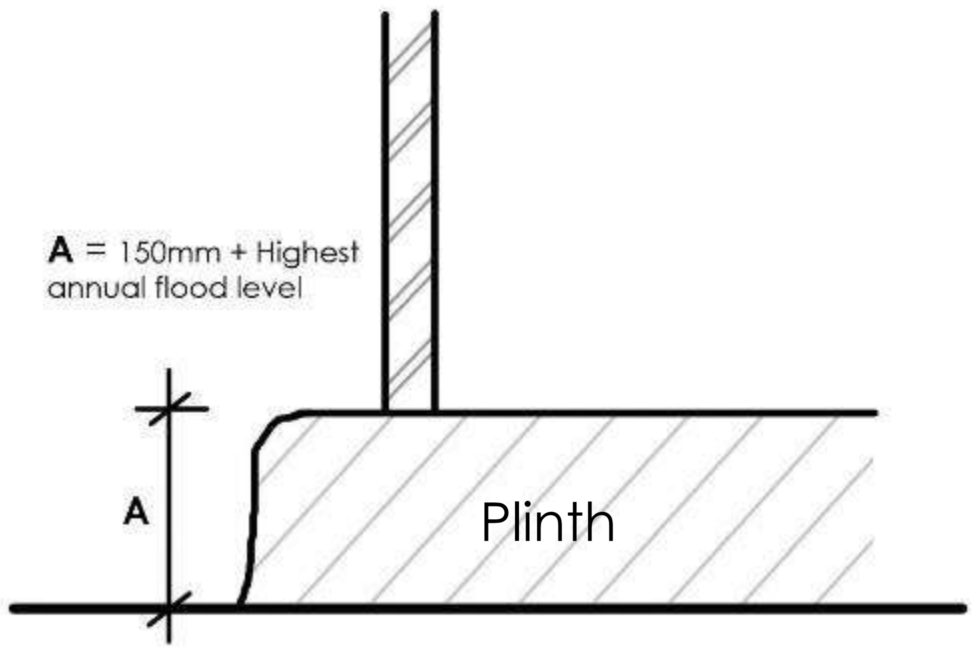
Here is an example of a building with it’s frame braced.

Wall

Roof

6. Protection from Water and Wind

<u>Plinth height</u>: To protect the house from floods, the plinth height must be designed **150mm higher than the highest annual flood level of the last 50 years.**



6. Protection from Water and Wind

Plinth Protection:

Why do we need to do this?

Plinth can get damaged because of scouring due to floods or tsunami.

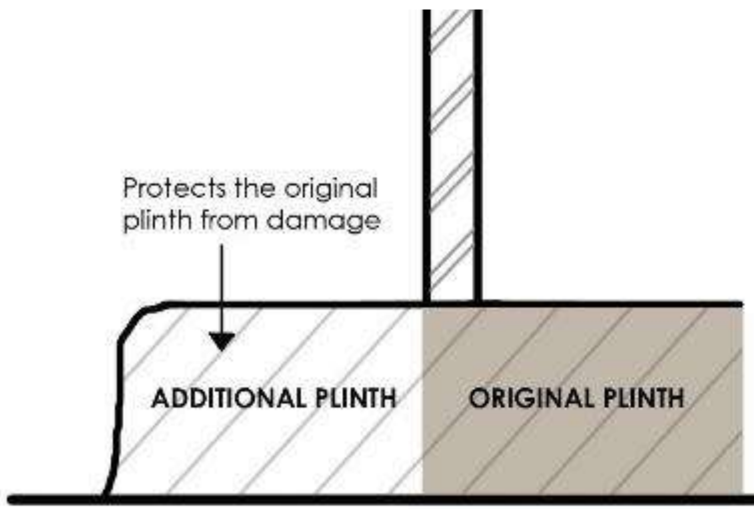
How can we achieve this?

