Importance of Geotechnical studies for Earthquake Resistant Building

V. V. Pancholi
Scientist, ISR
Gandhinagar

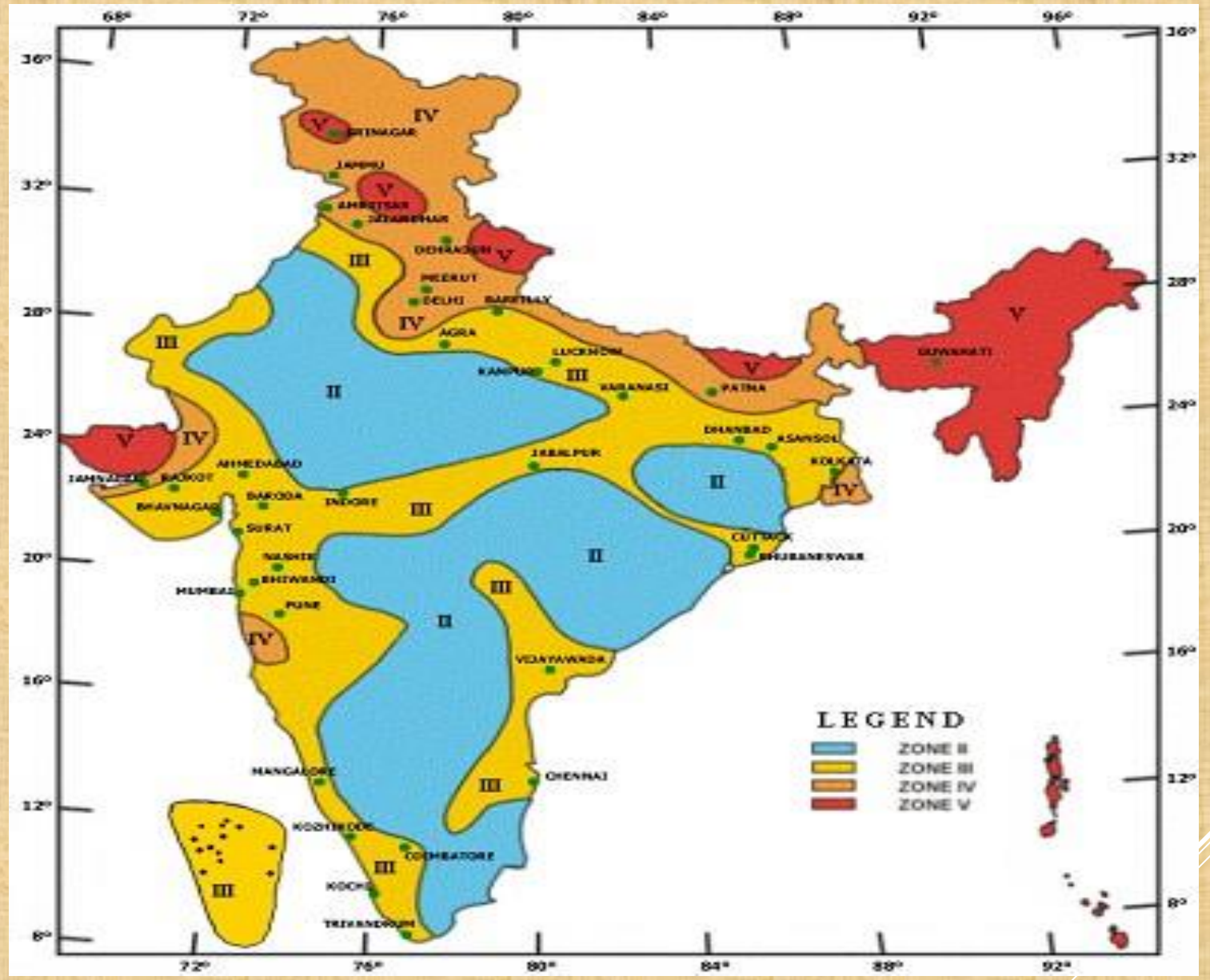
Seismic Microzonation

It is a process of dividing a seismically active region into sub-regions such that any characteristic of interest may be considered to be reasonably same over these micro zones.

