Earthquake Resistant Building Construction Note

Earthquake- The word earthquake is self explaining the earth-quake that means the earth shakes and we feel the vibrations caused by these motion. Earthquake are caused due to many reasons (later explained) but most commonly the term earthquake is used when shaking of the earth's surface is caused due to some disturbance occurring inside the earth.

Structure of Earth

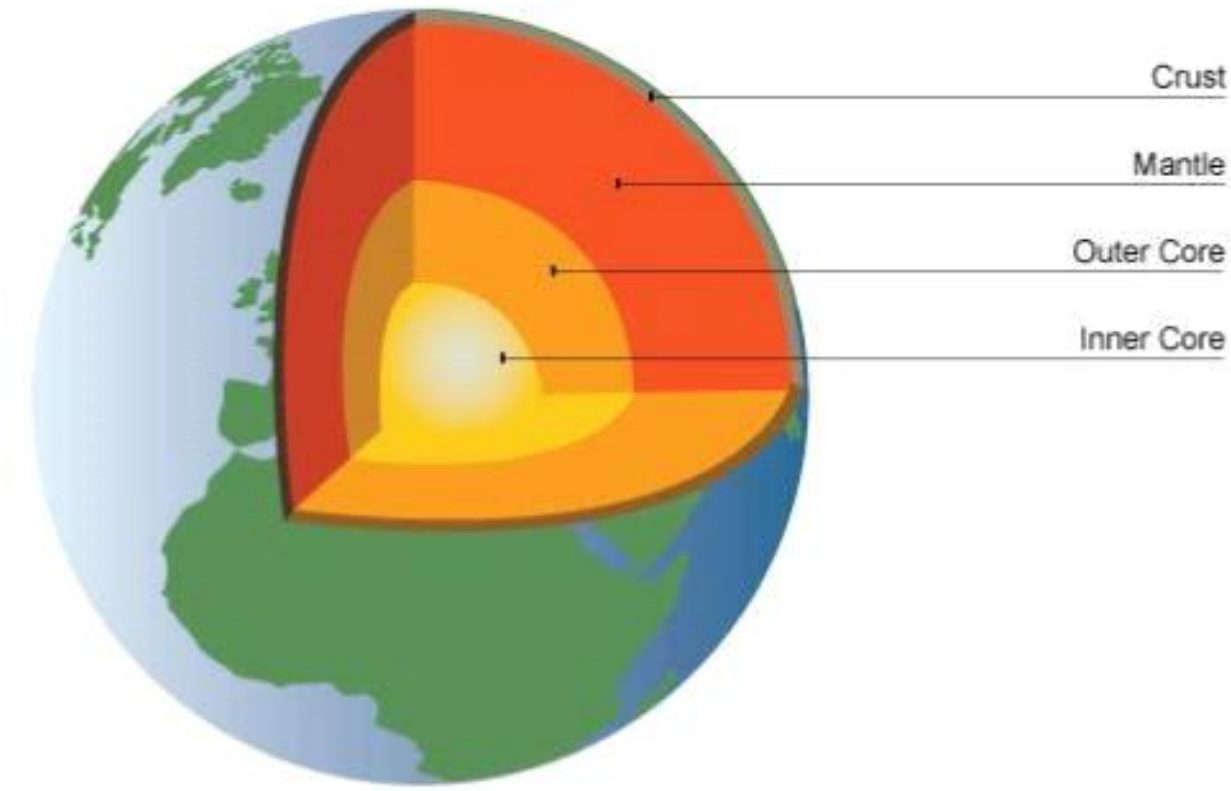

Plate tectonics – Theory of plate tectonics is based on the theory of continental drift which explains the origin of continents and oceans.

- According to this theory a long time ago, large amount of material masses joined together to form the earth.

- Large amount of heat was generated during this fusion. As the earth cooled down the heavier material sank to the center and the lighter ones towards the top. The upper part formed is called as crust and the inner part is called as core. The high temperature and pressure difference between the crust and core results in convection currents (like flow of water molecules when heated up). These currents result in circulation of the earth's mass form the crust to core and vice versa. The hot molten lava comes out and cold rock mass goes into the earth. This flow of material causes the crust and some part of mantle to slide on the outer core. This sliding of earth's mass takes place in different part of the earth. Called as Tectonic plates.

- The surface of earth consist of seven major tectonic plates and many small plates. These plates moves in different direction and at different speeds.

Thus resulting in rising and sinking of the continents. (formation of mountains and valleys)

- These movements result in the formation of mountains (Like Alps and Himalayas)

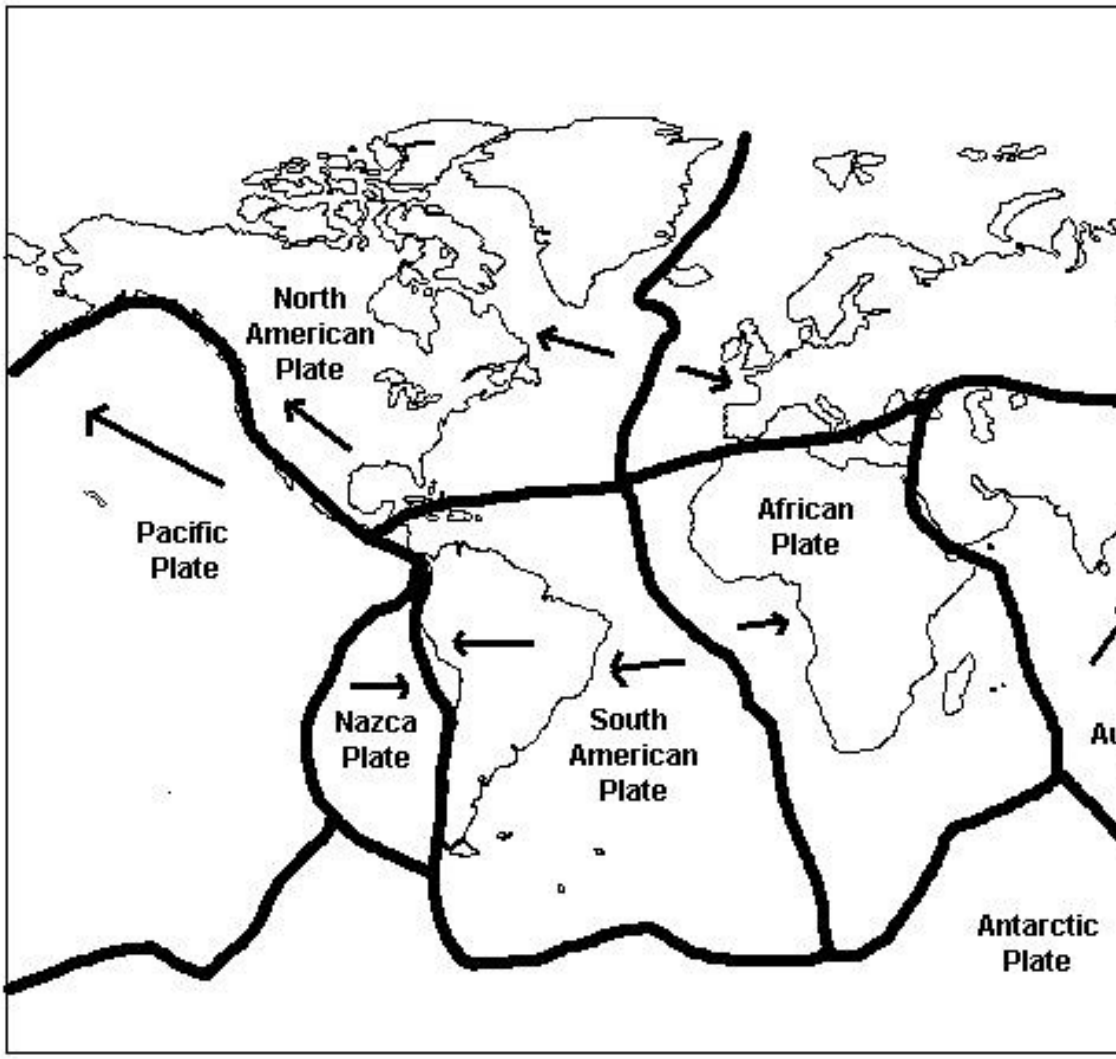
North
American
Plate
Pacific
Plate
African
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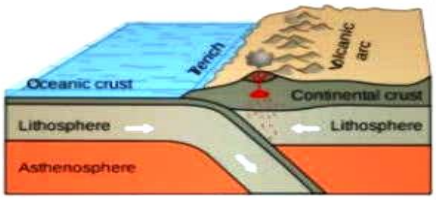
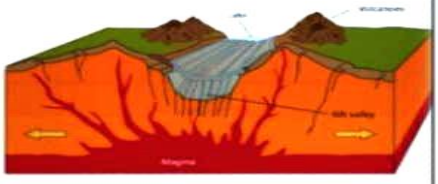
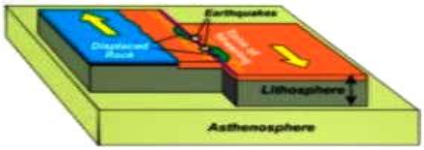
Plate

	Boundary Types		How the plates move	What can h
1.	**Convergent Boundary**		Towards each other	1. Earthqua 2. Mountain 3. Volcanoe
2.	**Divergent Boundary**		Away from each other	1. Earthqua 2. Sea floor 3. Volcanos
3.	**Transform Boundary**		Blocks slide past one another	1. Earthquak

- **Causes of Earthquake –** Earthquake are primarily caused due to two reason

1. Natural disturbances

a. Volcanic cause

b. Tectonic cause

2. Artificial disturbance

Natural disturbance –

- **Volcanic causes –**

Volcanic activity keeps on taking place in several parts of the world. Very often, it produces sudden out burst or explosions. This impact is sometimes strong enough to produce vibration in the nearby area. People living in Japan and Italy, have experience this type of earthquake

frequently. The damage caused due to this type of earthquake is confined within a few kilometers. All volcanic eruption don't produce earthquake.

- **Tectonic causes –**

Tectonic cause are those which occur inside earth. According to the theory of plate Tectonic, the curst layer is made up of rocks and is divided into many plates. These plates are constantly in motion in different direction and with different speeds. These plates have strain energy stored in them.

The earthquake which occur due to sudden release of strain energy as a result of sudden slip of fault is called as tectonic earthquake.

Artificial disturbance –

Sometime the surface of the earth vibrates due to man made or artificial disturbance.

- Nuclear test and explosions
- Mining blasts in the mining area
- A massive landslides along hill slops caused because of deforestation.
- Vibration induced due to heavy machinery used in industries or movement of heavy vehicles.
- Large and deep excavations.

All these causes occur over the earth's surface so these are also called as surface causes.

Terminology-

- ***Hypocenter*** – The point inside the surface of the earth from where the earthquake originate is termed as hypocenter. This is also known as focus. It is the point on the fault where the slip or the movement starts.

2. Epicenter- The point on the earth's surface vertically above the hypocenter is called as epicenter.

3. Focal depth- The depth of focus from the epicenter is called as focal depth. It is an important parameter in determining the extent of damage of an earthquake.

The focal depth of most of the major earthquake causing lot of damage in shallow depth.

4. Epicenter distance – Distance from epicenter to point of any interest is called as epicentral distance.

As the epicentral distance is increased the effect of earthquake become less. The damage is maximum at the epicenter and surrounding area.

- ***Fore shocks and after shocks*** – A fault rupture is not a simple one time movement that produce the earthquake. In fact we never have just one earthquake.

The fault movement generates a series of earthquake. Out of these the biggest one is called as earthquake (Main shock).

The smaller size earthquakes that takes place before a big earthquake are foreshocks. And those after the big earthquake are called after shocks.

Seismic waves-

When the earth shakes, it releases energy in the form of seismic waves which travel inside the earth and also on the surface of the earth.

The study of seismic waves and their records is very important in seismology. They not only help us in assessing the magnitude, intensity and location of the earthquake but also give us information about the interior of earth.

Types of seismic waves

1. Body waves
2. Surface waves

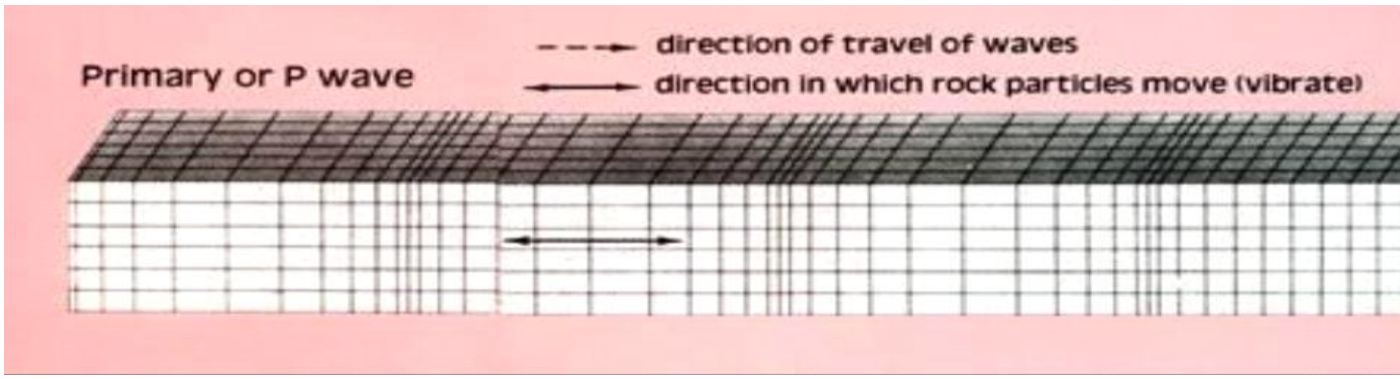
***1. Body waves* –**

The seismic waves which originate inside the earth and travel through the various layers of the earth in all directions are called as body waves. Body waves are of following two types.

1. Primary waves (P-wave)
2. Secondary waves (S-wave)

Primary waves (P waves) –

P-waves moves in a push and pull fashion like sound waves. Thus the material particles undergoes compression (Push) and extension (Pull) as shown in fig. below.



***Properties of P-waves*-**

- These are the fastest seismic wave and thus first to reach at the recording station.

- P-wave can travel through any material be it solid, liquid or gas.
- Their speed depends upon the density and compressibility of the material through which they are passing.
- These are longitudinal waves like sound waves which moves in push and pull fashion.
- P wave make loud thunderous noise near the epicenter.

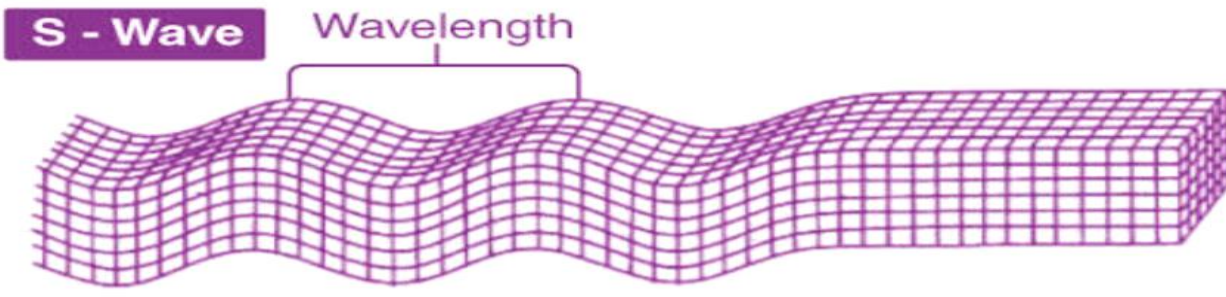
Secondary waves (S waves) –

S-wave are those body waves which propagate by vibrating the material particles at right angles to the direction of propagation.

These waves are transverse in nature like light waves. These are also called as shear waves.

Properties of secondary wave –

- S-wave are slower than P-wave and hence second to reach at the recording station.
- S wave can travel through solids only because liquids and gases do not have shear strength.
- S wave are transverse in nature like light wave.
- The velocity of S wave depends upon the density and shear strength of the material through which they pass.



Surface waves –

The seismic waves which travel along the surface are called as surface waves.

These waves do not propagate deep inside the surface of the earth. These are also called as long wave.

These waves can be visualized as the ripples caused by throwing a rock into water.

These waves are the slowest, thus last to reach the recording station.

Surface waves shakes the ground surface and are responsible for all the damage.

Occurring on the earth's surface.

These are most destructive in nature.

It is also of two type.

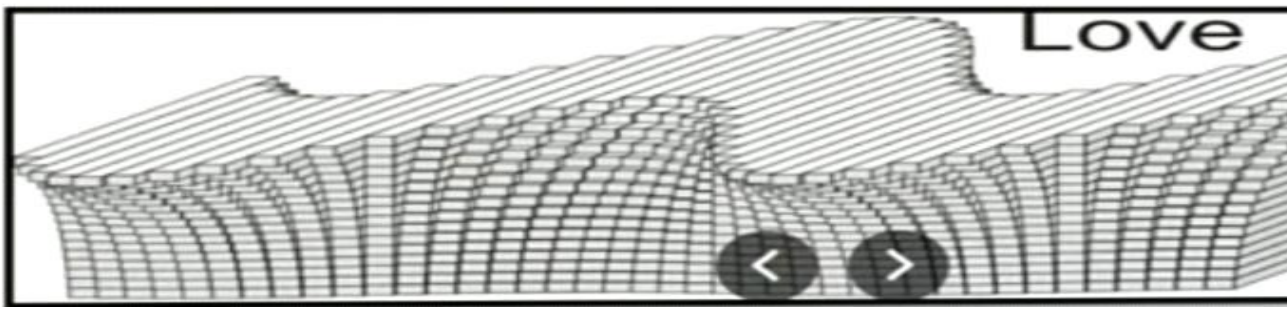
1. Love waves
2. Rayleigh waves

Love waves (L-wave) –

These waves were detected by seismologist A.E.H Love in 1911 and thus are named as Love wave.

Properties of love wave

- Love waves cause surface motion similar to S-waves. But with no vertical component, thus the motion is from side to side in a horizontal plane roughly parallel to the earth's surface
- Love wave travel faster than Rayleigh waves and like S-wave they do not move though liquid or air.
- Love waves along with S-waves cause maximum damage to the structure.

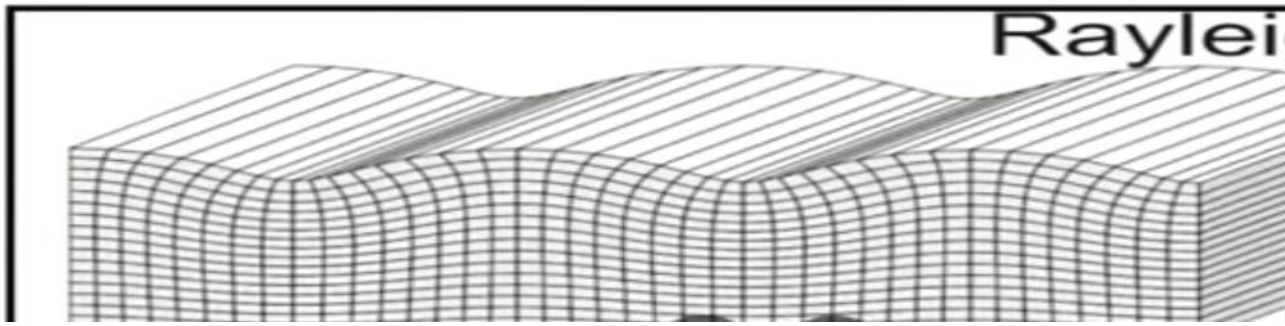


Rayleigh wave-

These waves are first discovered by Rayleigh in 1885. In these waves material particles vibrate in a backward elliptical path in the vertical plane.

Properties of Rayleigh wave

- The shaking produced by Rayleigh waves causes both vertical and horizontal movement.
- They advance in a backward rotation elliptical motion as shown in fig. given below.

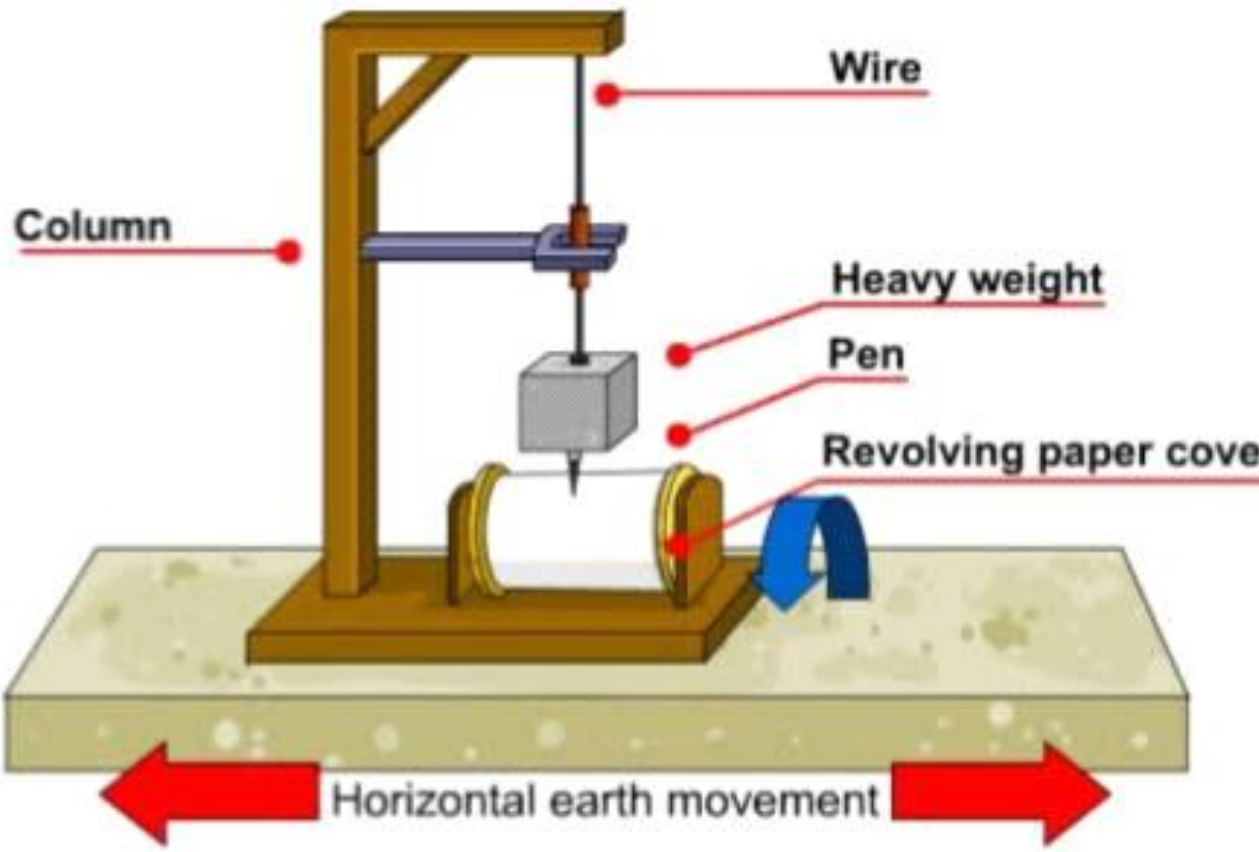


Seismograph –

Shaking of ground on the earth's surface is caused by seismic waves. The Instrument which measure earthquake shaking and record them is called as seismograph.

