Er. Indra Subedi

c) Determination of particle size distribution

It is also called as “grain size distribution” or “mechanical analysis” which means the separation of a soil into different size fractions. It is carried in two stages:

- **Sieve analysis**

  It is useful for soil having particle size **more than 75 micron (0.075mm)** i.e., for coarse grained soils.

  As per IS, Smallest sieve size is 45 microns.

- **Sedimentation analysis**

  It is useful for particle **finer than 75 microns**, i.e., fine grained soil (silt and clay) which cannot be separated by sieving. This method is based on **Stoke’s law** which is **valid for 0.2 mm to 0.0002 mm**. The sedimentation analysis is done either with the help of **hydrometer or a pipette**.

- **Hydrometer method**:

  It is used to determine the **density of soil suspension**.

  Hydrogen Peroxide (H_2O_2) is used to remove organic content.

  Hydrochloric acid of normality 0.2 N is used to remove calcium compounds.

  Sodium hexa meta-Phosphate is used as dispersing agent.

  Hydrometers are calibrated at 27^0 C.

  For other values of temperature, correction must be applied for temperature. Similarly, correction for hydrometer is also required. Correction for meniscus is always positive whereas correction for dispersing agent is always negative.

- **Pipette method**: It is the standard sedimentation method, in which suitable dispersion agents are added for proper dispersion of soil. Dispersion solution contains **7g sodium carbonate, 33g sodium hexameta phosphate and 1-liter distilled water.**

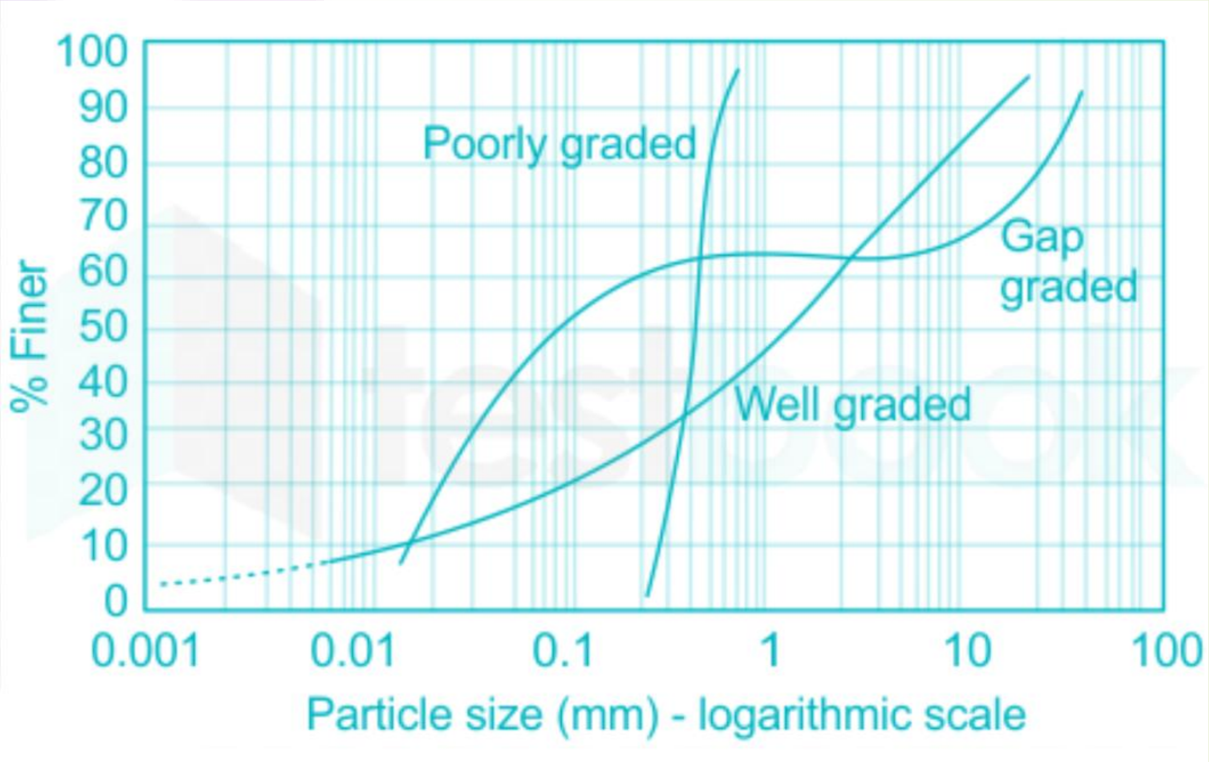
Gradation of soil:

