EARTHQUAKE RESISTANT DESIGN

(BCE-42)

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Topics Covered

UNIT- 1

- Seismological background: Seismicity of a region, earthquake faults and waves, structure of earth, plate tectonics, elastic-rebound theory of earthquake, Richter scale, measurement of ground motion, seismogram
- Concepts of Earthquake Resistant Design of Reinforced Concrete Buildings – Earthquake and vibration effects on structure, identification of seismic damages in R.C. buildings, Effect of structural irregularities on the performance of R.C. buildings during earthquakes and seismoresistant building architecture

Seismology

Combination of two words

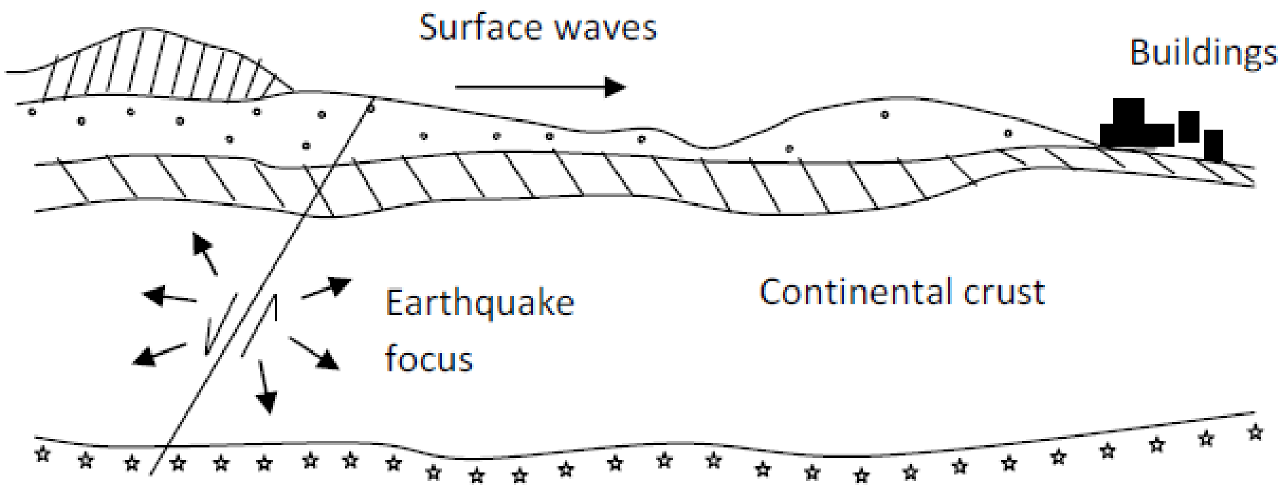
Seismos means **Earthquake**

Logos means **Science**

- Seismology is the study of the generation, propagation and measurement of seismic waves through earth and the sources that generate them.
- The study of seismic wave propagation through earth provides the maximum input to the understanding of internal structure of earth.

EARTHQUAKE

- Earthquake is the vibration of earth's surface caused by waves coming from a source of disturbance inside the earth. As the waves radiate from the fault, they undergo geometric spreading and attenuation due to loss of energy in the rocks. The seismic waves arriving at a site on the surface of the earth are a result of complex superposition giving rise to irregular motion that causes earthquake..



Earthquake Resistant Design of Structures, Pankaj Agrawal and Manish Shrikhande

EARTHQUAKE FAULTS

- The term fault is used to describe a discontinuity within rock mass, along which movement had happened in the past. Plate boundary is also a type of fault. Most faults produce repeated displacements over geologic time. Movement along a fault may be gradual or sometimes sudden thus, generating an earthquake.

The **STRIKE** is the direction of a horizontal line on the surface of the fault. Strike refers to the direction in which a geological structure is present. The strike direction may be defined as the direction of the trace of the intersection between the bedding plane.

The **DIP**, measured in a vertical plane at right angles to the strike of the fault, is the angle of fault plane with horizontal. Dip literally means slope or inclination. In structural geology dip is expressed both as direction and amount. The dip direction is the direction along which the inclination of the bedding plane occurs