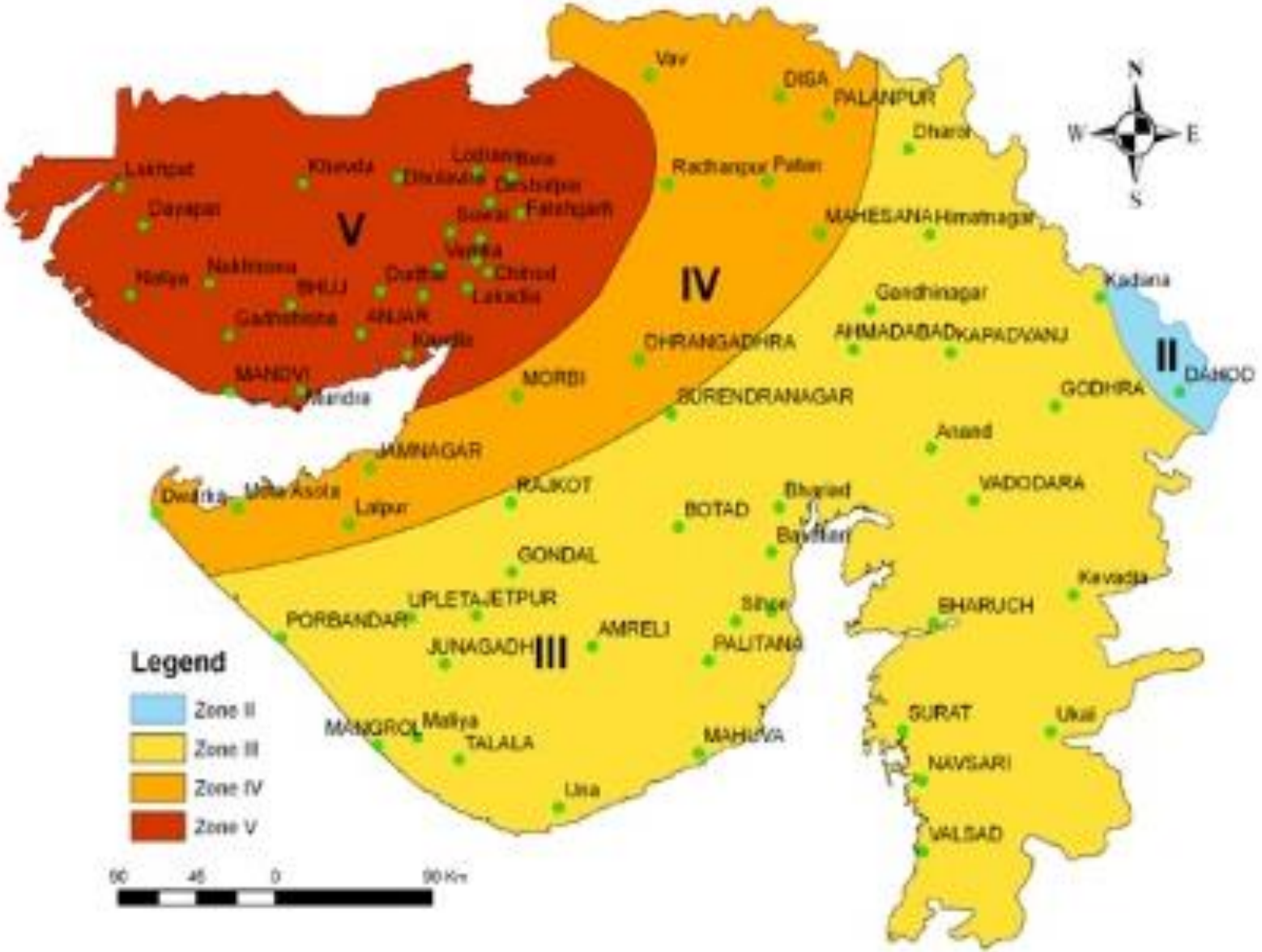
PROCEDURE :

Seismic Microzonation provides the expected level of shaking in a region and associated seismic risks such as liquefaction, land-slides, tsunamis etc. It involves a very detailed field investigation to evaluate future Hazards. It covers following areas to study

- Geotechnical study
- Geological study
- Geophysical study
- Geomorphological study



Seismic Zoning Map of INDIA Bureau of Indian Standards Criteria for earthquake resistant design of structures IS 1893 : 2002


Vav
DISA
PALANPUR
Dharoi
N
W
E
S
Radhanpur
Patan
MAHESANA
Himatnagar
Kadana
Gandhinagar
AHMADABAD
KAPADVANJ
DHRANGADHRA
MORBI
SURENDRANAGAR
GODHRA
Anand
VADODARA
JAMNAGAR
RAJKOT
BOTAD
Bhavnagar
GONDAL
UPLETA
JETPUR
PORBANDAR
JUNAGADH
AMRELI
PALITANA
BHARUCH
Kavadia
SURAT
Ukai
NAVSARI
VALSAD
MAHUVA
TALALA
Una
Mangrol
Mallya
Legend
Zone II
Zone III
Zone IV
Zone V
90
45
0
90 Km

Role of Geotechnical Engineering in Seismic hazard study

- It is a branch of civil engineering which deals with the study of sub-surface soil strata.
- It deals with application of geotechnical index properties of earth materials for safe, stable and economic design & construction of a civil engineering project.
- Geotechnical investigation done in seismic microzonation is a applied geotechnical engineering which mainly concentrate on
  - Drilling
  - Lab analysis
  - Soil modelling

DRILLING:-

Drilling is the first step towards sub-surface exploration.

The object of site exploration is to provide reliable, specific and detailed information about the soil and ground water condition of the site which may be required for a safe and economical design and execution of the engineering work.

Drilling Methods:

- Auger drilling
- Auger and shell drilling
- Wash boring
- Percussion drilling
- Rotary drilling

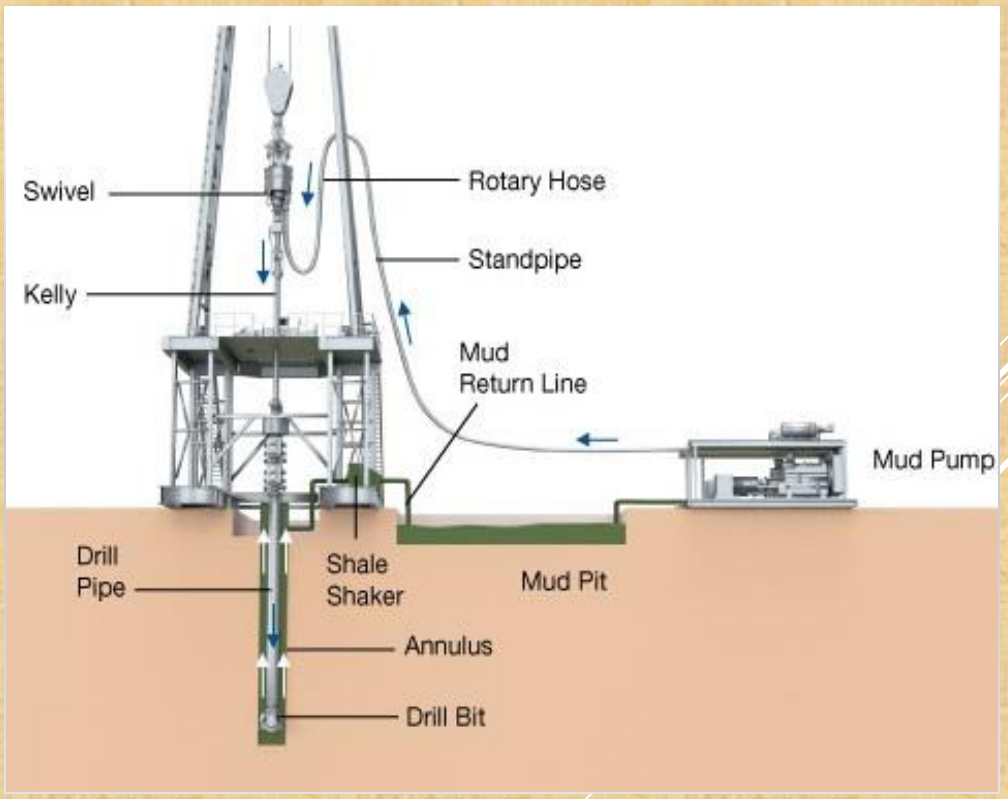
Rotary drilling is the most convenient method of advancing the hole in both rock and soils and conducting In-Situ test in Soil.