6. Protection from Water and Wind

<u>Plinth Protection</u>:

To achieve this,

1. Extended plinths (Baithak, Otla, Verandah) can be used.

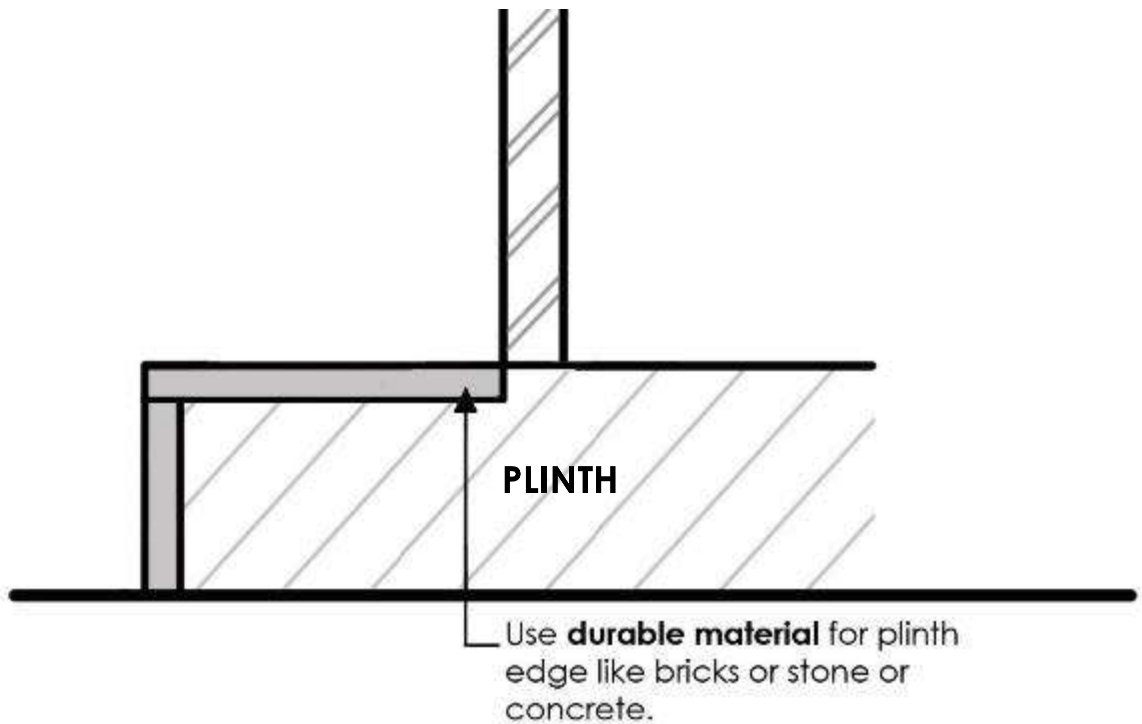


6. Protection from Water and Wind

Plinth Protection

To achieve this,

2. Protect the plinth edge by providing brick or stone lining.



6. Protection from Water and Wind

Roof Protection

Why do we need to do this?

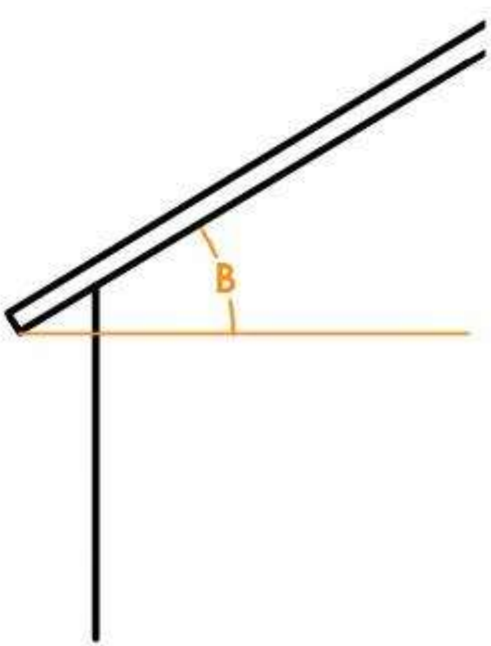
Heavy winds can uplift the roof and rainfall, on entering, can damage the structure. Leakage, over time, is a nuisance and can weaken the structure