Parts of a seismograph –

- Sensor
- Recorder

- 

Sensor-

- The sensor is used to sense or detect vibrations. It consists of a pendulum mass, string, magnet and support.

Recorder **–**

- The recorder is used to record the seismic vibrations on a paper. It consists of a drum, pen and chart paper. The chart paper is wrapped on the drum.

Timer –

- The timer is the motor that rotates the drum having chart paper at constant speed.

Working of a Seismograph –

The construction of typical seismograph consists a simple pendulum (a string and mass) is suspended freely but a magnet is tied around the string to dampen the oscillation.

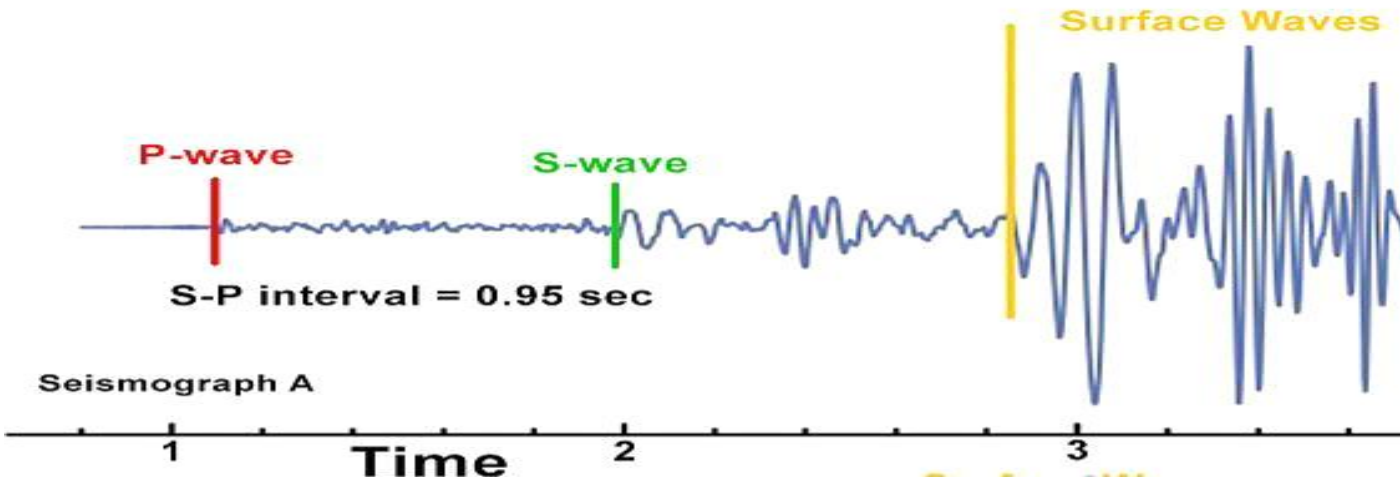
A pen Is attached at the tip of the pendulum which marks the movement or oscillations of the pendulum on the chart paper wrapped the rotation drum.

Whenever there is earthquake the vibrations are produced and the pendulum vibrates Simultaneously thus recording these vibrations on the paper with the pen.

Since the earthquake motion is two dimensional one such instrument is required in earth perpendicular direction to record a both the components of motion.

Seismogram –

The record of an earthquake is called as seismogram. In a seismogram the earthquake waves are recorded in the order, they arrive at the recording station. P- waves being the fastest, recorded first, followed by S-waves and then slowest L- wave.



Using the time the various waves takes to reach the station, the location of the epicenter and hypocenter, focal depth etc. can be determined.

The variation of ground acceleration with time, recorded at a point on ground during earthquake is called an **accelerogram.**

Uses of Seismogram –

- It is used for determining the epicenter of the earthquake.
- These are the records of the earthquakes, thus they are used for obtaining the seismic parameters which are used in design of structure and also for identifying the seismic zones
- Seismogram also help us in studying the seismic waves their nature and propagation which helps in assessing the time and severity of the earthquake.

Earthquake size-

Earthquake size is measure of the qualitative and quantitative effects of the vibrations produced by the earthquake.

Earthquake size is defined in terms of two things.

- Magnitude
- Intensity

Magnitude –

It is a quantitative estimate of the earthquake size. It is a measure of amount of energy released during the earthquake.

The magnitude of an earthquake is generally measured on Richter Scales.

Earthquake classification based on their magnitud

Group	Magnitude
Great	8 and higher
Major	7 – 7.9
Strong	6 – 6.9
Moderate	5 – 5.9
Light	4 – 4.9
Minor	3 – 3.9
Very minor	< 3.0

Intensity-

- It is a qualitative measure of the earthquake. It is a way of measuring or rating the effect of an earthquake at different sites.
- Intensity data are very much useful for the development of seismic risk map of an area or country.
- These map have got various uses like planning safe site for important structure like large dams and nuclear power plants and determination of historic seismicity of an area etc.
- Two scales are commonly used – (Modified Mercalli Intensity – MMI) & MKS scale. Both are similar and range from (1- least severity) to (XII-most sever)

It depends upon

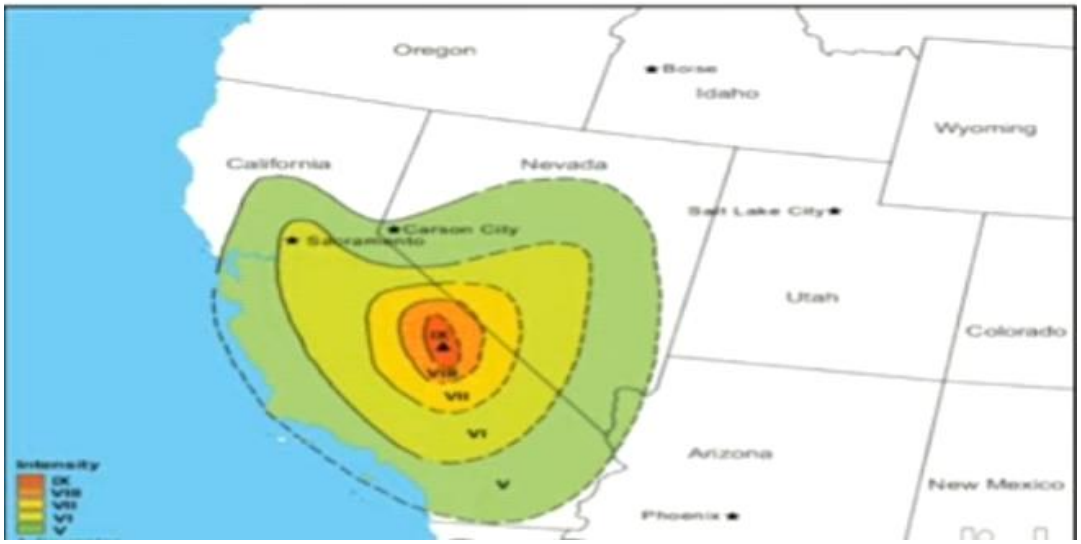
- Earthquake magnitude
- Distance from hypocenter or epicenter
- Type of foundation material
- Building style
- Duration of shaking

Comparison of Magnitude, intensity and Acceleration

Richter magnitude	Mercalli Intensity	Acceleration (% age)
2 and less	I – II	Usually not felt by people < 0.1 –
3	III	Felt indoor by some people, 0.2 –
4	IV – V	Felt by most people, 0.5 – 1.9
5	VI – VII	Felt by all, building damage, 2 –
6	VII – VIII	People scared, moderate damage , 1
7	IX – X	Major damage , 20 – 99.9
8 and up	XI - XII	Damage nearly total over 100

Isoseismal –

An imaginary contour line joining place of equal earthquake intensity is called as isoseismal and a map showing different isoseismal for a particular earthquake is called as and isoseismal map.



Classification of earthquakes

- Based of location
- Based on focal depth
- Based on their cause
- Based on their magnitude
- Based on the epicentral distance

Based on location –

- On the basis of location of occurrence of earthquake they are classified as

a. Interplate earthquake

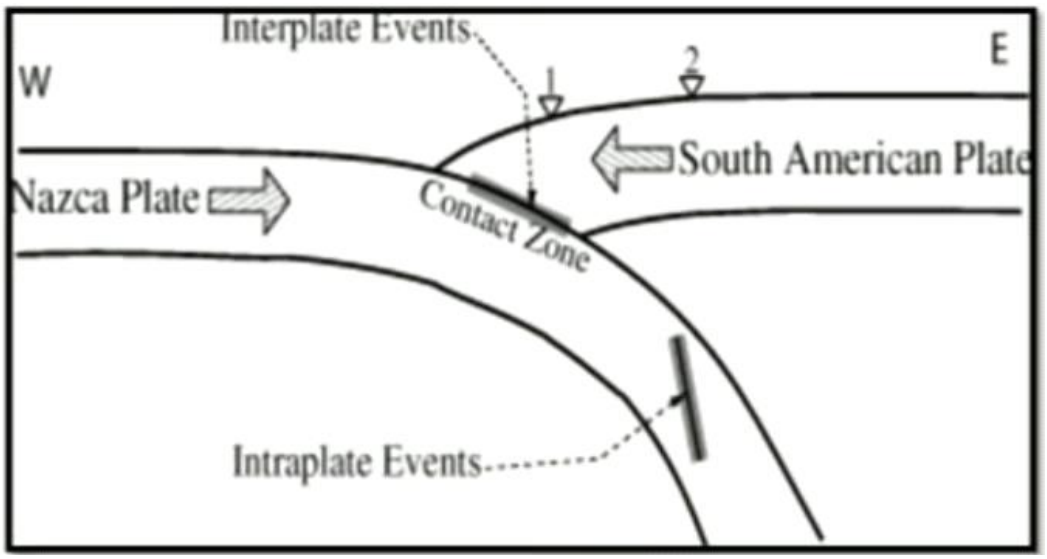
b. Intraplate earthquake

Interplate earthquake –

Most earthquakes in the world occur along the boundaries of the tectonic plates and are called interplate earthquake. It is seen that epicenter of about 99% of earthquakes are in the narrow zones of interplate boundaries.

Intraplate earthquake –

The earthquakes occurring within a plate itself away form the plate boundaries are called as intraplate earthquake



Based on focal depth –

The earthquake are classified into following three types based on focal depth

1. Shallow earthquake
2. Intermediate earthquake
3. Deep earthquake

Shallow earthquake –

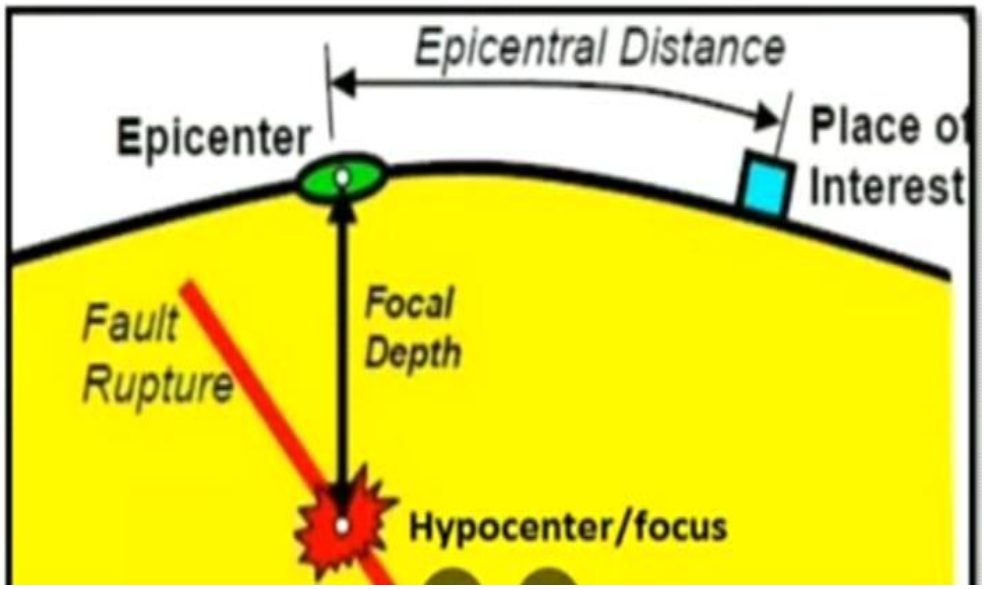
The earthquake whose focal depth is less than 70 km and called as shallow depth earthquake. Nearly 80% of earthquake are shallow, and are of great concern of civil engineers.

Intermediate earthquake –

Those earthquake in which focal depth is form 70 to 300 km are called as intermediate earthquake.

Deep earthquake –

The earthquake whose focal depth is greater than 300 km is called as deep earthquake.



Based on their cause –

The earthquake are classified into following two types on their cause of origin

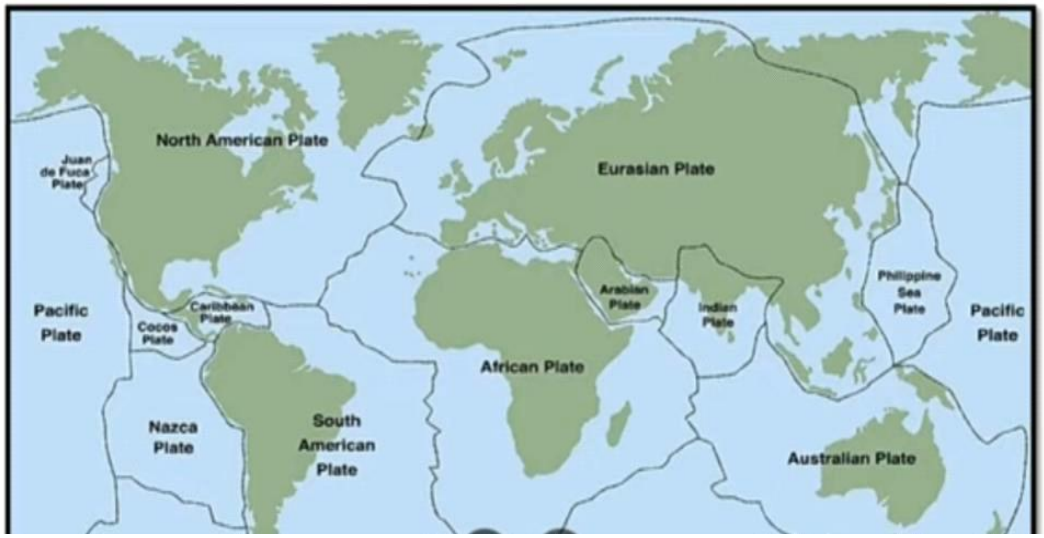
- Non tectonic earthquake
- Tectonic earthquake

Non tectonic earthquake-

The earthquake which are caused due to non tectonic reason like volcanic activities and man made reasons are called as non tectonic earthquake.

Tectonic earthquake –

The earthquakes which are of tectonic origin and are caused due to sudden slip in the fault of the tectonic plate of the earth are called as tectonic earthquake.



Based on Magnitude of earthquake –

The earthquake are classified as given below on the basis of their magnitude.

Type	Magnitude
Great EQ	8 and higher
Major EQ	7 – 7.9
Strong EQ	6 – 6.9
Moderate EQ	5 – 5.9
Light EQ	4 – 4.9
Minor EQ	3 – 3.9
Micro EQ	< 3.0

Based on epicentral distance –

On the basis of epicentral distance (affected area) the earthquake are classified

Into following three types

1. Local earthquake

2. Regional earthquake

3. Teleseismic earthquake

Local earthquake –

The affected area is very less within 500 km of the epicenter of the earthquake

Regional earthquake –

The affected area due to the earthquake is with in 500 km to 1000 km of the epicenter of earthquake

The affected area is greater than 1000 km of the epicenter of the earthquake.

Seismic zoning –

The seismicity or earthquake activity at a place is assessed by its distance form the fault rocks, and from the past records.

It varies in different parts of a country or region. It is seen from the past records that earthquake activity are more or less same in a particular are or zone.

Therefore a country can be divided into zones of similar seismic activity.

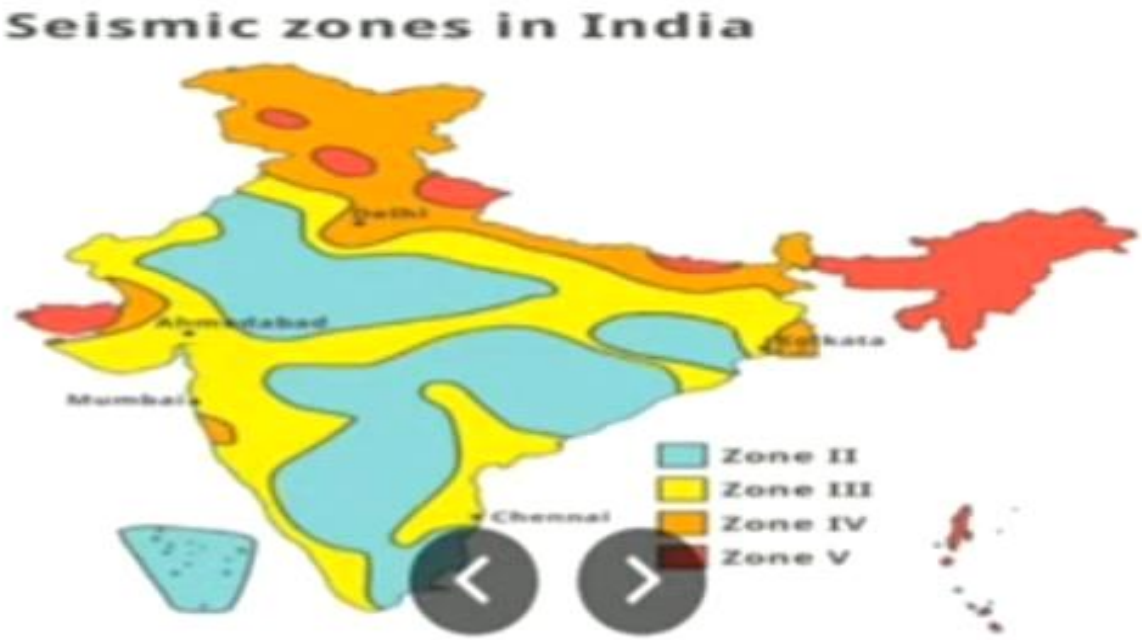
Seismic zoning can be defined as dividing a country or region into smaller zones on the basis of their seismicity or earthquake activity.

It depends upon the following

- The seismic history of a region. It means the detail study of the earthquake that have occurred in past, their characteristics like magnitude, intensity and extent of damage etc.
- The tectonic features of the plate which could cause an earthquake in future.

Seismic zones of India –

The different geology at different location in the country implies that the possibility of damaging earthquakes takes place at different locations is different. Thus a seismic zone map is required to identify these region. Based on the levels of intensity during past earthquakes the 1970 zone map divided India into five zones (I, II, III, IV & V) The map has been revised lastly in 2002 and it has holy for seismic zone – (II, III, IV & V)



Loads

Loads coming on the structures are basically of two types

- Static load
- .Dynamic load

Static load -

These are those loads which are not changing with time. For example dead loads, imposed loads of furniture, surface finishing, snow load etc. The live loads of people and erection loads are also considered as static while analyzing structures.

Dynamic loads –

The loads which vary or changes with time are called as dynamic loads.

For example wind load, moving loads, machine vibrations, impact and blast loads etc. are dynamic loads.

Dynamic loads are also of two types -

Periodic Loads -

These loads are caused due to periodic nature of vibrations which means the motion repeats itself after equal interval of time.

Rotating machine parts, vibration of pipeline structures caused by steady flow are some example of periodic loads

Non-Periodic or Random loads -

The dynamic loads which don't follow any particular pattern over a period of time

Are called as non-periodic or random loads.

Examples earthquake loads, blast induced loads

In general most of the civil engineering structures are analyzed by assuming that the applied loads are static.

- The structure is rarely subjected to dynamic loads
- The dynamic analysis is very complicated and time consuming

But this tendency of ignoring the dynamic loads may result in disaster some time. Thus they should be taken into account properly while analyzing and designing the structures

Fundamental natural period –

Let us study the behavior of a building during earthquake shaking.

When the ground shakes, the base of a building moves with the ground and the building also vibrates backward and forward (oscillations).

The time taken in seconds for completing one cycle of oscillations is called Fundamental natural period (T) of the building.

The value of (T) depends on the following

1. Building flexibility

2. Mass

Building Flexibility-

If the building is flexible then movement is larger that means the time taken for completing one cycle of oscillation will be more and hence fundamental natural period will be higher.

Mass –

If the mass is more then longer is fundamental natural period (T). In general taller buildings are more flexible and have larger mass and therefore a larger fundamental period. On the other hand low to medium rise building have smaller (T).

On the basis of T building may be classified as

- Rigid Building – (T < 0.3 seconds)
- Semi rigid building-(0.3 s<T<1.0 s)
- Flexible building – (T >1.0 s)

CHAPTER -2

CONTENT.....