Rotary drilling:- Rotary drilling is the most convenient method of advancing the hole in both rock and soils. A drill bit is fixed to the lower end of the drill rods and is rotated by a suitable chuck. Also, it is always kept in firm contact to the bottom of the hole

- For drilling purpose, we have adopted Rotary Drilling for sub-surface exploration in our project.

Types of samples collected in Drilling :

- Disturbed Sample (DS)
- Undisturbed Sample (UDS)
- SPT Sample



Standard Penetration Test

Standard Penetration Test (SPT) is the most commonly used in situ test for soil.

The sampler is driven into the sediments by dropping a hammer of 63.5 kg from the top. Weight falling through a height of 75cm. SPT is the measure of number of blows required to drive the SPT sampler every 15 cm at a prescribed depth. The same process is repeated thrice. The number of blows recorded for the first 15 cm is disregarded or considered as "Seating Value". The number of blows recorded for the last two 15 cm intervals are added to give Standard Penetration Test ('N' value) and are regarded as the "Penetration Value".

Spilt spoon sampler

Correction of SPT N value

The SPT values obtained from the site investigation must be corrected to remove the errors. The N values obtained from the SPT data should be corrected to get the standardized (N1)60

$$(N1)60 = N*C_N *C_R *C_S *C_B *C_E$$

N - Measured SPT value

C N = correction for overburden pressure

C R = correction for short rod length

C S =correction for sampler

C B =correction for bore-hole diameter

C E = correction for hammer energy efficiency

LAB ANALYSIS

- After Drilling, our Geotechnical Investigation moves to lab. analysis. Lab analysis is done as :

  - ❖ Physical analysis
  - ❖ Mechanical analysis

Physical analysis

- ❑ Grain size analysis:- For determination of % of soil particle present in the sample
- ❑ Consistency of soil:- For determination of Plasticity index of doil
- ❑ Density, Moisture content
- ❑ Specific gravity

Grain size analysis

❑ Sieve analysis

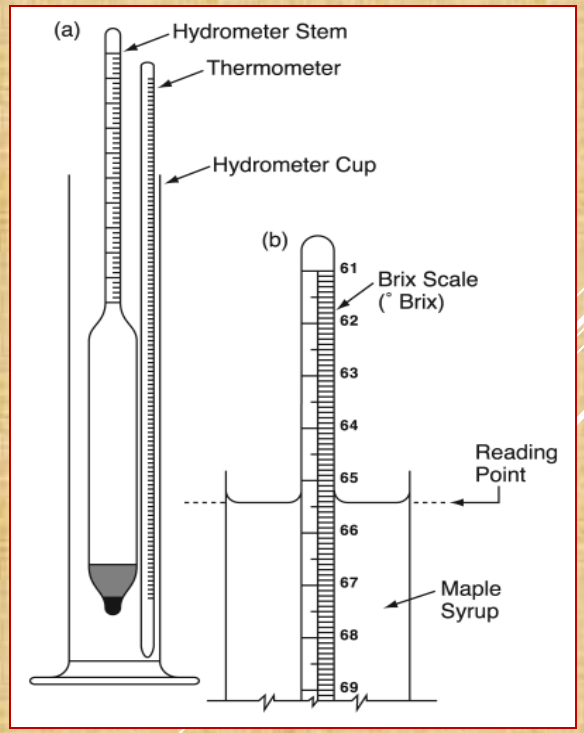
- Sieve analysis is the method of grain size distribution for coarse-grained soils. Sieve stack, formed by several sieves arranged in descending order from top to bottom, are used.

Sieves

Grain type	Grain size (mm)
Gravel	> 4.75
Sand	4.75 to 0.075
✓ Coarse.	4.75 to 2.00
✓ Medium	2.00 to 0.425
✓Fine	0.425 to .075
Silt	.075 to 0.002
Clay	< 0.002

❑Hydrometer analysis

- Hydrometer test is done for fine-grained soils. It is based on Stokes' law, according to which the velocity at which grains settle out of suspension, is dependent on their shape, weight and size.



Hydrometer

➢Consistency of soil (Atterberg limit)

✓Plastic Limit (PL)

The plastic limit is the minimum % of water content where the soil starts to behave like plastic from semisolid state.

