Earthquakes

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- Vibrations induced in the earth’s crust due to internal or external causes that virtually shake up a part of the crust and all the structures and living and non-living things existing on it.

Terminologies

- **Seismology:**

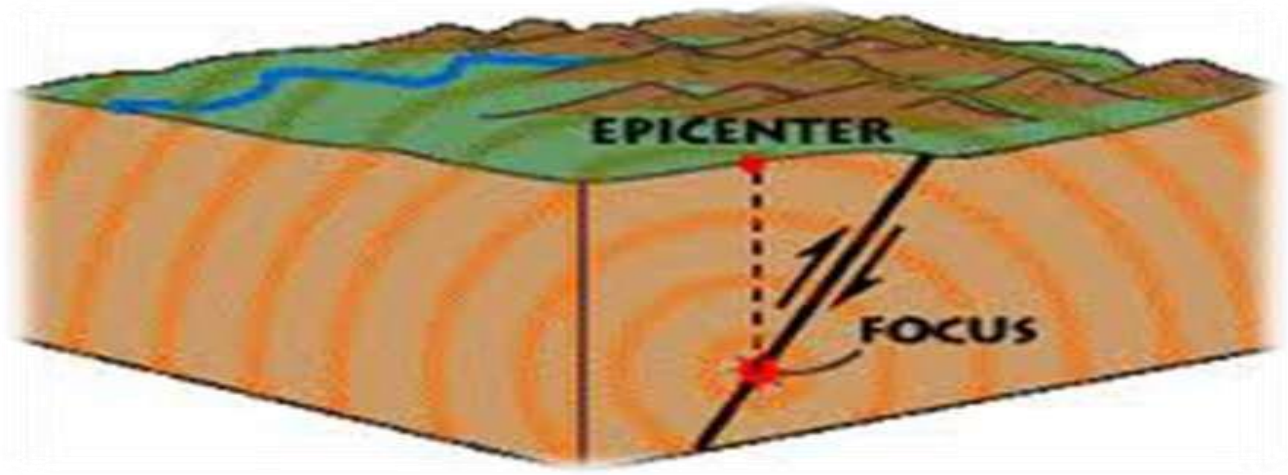
The science dealing with the study of earthquake in all their aspects is called seismology.

- **Focus:**

Focus is the point on the fault where rupture occurs and the location from which seismic waves are released.

- **Epicenter:**

Epicenter is the point on the earth’s surface that is directly above the focus ,the point where an earthquake or underground explosion originates.



- **Magnitude:**

- Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs.

- **Intensity:**

- Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment

SEISMIC WAVES

- During each earthquake, elastic waves are generated at the focus. these waves are called seismic waves and they travel in all directions with their characteristic velocities.

- There are several different kinds of seismic waves, and they all move in different ways. The two main types of waves are body waves and surface waves.

- **Body waves** can travel through the earth's inner layers, but
- **Surface waves** can only move along the surface of the planet like ripples on water.