Traditionally build construction in india

- **In india, masonry construction are generally done by using locally available material**

- **Stone , Brick, Timber ,Mud, Concrete blocks**
- **this materials are along with different type of motar**
- **in india, lime mud, cement, and send are generallyt used in fixed proportions as motar**
- **the topography of the area and the locally available material.**

Behaviour of masonry construction during earthquake

- A masonry building has three basic components

1.Roof -

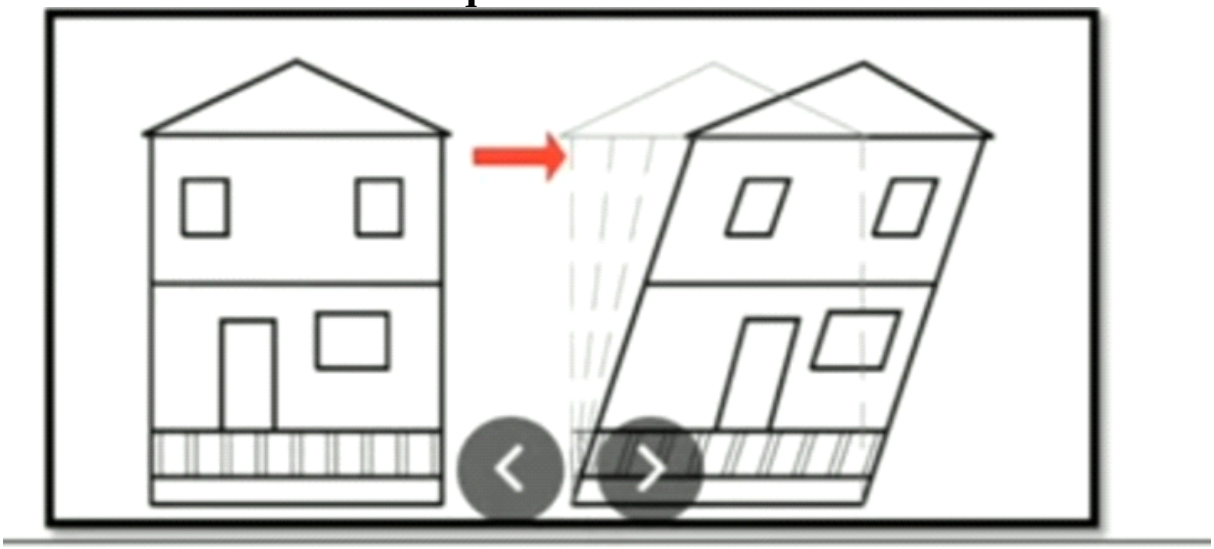
- Mosonry building generally have heavy roof which results in the higher earth quick force

2. Walls-

- These are mostely load bearning. the walls transfer the vertical load intertial force from the roof to the foundation.

3. foundation -

- **It is the part below the ground level whichj transmit all the force to soil safely**
- **During an earth quake the groung shakes in all three diraction but hoprizantal vibrations are the most damaging to masonry building**
- **These horizontal vibration result in large horizontal inertia force.**
- **these horizontal force are transferred to the wall or colums form the roof and then to the foundation and finally to the soil.**
- **the inertia force act opposite to the direction of earthquake motion and are resersible in nature .**
- **thus at any instant some wallm of the building are pallel and some walls are transverse to the direction of ground motion caused due to earthqake .**



Failure Mechanism of masonry building

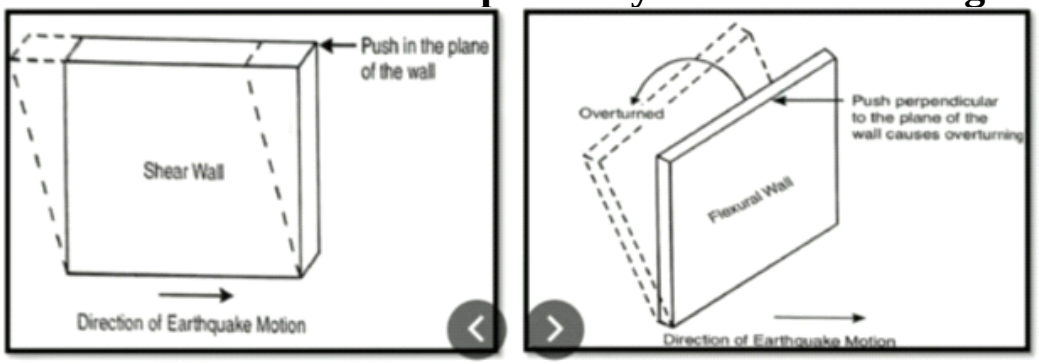
- **A masonry building can fail in various ways under the action of earthquice force.**

1 Out of plane failure
2 In plane failure
3 Diaplhragm failure
5 Failure due to openings in the wall
6 Pounding

7 Non - structural compoinent failure

Out of plane failure

- **Let us again consider the wall as shown in fig below**
- **the wall is transverse to the direction of earthquake motion.**
- **Thus force tend to overturn or bend the wall as shown in fig. below.**
- **the wall has very less resistance in this direction duo to small depth .**
- **Thus the wall will collapse easily due to overtuning**



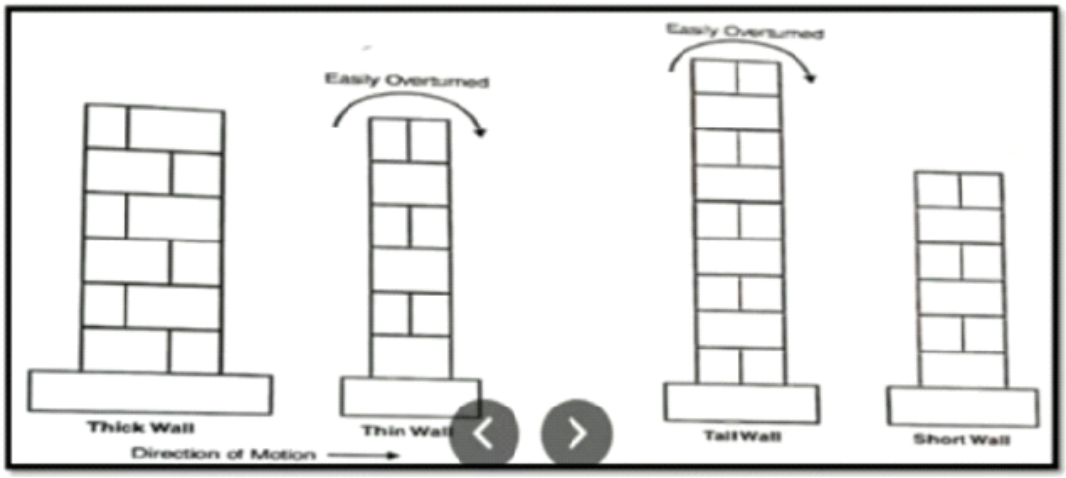
- **Masonry is very weak in tension and hence it cracks .**
- **this cracking can lead to full or partial collapse of the wall .**
- **this type of failure is called as out of plane failure .**

this type of failure features.....

- **vertical crack in the corner of walls and at T- junction**
- **cracks at inlet and top of pires**
- **crack at the level roof**

- **peeling of masonary**
- **collapse of the external wall**

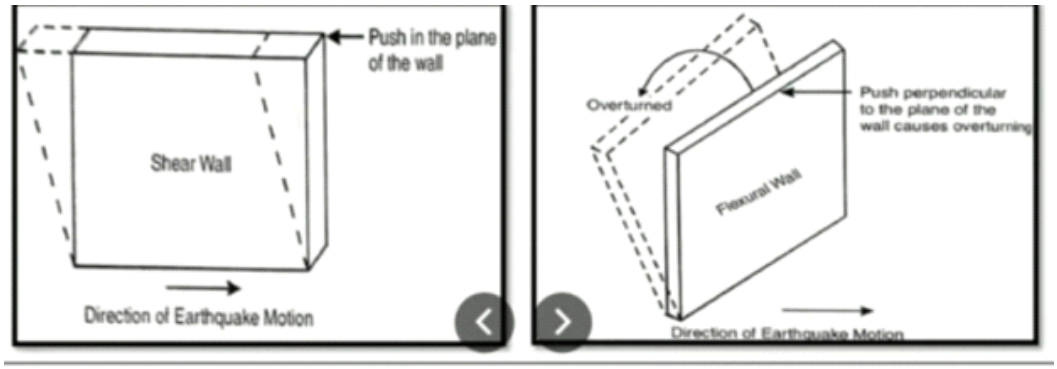
- **The tenden of the walls to overturn when pushed in the perpendicular direction is inscreased with the length of the wall .**
- **Long unsupported lengh means easier collapse .**
- **similarly tall and slender walls are easily overtuned during earthquicke motion.**
- **thus the tendency of a wall to overtune can be reduced by limiting its lenght to thickness and hight to thickness ratio.**



In plane failure.....

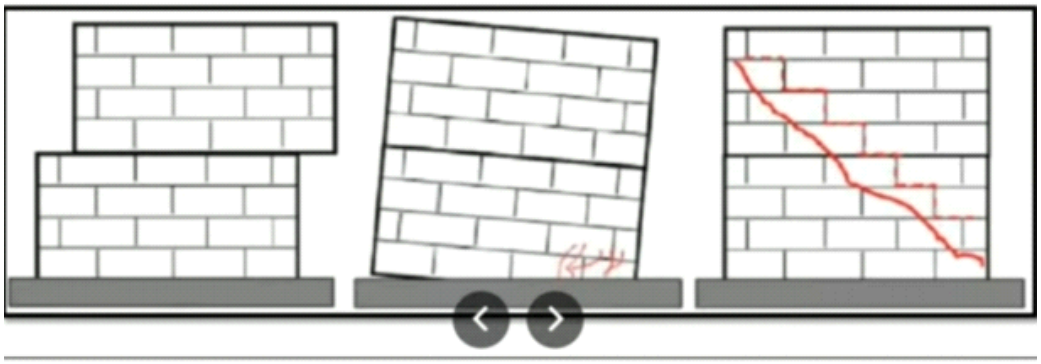
- **let us consider the wall as shown in fig**

- **this walls is subjected to ground motion in its plane**
- **thus it is subjected to inertia force which cause shear and bending in the wall**
- **this wall offers good resistance because of large depth in the of the building**
- **the damage is more if the wall is long and slender**



The other features of in plane failure are following .....

- **Digonal tension cracks in short pires between opening**
- **vertical cracks at walls intersecttions**
- **curing of corners**
- **separation and expuision of the corner of two walls .**



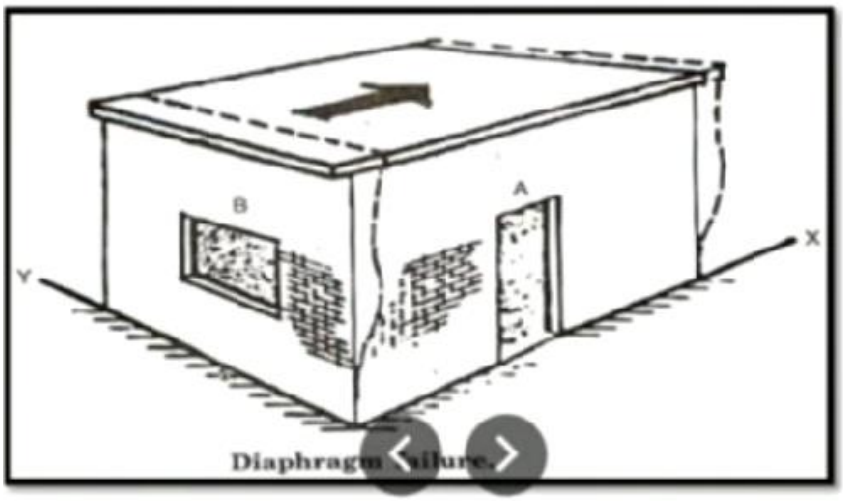
connection failure.....

- **now consider the wall A and B together as shown**
- **for the given direction of earthquicke shaking**
- **walls A act as shear and wall B act as flexural wall**

- **wall B are subjected to overturing and wall A are subjected to shear and bending in plane of wall .**
- **if the wall are tied together properly to shear and bending then they act like a box**
- **thus the box action provides greather resistance to the horizantal loads**
- **But if the walls are not tied together properly then walls B wilol overtune and may cause collapse of the building as whole.**
- 

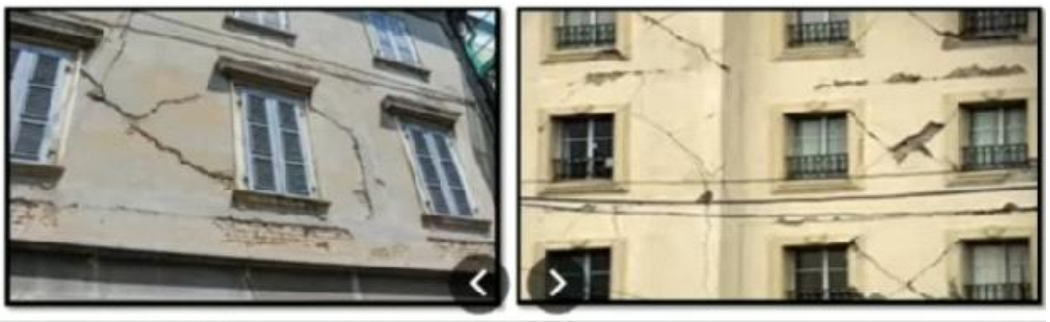
Diaphragm failure .....

- **Consiuder a building with roof and the walls subjected to earthquicke**
- **the roof is subjected to earthquicke force**
- **the roof slab will transfer the earthquick force to the wall causing nshearing and bending in the horizontal plane**
- **this action is called as diaphragm action**
- **Due to earthquick force the failure cracks develop near the corners of the wall and may lead to separation of the walls and in turn collapse of the building**



Failure due to opening in wall.....

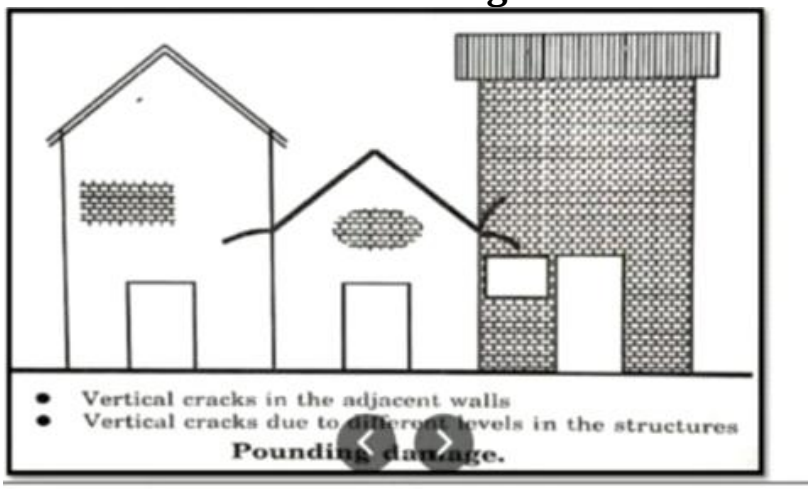
- **Openings are necessary in a building but he location and size of the openings in walls affects the performance of masonry building in earthquicke**
- **Openings obstruct the flow of forces form one wall to another**
- **The large openings in shear wall reduce the strength of wall against the inertial force**
- **this type of failure resulting in diagonal cracks in the area of masonry between opening and cracks at the levels of opening also**
- **thus it is best to keep all opening small and away form the corners**



Pounding.....

- **when the roofs of two adjacent building are at different then during earthquake the brickwork faces hit against eath other this is called as pounding**

- **it results into cracking of the wall**



Non structural components failure

- Non structural failure is that due to which strengh and stability of building is not affected
- such damage occurs generally under moderate earthquakes

Some non structural component failure are.....

- **Falling of plaster from walls and ceiling**
- **cracking and overtuneing of masonry parapets , rood chimneys and balconies**
- **cracking of glass panes**
- **Falling of loosely place objects , overtuning of cupboardas etc.**

CHAPUTER - 3

Special techniques in seismic desigh of structure

- **Decoupling system**
- **Sliding system**
- **seismic dampers**

New technicques in seismic resistant design

- In order to minimize structural damage and to control structural response, the dynamic interaction between tha earthquake ground motion and the structure cab be modified.

Tha control is based on the following two approaches.

1.Modification of dynamic characteristics of the structures

2.Modification of tha energy absorption capacity of the structures

Devices for seismic control-

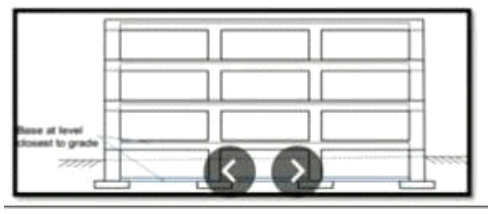
- For this purpose following two types of devices may be adopted

A. Either to prevent an earthquake force from acting on a structure.This type of device is known as base isolators

B.To absorb a part of the seismic enargy.This type of device is known as dampers

Base isolation

- Base isolation provide a means of limiting seismic effects entering into the buildings
- In seismic isolation a gap is created in the fundamental period of vibration of the structure or building and the predominat period of the earhquake induced ground motion,i.e. they shouid not coincide.
- The main feature of the base isolation technology is to introduce flexibility in the building
- The base isolators have been found most effective for low rise to medium rise building located on hard ground with large mass.
- It has not been found suitable for use in a high rise building due ot large overturning moment . However base isolation technology is costly and complex.

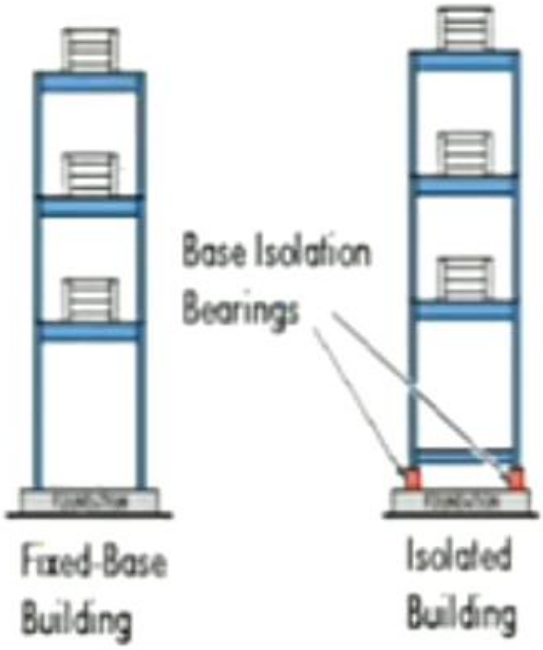


Need for base isolation -

1. When the building is to be located in highiy seismic activity prone areas.
2. It is essential service buildings as hospital,water tank etc. which are essential to be operational even after the earthquake
3. In the construction of precast ormasonry construction.
4. To minimise the damage to primary and secondary structural members
5. To minimise the cost of repair and strengthening structures after the earthquake.

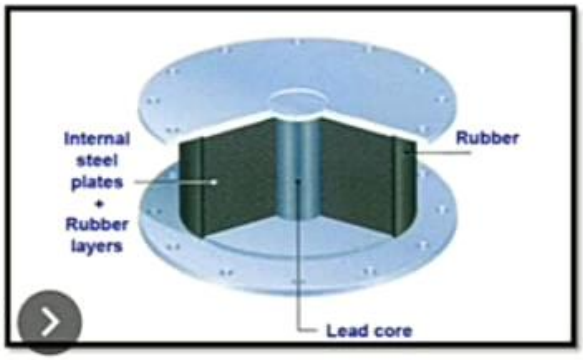
Types of seismic base isolation system -

1. Decoupling system
2. sliding system

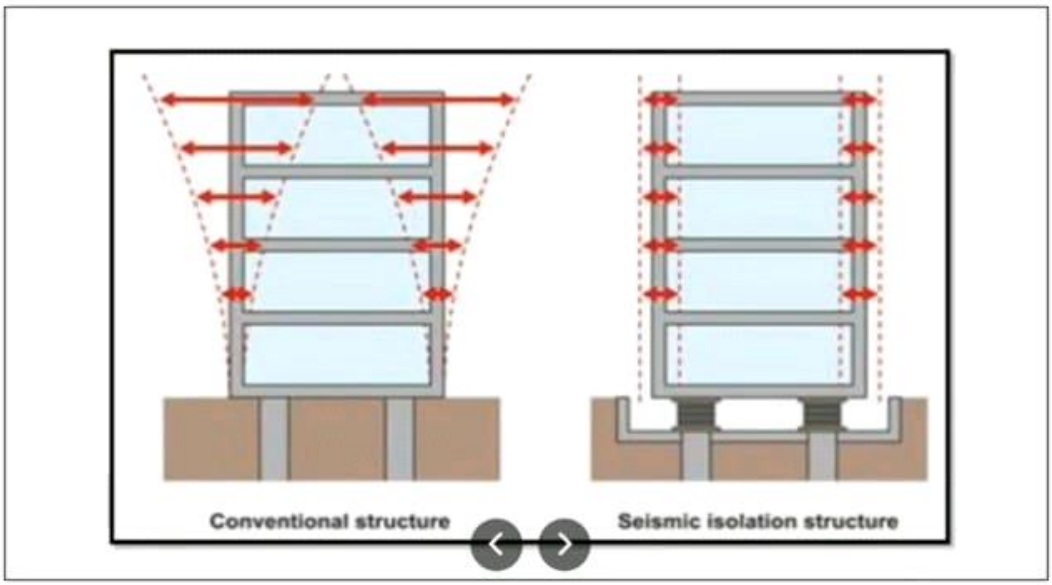


Decoupling system -

- This is the most wildely adopted system . In this approach the building or the structure is decoupled from the horizontal component of the seismic ground motion by interposing a layer with low horizontal stiffness between the structure and its foundation .
- The most widely used base isolator are made of laminated rubber pads similar to the bridge bearings.
- These pade are consisted of thin layers of natural rubber that are vunlcanized and bonded to steel plates.


Internal
steel
plates
+
Rubber
layers
Rubber
Lead core


ISOLATION SYSTEMS

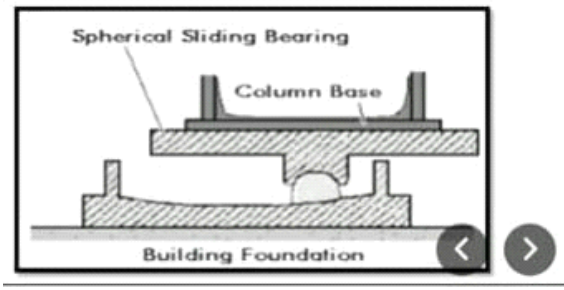


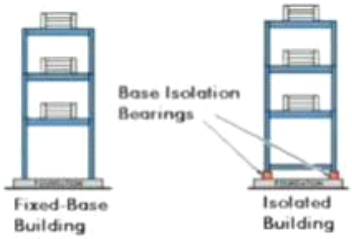
Properties of isolation system -

1. The isolation system should be strong enough to support the structure.
2. It should be able toprovvide additional horizontal fiexibility and dissipation of energy.
3. Under the maximum wind load this isolation system should have adequate stiffness.
4. When subjected to earthquake forces it should yield slightly greater than maximum wind load.