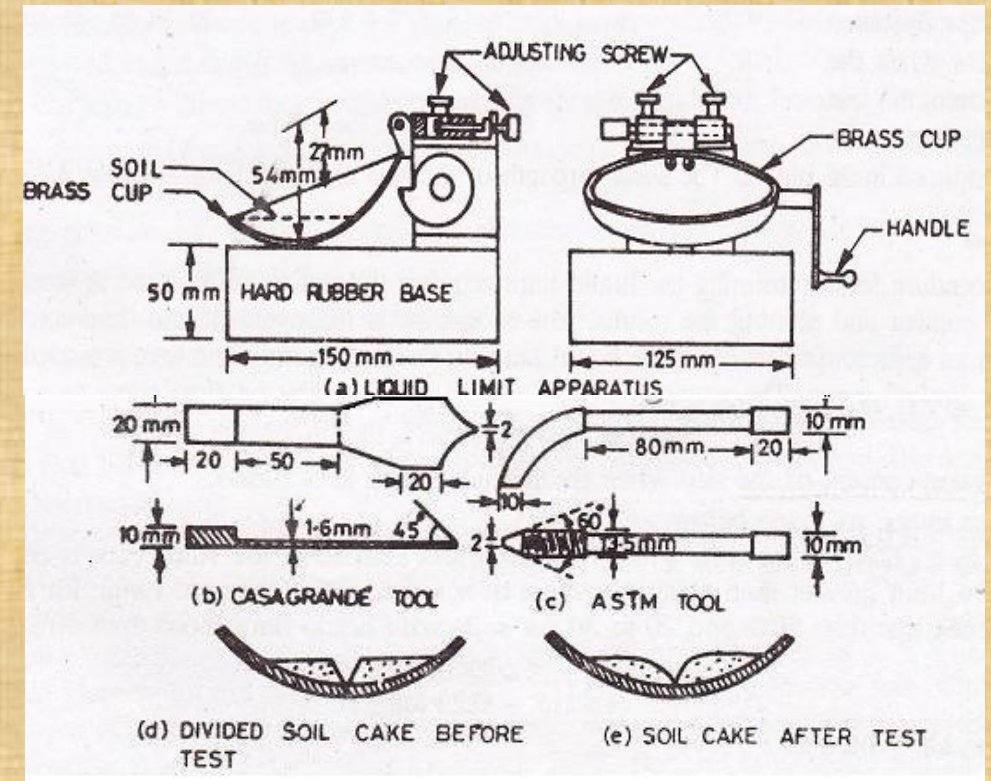
✓Liquid Limit (LL)

The liquid limit is the minimum % of water content where the soil starts to behave like liquid from plastic state.

✓ Plasticity Index (PI)

It is the difference between the Liquid Limit and the Plastic Limit.

PI = LL - PL



Casagrande apparatus

➢Moisture content

✓Moisture content (w) is defined as the ratio of weight of water (W_w) to the weight of solid (W_d) in the given mass of soil . It is expressed in percentage(%).

$$w = \frac{W_w}{W_d} * 100$$

➢Density

✓ The density(ρ) of soil is defined as the mass(M) of the soil per unit volume(V).It is expressed in terms of g/cm^3 or kg/m^3

$$\rho = \frac{M}{V}$$

➢Specific gravity

Specific gravity (G) is define as the ratio of the weight of a given volume of soil solids at a given temperature to the weight of an equal volume of water at that temperature.

$$G = \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$$

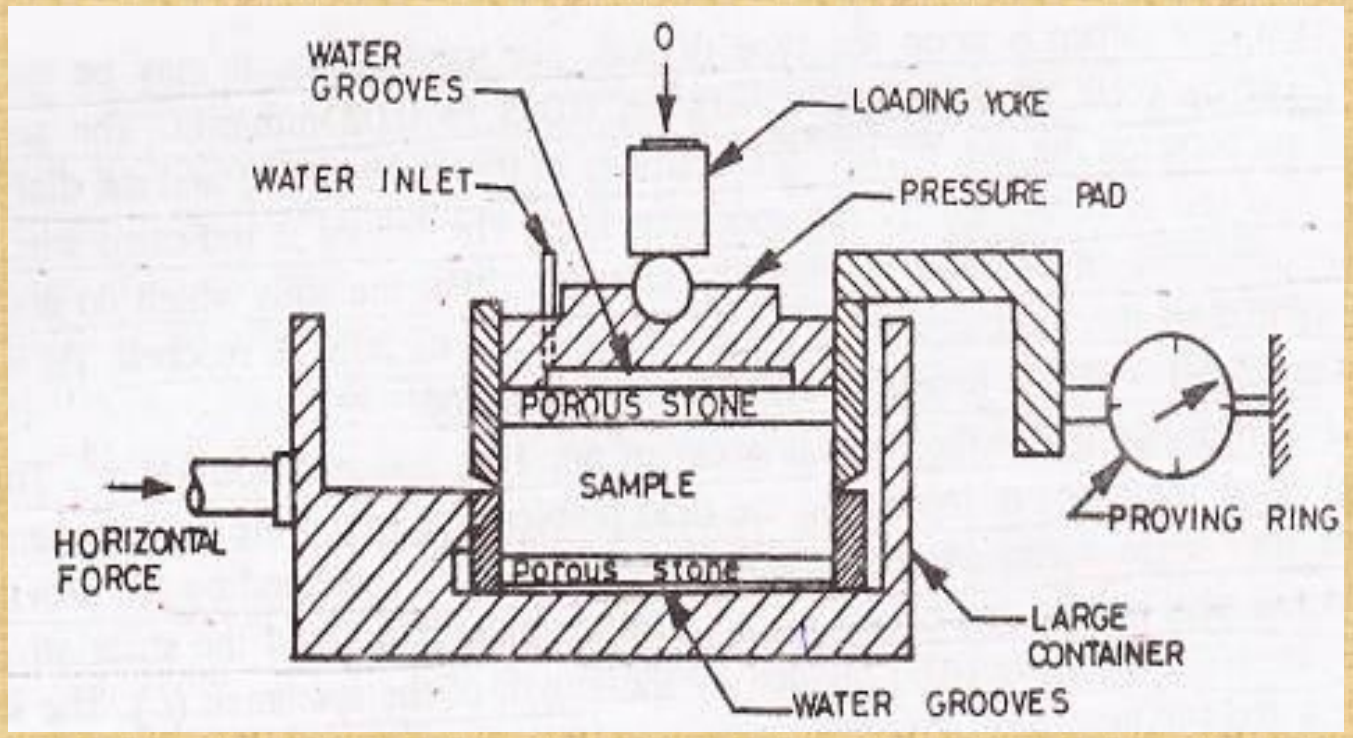
W_1 = weight of empty bottle
W_2 = weight of bottle +soil
W_3 = weight of bottle +soil +water
W_4 = weight of bottle +water