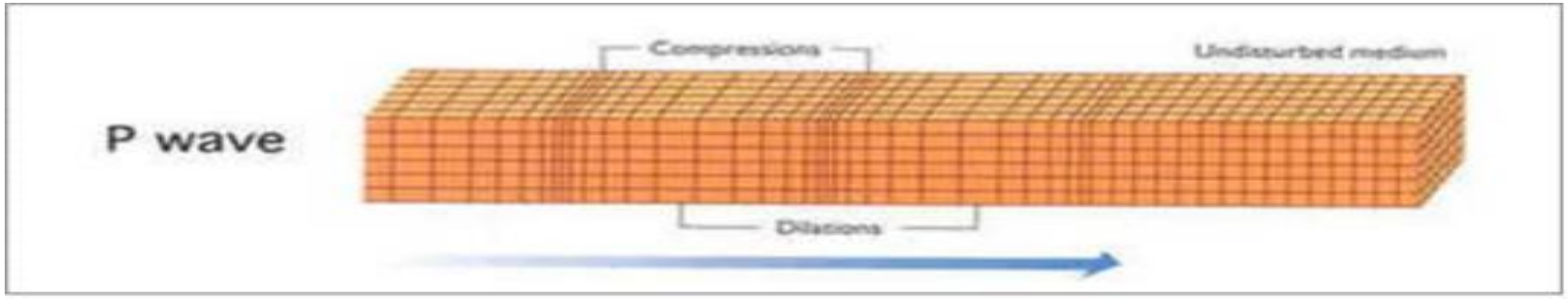
Body Waves

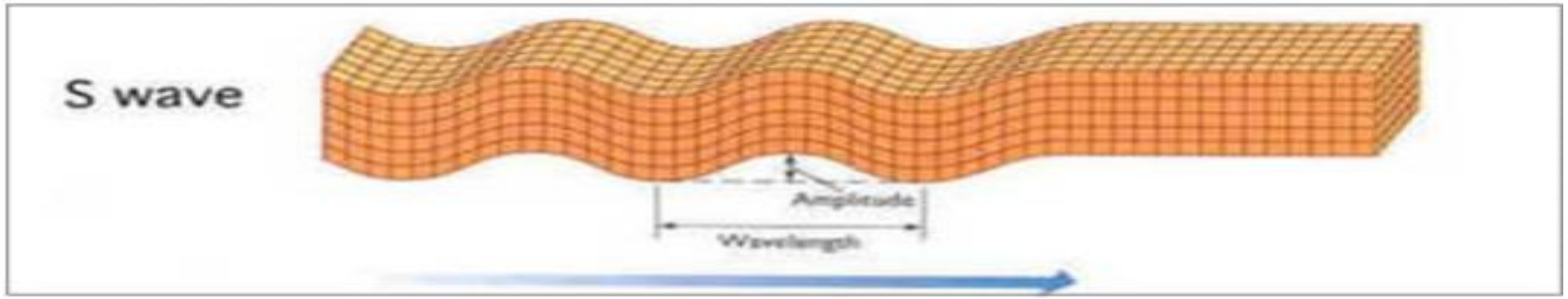
- Traveling through the interior of the earth, body waves arrive before the surface waves emitted by an earthquake. These waves are of a higher frequency than surface waves.

- **P Waves:**
- The first kind of body wave is the P wave or primary wave. This is the fastest kind of seismic wave, and, consequently, the first to 'arrive' at a seismic station.
- The P wave can move through solid rock and fluids, like water or the liquid layers of the earth.
- It pushes and pulls the rock it moves through just like sound waves push and pull the air.
- P waves are also known as compressional waves, because of the pushing and pulling they do.
- Subjected to a P wave, particles move in the same direction that the wave is moving in, which is the direction that the energy is traveling in, and is sometimes called the 'direction of wave propagation

S Waves

- The second type of body wave is the S wave or secondary wave, which is the second wave you feel in an earthquake.
- An S wave is slower than a P wave and can only move through solid rock, not through any liquid medium.
- S waves move rock particles up and down, or side-to-side perpendicular to the direction that the wave is traveling in (the direction of wave propagation).





Surface Waves

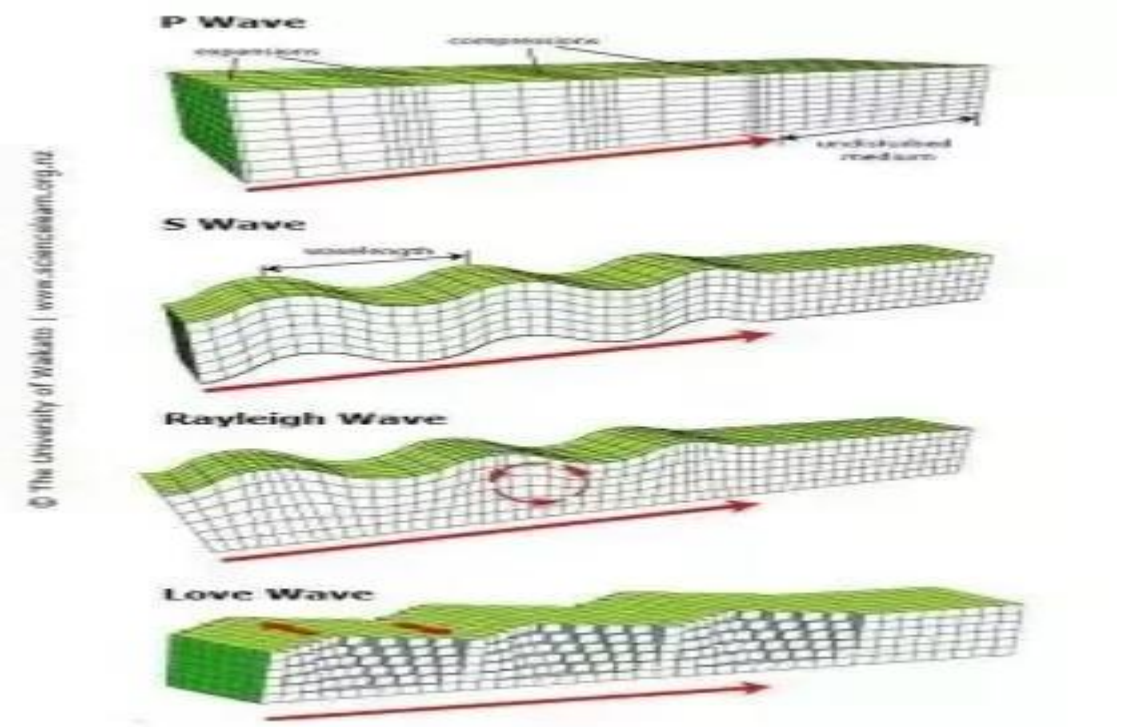
- Travelling only through the crust, surface waves are of a lower frequency than body waves, and are easily distinguished on a seismogram as a result.