Types of Faults

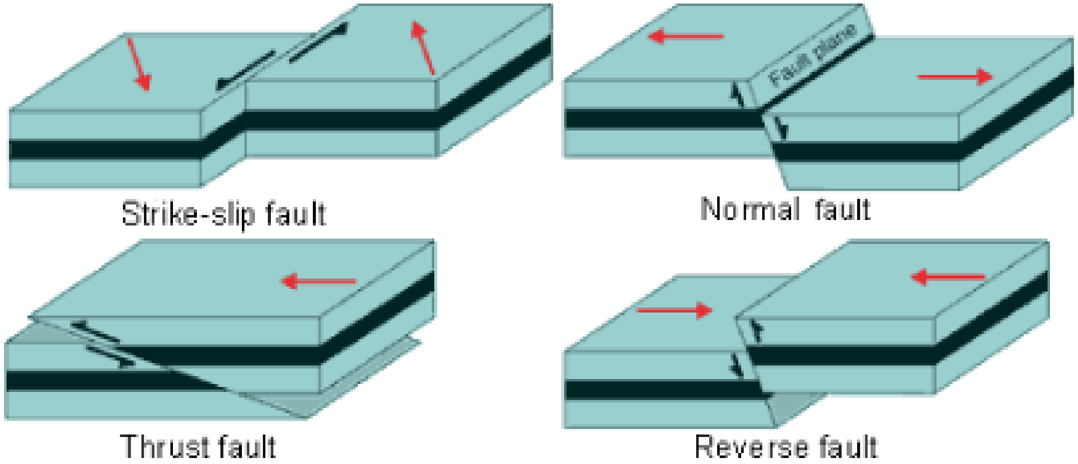
Based on relative movement of the hanging and foot walls, faults are classified into:-

In a **NORMAL FAULT**, the hanging wall has been displaced downward relative to the footwall.

In a **REVERSE FAULT**, the hanging wall has been displaced upward relative to the footwall

In a **WRENCH FAULT**, the foot or the hanging wall do not move up or down in relation to one another.

THRUST FAULTS, which are a subdivision of reverse faults, tend to cause severe earthquakes.



https://www.manxgeology.com/foldsfaults/

Types of Faults

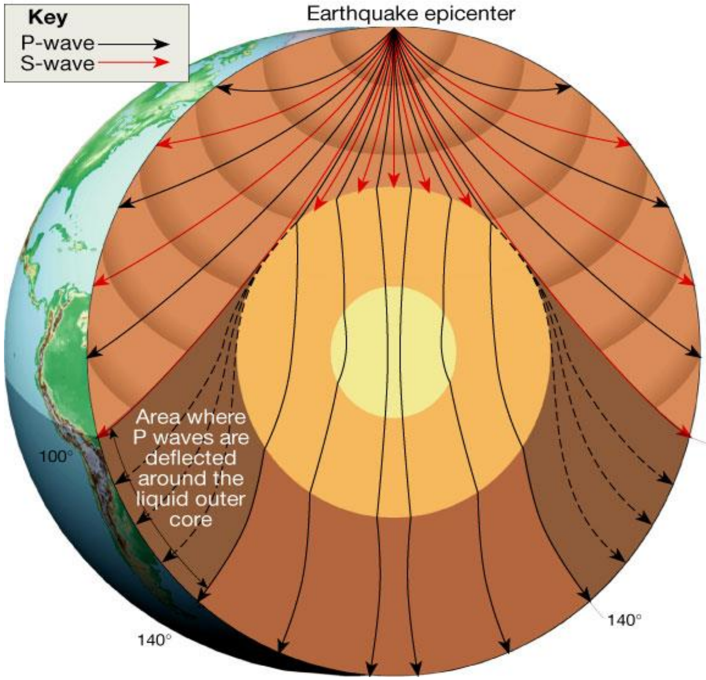
EARTHQUAKE WAVES

Earthquake vibrations originate from the point of initiation of rupture and propagates in all directions. These vibrations travel through the rocks in the form of elastic waves.

These earthquake waves are mainly three types:-

1. **Primary (P) Waves**
2. **Secondary (S) Waves**
3. **Surface Waves**

Earth's Interior Showing P and S Wave Paths



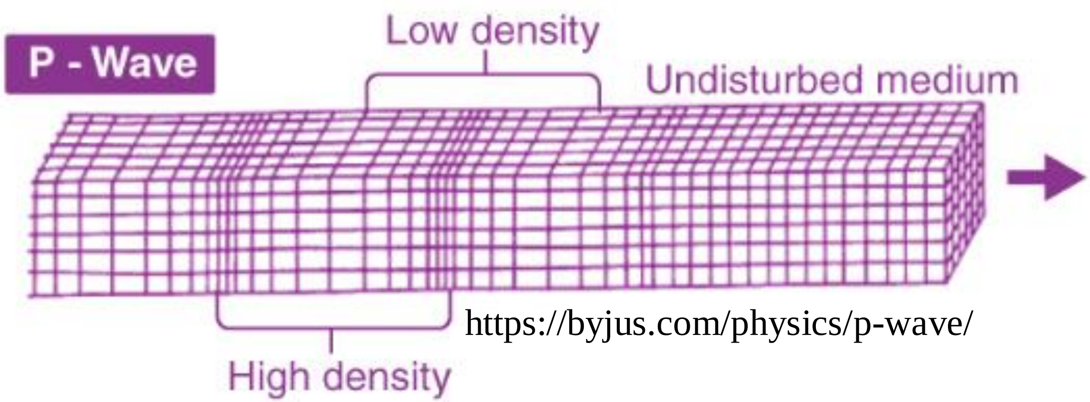
https://www.slideshare.net/jundel3/chapter-7-43935961