- Mechanical tests

  - ❑ Direct shear test
  - ❑ Cyclic triaxial test

➢ Direct shear test

- It is a mechanical method to determine the shear parameter (cohesion , angle of friction) of soil.
- In this method, the soil sample is subjected to two directional loadings (vertical & horizontal).
- Vertical loading is applied from a loading yoke and shear force is applied horizontally leading to shear failure in horizontal direction.



Typical setup of shear box

•Thus the shear strength of soil sample is determined using coulomb's formula :

$$S = c + (\sigma * \tan \phi)$$

Where, S = Shear strength of soil sample

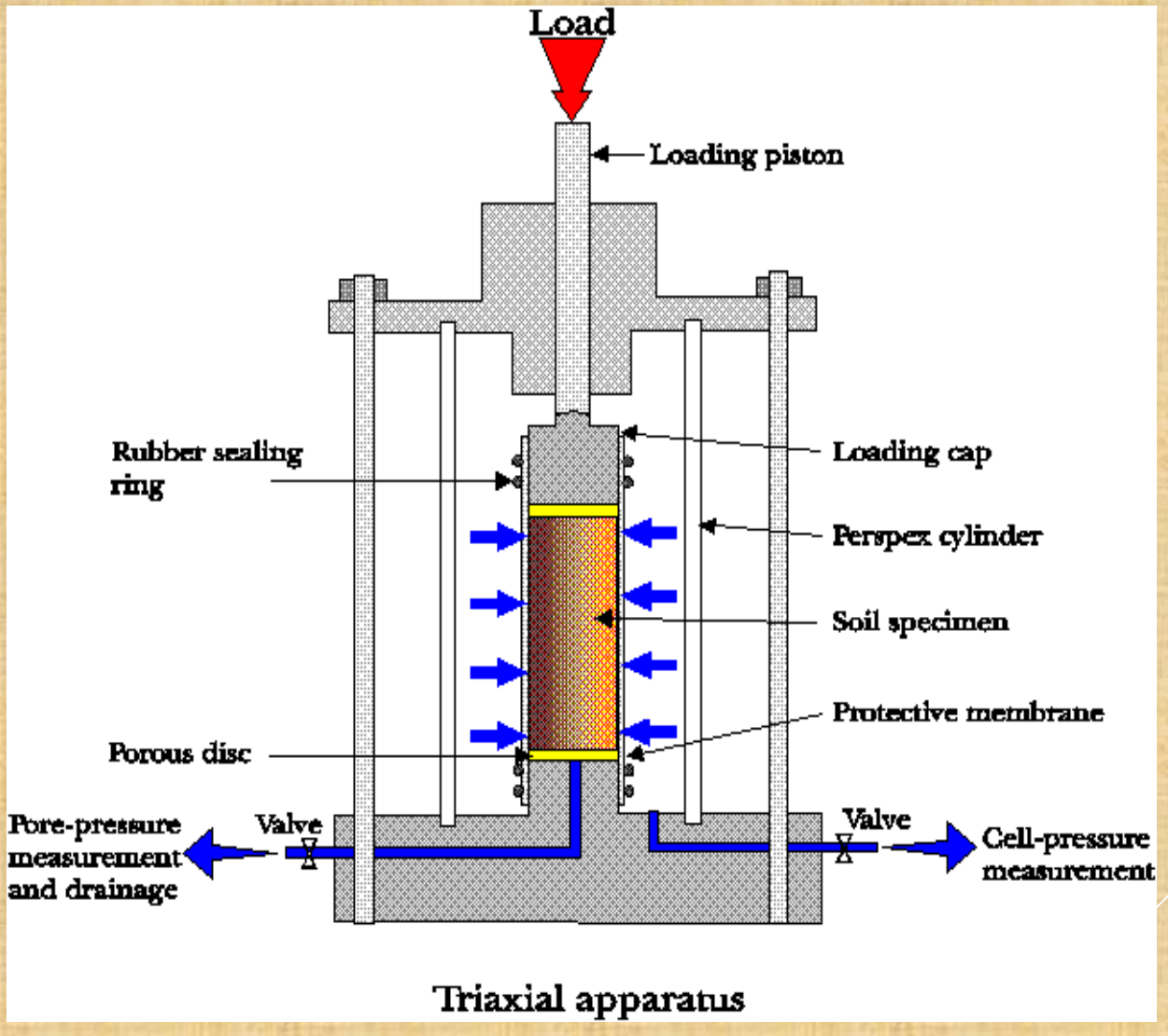
c = Cohesion of soil sample

σ = Effective stress in soil sample

ϕ = Angle of internal friction of soil particles

Triaxial shear test :

- ✓ It is also a mechanical method to determine the shear strength of soil.