- Though they arrive after body waves, it is surface waves that are almost entirely responsible for the damage and destruction associated with earthquakes.

- This damage and the strength of the surface waves are reduced in deeper earthquakes.

Love Waves

- The first kind of surface wave is called a Love wave, named after A.E.H. Love, a British mathematician who worked out the mathematical model for this kind of wave in 1911.
- It's the fastest surface wave and moves the ground from side-to-side. Confined to the surface of the crust, Love waves produce entirely horizontal motion.



Rayleigh Waves

- The other kind of surface wave is the Rayleigh wave, named for John William Strutt, Lord Rayleigh, who mathematically predicted the existence of this kind of wave in 1885.
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- A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean.

- Because it rolls, it moves the ground up and down and side-to-side in the same direction that the wave is moving.

- Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.

Classification of earthquake

- **Based on depth of focus:**

- **shallow earthquakes**: depth of focus lies upto 60km
- **intermediate earthquakes**: depth of focus between 60km and 300km
- **deep seated earthquakes**: depth of focus between 300km and 700km

- **Based on magnitude:**

class	Magnitude
A	>7.8
B	7.0-7.7
C	6.0-7.0
D	5.3-6.0
E	<5.3

Cause of origin as basis:

- **Tectonic earthquakes:**

- which are caused dur to faulting or relative displacements of blocks of the crust of the earth along rupture planes.