Sliding isolators -

- Sliding isolators are also known as friction pendulum system. This system has been devloped on the principle of pendulum .
- In such a device an upper rotating ball or an articulated slider (articulated means a body composed of seral parts) moves on aconcave surface as shown in fig.
- It has been found that all type of base isolators are not useful for all types of struture .hence a careful study should be made to select the suitable base isolator for a structure .



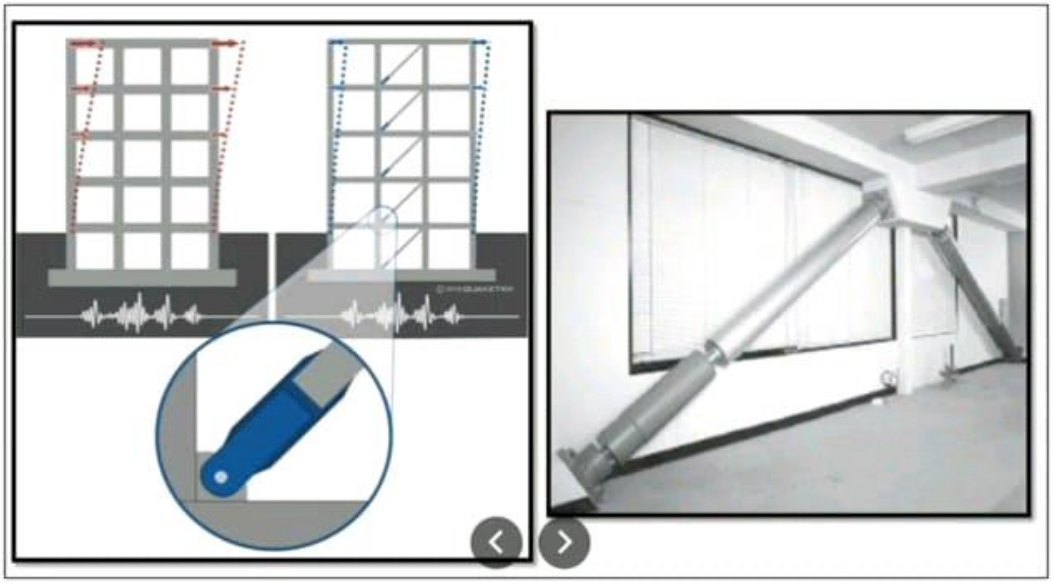


Seismic dampers -

- The artificial device introduced in structures to improve their seismic performance and to control sesmic damage is called dampers .
- The dampers are installed in place of structural element such as diagonal bracing .
- These dampers absorb seismic energy during an earthquake .These dampers are not use to support the structures.

Types of dampers -

1. Hydraulic dampers.
2. Friction dampers.
3. Yielding dampers.
4. Metallic dampers.
5. Steel damper.



Chapter-4

* Strengthening and Retrofitting techniques of Traditionally built construction*

1. Grouting
2. Geniting
3. Shotcrete
4. Splint and bandages
5. Confined brick masonry
6. Prestressing
7. Jacketing
8. Use of FRP

*Introduction-

Till to date, earthquakes are one of the most unpredictable and devastating natureal disaster

which cause extensive damage to the building / structures.
This damage results in loss of lives and property. Thus, it is very important on the part of civil engineers to build structures with high seismic performance.

Two types of building need to be retrofitted –

1. Earthquake damaged building -

- The buildings which are damaged or weakened by the earthquakes thus making them unfit or unsafe for future use.

2. Weak building- Building which have not experienced severe earthquake but are seismically weak and are vulnerable to earthquake.

- Various codes and standards are published by Bureau of Indian Standards to help the structural engineers in this field.
- This chapter explains various strengthening and retrofitting methods used for traditionally built buildings and RCC buildings.

Need of Retrofitting -

- As discussed above the need of retrofitting and strengthening is to increase the available seismic resistance of the weak/old or earthquake damaged buildings.

- In addition to this retrofitting of a building is also required to be done in the following cases.

1. Up gradation of a code –

- As the experience of the civil/structural engineers in increasing codes/standards are also bring upgraded from time to time.
- Thus the building designed by the code, which has been revised need to be retrofitted to fulfill the latest codal provisions.

2.Change in use of buildings -

- Whenever there are changes in the use/occupancy of a building, for example public building converted to an industrial building or residential building to office building etc. there is a need to retrofit or strengthen the building to satisfy the codal provision as per the present class of the building.

3. Important buildings -

- Important buildings such as hospitals, schools, historical monuments, etc. need to be strengthen and restored form time to time to counter the effects of aging and weathering.

4. Retrofitting and strengthening -

- It is also needed in the case of extension or expansion of the building.

Note-

- The relative cost of retrofitting to construction determines what is to be done if the cost of retrofitting is less than 50% of the reconstruction cost these retrofitting is done.

Retrofitting of buildings -

- Various methods /techniques are used for retrofitting of buildings. These method are broadly classified into two types

1. Local retrofit method

2. Global retrofit method

1. Local Retrofit methods -

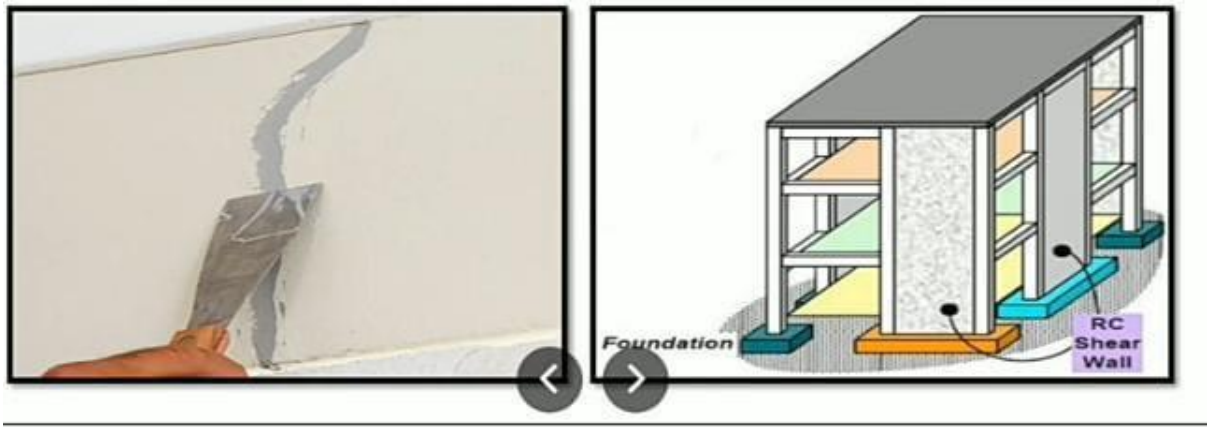
- These are the most commonly used methods which results into the up gradation of the individual member/elements of a building which are seismically weak.
- These are economical as compared to global retrofit methods.

- These retrofitting methods do not lead to any change in the design or geometry of the building

- **For example** - Repair of cracks in a wall, jacketing of beams or columns etc.

2. Global Retrofit method -

- These methods aim to increasing the seismic resistance of the structure as a whole in terms of stiffness, strength and ductility.
- These are costly methods and may results in change in the geometry of the building.
- For example - adding new elements to the building like shear wall, infill wall, column etc.



Retrofitting of traditionally build constructions -

- Bureau of Indian Standards has published IS 13935: 1993 code for repair and seismic strengthening of masonry building which includes various guidelines and methods regarding retrofitting and strengthening measures for a masonry building some conventional method of retrofitting of brick

and stone masonry construction are explained here with their suitability conditions.

Grouting -

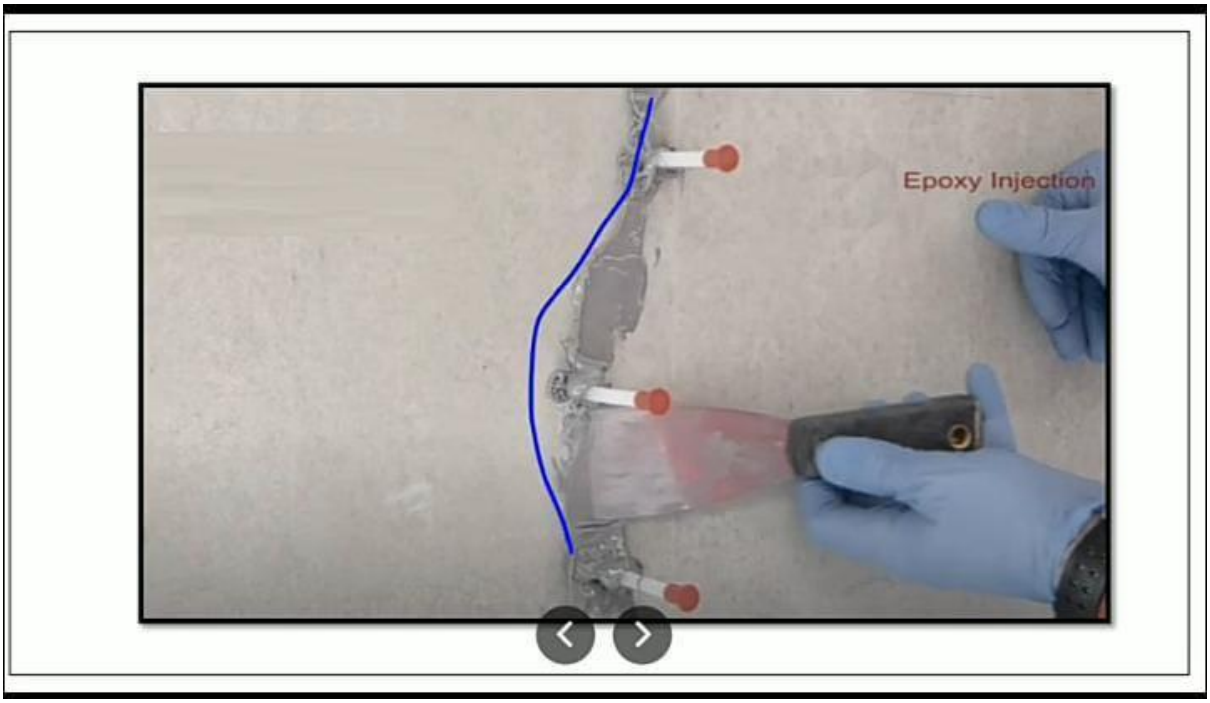
- Repairing of cracks is an important feature of retrofitting/strengthening. All types

of cracks must be repaired as they tend to masonry.

- It consists of pressure injection of epoxy or cement mortar into the crack

Cracks up to 1 mm width…… epoxy injection under pressure

Cracks up to 5 mm width……..Cement mortar with epoxy (reinforcement along with the wire mash)



THE STEPWISE PROCEDURE FOR GROUTING IS AS FOLLOW-

- Plastic injection parts are placed along the cracks on both sides of the member at suitable spacing.
- Port should be secured in place with some sealant. After the sealant has set, a pressure injection of epoxy resin or cement grout is applied at the bottom of the crack, if it is a vertical crack and at one end of crack, if it is a horizontal crack.
- The process of injecting grout is done till the epoxy or cement grout penetrates into the crack fully and is seen flowing form opposite side of the member.

Guniting-

- For cracks wider than 5 mm or for area where the masonry or concrete has crushed, the process of repair is slightly different, and is called as guniting.
- Guniting is application of expansive cement mortar or quick setting mortar or epoxy cement mortar, pneumatically on the surface of the masonry in the form of slab.

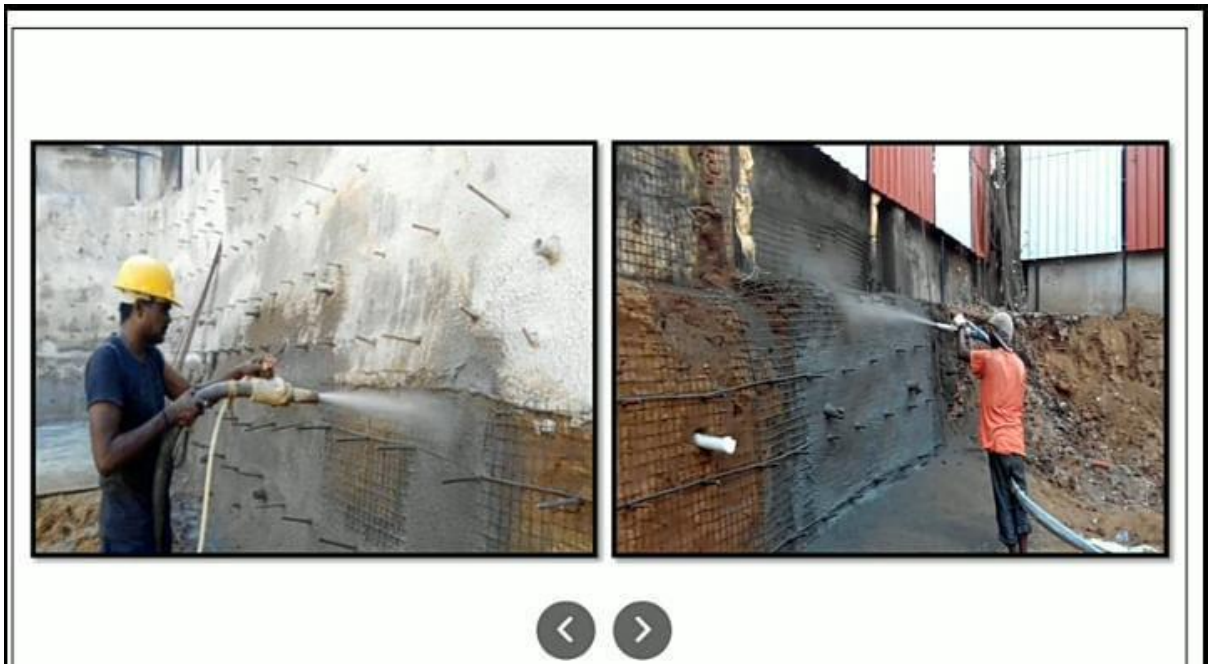
- It may be done on both sides of the wall, if necessary. The thickness of granite layer is 8-10 cm

The stepwise procedure for guniting is as follow.

1. Remove all loose material and prepare the surface by making it rough and wet.

2. Apply gunit (expensive cement mortar or quick setting cement etc.) under pressure on the prepared surface.

3.In the case of crushed walls, which need to be strengthened reinforcement in the form of wire mash is placed on the damaged / cracked surface and nailed / bolted properly to the wall, then it is covered by mortar to give strength and protections eh reinforcement.

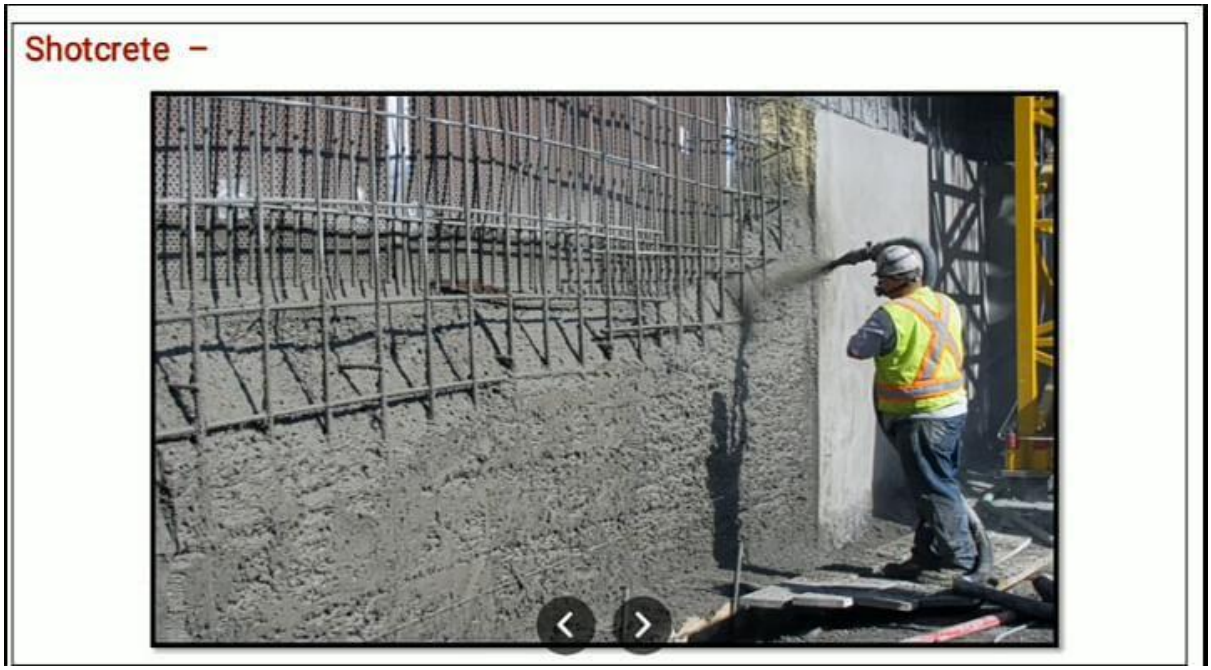


Insetion of through/bond stones (stone masonry)-

- Stone masonry houses have very thick wall which tend to bulge and separate into layers. For such wall, through stones of length equal to thickness of wall are inserted at regular intervals into the wall along the vertical as well as horizontal direction.

- These stones are fixed with cement and mortar.

- In the care of bulged wall the affected portion of the wall is removed reconstructed and voids are filled with cement grout.



Shotcrete-

- It is a very important technique to strengthen the load bearing masonry are weak or damaged.

- Shotcrete is cement mortar or cement concrete mortar (coarse aggregate size should be less than 10 mm) conveyed through a hose pipe and pneumatically applied to a prepared concrete or masonry surface under high velocity.

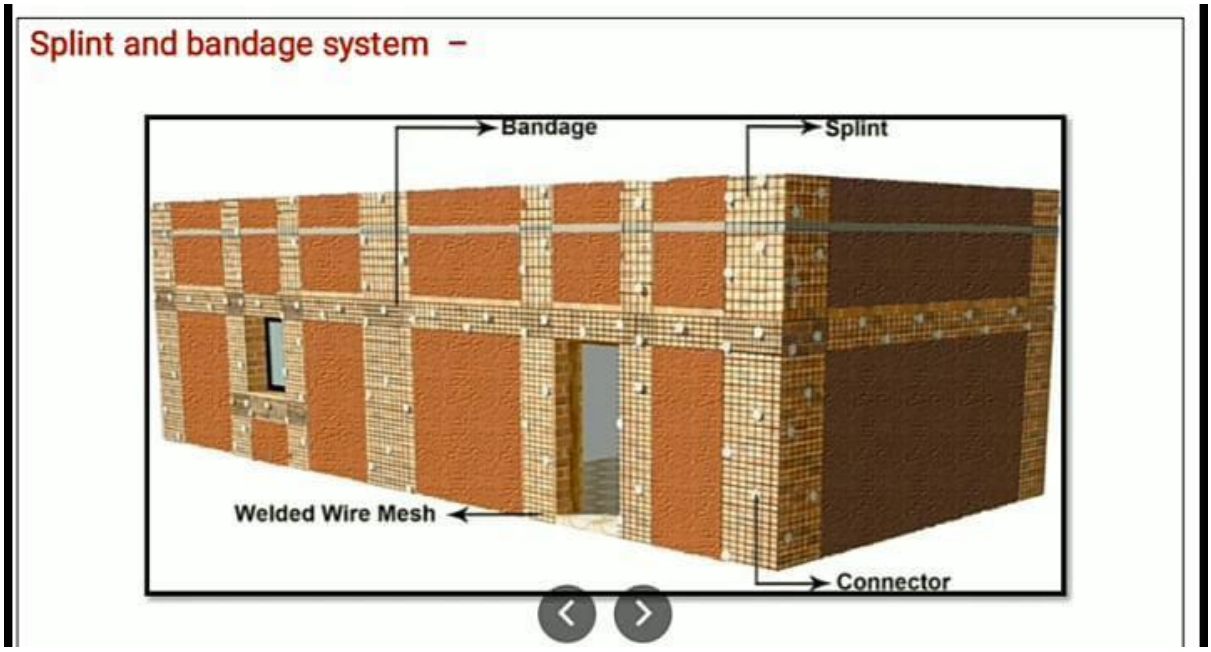
  The stepwise procedure for shotcrete is as follows-

1. Clean the surface and remove all loose material

2. Wet the surface properly and make it rough for bonding. If required epoxy material for adhesion. , apply suitable

3. Apply shotcrete very carefully so that it form a homogenous layers and the appearance of building is not altered

4. Proper curing time is given to avoid shrinkage and cracking
5. In case of damaged masonry wall reinforcement is also put before strengthen the masonry.



Splint and bandage system-

- It is a very common method of strengthening the masonry buildings. It is done by providing vertical and horizontal reinforcement (wire mash) on both outer and inner surface at critical section of the buildings.

- The horizontal bands are called as bandage and the vertical steel is called as splint.