Primary (P) Waves

These are known as primary waves, push-pull waves, longitudinal waves, compressional waves, etc. These waves propagate by longitudinal or compressive action, which mean that the ground is alternately compressed and dilated in the direction of propagation

The P-waves propagates radial to the source of the energy release and the velocity is expressed by :-

$$Vp = \sqrt{\frac{E}{\rho}\frac{(1-\nu)}{(1+\nu)(1-2\nu)}}$$



https://byjus.com/physics/p-wave/

where E is the Young's modulus; ν is the Poisson's ratio (0.25); and ρ is the density

Nature of propagation of P waves

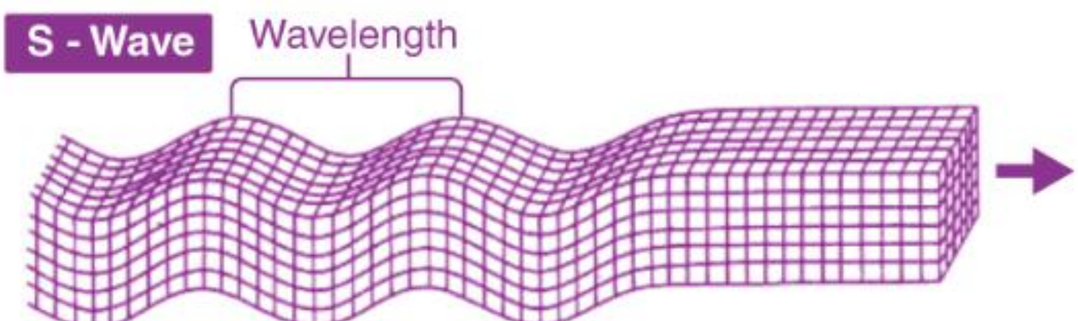
Secondary (S) Waves

These are also called shear waves, secondary waves, transverse waves, etc. Compared to P waves, these are relatively slow. These are transverse or shear waves, which mean that the ground is displaced perpendicularly to the direction of propagation. These waves are capable of traveling only through solids. If the particle motion is parallel to prominent planes in the medium they are called SH waves and if the particle motion is vertical, they are called SV waves.