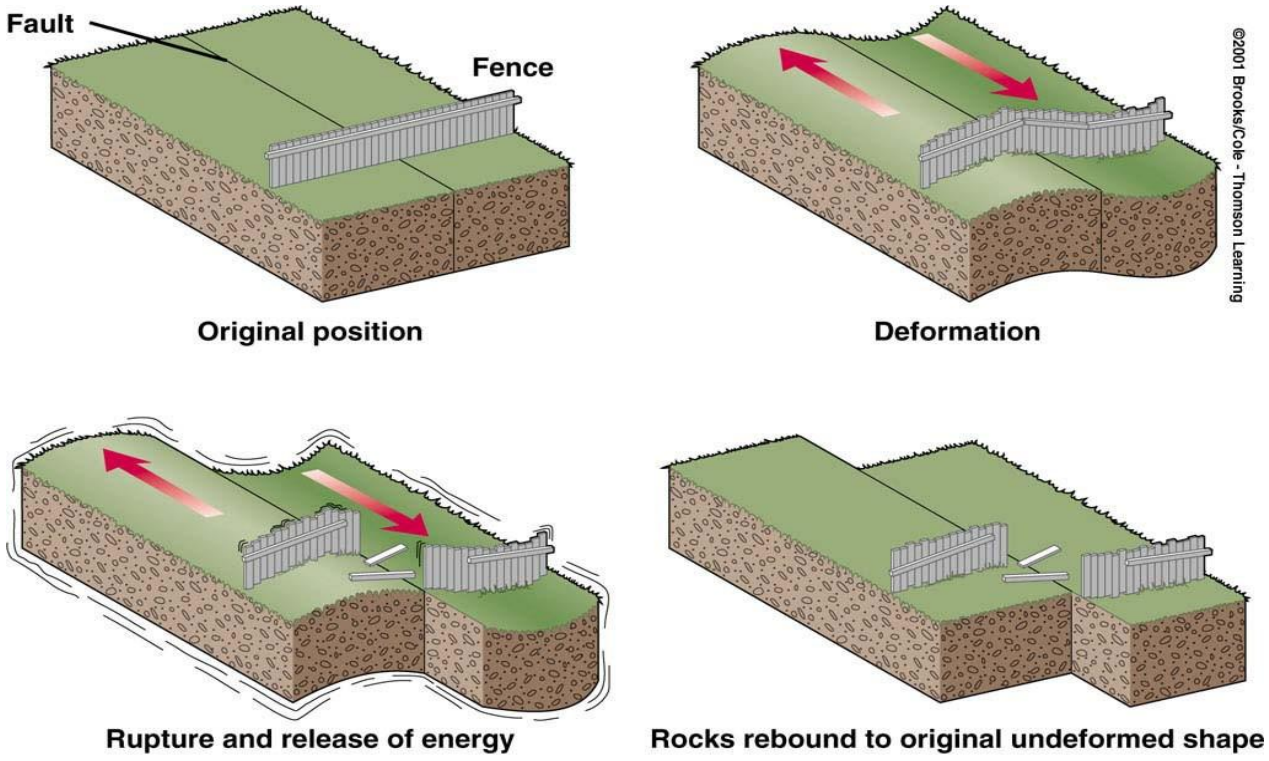
- **Non-tectonic earthquakes:**

- which owe their origin to causes distinctly different from faulting such as volcanic eruption,landslides.

Causes of Earthquake

- Earthquakes are caused by sudden tectonic movements in the Earth’s crust.

- **<u>Elastic Rebound Theory:</u>**



- Accordingly rocks are belived to behave as elastic masses towards operating stresses.
- When they are stressed the rocks respond by bending as a first reaction.
- When the stress continue, the elastic limit may be reached and rupture may develop associated with displacement of the blocks along surface of rupture.
- The plane of rupture and displacement is called the fault plane and faulting.
- The displacement is associated with a rebound or readjustment of curvature developed due to bending during stressing.
- At the time of this process of rebound, most of the elastic energy stored during stressing is released at the place of displacement in the form of energy waves, or the seismic waves.

Effects of earthquake

- The destructive effects of an earthquake can be classified into primary and secondary effects.