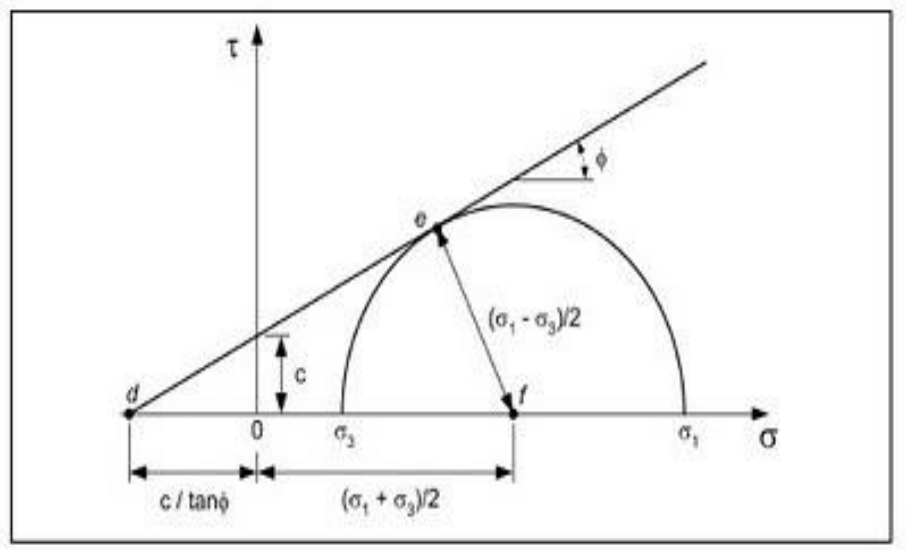


Triaxial apparatus

- This method is similar to Direct shear test but only difference is that the soil sample is subjected to three directional loadings (one-vertical & two-horizontal).

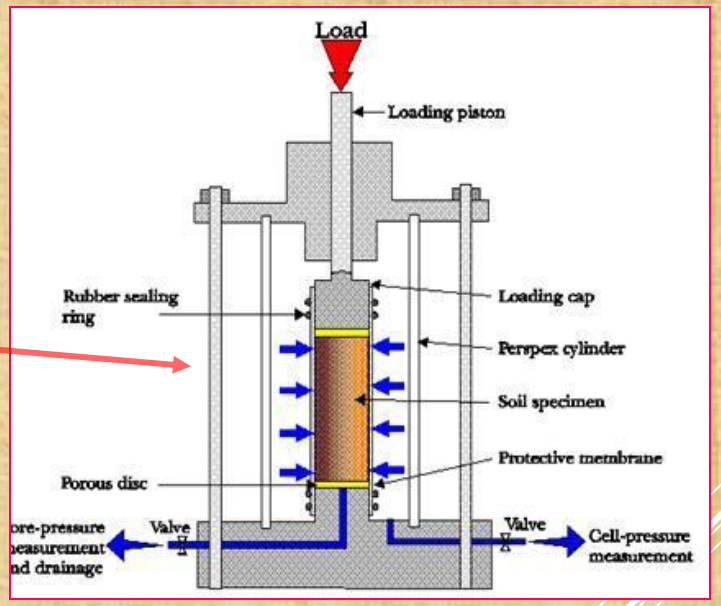
- Here, vertical load is applied by loading frame and horizontally confining pressure is applied by fluid pressure surrounding the soil sample.

- In case of triaxial test, we can apply cyclic loads on soil sample to examine the shear strength of soil of seismic zones.



Finally, graph is plotted between normal stress, 'σ ' (x axis) and shear stress, 'τ ' (y- axis). And Mohr's circle is drawn to get cohesion, 'c' & angle of internal friction, 'ϕ'.

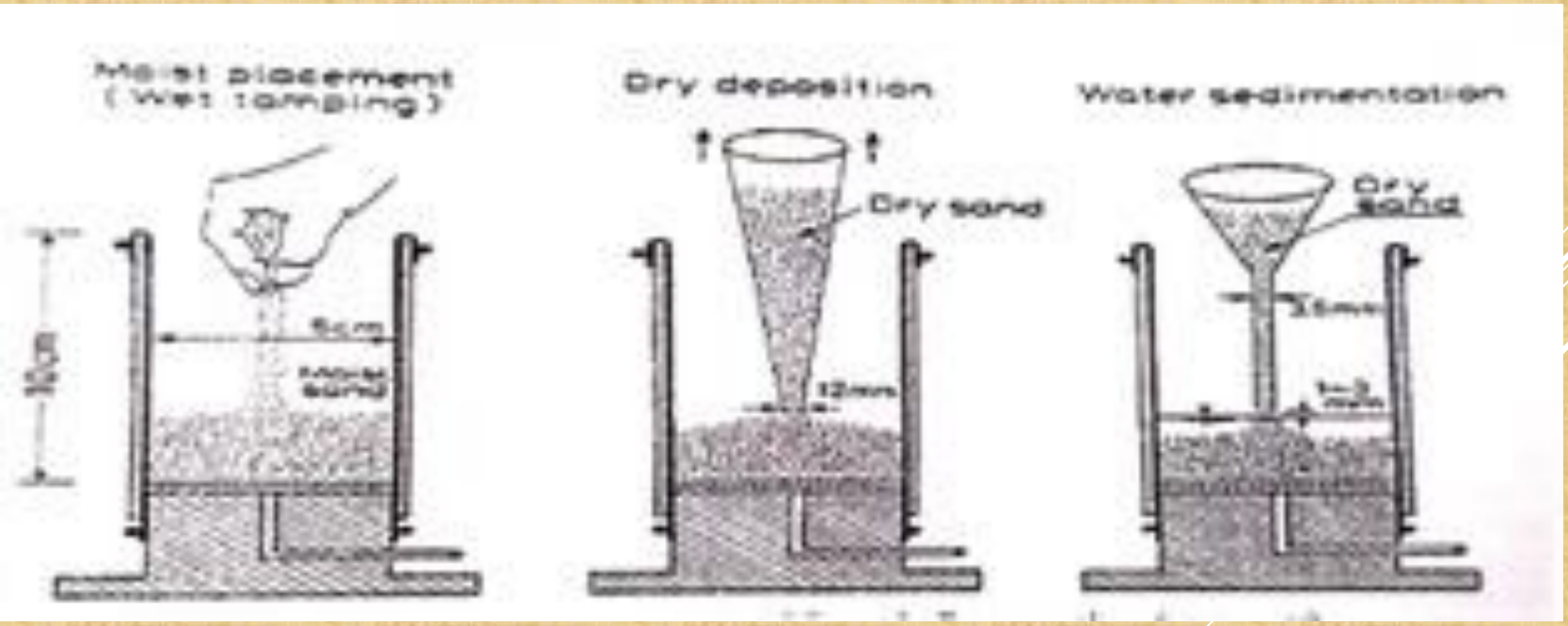
Liquefaction potential can also be determined by using Cyclic triaxial Instrument in Lab