Advantages of this system are following-

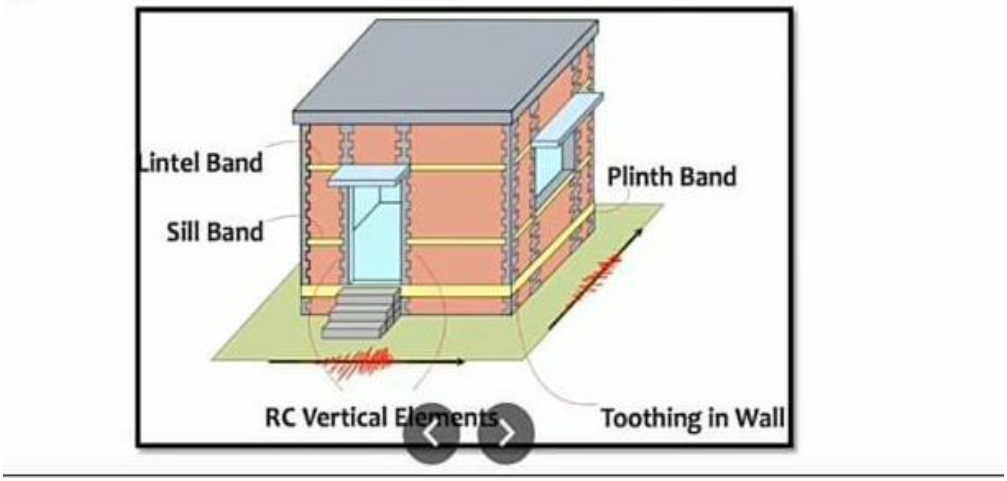
1. The reinforcement provides additional strength to the masonry

2.Ductility is increased

3. This system binds the masonry element together so that the act as one unit and box action is achieved.

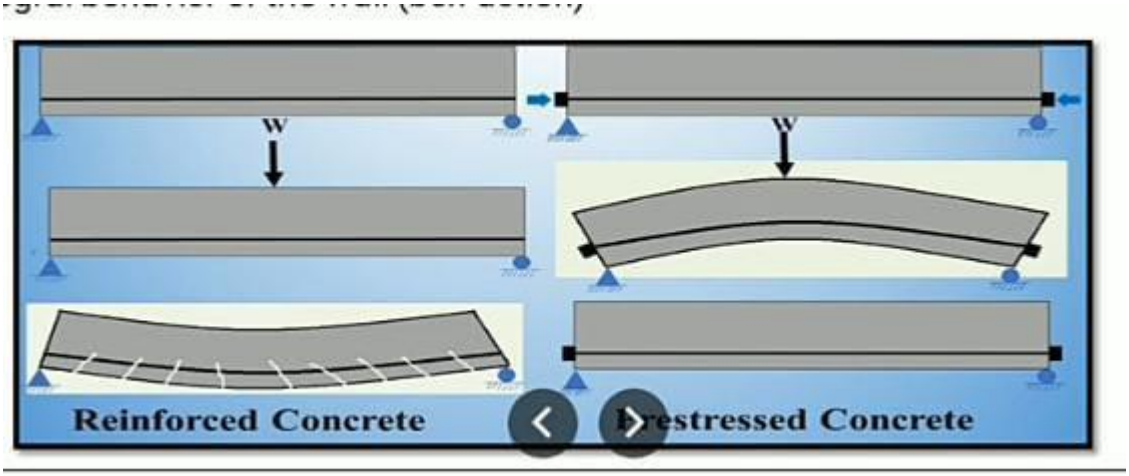
Confining the masonry-

- In order to increase the structural integrity, reinforcement concrete elements (columns) may be inserted, around the wall panels or in the middle of the wall.
- This will not only make the masonry confined but also increase the ductility and the strength.



Prestressing -

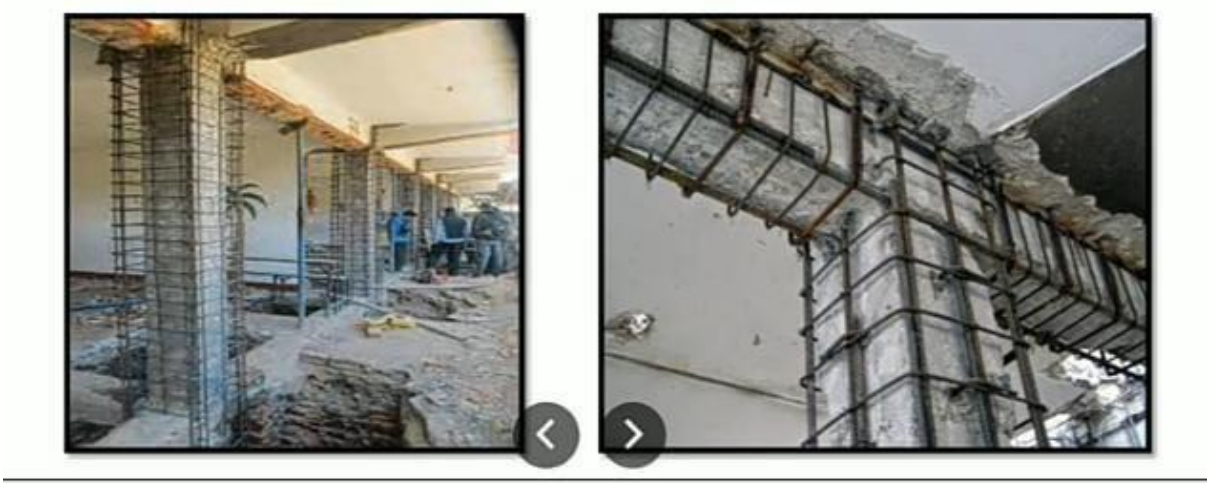
- It is a technique by which internal stresses of suitable magnitude are induced in the structure so the stresses form the external loads are counteracted to desired degree prestressing is used for strengthening and retrofitting of seismically weak and damaged walls.
- Prestressing not only increase the strength of the wall but also help in achieving integral behavior of the wall (box-action)



Retrofitting of R.C.C. building -

1. Local Retrofitting methods -

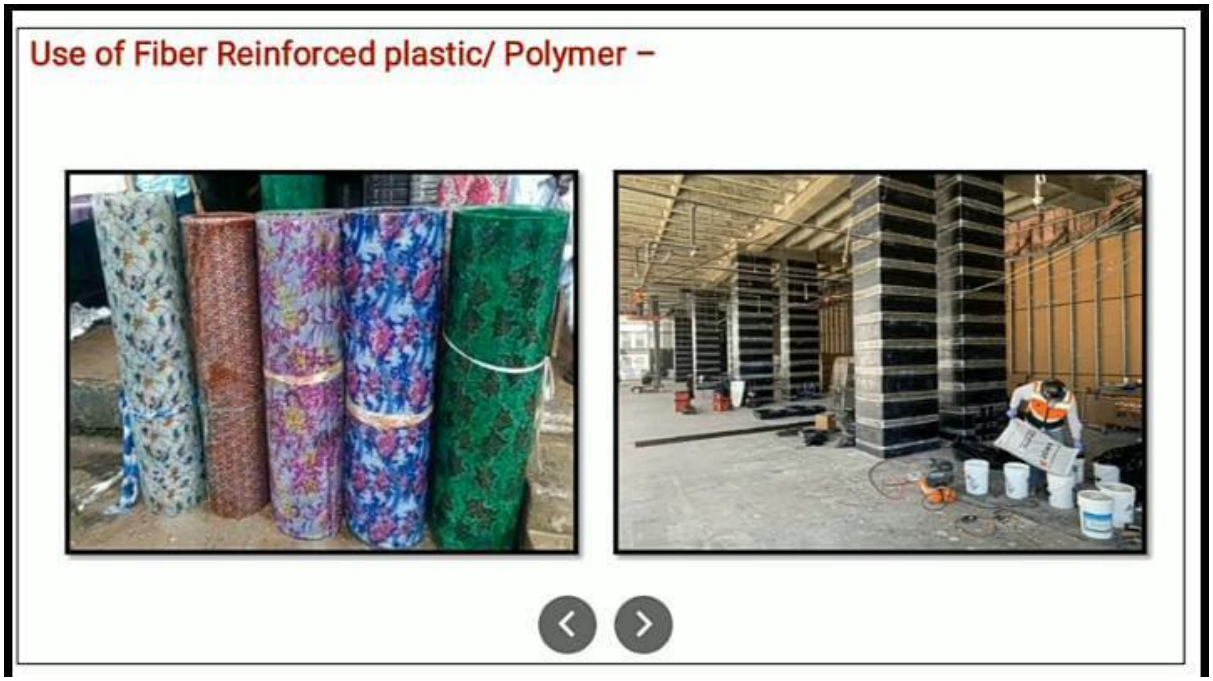
- Various types of local retrofitting method are used for enhancing the strength of the individual element of RCC building (beam, column etc.)



Jacketing –

- It is the most commonly used technique for strengthening column and beams in a weak, old or damaged RCC building.
- Jacketing results in increased moment resisting capacity of the member due to additional steel reinforcement.
- For strengthening column an additional area of longitudinal street and lateral reinforcement is provided all around the existed column and concrete is poured in to cover it properly.
- Jacketing of RCC beam can be done by providing extra reinforcement and covering it by proper thickness of concrete cover.

- Seismically weak columns are also strengthened by jacketing it with steel plates. In this method steel plates are glued to the existing column by epoxy material and by anchor bolts.



Use of Fiber Reinforced plastic/ Polymer –

- Use of fiber reinforced plastic sheets is very popular now a days.

- These are used for strengthening beams, columns and slabs. For strengthening column FRP sheets are glued on to the concrete all around using epoxy resin.

For beams the FRP sheets are used as follow

a. For strengthening of the tension zone by gluing FRP sheet to the tension face.

b. For strengthening against the shear by gluing FRP sheet on the vertical side of the beam near the supports.

- Before sticking FRP sheets the cracks should be repaired with epoxy resin.

- Cement plaster or shortcrete can be done over FRP sheets to protect them form weathering.

Replacing the Damaged/worn out Steel –

- In the case of very old or damaged beams and columns sometimes the reinforcement is worn out buckled or damaged such that it does not serve its purpose.

- In these case the concrete cover is removed from the affected portion out or buckled steel is removed.

- New steel reinforcement is placed and welded properly to the old steel and cover is provided by high strength cement grout.

Global retrofit method -

- These methods result in the overall increase in the seismic resistance of the structure.

- These are costly methods as compared to local method and generally cause change in the design/geometry of the structure.

- Most common method under this category are discussed below .

Adding shear walls/infill wall/Bracing-

a. Shear wall are used for increasing the lateral strength of RCC building. Thus addition of new shear wall is the best and simple method for improving the seismic performance of a building the new shear wall should be placed in a symmetrical manner.

b. Infill wall are also used with proper anchorage to the frame as a retrofitting technique for improving strength of the building.

c. Steel bracing may be used for increasing strength and stiffness of the building.

chaptur- 5

- **Disaster Disaster Management**
- **Disaster Rescue**
- **Psychology of Rescue**

Introduction -

- A disaster is a phenomenon which puts humans and property in a dangerous and disadvantageous situation. The disasters can be natural or man-made.

Natural disaster-

- Wind related - Cyclone, storm, hurricane, tornado etc.
- Water related - Floods, cloud burst, drought
- Earth related - Earthquake, tsunamis, avalanches, landslides, volcanoes

Man made disaster-

- . War/battle/riots
- . Accidents of train/vehicles/airplanes
- Industrial accidents
- Fire and forest fires
- Nuclear explosions/accidents
- Deforestation/soil erosion/air/water pollution
- These disasters are regular phenomenon in the world. Whatever by the type of disaster, the result is loss of lives and damage to the properties.
- Thus it is necessary to reduce these effects by planning before hand. Disaster
- management is the discipline dealing with the avoiding risk caused due to hazards/disaster.

- It involves preparing supporting and rebuilding society when natural or man-made disaster occur.

Disaster management -

- Some of the disasters can be predicted while some cannot. Earthquake not possible till to date.

- Thus this chapter focuses on the essentials of rescue operation like rescue worker, rescue plan, safety aspects, casualty management etc.

- The measures to reduce the adverse effects of disasters is disaster management. It consists four phases.

1. Mitigation 2. Preparedness

3. Response

4. Recovery

Mitigation -

- Mitigation efforts prevent hazards from developing into disaster or to reduce the effects of disaster or to reduce the effects of disasters when they occur.

- Example of mitigation are strengthening and retrofitting of buildings to make them earthquake resistance, creating awareness in public about earthquake through media and schools so that they should know what to do during earthquake.
- It also include enforcement of building codes and their revision form time to time.

Preparedness-

- In the preparedness phase, emergency managers develop plans of actions for when the disaster strikes.

- It include the proper training programs for rescue worker, maintenance and checking of equipment and emergency services, evacuation plans and control of supplies etc.
- It also include developing volunteers form common people to work during rescue operation.

Response

- The response phase is the reflection of country's readiness to cope quickly and effectively during and after disaster. It include the mobilization of necessary emergency services like police, volunteers, fire fighters and NGO's.

- A well practiced plan developed in preparedness phase can results in an effective rescue efforts.

- Rehearsals of rescue plans is essential to achieve optimum output in the response phase, medical facilities should be checked and enhanced from time to time.

- For example to facilitate emergency operation, the earthquake prone regions

should be equipped with a number of emergency centers.

- The role of such center should be to maintain stock of food, medicine, building material etc. for emergencies.

- They should also do the task of survey, assessment of damages and teaching of evacuation measures to common people.

Recovery

- The aim of the recovery phase is to restore the affected area. Recovery phase is mainly concerned with rebuilding destroyed property, re-employment, repair of other essential infrastructures and services.

- The recovery phase starts when the immediate threat to human life has reduced.

In the long term disaster, like wars, famine etc. which may last up to many months the recovery phase starts early.

- The recovery phase is generally long and may take upto five years.
- There are three main categories of recovery phase.
- a. **Restoration** - Restoration of essential services, homes and other infrastructure.
- b. **Rehabilitation** - Physical and mental treatment of affected people.
- c. **Reconstruction** - Reconstruction of collapsed building and infrastructure. - All these phases should follow one after the other and the cycle should be completed for effective and result oriented disaster management programme.

Disaster Rescue - The aim of rescue is to save life and minimize injury to people and damage

property. Rescue involves many function. Some of the common rescue function are

1. To remove trapped people and support them during rescue operations
2. To recover and identify the dead.
3. To provide support to the other services or teams In order to achieve the aim of rescue all rescuers should be trained properly..

Psychology of rescue

- Because operation is also full of danger. People tend to react differently to danger. But mostly there is a feeling of anxiety and fear in

all the persons because it is not just the victim who faces the danger but rescuer also face the same danger in order to rescue the victim

- Dangers are still present when the main danger has passed.

- The main difference between the condition of rescuer and victim is that the rescuer is better able to handle the situation because he can for see the danger and he is well equipped.

- It is normal to be anxious and feel fear during danger. Other emotions which arise during a rescue operation are pity, disgust, contempt, pride, concern and many more.

- The pressure of urgency or emergency is always their on rescuer. It decreases the efficiency of the rescue operation. The rescuer must understand the psychology of victims also in addition to the physical needs. He should help them to coming out of the trauma.

CHAPUTER - 6

COTENT

Rescue workers

1. Survivors 2. Untrained worker

3. Trained worker

Rescue plan

1. Reconnaissance 2. Problem solving

Rescue workers -

- Resizing Rescue workers are those persons who are involved in rescue operations. Mainly three types of rescue workers are there

1. Survivors -

- Survivors are those persons who have escaped in the danger i.e. they are not injured.

- The first reaction of survivors is to help their neighbors and families.

- Sometime they don't know what to do but feel that they must do something. Their intention is good but sometime it hamper or interrupt the function of trained rescuer teams. example in case o Screenshot has been saved to/Pictures/Screenshot

emergency, the first group to start rescue work is of the survivors. But there is danger also involve with this group of rescue workers because they are untrained.

2. Untrained people -

- The second group of rescue worker are those people who witness the event or are in the neighborhood of the event.

- Some of theses people have a desire to help the victims. They also brings necessary things with them and can be very effective if these things are properly supervised.
- But a large number of people are curious and just want to watch without helping rescuers and victims. They can cause interference in rescue operation and should be controlled.

3. Trained People -

- These are the last one toarrive at the scent.These are the trained rescuers from police, fire NGO's and state emergency departments.
- These people know what to do and how to use the available resources and material. They can also take the help of untrained people

efficiently to carry out rescue operation in proper way.

RESCUE PLAN -

- The rescue operation should be performed in a planned way. The success of rescue operation depends on the planning of it.
- It consists of following major stages.

THE RECONNAISSANCE -

- Every member of the rescue team must be trained in rescue reconnaissance. In most of the cases team leader does that, but if he has deployed some person for conducting reconnaissance, then the person should take and report the observations back to the leader.

- The reconnaissance of the disaster area/site should result in an accurate assessment of

a. The number and location of casualties
b. Dangerous situation such as gas leak, electricity,overhanging walls,unsafe structural components or anything else which may endanger rescue workers or survivors.
c. Access to the causalities
d. The extent and type of damage
e. Emergency services available and disrupted
f. Available resources, both personnel and euipment.
g. An approximate analysis of time the task will ake with available resources.
. Support agencies

- 2.**PROBLEM SOLVING PROCESS**---

- This is also called as appreciation process. It is a simple method of problem solving

which involves logical assessment of the situation and the reconnaissance.

- It results in the formation of a workable plan. Experienced persons may use their

experience and intuition also to make the rescue plan more effective.

- The problem solving process has six steps.

Define the problem -

- The problem to be solved should be clearly defined in terms of the task. Which is to be performed. If the problem is too large or complex to tackle easily, then it may be divided into a number of small elements, which are connected properly.

2. State the aim -

- The aim is a clear picture of what the rescue team has to do in order to solve the problem. The aim should be clear brief and achievable, for example one of the aim during an earthquake rescue operation can be - to rescue the casualty from the basement floor.

3.Consider the factors -

- The factors to be considered in a rescue operation may include

a. Number and location of causalities
b. Time
c. Topography of the area
d. Weather
e. Available resources, both personnel and equipment
f. Support requirements and availability
g. Communication
h. Priority of tasks

- Each factors should be considered and all the "ifs" and "then" should be analyzed properly. Each factor should lead to some conclusion for example

Factor

- A person legs are trapped under a heavy steel beam

Conclusion -

- The rescue team must use cutting and lifting equipment carefully to free the person.

4. Determine all possible solutions -

Consider all possible solutions, that are practical for achieving the aim. This is doneby considering all the factors listed above

5. Decide on the best possible solution -

- At this stage one of the best possible solution is selected which takes into account all the factors.
- It is the solution with the most advantages and least disadvantages.

6. Plan-

- On the basis of best possible solution the plan is developed. The plan must be simple and it must related directly to the aim.
- When the rescue plan is completed it should be checked thoroughly with proper reasoning.
- After the rescue plan is prepared the rescue team should start the action without delay.

- The team leader should decide and deploy persons for various tasks and give.

CONTENT

- **Rescue step by step**
- **Rescue equipments Safety in rescue operation**
- **Debris clearance**
- **Causality management**

Rescue by steps-

- A six phase process for rescue operation at a collapsed structure is given below which explains the rescue operation by steps

- Phase 1- Reconnaissance and survey
- Phase 2- Elimination of utilities
- Phase 3-Primary surface search and rescue
- Phase 4- Exploration of all voids
- Phase 5-Access by selected debris removal
- Phase 6-Terminate by general debris removal

- The **(REPEAT)** acronym helps the rescuers in learning and remembering these six Phase

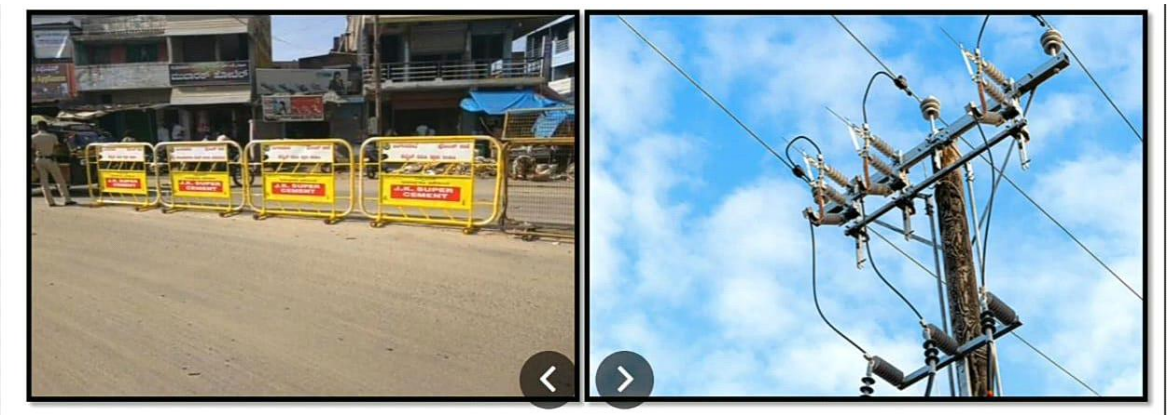
Phase 1 - Reconnaissance and survey

- After reaching the hazard site, it is difficult to conduct through reconnaissance and survey.
- During this question victims, witness and other who are able to provide information such as occupancy of the building, location of victims and potential hazards etc.
- Survey involves a visual inspection of the site and may identify the type and size of structure, collapse patterns, possible hazards and location of victims etc.

Phase 2 - Elimination of utilities (Risk assessment and control)

- It is one of the most important phases. It involves the assessment of risk and controlling them with the measures available to the rescuers.

- For example barricading the site or shutting of power supply etc, it is necessary to control all the possible risks as soon as possible other wise it may result in more disaster.



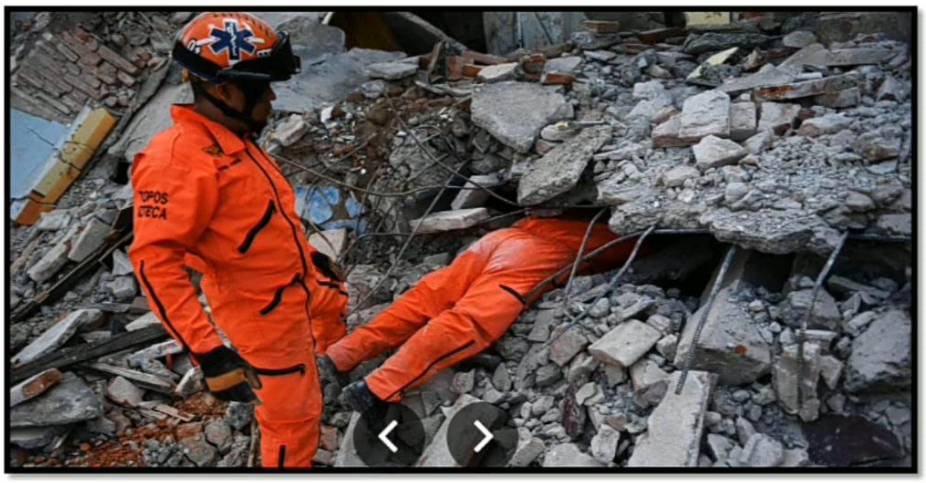
Phase 3- Primary surface search and rescue

- The third phase include searching surface areas around the collapse or damaged structure.
- Any injured person or lightly trapped person should be immediately attended.
- During the primary surface search, rescuers may become aware of victims located with in the voids or with in damaged structures.
- The location of victims should be markedand reported to trained person with appropriate equipment for safely extraction of victims.

Phase 4 - Exploration of all voids-

- In this phase, specially trained and equipped rescuers explore those place which have been marked during primary surface search.

- All the places, where the trapped victims might have survived the collapses, are explored although there is no evidence of the presence of such victims.
- If possible technical device can also be used to know the location of the trapped victims



Phase 5-Access by selected debris removal

- It involves the removal of selected debris for accessing the trapped victims. This require the removal of selected debris for accessing the trapped victims.

- This requires specially trained personnel and equipments. As the time chances of survival of victims decreases. Thus the rescue operation should be carried out speedily but safely.