- **Primary effects:**

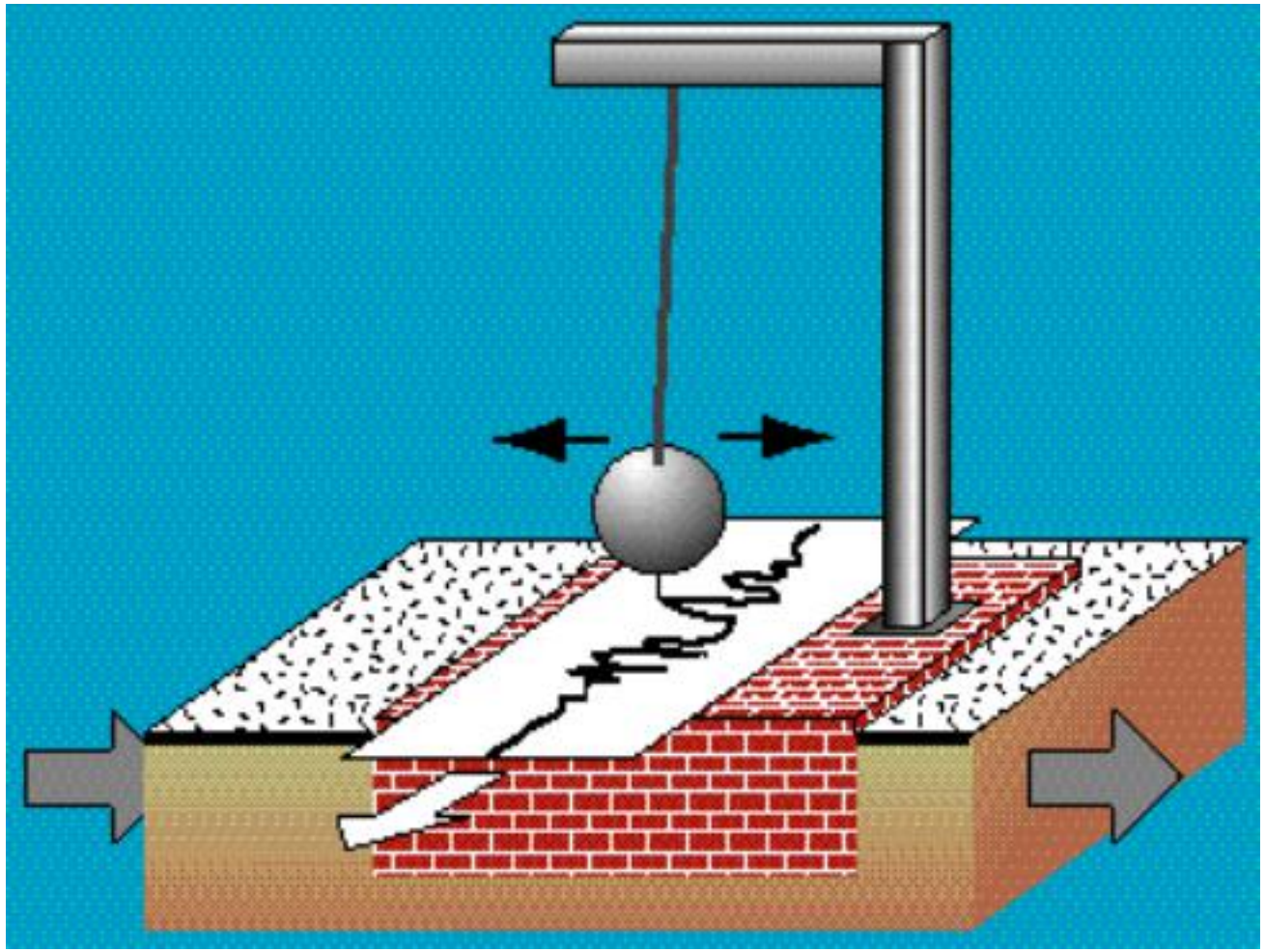
They are the immediate damage caused by the quake, such as collapsing buildings, roads and bridges, which may kill many people. Those lucky enough to survive can suffer badly from shock and panic.

- **Secondary effects:**

They are the after-effects of the earthquake.

  - Tsunamis
  - Soil liquefaction
  - Fire
  - Disease and famine
  - Landslides

- Seismographs are instruments used to record the motion of the ground during an earthquake.
- They are installed in the ground throughout the world and operated as part of a seismographic network.
- The earliest "seismoscope" was invented by the Chinese philosopher Chang Heng in A.D. 132. This did not, however, record earthquakes; it only indicated that an earthquake was occurring. The first seismograph was developed in 1890.
- A seismograph is securely mounted onto the surface of the earth so that when the earth shakes, the entire unit shakes with it EXCEPT for the mass on the spring, which has inertia and remains in the same place.
- As the seismograph shakes under the mass, the recording device on the mass records the relative motion between itself and the rest of the instrument, thus recording the ground motion.
- In reality, these mechanisms are no longer manual, but instead work by measuring electronic changes produced by the motion of the ground with respect to the mass.
- A seismogram is the recording of the ground shaking at the specific location of the instrument. On a seismogram, the HORIZONTAL axis = time (measured in seconds) and the VERTICAL axis= ground displacement (usually measured in millimeters).



TSUNAMI

- A tsunami is a natural disaster which is a series of fast-moving waves in the ocean caused by powerful earthquakes, volcanic eruptions, landslides, or simply an asteroid or a meteor crash inside the ocean.

- tsunami creates large waves in the oceans like winds which have crest and troughs, wave period, wave length and wave height.

- some of effects of tsunami on construction and desirable design solutions determined by government of india are outlines below:

1. **Effect :** Flooding of lower floors, action of hydrostatic forces such as pressure on walls, effect of uplift forces during flooding

   Solution : Raise the bulding above flood level and design for static water pressure on walls

2. **Effect** : Slope failure due to saturation or loss of bearing capacity.