The shear wave velocity is given by

$$Vs = \sqrt{\frac{E}{2\rho(1+\nu)}} = \sqrt{\frac{G}{\rho}}$$

Nature of propagation of S waves



Where G is the shear modulus

$$G = \frac{E}{2(1+\nu)}$$

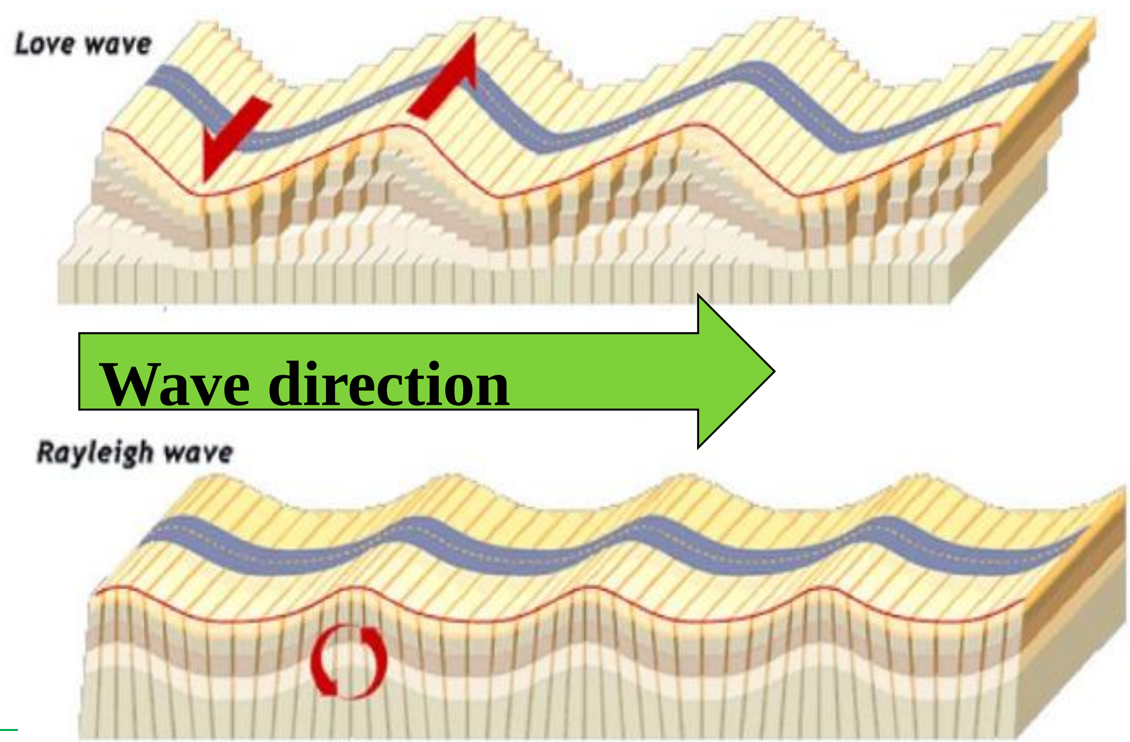
https://byjus.com/physics/p-wave/

Surface Waves

When the vibratory wave energy is propagating near the surface of the earth rather than deep in the interior, two other types of waves known a Rayleigh and Love waves can be identified. These are called surface waves because their journey is confined to the surface layers of the earth only. Surface waves are the slowest among the seismic waves.

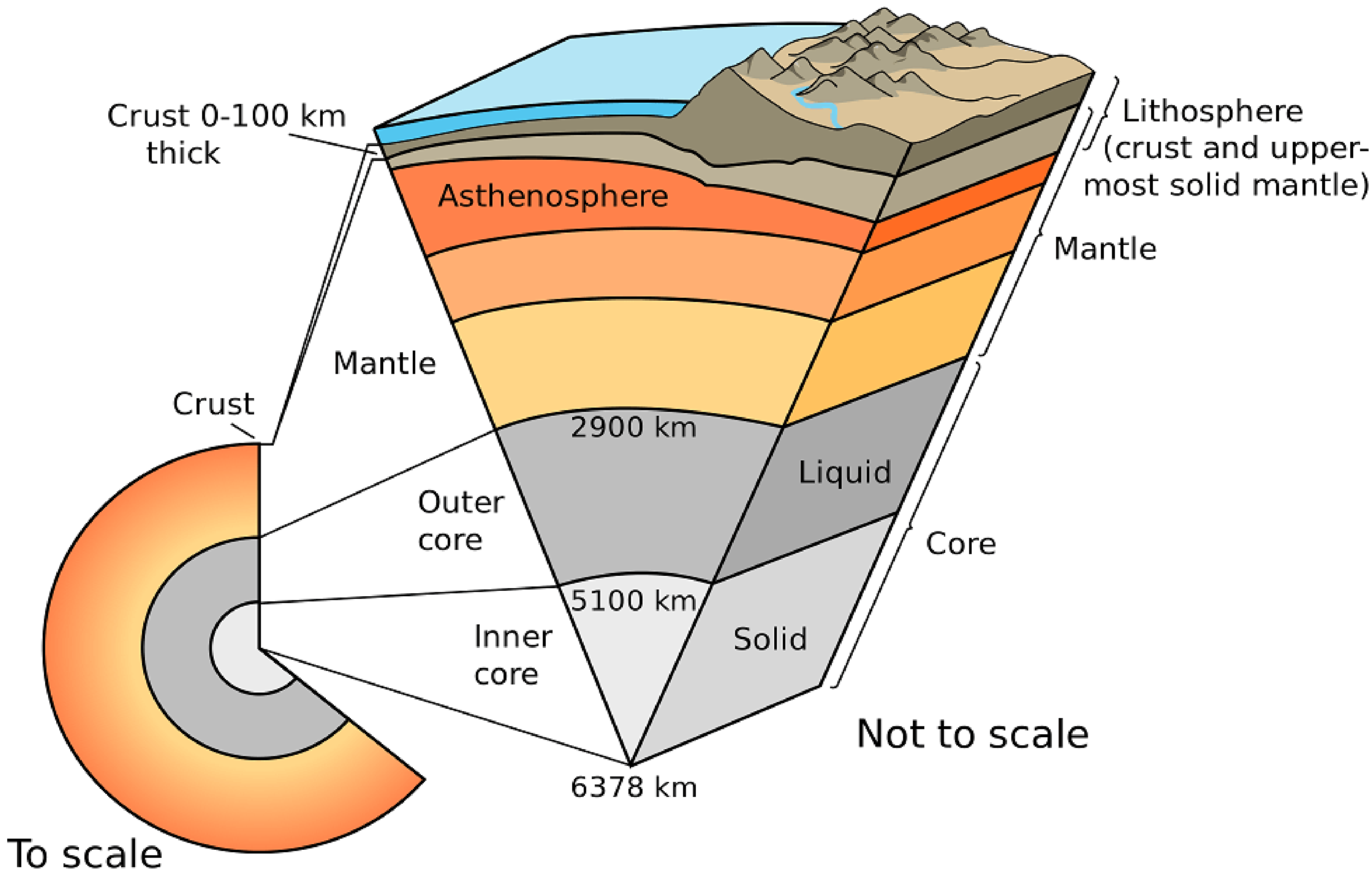
L-waves : travel along the Earth's surface at slow speed back and forth.