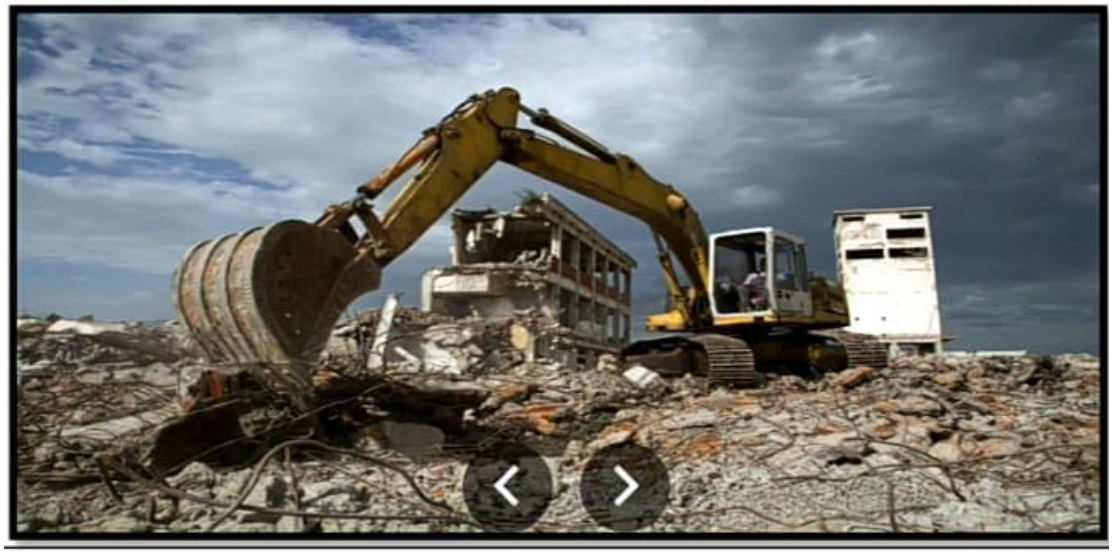
- It is essential to locate all victims before starting phase 6

Phase 6 - Terminate by general debris removal -

- It involves the use of heavy plant and machinery to remove all the debris in an
- attempt to recover and account for all victims.
- This phase also involves use of forensic processes to identify victims.

- It is impossible to tell from external inspection whether victims buried in the debris will be alive or not.

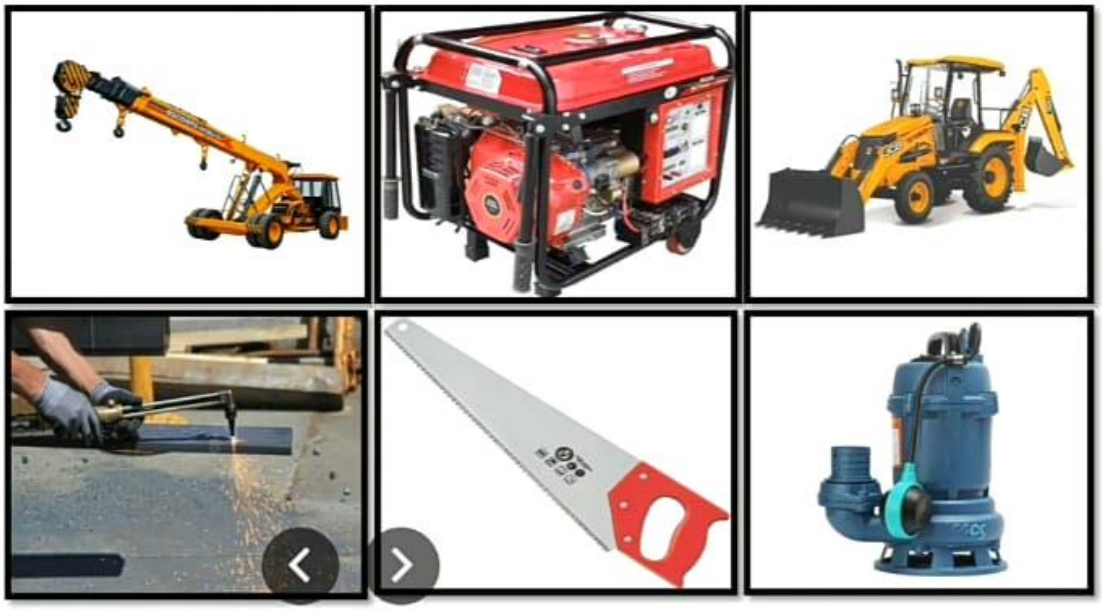
- Thus the effort should be continued to save lives, no matter how long it take.



Rescue equipments -

- The rescue operation required lot of equipments. The equipment to be used depends upon the type of task involved. It is necessary to check the equipment before and after use. It should be in a proper working conditions.

1. JCB/bull dozers
2. Excavators
3. Dumpers
4. Cranes
5. Air compressors
6. Gas cutter
7. Generators
8. Pumps
9. Fire extinguishers
10. Rops and chains
11. Ladders EITHER



Safety in rescue operations -

- The rescue operation involve lot of works which need skills like clearing of debris, operation of equipments, working in dangerous environment like fire and collapsed structure etc.

Basic precaution -

1. Regularly and carefully check the equipment both before and after the use
2. Ropes can wear and rot, batteries can corrode equipment, machinery can break down.

3. Faulty equipment can cost lives. Immediately label the faulty equipment and send it for repair or replace it.

4. Protect people at heights or depths with care and monitoring
5. Never ignore the safety limits
6. Control the emotion during rescue operation

Rescue worker safety -

1. Wear helmets at all the time of risk.

2. Gloves should be used while clearing debris with hands

3. Dust mask or filter should be of standard quality and to be used when required

4. Safely goggles should be used for protecting eyes

5. Clothing should be protective according to the hazard (fire, flood etc.)

6. Safety boots and knee or elbow protection when moving over debris

7. Sun screen and hat for working in the hot sun 8. Water to prevent dehydration

9. Whistle is to be provided for emergency times

Casualty safety -

1. The injured person should be given care and first aid immediately.

2. They should be handled in a safer way and made comfortable

3. The damaged building parts or the debris should be handled such that no more injury is done to the people trapped inside

4. The safety measure should be discussed during the training and exercises along with the dummy casualties

5. The injured persons are sent to the hospitals by the ambulances or other vehicles. These vehicles should be driven by trained drivers

Equipment safety -

1. All equipments should be of standard quality and operated as per instructions. They should be operated by trained persons.

2. While using power tools such as disc cutter or saws, the operator should wear safety goggles and gloves and take proper care to avoid jamming of blades

3. If the cutting operation is near the trapped casualty, the cutting blades should be directed away form the casualty body.

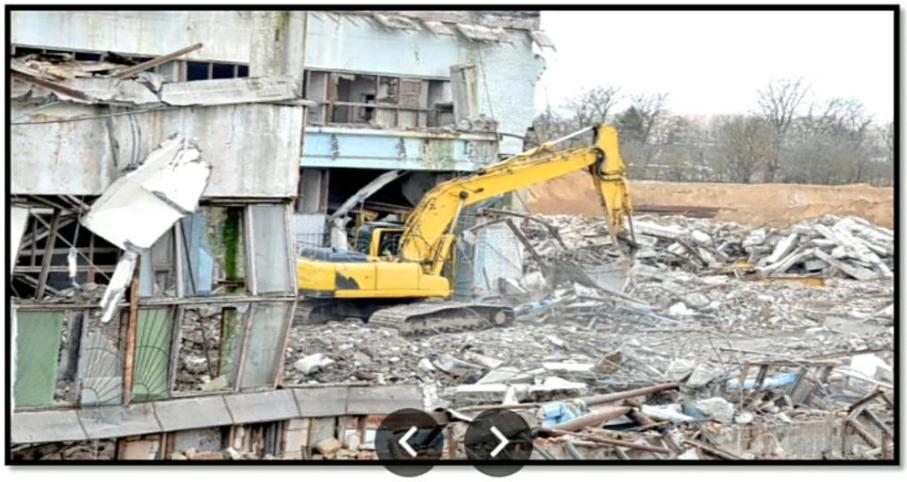
4. Proper care is to be taken while load lifting operation to prevent total collapse or slippage or dropping

5. All rescue equipment should be checked before and after use.

DEBRIS CLEARANCE-

- In a disaster, where collapse or damage of structure is there, the people are usually buried or trapped inside the debris.

- Thus for extracting the people out of debris the debris are to be removed or cleared. Clearance of debris require special methods to avoid injury to trapped people.



Method of debris clearance -

- When debris clearance is required for rescue purposed, move the debris clear of the collapsed building.

- Remove debris by hand, piece by piece until the casualties are uncovered and freed.

- It is best to form a human chain. Sometime it is necessary to cut a lane through the debris to reach a casualty.

- Great care should be taken in doing so and it should be ensured that the side of the lane do not collapse.

- Timbering and strutting can be done, where necessary to prevent the collapse of the sides.

Precautions in debris clearance -

a. Identify suitable escape path and keep them clear.

b. Use the edged tools very carefully, while removing debris.

c. Remove debris close to casualties by hand.

e. Do not climb cover debris during the clearing operation unless absolutely necessary.

f. Remove debris only, when it is certain that no further collapse will be caused

g. Operate heavy equipment only as per instructions

h. Carefully observe the movement of damaged parts of building, while removing debris.

Casualty management -

- In a disaster like earthquake, the rescue operation is difficult and long. The people are generally trapped inside the debris. They are to be taken out very carefully.

- The method used for casualty removal depend on the location of the casualty and the type of injury sustained.

- In some rescue operations, casualties will have to be lowered form the upper floors of building.

- Causalities are to be handled carefully by rescue workers so that more injuries does not occur.

- Their safety is very important. All the rescue worker should be given First Aid Training and they should be well equipped to give first aid to the injured person.

- Speed of casualty removal is important but safety and proper handling is also important.

- Rescue leader should conduct exercise in the removal of casualties using live people as casualties.

- This will help the rescue worker to understand the problems faced while handling the casualties.

Content - 7

- Introduction to IS 1893 (Part 1): 2002
- Seismic zones of India Load Combination
- Equivalent lateral force procedure

Introduction to IS 1893 (Part 1): 2002-

- Indian standard 1893 is based on the seismic data collected form studies of Indian earthquakes.
- The first seismic code was published in 1962 as IS 1893 "Recommendations for earthquake resistant design of structures.
- The last (fifth) revisions was done in 2002. in this revision the code has been divided into the following five parts.

1. Part 1-General provisions and building

2. Part 2-Liquid retaining tanks - elevated and ground supported

3. Part 3-Bridges and Retaining walls

4. Part 4-Industrial structures including stack like structures

5. Part 5-Dams and embankments

Seismic zones of India -

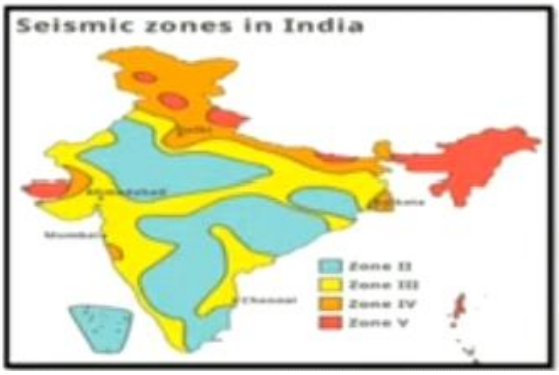
SEISMIC ZONE OF INDIA

- The different geology at different location in the country implies that the possibility of damaging earthquakes takes place at different locations is different.

- Thus a seismic zone map is required to identify these region.

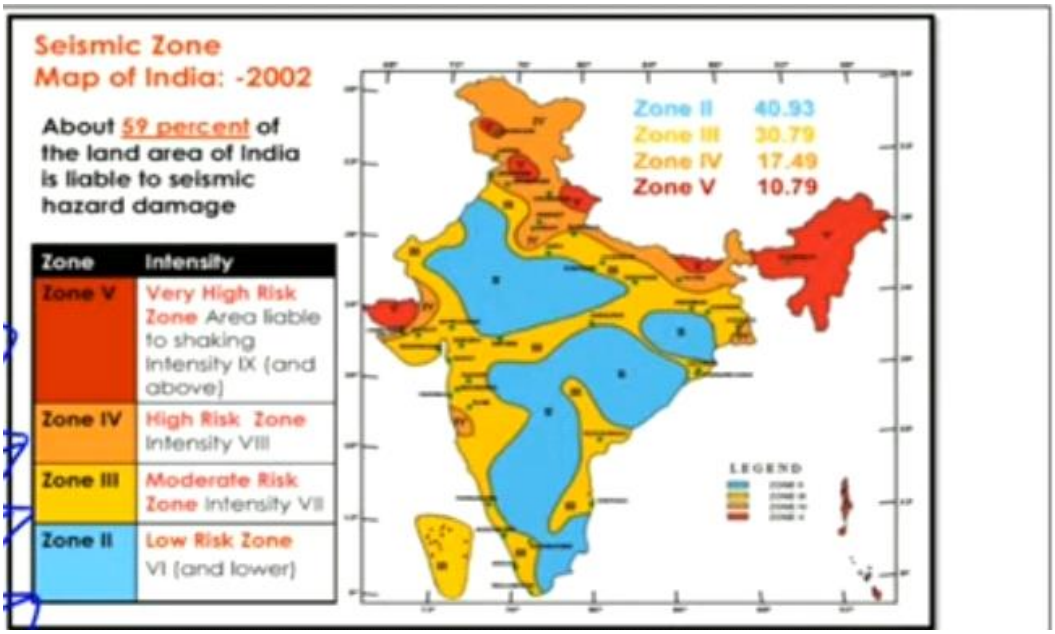
- Based on the levels of intensity during past earthquakes the 1970 zone map divided India into five zones (I, II, III, IV & V) .

- **The map has been revised lastly in 2002 and it has only four seismic zone - (II, III, IV&V).**



Seismic Zone Map of India: -2002

About 59 percent of the land area of India is liable to seismic hazard damage.



Assumptions -

- **IS 1893 code gives assumptions for the earthquake resistant design of structures which as follow**

a. Earthquake causes ground motion which are very complex in nature. It is assumed that resonance (between the motion of structure and ground motion) will not occur as it would need time to build up.

b. It is assumed that earthquake will not occur simultaneously with wind or maximum flood or maximum sea waves.

c. The value of elastic modules of material for dynamic analysis is taken as same for static analysis.

Increase in permissible stresses in materials -

- When earthquake forces are considered along with other normal design force, the permissible stresses in material way be increased by one third. However,
- for steel the stress will be limited to yield stress or 0.2percent proof stress.

Load Combination -

- IS 1893 discusses various load combinations for design of structures while considering earthquake forces. For limit state design of reinforced concrete and prestressed concrete structure, the following load combination should be used.

1. 1.5 (DL+IL)

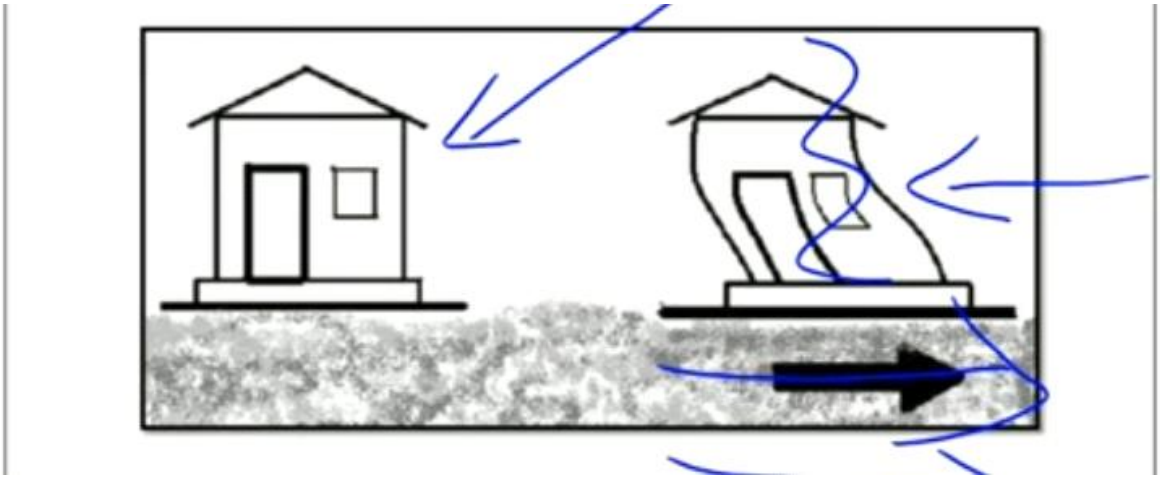
2. 1.2 (DL+IL+EL)

3. 1.5 (DL EL)

4. 0.9 DL EL

- DL = Dead load
- IL = Imposed load
- EL = Earthquake load
- + and - sign with earthquake load is taken because earthquake load is reversible in direction.

Equivalent lateral force procedure



Equivalent lateral force procedure -

- It is the simplest method of analysis and require less calculation. In this method, each mass in a building is subjected to an equivalent lateral force.

- Although earthquake force in dynamic but routine design is done by assuming it to be static.

- The equivalent lateral force is determined according to the

fundamental period of structure given in IS 1893.

- In this method the design base shear shall first be calculated and then distributed along

- the height of the building as explained below.

Determination of base shear-

- The total design lateral force or design base shear should be determined by the following expressions as per IS 1893

$$V_b = A_h - W$$

- Vb = it is the total design lateral force at the base of a structure.

- **W is the seismic weight of the building which is the sum of seismic weight of all floors. The seismic weight at any floor level is equal to the dead weight of the floor**

- **system and appropriate amount of imposed load.**
- **The weight of floor system is dead weight of slabs, beams and half of the weight of columns and walls above and below the floor.**
- **Percentage of imposed load to be considered in seismic weight calculation are given in table in IS 1893**

Percentage of imposed load to be considered in seismic weight calculation (Clause 7.3.1)	
Imposed uniformity distributed load	Imposed load
Up to and include 3.0 kN/m^2	25%
Above 3.0 kN/m^2	50%

A = Design horizontal seismic coefficient for a structure

Ah = ZIS/ 2Rg

Z= Zone factor given in table below. It depends upon the seismic zone in which structure is located.

Zone factor (Clause 6.4.2)				
Seismic Zone	II	III	IV	V
Seismic intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

i = importance factor, It is a factor used to obtain the design seismic force depends upon the functional use of the structure.

- **The minimum value of importance factored are given below**

Importance factors (I)		
Sr. No.	Structure	Importance factor
1	Important service and community buildings such as hospitals, schools, monumental structure, emergency building like telephone exchange, television stations, radio station, railway station, fire station, assemble halls and subway station, power stations.	1.5
2	All other building	1.0

Note-

- **The design engineer may choose values of importance factor (1) greater than**

those mentioned above

- **Building not covered in above table may be designed for higher value of (1)**

- **depending on economy, strategy consideration like multi-story buildings having several residential units.**

- **This does not apply to temporary structures like excavation, scaffolding etc. of short duration.**

- **R=Response Reduction factor**

- **It depends on the expected seismic damage of the structure**

- **This factor represents the structure's ductility characteristics. The value of R increase with structures ductility The code IS 1893 gives the value of R in table 7**

Table 7 Response Reduction Factor [1], *R*, for Building Systems

(*Clause* 6.4.2)

Sl No.	Lateral Load Resisting System	*R*
(1)	(2)	(3)
	Building Frame Systems	
i)	Ordinary RC moment-resisting frame (OMRF)[2]	3.0
ii)	Special RC moment-resisting frame (SMRF)[3]	5.0
iii)	Steel frame with	
	a) Concentric braces	4.0
	b) Eccentric braces	5.0
iv)	Steel moment resisting frame designed as per SP 6 (6)	5.0
	Building with Shear Walls[4]	
v)	Load bearing masonry wall buildings[5]	
	a) Unreinforced	1.5
	b) Reinforced with horizontal RC bands	2.5
	c) Reinforced with horizontal RC bands and vertical bars at corners of rooms and jambs of openings	3.0
vi)	Ordinary reinforced concrete shear walls[6]	3.0
vii)	Ductile shear walls[7]	4.0
	Buildings with Dual Systems[8]	
viii)	Ordinary shear wall with OMRF	3.0
ix)	Ordinary shear wall with SMRF	4.0
x)	Ductile shear wall with OMRF	4.5
xi)	Ductile shear wall with SMRF	5.0

Sa/g= Average response acceleration coefficient

- **It is a factor which represent the acceleration response of the structure under earthquake ground vibration.**

It depends on the natural period and damping of the structure.

The fundamental natural period for building are given in clause 7.6 of IS 1893

- **Ta=0.075 h0.75-for moment resisting frame building brick infill walls**
- **Ta=0.085 h0.75-for moment resisting steel building without in fill walls**
- **Ta=0.09 h/vd for all other building including moment resisting frames with brick infill walls.**

h = is the height of building in m.