   Solution : Evaluating shear strength of soil

3. **Effect** : Hydrodynamic forces that are likely to push front faces of the building and may also cause drag effect

   Solution : The building should be firmly anchored to foundation and additional design strength imparted agaimst water forces.

Tsunami Warning System

- Tsunami warning centre is based on the concept that tsunamis travel at a **much slower velocity** than earthquake waves.

- Hence if focus of an earthquake is found located near or close to a coastal area in the sea, some time may be available to evacuate the people up to 2-3 km away from risk zone.

- All earthquake do not cause tsunamis.

- It is only the earthquake causing a **vertical displacement** that are known to **generate tsunamis**.

- Tsunami warning system is located near **Honolulu, Hawaii** which provides tsunami related information to 28 international member states.

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Geotechniques & Applied Geology

Geotechnical Engineering :-

Three Phases of Soil :- Solid Particles
Water
Air.

Phase diagram of Soil :-

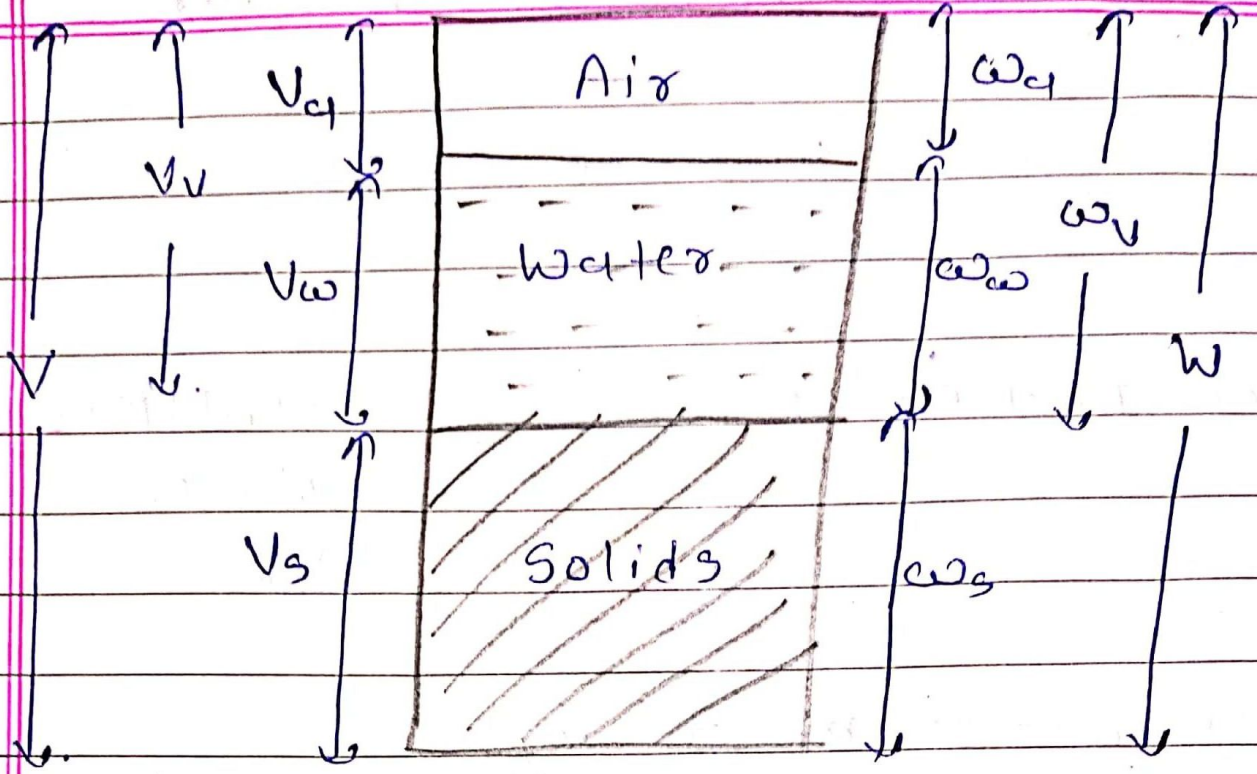
Three Phases of Soil

- Partly dry & Partly Saturated Soil → Three Phase diagram
- Fully dry Soil
- Fully Saturated Soil

(Fully dry Soil + Fully Saturated Soil) → Two Phase diagram

Three phase diagram :-

Solids, water and air presents.