Rayleigh waves: travel along the Earth's surface similar to an ocean wave.



https://www.sms-tsunami-warning.com/pages/seismic-waves

Internal Structure of Earth



https://www.youtube.com/watch?v=dkdZnD5ck-I&feature=emb_title

Plate Tectonics

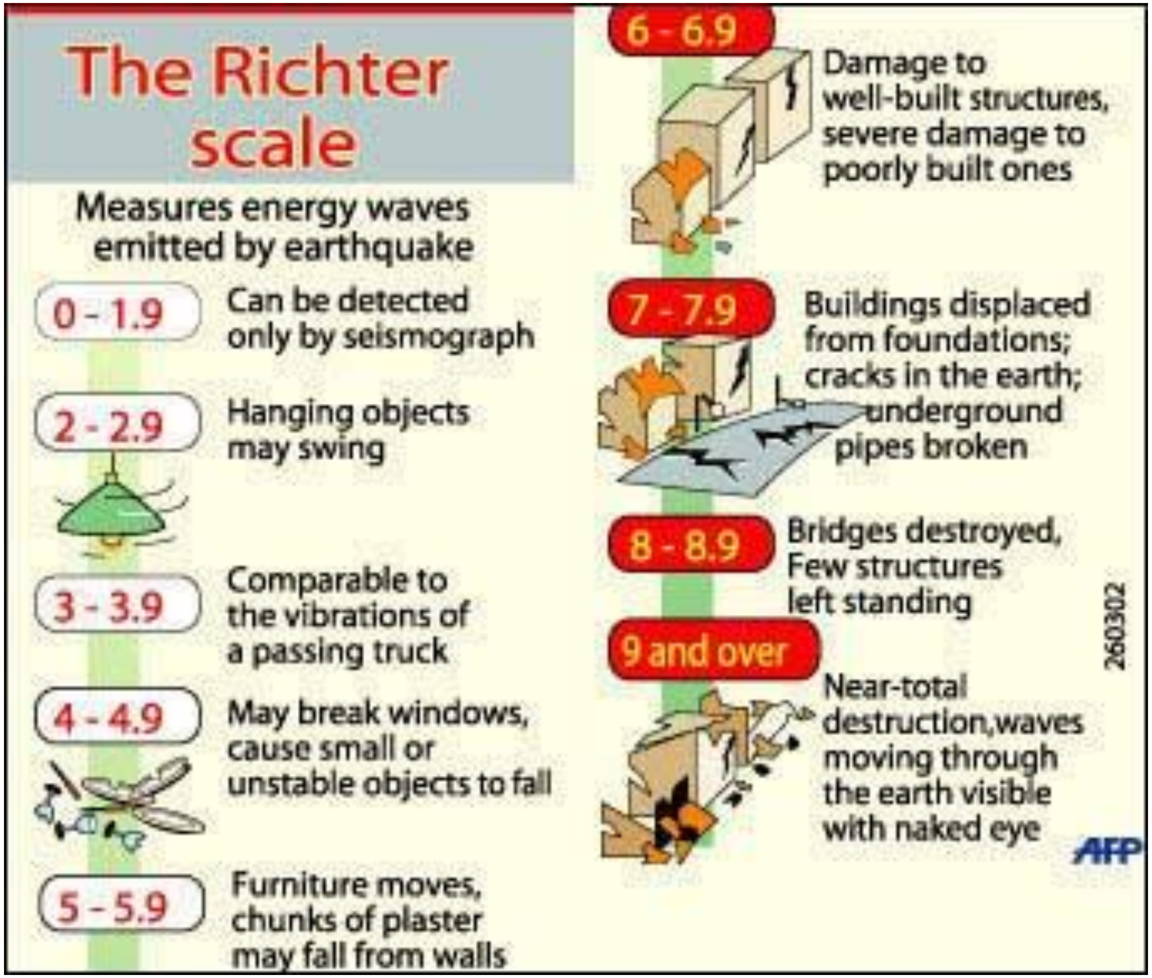
The theory of plate tectonics, presented in early 1960s, explains that the lithosphere is broken into seven large (and several smaller) segments called plates. The upper most part of the earth is considered to be divided into two layers with different deformation properties. The upper rigid layer, called the lithosphere (150 km) and lower layer, called the asthenosphere, extends down to about 700 km depth.