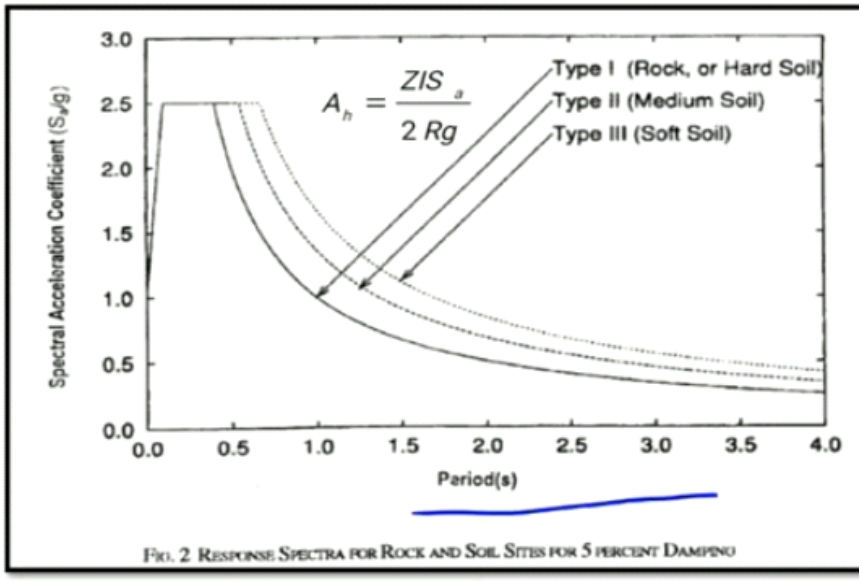
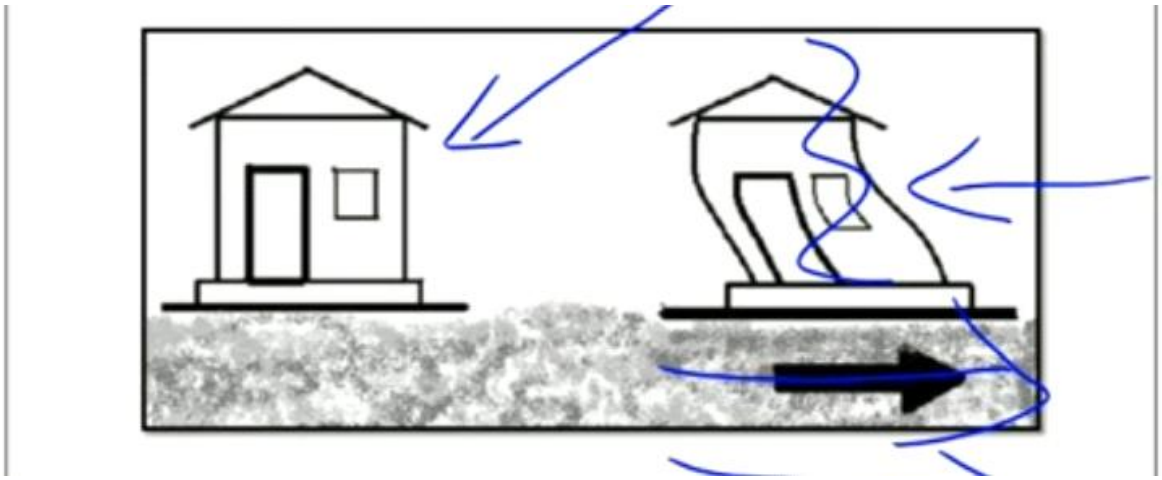


FIG. 2 RESPONSE SPECTRA FOR ROCK AND SOIL SITES FOR 5 PERCENT DAMPING

A = ZIS/2Rg

V = A.w



CONTENT-

- **Behaviour of brick masonry walls during an earthquake**

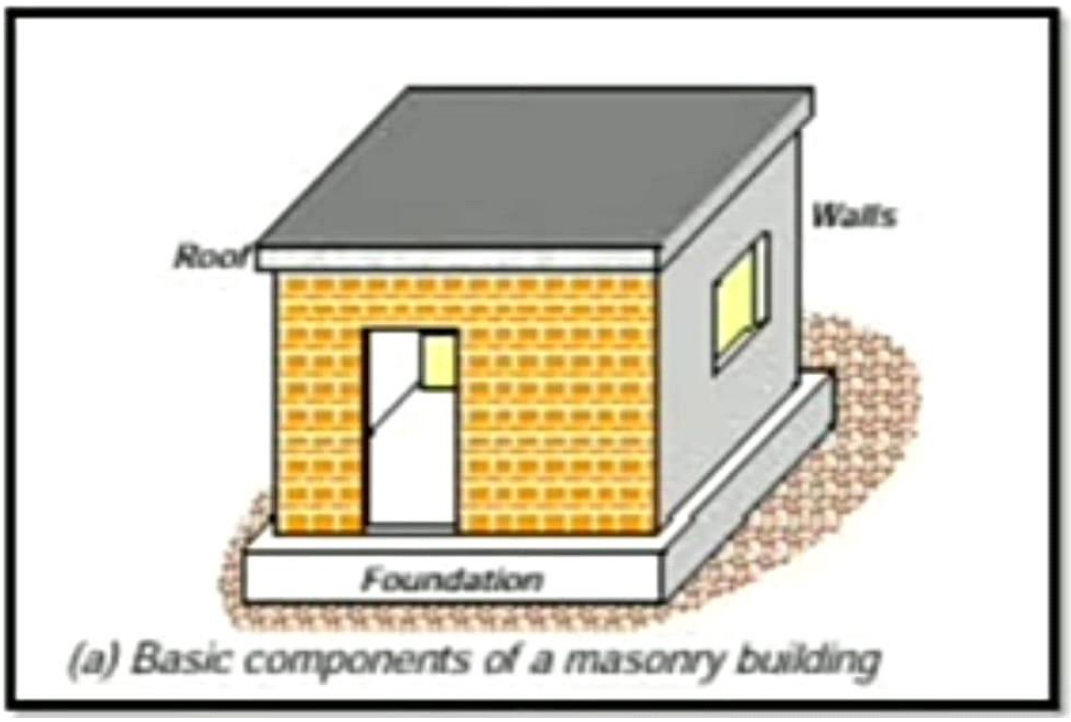
- **Measures to improve behaviour of masonry walls**
- **Earthquake resistant features**

Behaviour of brick masonry walls during an earthquake -

- The brick masonry building are brittle structure. They are one of the most vulnerable type of building of all the types during earthquake it caused large number of deaths in such construction.

- Thus it is essential to improve the performance of brick masonry building during the earthquake .

- To achieve this objective a number of earthquake resistant feature may be introduced.



(a) Basic components of a masonry building

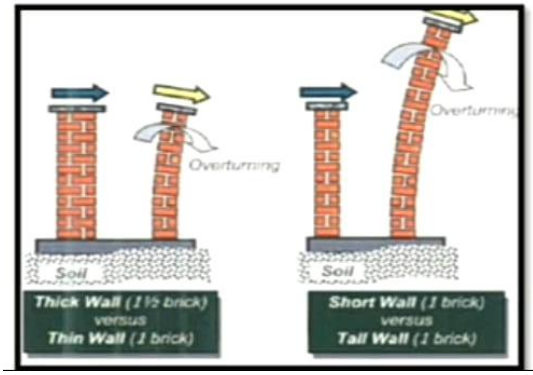
Walls -

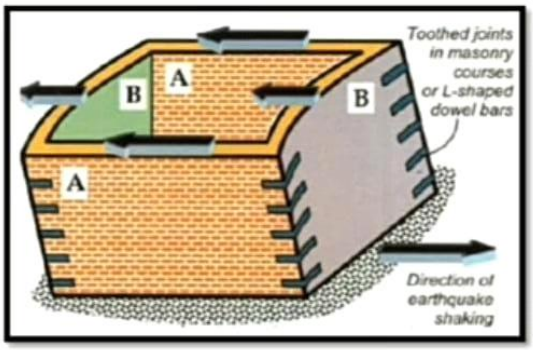
- The walls topples down easily if pushed horizontally at the top in a direction perpendicular to the weak plane, but offers much resistance if pushed along the length known as strong plane or direction.

- The ground shakes simultaneously in x, y, and z direction during an earthquake. For normal masonry building, the horizontal vibration are considered most damaging.

- If all the walls are not tied together to act as one unit like a box, then the walls loaded in their weak direction will tend to topple.

- To ensure good seismic performance all walls must be joined properly to the adjacent walls.





Measures to improve behaviour of masonry walls -

- A simple way to improve the seismic performance of such walls during an earthquake is by making them to act together as a

box along the roof at top and with the foundation at the bottom.

- To ensure a box like action to develop many construction aspects are required to be adopted as follow.

1. Ensuring good interlocking of masonry courses at the junction.

2. Use of horizontal bends at different levels specially at lintel level.

3. Keeping size of opening such as doors and windows small, the smaller the size of openings, larger the resistance offered by walls.

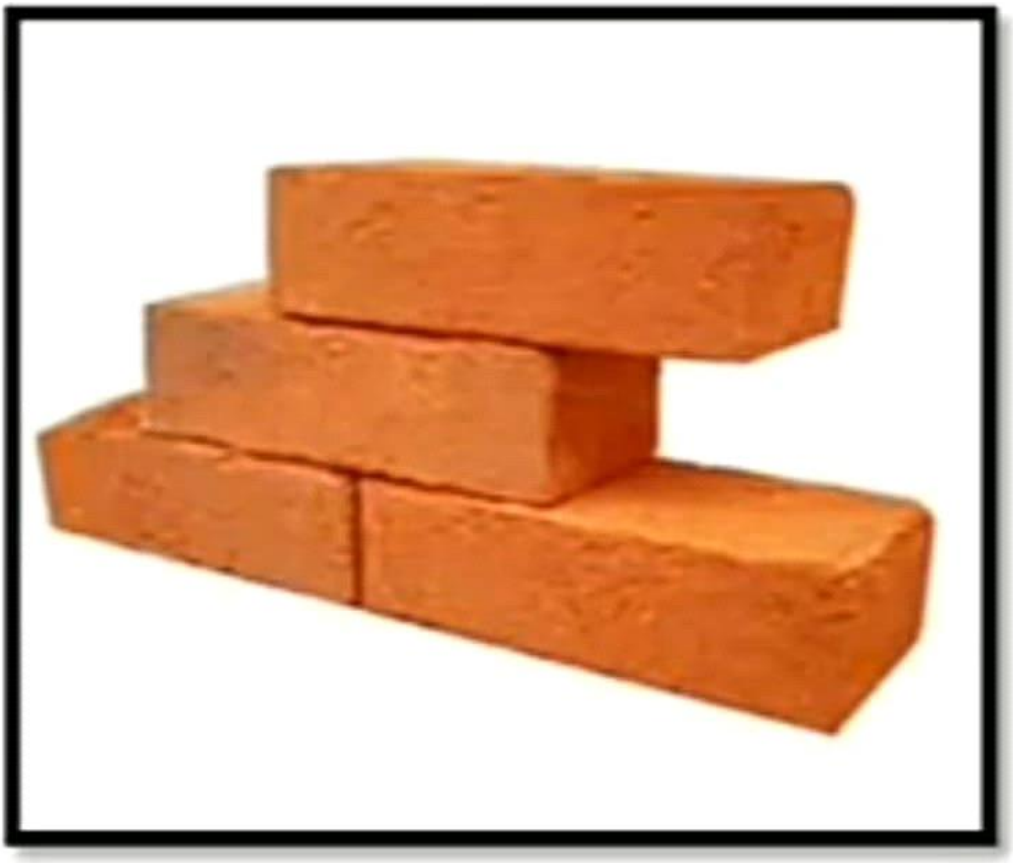
4. The tendency of toppling of walls can be reduced by decreasing the slenderness ratio i.e. by limiting the height to thickness ratio and length to thickness ratio. A wall that is too long or too tall in comparison to its thickness is specially vulnerable to damage during an earthquake.

Choice and quality of building material -

- Most commonly in masonry building burnt clay brick are used. These bricks are inherently porous and absorb much water.

- The excessive absorption of water from the mortar results in poor bond between the mortar and bricks.

- Thus before use, the bricks must be soaked in water for about 30 minutes or water is sprayed over the bricks. This will minimize the absorption of water by bricks from the mortar and help to retain the strength of the mortar.



Types of mortar used -

- **Various types of mortar can be used-**

a. Mud mortar - it is the weakest types of mortar. It crushes easily when dry. It flows outwards and has least earthquake resistant. Hence it is not effective in seismic regions.

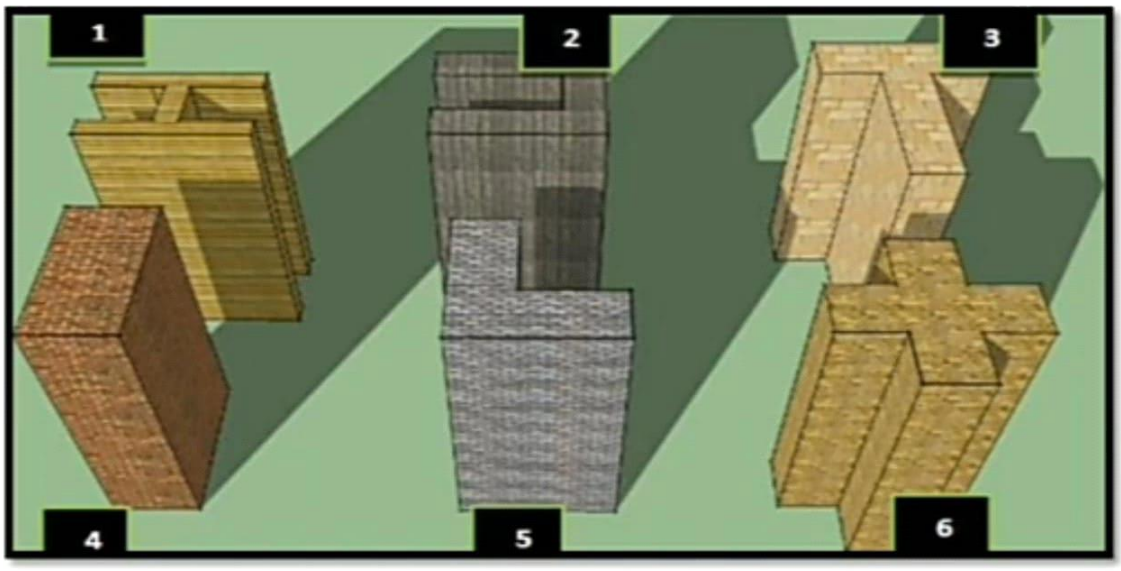
b. Cement sand mortar - This mortar has sufficient tensile and shear strength 1:3 to 1:4 proportion mortar has been found satisfactory in all categories of construction in seismic regions.

C. Cement, sand, lime mortar - This mortar has been found most suitable in seismic zones. This mortar mix provides excellent workability for laying bricks, stretches with out crumbling at low earthquake shaking and bonds well with bricks.

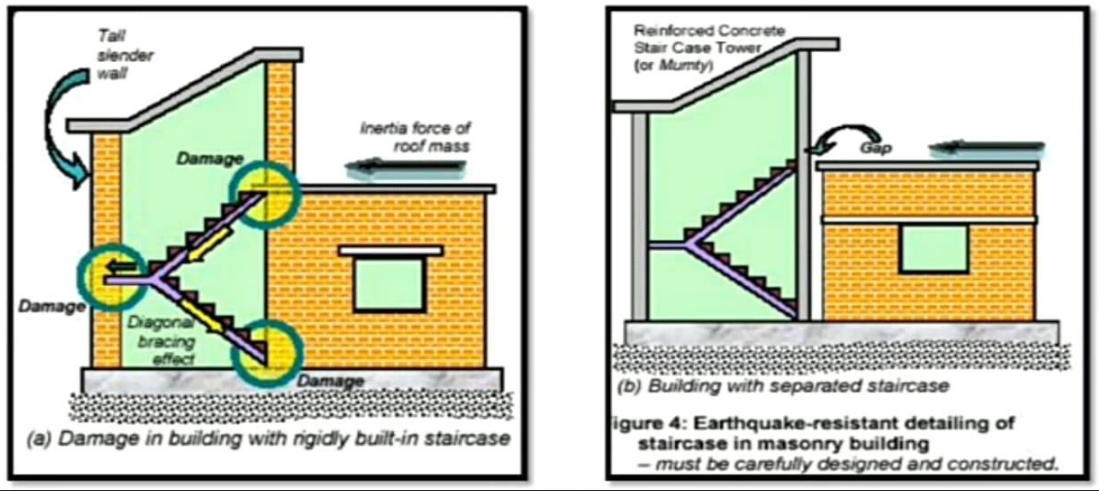
Earthquake resistant features -

- To develop good box action in masonry building and to improve their seismic performance Indian standards have suggested a number of measures as follows.

1. Building plans in shapes of L, T, E and Y should be separated into simple rectangular blocks in plan. During earthquake these blocks can oscillate independently and even hammer each other



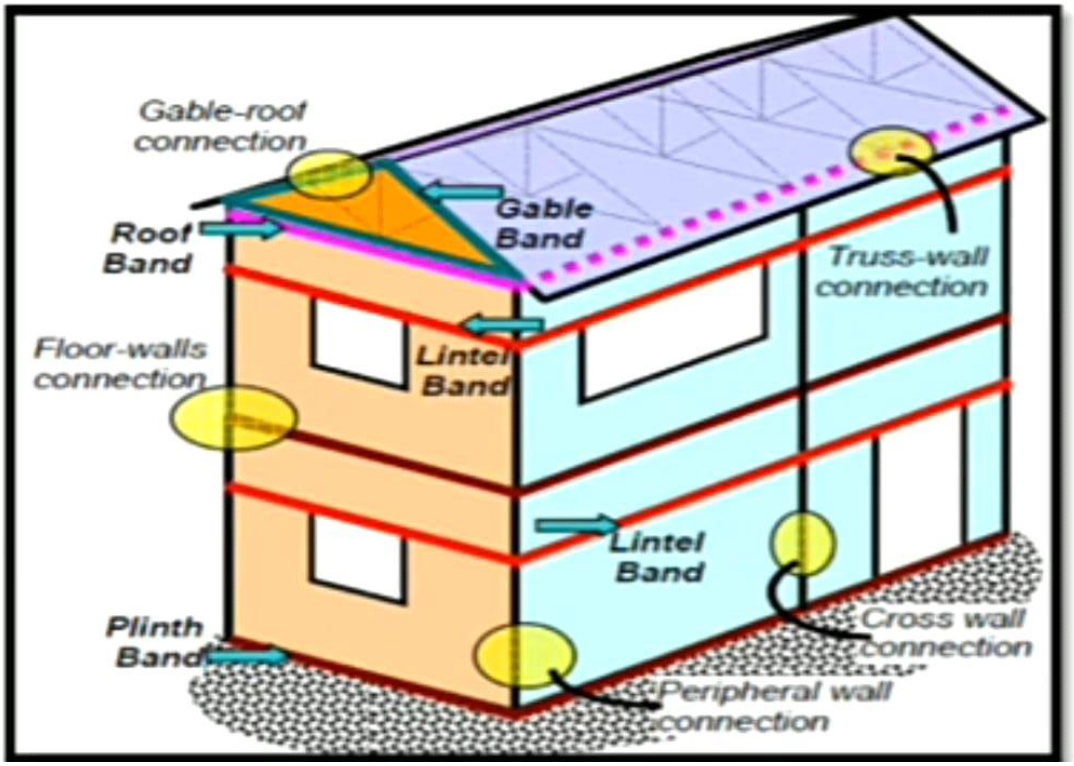
2. In masonry building inclined stair case slab as shown in offers another cause of worry. Such a inclined slab stair case connected integrally acts like a cross brace between floors and transfers large horizontal forces at roof and lower levels shown in circles in the fig. given below. These area are potential damages spots in the masonry buildings if not counted properly in the design and construction of the stair case.

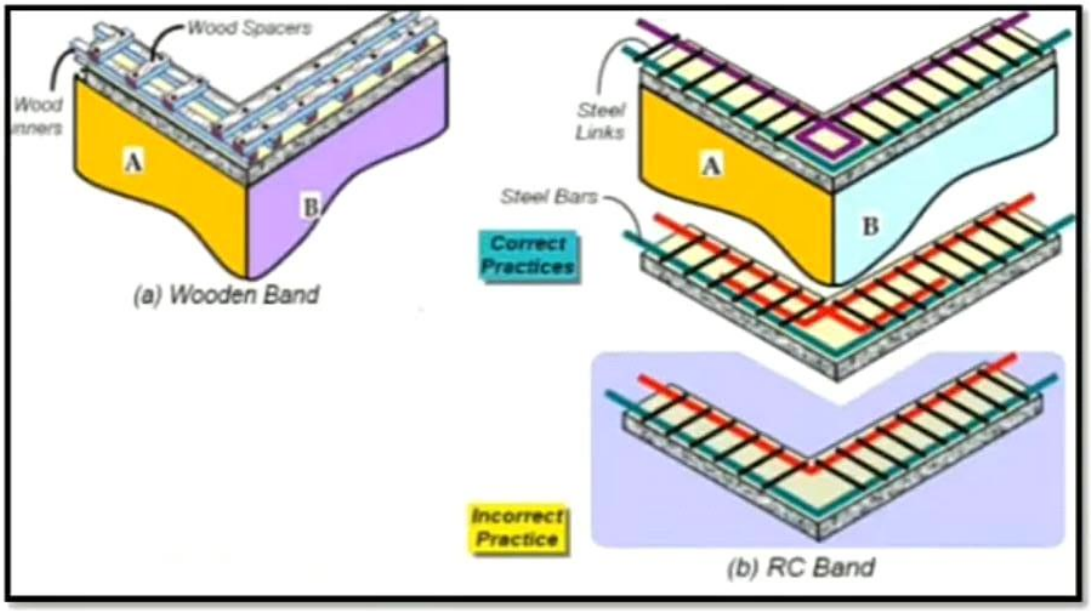


igure 4: Earthquake-resistant detailing of staircase in masonry building
– must be carefully designed and constructed.

Role of horizontal bands

- In masonry building the horizontal bands have been found most effective and important earthquake resistant feature.
- These bands are provided to hold the masonry building as a single unit by tieing all the walls together.
- These bands works similar to a closed belt tied around the card board boxes to hold them together.





Types of horizontal bands-

1. Gable band -

- Gable band are provided only in building having pitched or sloped roofs. it is very important band in sloped roof.
- The roof band in sloped roofs supported the tie beam of the truss as shown in fig.below.
- In buildings with flat reinforced brick or RCC slab the roof band is not required as the roof slab plays the role of a band.

2. Roof bands -

- Roof bands are provided at the roof level to hold the walls together. But in buildings with flat reinforced brickwork or RCC slab roofs, roof bands are not provides as the roof slab itself plays the role of roof band.

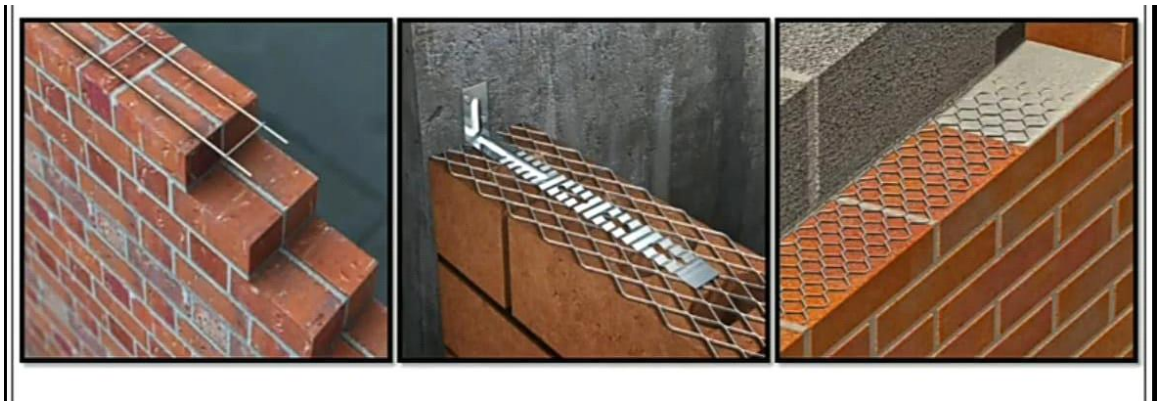
3. Lintel band -

- It is the most important band of all the bands and needs to be provided in almost all building. It is provided at door and window top level as shown in fig. given below.