a) Sample Preparation

There are three kinds of techniques widely used for preparing samples for cyclic triaxial testing .

- Moist Placement Method
- Dry Deposition Method
- Water Sedimentation Method



b) Saturation

After the specimen is ready it is needed to be saturated. For this, firstly CO_2 is passed slowly through the specimen for about 15 to 20 minutes depending on the fine content followed by de-aired water at very low gradients of less than five to get a higher initial saturation.

Once a desired volume of water is collected, the specimen is saturated by increasing the back pressure at regular intervals while keeping the effective confining pressure at 30-35kPa and the Skempton's pore water parameter is periodically monitored until a value of 0.95 or more is achieved indicating that the specimen is especially saturated.

$$\Delta B = \Delta u / \Delta \sigma_3$$

The criterion for saturation of the test is given by the Skempton's constant, B, which is 1 for a fully saturated specimen.

c) Consolidation

Once the acceptable degree of saturation is obtained, the specimen is consolidated isotropically to a desired effective stress.

The process of consolidation is assumed to be complete if there is no change in the volume change readings for a sufficient time and the pore pressure remained stable during that period.

The duration of consolidation varies from a minimum of 4 minutes for clean sand to a maximum of 40 minutes for 8% clay mixed samples. More time is given to the samples with more fines and less relative density.

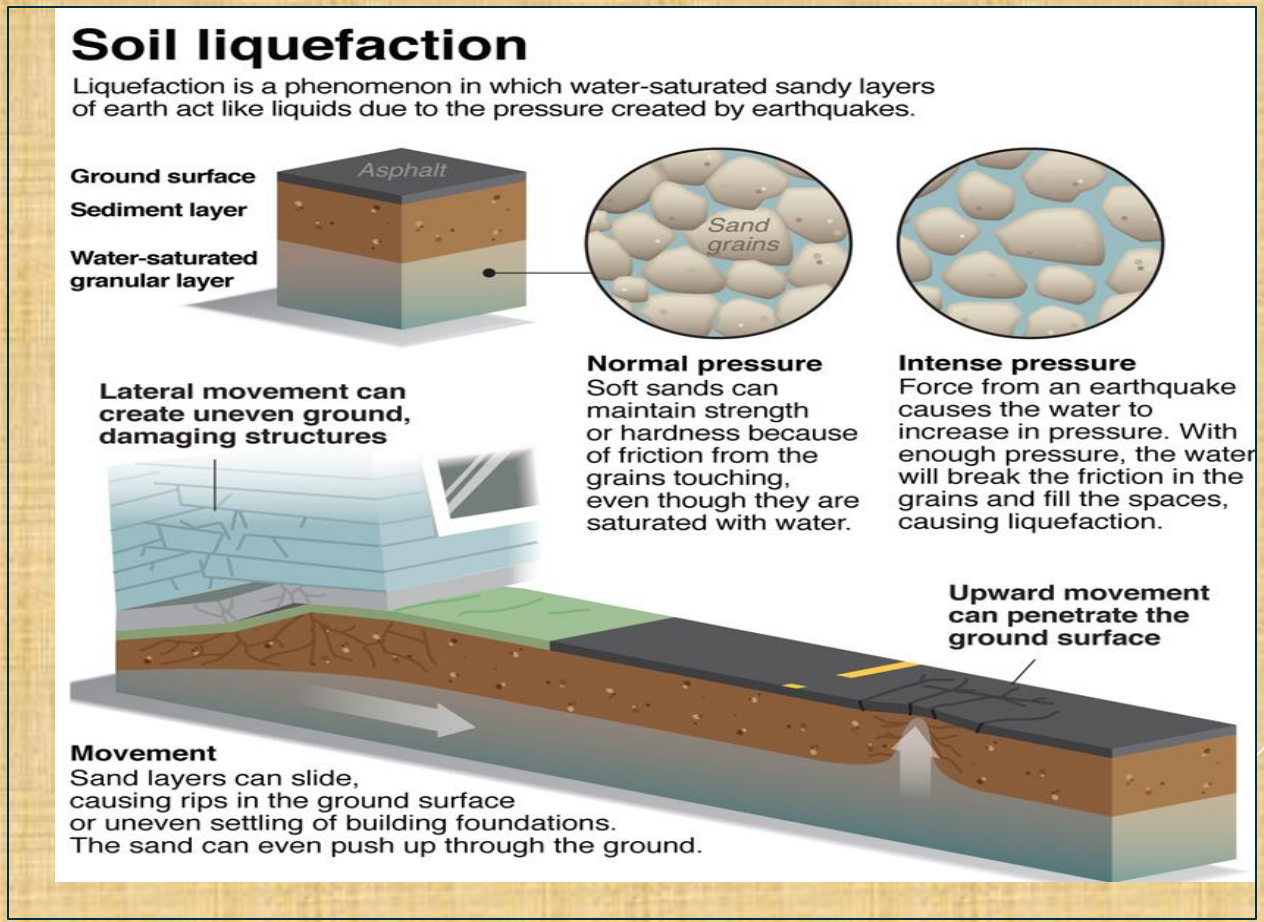
The volume change during the process of consolidation and reconsolidation is noted down and the void ratios, relative densities etc are recalculated.