The continental sized plates are African, American, Antarctic, Indo-Australian, Eurasian and pacific plate. Apart from this, several smaller plates like Andaman, Philippine plate also exist.

This theory requires a source that can generate tremendous force is acting on the plates. The widely accepted explanation is based on the force offered by convection currents created by thermo-mechanical behavior of the earth's subsurface. The variation of mantle density with temperature produces an unstable equilibrium. The colder and denser upper layer sinks under the action of gravity to the warmer bottom layer which is less dense. The lesser dense material rises upwards and the colder material as it sinks gets heated up and becomes less dense. These convection currents create shear stresses at the bottom of the plates which drags them along the surface of earth.

RICHTER SCALE

The Richter magnitude scale is a scale of numbers used to tell the power (or magnitude) of earthquake. Charle S Richter developed the Richter Scale in 1935. His scale worked like a seismogram, measured by a particular type of seismometer at a distance of 100 km from the earthquake.

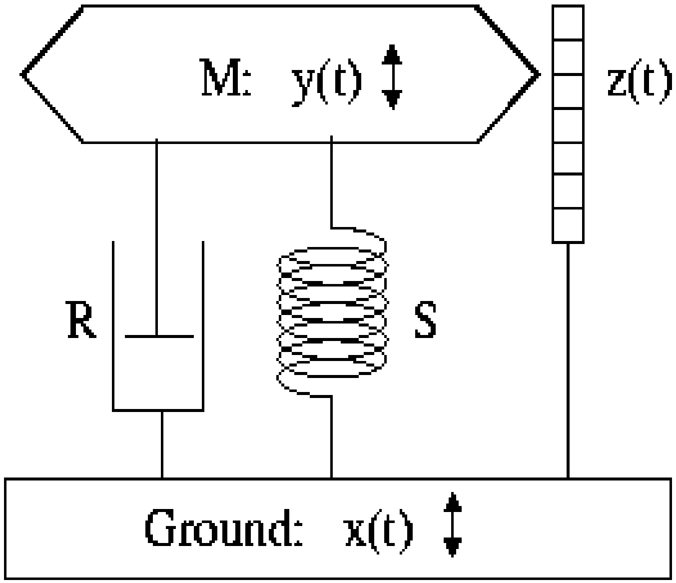


https://www.sms-tsunami-warning.com/pages/richter-scale#.X6Ef-lgzbIU

Different warnings and destruction according to Richter scale earthquake magnitude

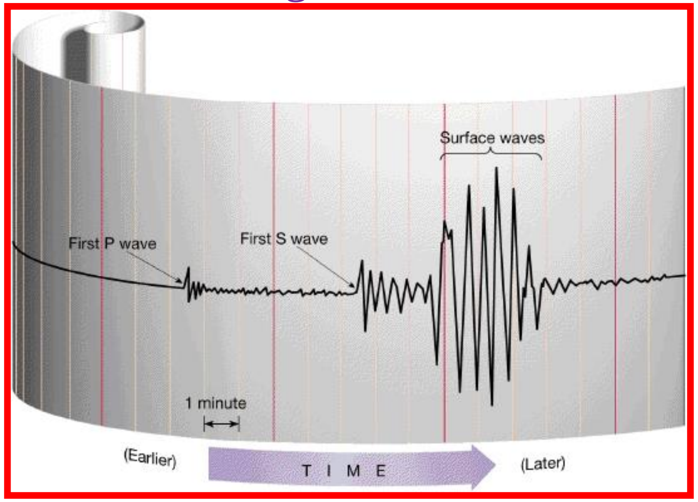
Seismogram

Seismometer: A seismometer is a sensor used to detect weak ground motion. The most common type of seismometer is made from a pendulum or a mass mounted on a spring.



Seismograph: A sensitive instrument that can detect, amplify, and record ground vibrations too small to be perceived by human beings. Seismographs are primarily used to record the motion of the ground produced by earthquakes.

Seismogram Printout



Seismogram: A graph showing ground motion versus time. On a seismogram, the X-axis denotes time while the Y-axis denotes ground displacement.

Accelerograph: A ground motion recorder whose output is proportional to ground acceleration.

https://www.slideshare.net/jundel3/chapter-7-43935961

Vibration effects on Structures

Structures are subjected to Two types of Loads

1. Static loads
2. Dynamic Loads

Equation of Static Equilibrium

$$F = K\,Y$$

F - External Force, K – Stiffness of Structure

Y – Resulting Displacement

KY is the restoring force which is used to resists the applied force.