- It tie the walls together and create a support for walls loaded along the weak direction form walls loaded in strong direction.

REINFORCED BRICK WORK -

- In masonry building steel bars, wire mess etc should be used to improve the strength of brick work which is very helpful during an earthquake.



Content-

- **Introduction of IS 13920: 1993**
- **General specifications**
- **Codal provision of Flexural member**
- **Codal provision of Column**

INTRODUCTION

- Provision of ductile detailing in the members of reinforced concrete building are given in IS-13920:1993 titled " Ductile Detailing of Reinforced Concrete Structure subjected to seismic forces.

- These provision are for the anchorage, splices, bar cut offs and joint details etc. it is observed in past earthquakes that the problems in structural detailing may also be one of the cause of damage.

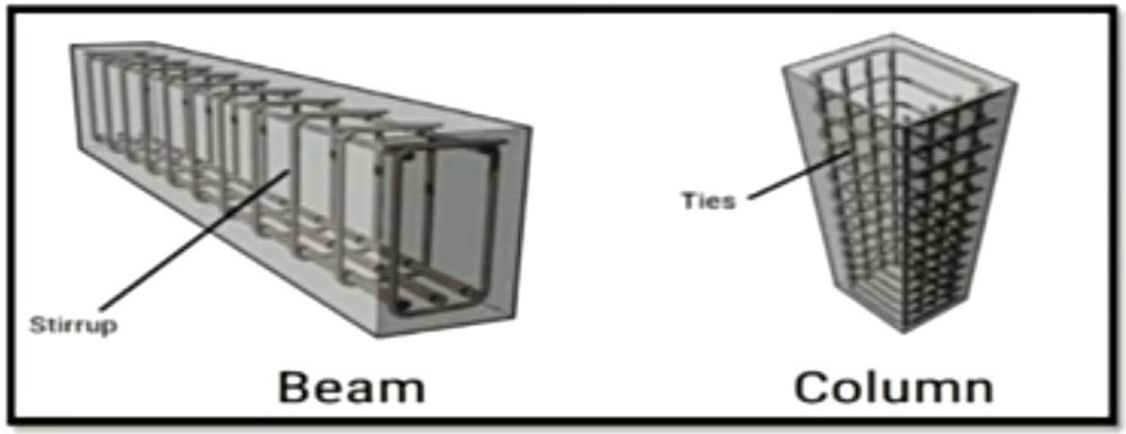
- Thus this chapter focuses on the provisions of distilling detailing for RC building and important clauses of IS-13920:1993 to understand the importance of ductility of reinforced concrete subjected to seismic forces.

Codal provision of IS 13920: 1993- General specification (Clause 5.0)

- The design and construction of reinforced concrete buildings should be as per **IS 456:2000** except as modified by this code.

- For all building which are more than 3 story in height the minimum grade of concrete used shall be **M20.**

- Steel reinforcement of grade Fe415 or less shall be used. Strong steel is not preferred in earthquake prone region because low strength steel are more ductile, show long yield and greater breaking strain.



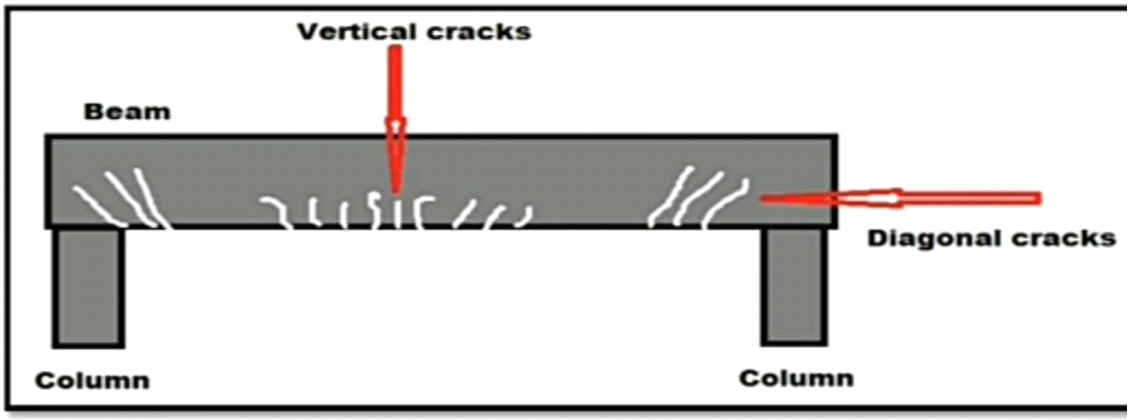
Flexural members (Clause 6.0)

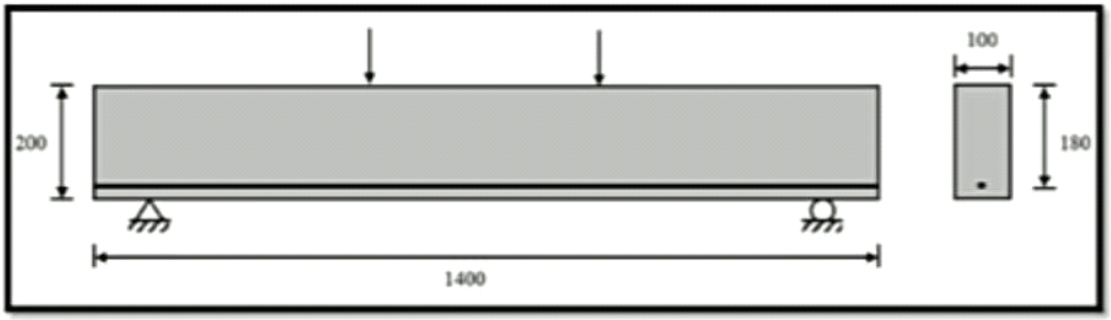
- The beams and slabs are flexural members which are designed to resist flexure (bending). The cracking pattern of a beam is shown in fig. given below.

- The vertical cracks at the centre are the bending or flexure cracks. The crack at the end are diagonal tension cracks caused due to shear.
- Reinforcement is provided to avoid all types of cracking. The various provisions of reinforcement and detailing for beam are as follows.

1. The flexural members are subjected to very little axial stresses. The factored axial stress on these members under earthquake loading shall not exceed 0.1 fck
where fck is the characteristic compressive strength of concrete.

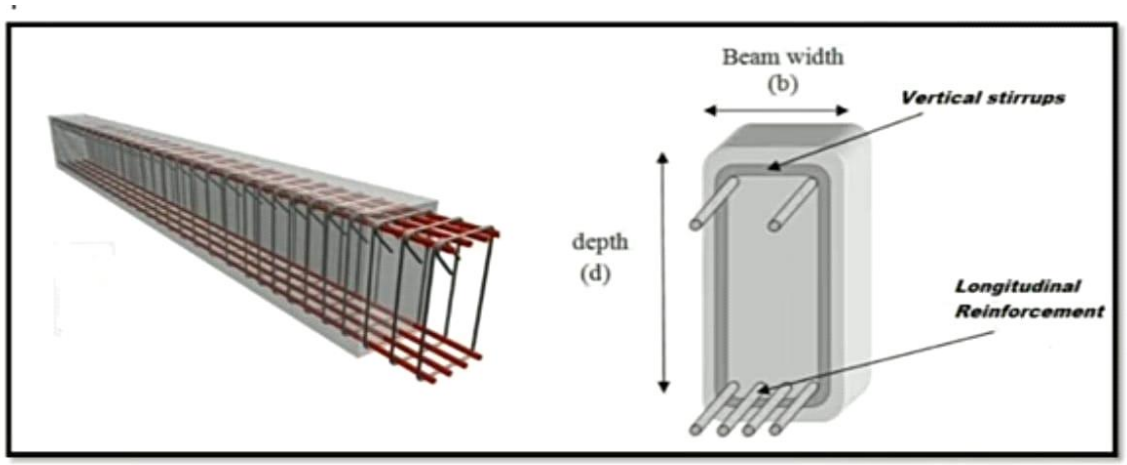
2. The member should have width to depth ratio of more than 0.3.
3. The minimum width of the member is 200 mm.
4. The depth of the member should be less than one fourth of the clear span.





Longitudinal Reinforcement -

- Longitudinal bars are provided in the beams to resist bending cracks. In frames, both top and bottom faces of the beam are subjected to tension, thus steel bars are required on both faces at the ends and on the bottom face at the middle portion of beam.



Codal recommendations for longitudinal reinforcement in a beam.

1. At least two bars go through the full length of the beam at the top as well as the bottom of the beam.

2. At the ends of the beam, the amount of steel provided at the bottom is at least half of that at top.

3. The steel provided at each of the top and bottom face of the members at any section shall be equal to one fourth of the maximum negative moment steel provided at the end of the beam.

4. Steel reinforcement bars are available in lengths of 12-14 m, thus it is necessary to overlap bars. If longer bars are required such lap of then longitudinal bars should be made away form the column face.

5. The bars should not be overlapped at the location where the beam is subjected to greater moment (e.g. - middle length of the beam).

6. The lap length should not be less than the bar development length in tension.

7. At the overlapping length, vertical stirrups should be provided over all the overlapping
(spliced length and at a closer spacing) zone.

8. Not more than 50% of the bars shall be spliced at any section.

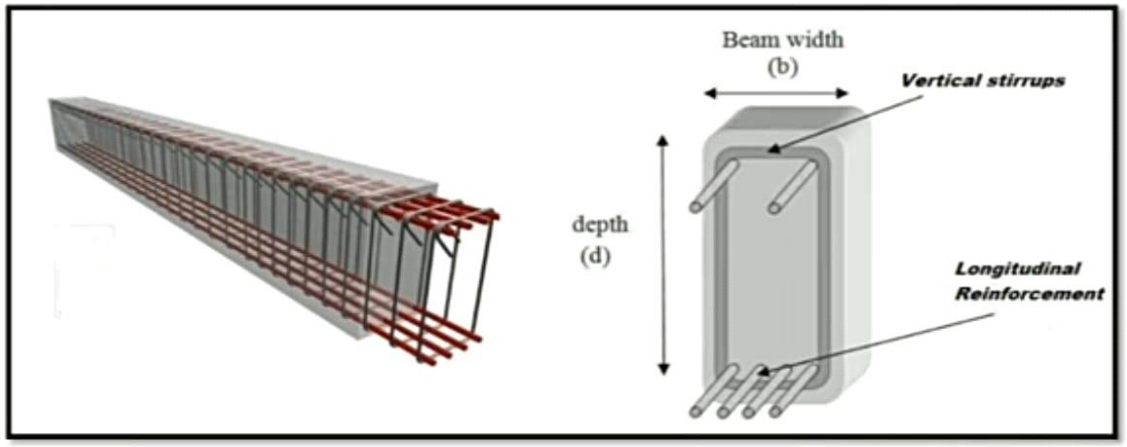
Transverse Reinforcement (Stirrups) -

Stirrups in RC beam has following functions

a. They carry the vertical shear force and hence resist diagonal shear cracks

b. They prevent the concrete form bulging outwards

C.The prevent the buckling of the longitudinal bars



IS-13920:1993 gives following recommendation related to stirrups in reinforced concrete beams (Clause 6.3 of code)

a. The diameter of stirrups must be at least 6 mm. In beams having clear span more than 5 m the diameter of stirrups must be at least 8 mm.

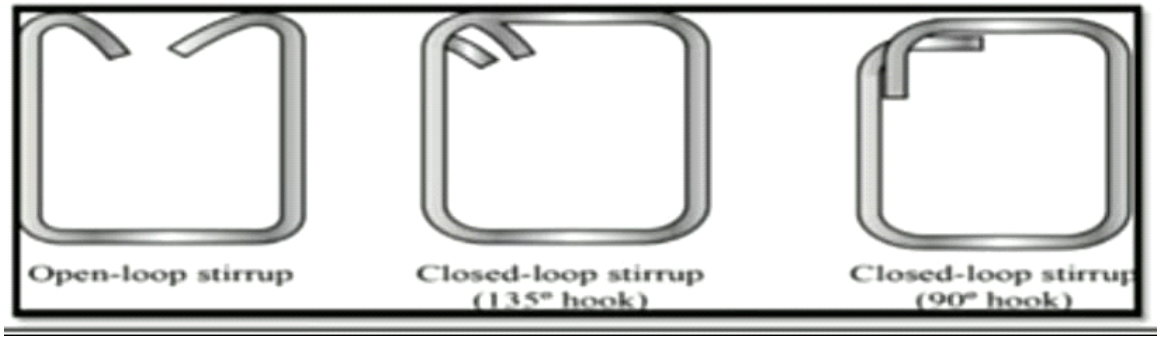
b. Both ends of the vertical stirrups should be bent into a 135° hook and extended sufficiently beyond it to prevent opening of the hook as shown in fig. below

C. The maximum spacing of stirrup should not exceed half the depth of beam.

d. The spacing of stirrups over a length of 2d at either end of a beam should not exceed -

1. d/4 .
2. 8 times the diameter of the smallest longitudinal bar but in no case less than 100 mm.

e.The first stirrup should be at a distance not greater than 50 mm form joint face

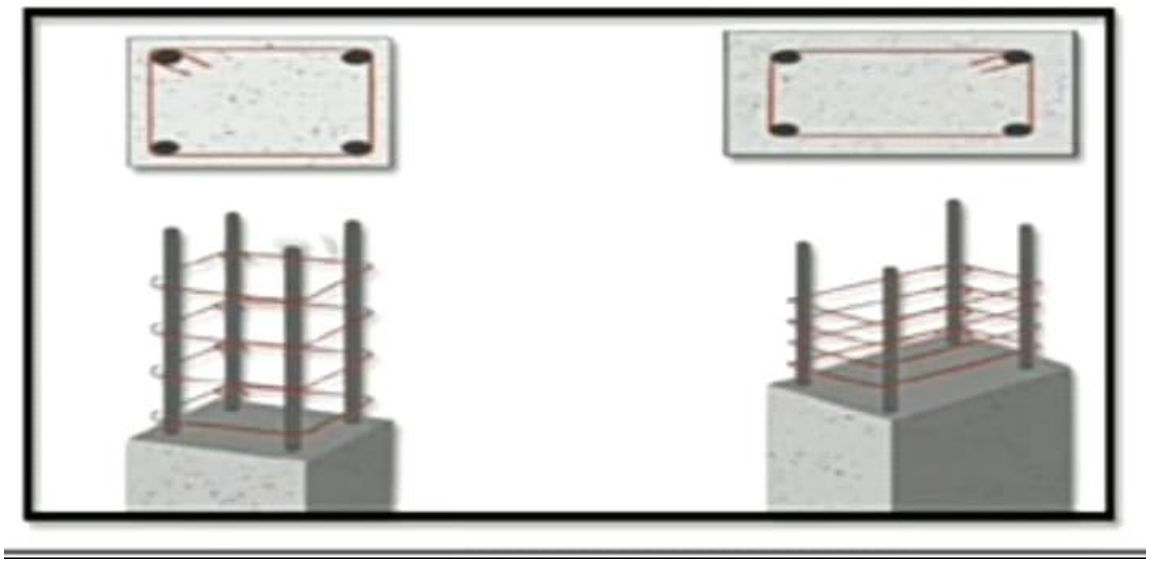


Columns and frame members subjected to axial load and bending (Clause 7.0)

Columns are the vertical compression members which are subjected to axial load and bending. They contain two type of reinforcement

a. Longitudinal bars

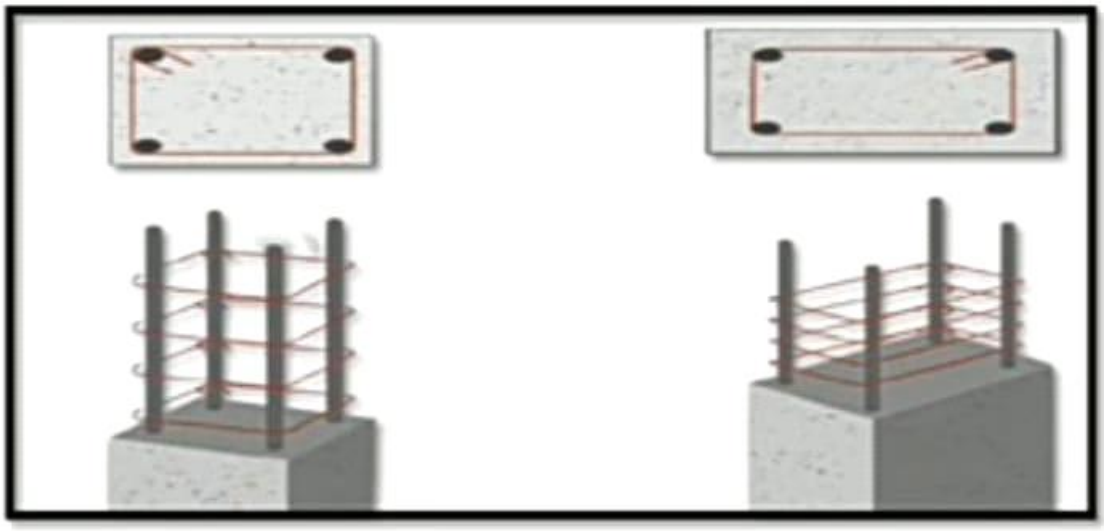
b. Transverse reinforcement.



- **The codal provisions applicable to column and to frame members which have a factored axial stress > 0.1 fck under the effect of earthquake load are given below.**

1. The minimum dimension of the member should not be less than 200 mm. In frame which have beams with centre to centre span exceeding 5 m or columns of unsupported length exceeding 4 m, the shortest dimension of the column should not be less than 300 mm.

2. The ratio of cross sectional dimensions (shortest / other dimension) should not be less than 0.4



Longitudinal Reinforcement of columns (Clause 7.2)

- In the case of RC columns it is very common practice to lap columns bars. The lap length depends on types of reinforcement and concrete

1. Lap length should be provided ONLY in the middle half of the column and not near its top or bottom ends.

2. Only half the vertical bars in the column are to be lapped at a time in any storey
3. When laps are provided ties must be provided over the entire lap length at spacing not exceeding 150 mm centre to centre

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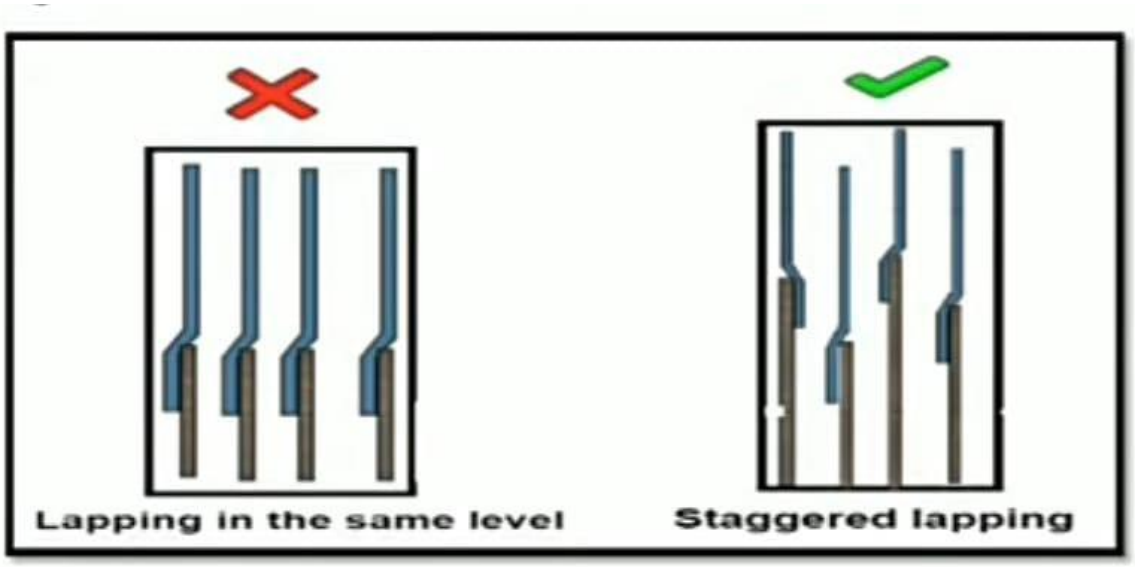
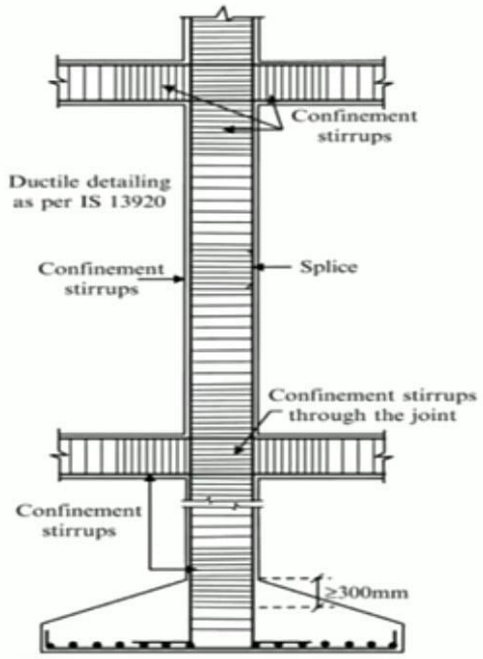

Lapping in the same level
Staggered lapping


Confinement stirrups
Ductile detailing as per IS 13920
Confinement stirrups
Splice
Confinement stirrups through the joint
Confinement stirrups
≥300mm

Transverse Reinforcement of column

- Transverse reinforcement of lateral lies in column also serve three purpose.

1. They carry the horizontal shear forces induced by the earthquake. Thus prevent diagonal cracking
2. They hold together the vertical bars and keep them in
3. They prevent buckling of the vertical bars.

The following are the codal provision for lateral ties of a column (Clause 7.3)

a. Transverse reinforcement for circular column should be spiral or circular.

b. For rectangular column, lateral ties is a closed stirrup having a 135° hook with appropriate extension of 10 times bar diameter but not less than 75 mm

c. The parallel legs of ties should not be more than 300 mm apart, if it is more than 300 mm then a cross tie or a pair of over lapping ties are required

d. The spacing of ties should not exceed half the least lateral dimension except where special confining reinforcement is provided.