V_a = Vol. of air in soil mass

V_w = " " water " "

V_s = " " Solids " "

$V = V_v + V_s$

$$V = V_a + V_v + V_s$$

W_a = wt. of air in soil mass

W_s = " " Solids " " "

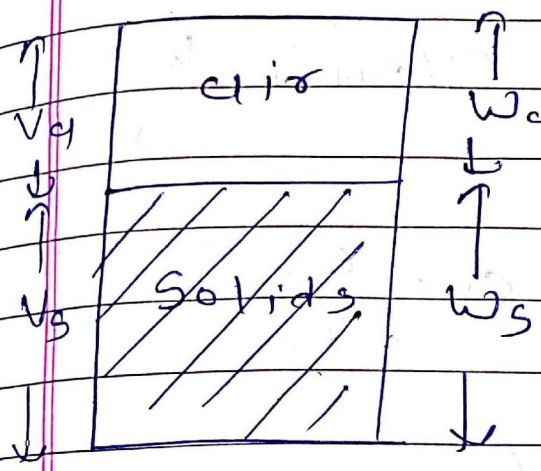
W_v = " " Voids " "

$W = W_v + W_s$

$$W = W_a + W_w + W_s$$

$$W = W_w + W_s \quad (\because W_a = 0).$$

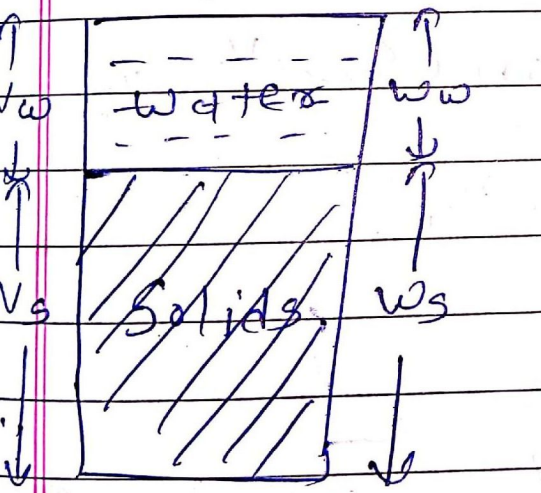
Two phase diagram For fully dry :-



$$V = V_a + V_s$$

$$W = W_s \quad (\because W_a = 0)$$

Two phase dia. for fully Saturated :-



$$V = V_w + V_s$$

$$W = W_w + W_s$$

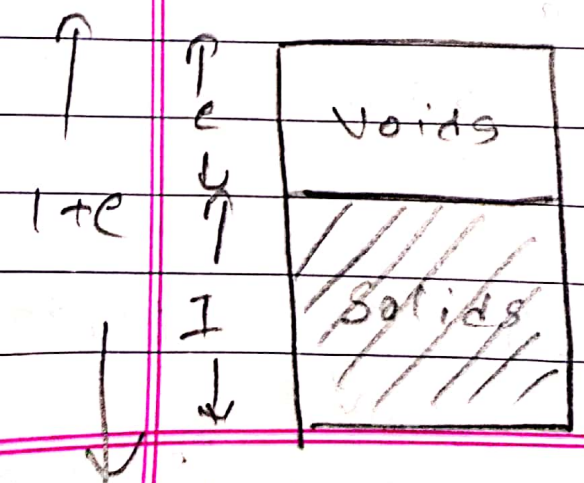
Water content $= \frac{M_W}{M_S} \times 100$

Bulk unit wt. $= (\gamma_b) = \frac{W}{V}$ ... N/m

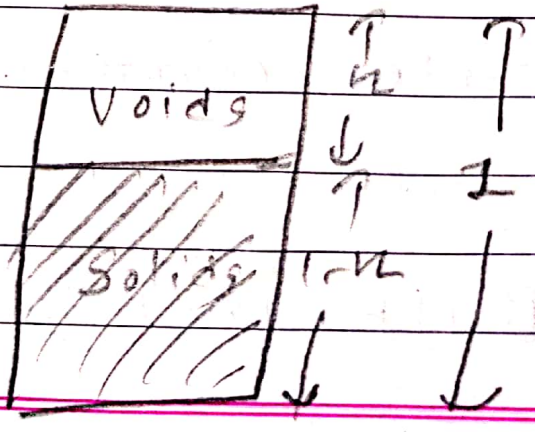
- Dry unit wt. $(\gamma_d) = \frac{W_d}{V}$ ..... KN/m³
- Saturated unit wt. $(\gamma_{sat}) = \frac{W_{sat}}{V}$
- Specific gravity $G = \frac{W_s}{W_w}$
- Void ratio $e = V_v / V_s$
- Porosity $\eta = V_v / V$
- Degree of Saturation $(S_r) = V_w / V_v$
- Air Content $a_c = V_a / V_v$