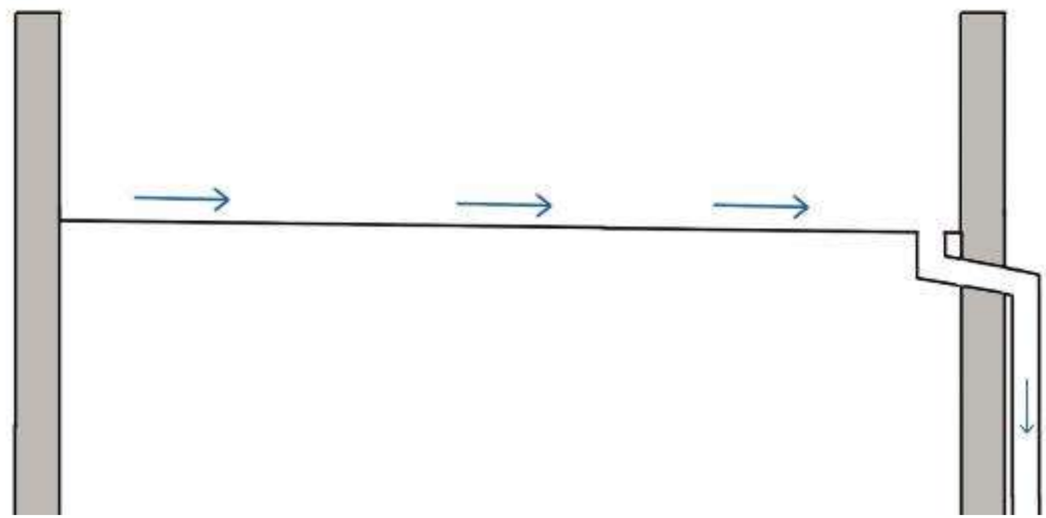
How can we achieve this?

6. Protection from Water and Wind

Roof Protection

1. The angle of the slope is determined by the amount and intensity of rainfall. If flat roof, at least a minimum slope for drainage must be ensured.

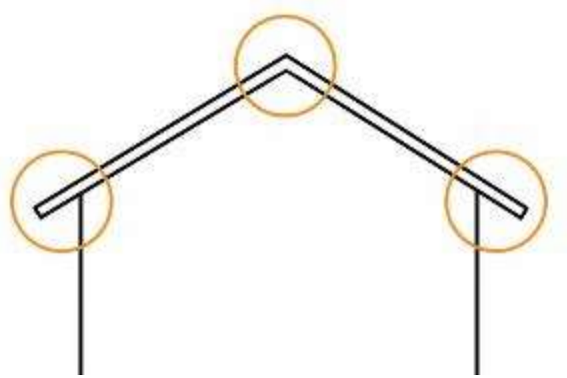




6. Protection from Water and Wind

Roof Protection

2. Joints of the roof must be **strong** and **leak proof.**



3. Materials used must be **sturdy**, **water resistant** and **durable**.

Discussion

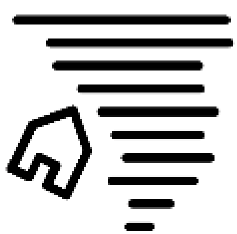
How these Hazard Resistant Principles are incorporated in houses in your area?

Do they work? Are they adequate?

Summary

Earthquake: Use of ductile materials allows the house to get damaged and not collapse. The house needs to come back to it’s original position. Bracing and bands help transfer loads to the ground more quickly, thus withstanding the shock.

Flood: The house should above the expected flood level and be strengthened at the base to resist erosion and scouring.



Cyclone: If the roof is heavy and well anchored, it has less chances of being unhinged and flying away.

To resist most hazards, the house must be well sited and anchored properly to ground.