Equation of Dynamic Equilibrium

$$Ma + Cv + Ky = F(t)$$

Where Ma is inertial force and Cv is damping force which helps Ky to resist applied force.

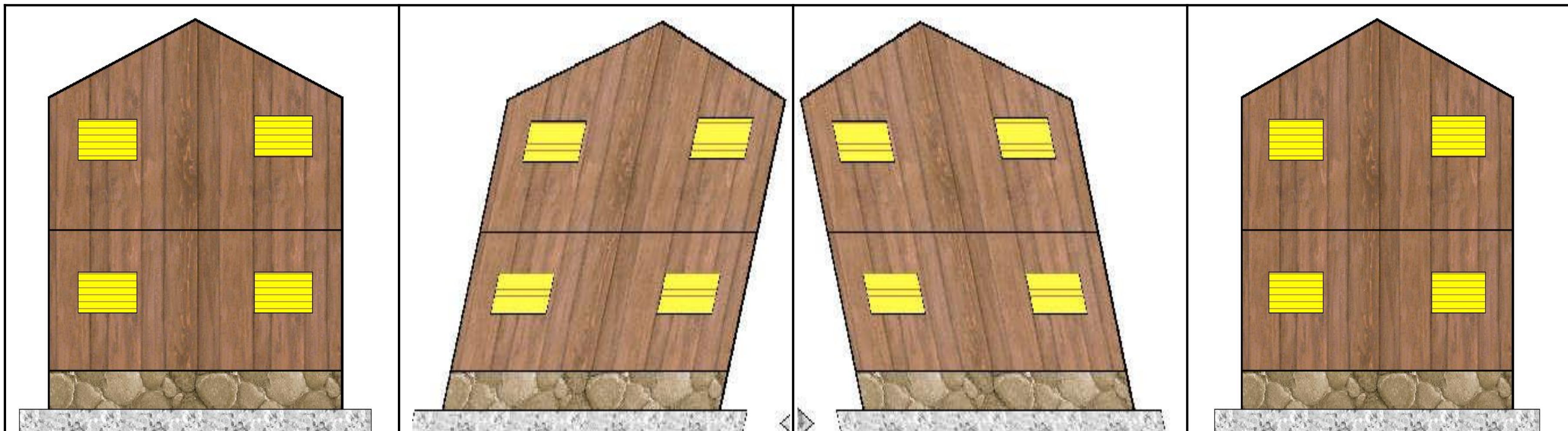
These two force are resulting from the induced Acceleration and Velocity in the Structure

Under the action of dynamic loads the structure vibrates, that is

(a) The structure develops significant level of inertia forces.

(b) Significant level of mechanical energy is stored as kinetic energy.

Direction of Inertia Force



Building at Rest	Ground Accelerates to Left	Ground accelerates to Right	Ground & Building at Rest