Liquefaction : A seismic hazard

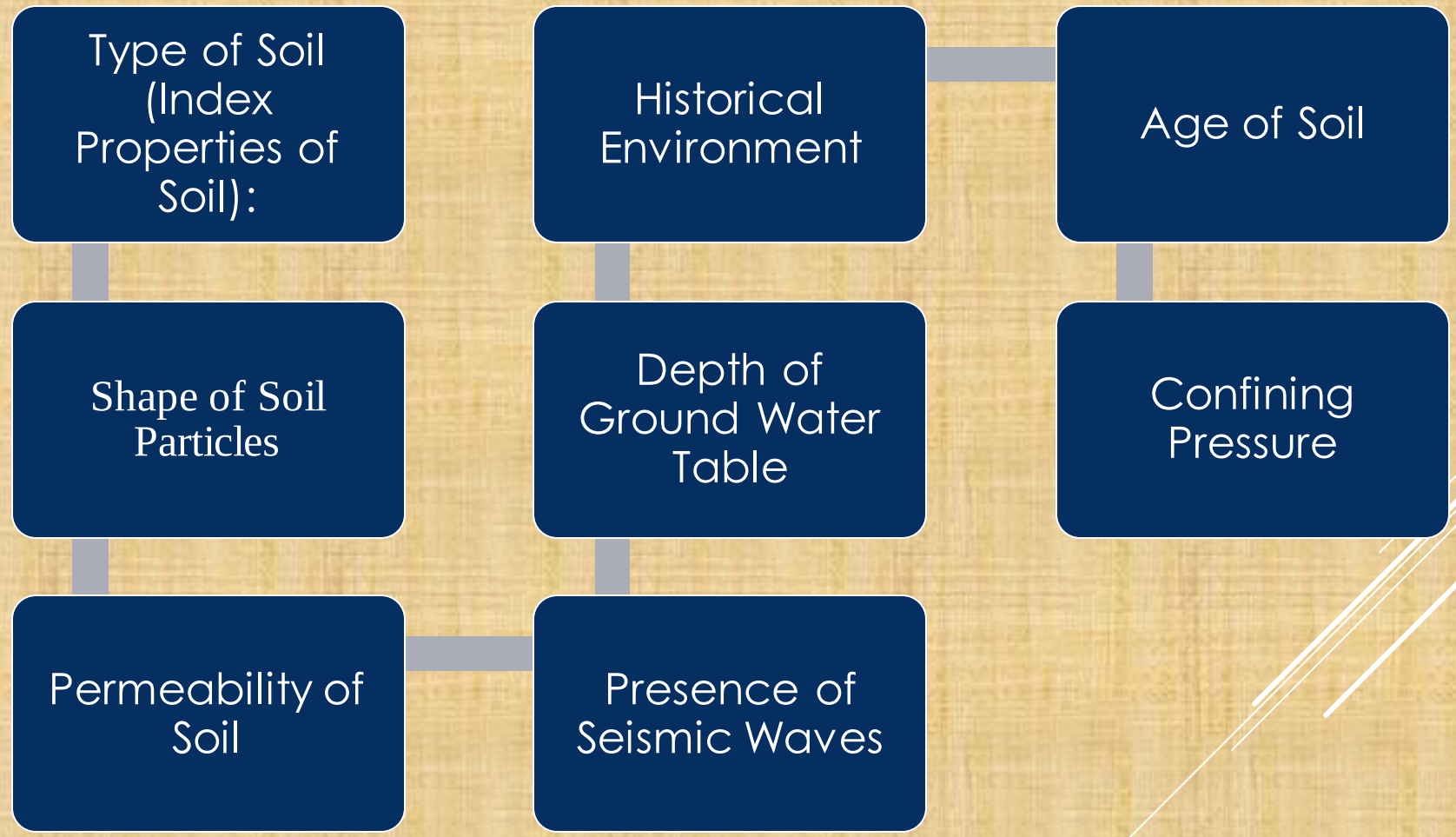
It is a natural phenomenon in which the soil particles beneath the earth surface starts to behaves like liquid due to the monotonous loading, cyclic loading or/and sudden shocks during earthquakes.

Mechanism :

- ✓During earthquake, the sudden load is taken by the water present in pores and increases the pore water pressure.
- ✓ Since time been, if the pore pressure exceeds over-burden pressure, the soil particles looses its shear strength and it starts behaving like viscous liquid rather than solid.



FACTORS AFFECTING LIQUEFACTION SUSCEPTIBILITY



Evaluation of liqefaction potential :

The evaluation of liquefaction potential involves two stages :

a) Evaluation of earthquake loading

It is expressed in terms of Cyclic Stress Ratio (CSR).

b) Evaluation of soil strength against earthquake loading

It is expressed in terms of Cyclic Resistance Ratio (CRR).

Cyclic Stress Ratio (CSR)

$$CSR = 0.65 * \frac{a\max}{g} * \frac{svo}{s'vo} * rd$$

Where, $\mathbf{a_{max}}$ = Peak Ground Acceleration (at surface)

$\mathbf{s'_{vo}}$ = Effective overburden pressure

$\mathbf{s_{vo}}$ = Total overburden pressure

rd = Depth reduction factor

Cyclic Resistance Ratio (CRR).

Liquefaction resistance can be obtained by both lab test as well as field test.

Liquefaction resistance of soil from lab test :

a) Cyclic triaxial test

Liquefaction resistance of soil from field test :

a) Standard penetration test (SPT)
b) Cone penetration test (CPT)
c) Shear wave velocity (Vs) test

Thank You