$$a_c = 1 - S_r$$

- Derive :- $e = \frac{n}{1-n}$ OR $n = \frac{e}{1+e}$



Soil element in e.



Soil element in n

$$n = \frac{V_v}{V} = \frac{e}{1+e}$$

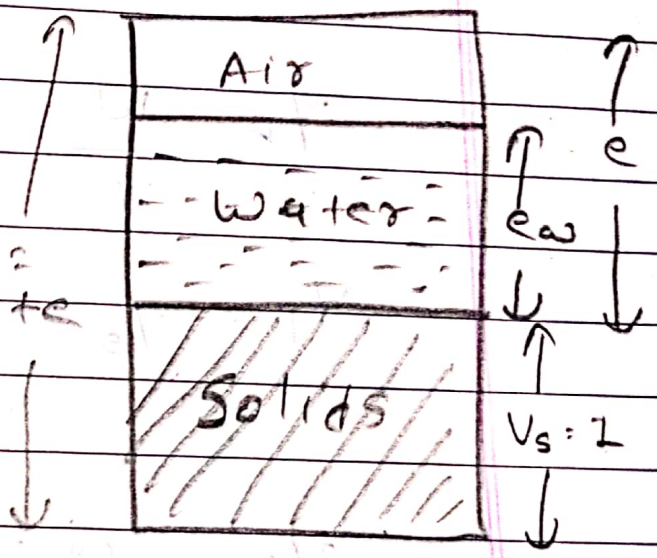
$$e = \frac{V_v}{V_s} = \frac{n}{1-n}$$

\# Derive :- $e = w \cdot G / S_r$

$$S_r = \frac{V_w}{V_v}$$

$$\therefore S_r = e_w / e$$

$$\therefore e_w = e S_r \quad \text{---(1)}$$



Now, $w = w_w / w_s$

$$w = \frac{\gamma_w V_w}{\gamma_s V_s} \quad \left(\because \gamma_s = w_s / V_s\right)$$

$$\therefore w = \frac{\gamma_w e_w}{\gamma_s \cdot 1}$$

$$\therefore w = \frac{\gamma_w \cdot e_w}{G \cdot \gamma_w} \quad \left(\because G = \gamma_s / \gamma_w\right)$$

$$\therefore e_w = w \cdot G \quad \text{---(2)}$$

From eqn (1) & (2)

$e S_r = \omega . G_T$

$\therefore e = \frac{\omega . G_T}{S_r}$

Derive :- $\gamma_b = \frac{(G_T + e S_r) . \gamma_w}{1 + e}$

$\gamma_b = \frac{W}{V} = \frac{W_s + W_w}{V}$

$\gamma_b = \frac{\gamma_s . V_s + \gamma_w . V_w}{V}$

$\therefore \gamma_b = \frac{G_T \gamma_w + e_w \gamma_w}{1 + e}$

$\therefore \gamma_b = \frac{(G_T + e S_r) \gamma_w}{1 + e}$

For dry Soil $\therefore \gamma_d = \frac{G_T \gamma_w}{1 + e}$

For saturated Soil : $\gamma_b = \frac{(G_T + e) \gamma_w}{1 + e}$

Derive :- $\gamma_d = \gamma_b / 1+\omega$

$\omega = \omega_\omega / \omega_d$

$\therefore 1+\omega = \frac{\omega_\omega + \omega_\omega}{\omega_d}$

$\therefore 1+\omega = \frac{w}{w_d}$

$\therefore w_d = w / 1+\omega.$

$\therefore \frac{\omega_d}{V} = \frac{\omega}{(1+\omega)\, V}$

$\therefore \gamma_d = \gamma_b / 1+\omega.$ $\quad (\gamma_b = w/v)$