https://sjce.ac.in/wp-content/uploads/2018/01/EQ2-Earthquake-Effects.pdf

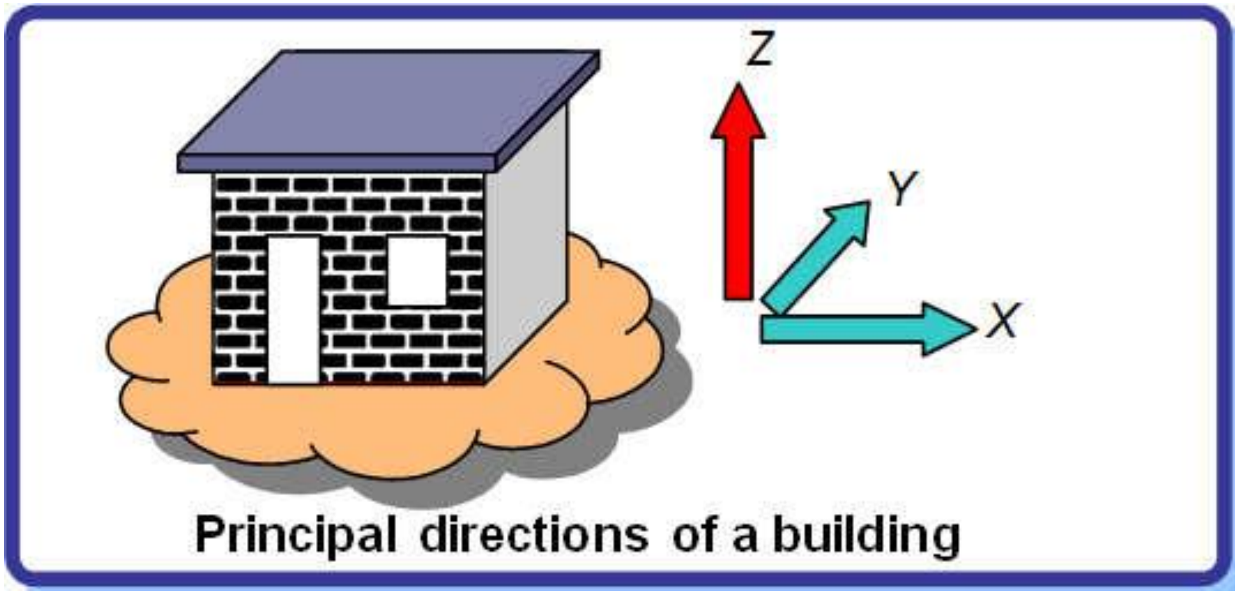
Seismic effects on structures

1. Inertia Force

When the ground moves, the building is thrown backwards, and the roof experiences a force, called *Inertia Force.*

The walls or columns are flexible, the motion of the roof is different from that of the ground (F=M x a) more mass means higher inertia force. Therefore, lighter buildings sustain the earthquake shaking better.

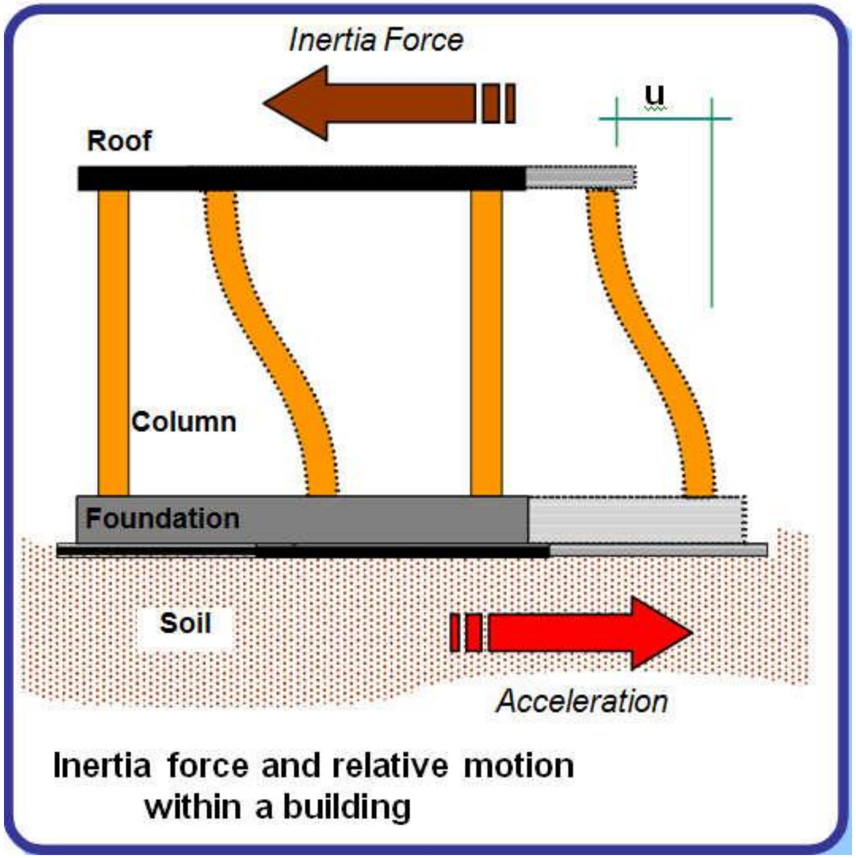
2. Horizontal and Vertical



Shakinghttps://constructionduniya.blogspot.com/2012/01/earthquake-resistant-construction.html

3. Effect of Deformation in Structures

1. The inertia force experienced by the roof is transferred to the ground via the columns, causing forces in columns.
2. The columns undergo relative movement (u) between their ends
3. Horizontal displacement **u**, larger is this greater the internal force in columns.
4. Also, the stiffer the columns are, larger is this force. these internal forces in the columns are called stiffness forces.
5. the stiffness force in a column is the column stiffness times the relative displacement.



Inertia force and relative motion within a building

https://sjce.ac.in/wp-content/uploads/2018/01/EQ2-Earthquake-Effects.pdf

Textbooks

1. Earthquake Resistant Design of Structures - P. Agarwal & M. Shrikhande

2. Dynamics of Structures Theory and Applications to Earthquake Engineering - Anil K. Chopra

3. Dynamics of Structures - R.W. Clough & J. Penjien

4. I.S. Codes No. 1893


THANK YOU