- The curve which spreads over a large range of particle size represents well graded soil whereas those confined to narrow range of particles represents uniform or poorly graded soil. Soil in which some particles are missing which is represented by horizontal line are called gap graded soil.
- The size corresponding to 10% finer, 30% finer and 60% finer have been designated as D_{10}, D_{30} and D_{60} respectively. D_{10} is also called effective size or effective diameter.

$$Uniformity\ Coefficient\ (C_u) = \frac{D_{60}}{D_{10}}, (measures\ particle\ size\ ranges)$$

$$Coefficient\ of\ Curvature\ (C_c) = \frac{{D_{30}}^2}{D_{60} \times D_{10}}, (also\ called\ coefficient\ of\ gradation)$$

- For well graded soil, $1 < C_c < 3$.
- For well graded gravel, $C_u > 4$, and for well graded sand $C_u > 6$.
- For poorly graded (uniform) soil, C_u is nearly unity.



CBACA

1. Strokes law is used to determine:
   a. Specific gravity of soil solids
   b. Density of soil suspension
   c. Grain Size distribution of soil finer than 0.075 mm
   d. All of the above
2. The smallest sieve size according to the Indian Standard is:
   a. 0.0045 mm
   b. 0.045 mm
   c. 0.45 mm
   d. 0.154 mm
3. Sieving is not practicable for grain size smaller than about:
   a. 0.075 mm
   b. 0.095 mm
   c. 0.15 mm
   d. 0.2 mm
4. According to Indian Standard, in a 2 mm sieve:
   a. There are two holes
   b. Each sieve is circular and its diameter is 2 mm.
   c. Each sieve is a square and its side is 2 mm.
   d. There are two holes per cm length of the mesh.
5. Stroke’s law does not hold good if the size of the particle is smaller than:
   a. 0.0002 mm
   b. 0.002 mm
   c. 0.02 mm
   d. 0.2 mm

ADACA

6. The effective size of the soil is:
   a. D_{10}
   b. D_{20}
   c. D_{40}
   d. D_{60}
7. The uniformity coefficient of the soil is defined as the ratio of:
   a. D_{40} to D_{10}
   b. D_{40} to D_{20}
   c. D_{50} to D_{10}
   d. D_{60} to D_{10}
8. A soil having particles of nearly the same size is known as:
   a. Uniform soil
   b. Poor soil
   c. Well Graded Soil
   d. Coarse Soil
9. A soil having uniformity coefficient more than 10, is called:
   a. Uniform Soil
   b. Poor Soil
   c. Well Graded Soil
   d. Coarse Soil
10. Which of the following statement is true for Hydrometer method of sedimentation Analysis?
   a. Correction for meniscus is always positive whereas correction for dispersing agent is always negative.
   b. Correction for meniscus and dispersing agent both are always negative.
   c. Correction for meniscus and dispersing agent both are always negative.
   d. Correction for meniscus is always negative whereas correction for dispersing agent is always positive.

Consistency Limit:

- The fine soil has small size but large number of voids. So the fine soil specially clay has high capacity to retain high moisture content, so variation of moisture due to contact with heat or water.
- The variation of moisture in fine soil gives two effect:

Volume Instability	Change in Behavior
Swelling & Shrinkage	Below SL: Solid In-between SL and PL: Semi Solid In-between PL and LL: Plastic In LL and above: Liquid

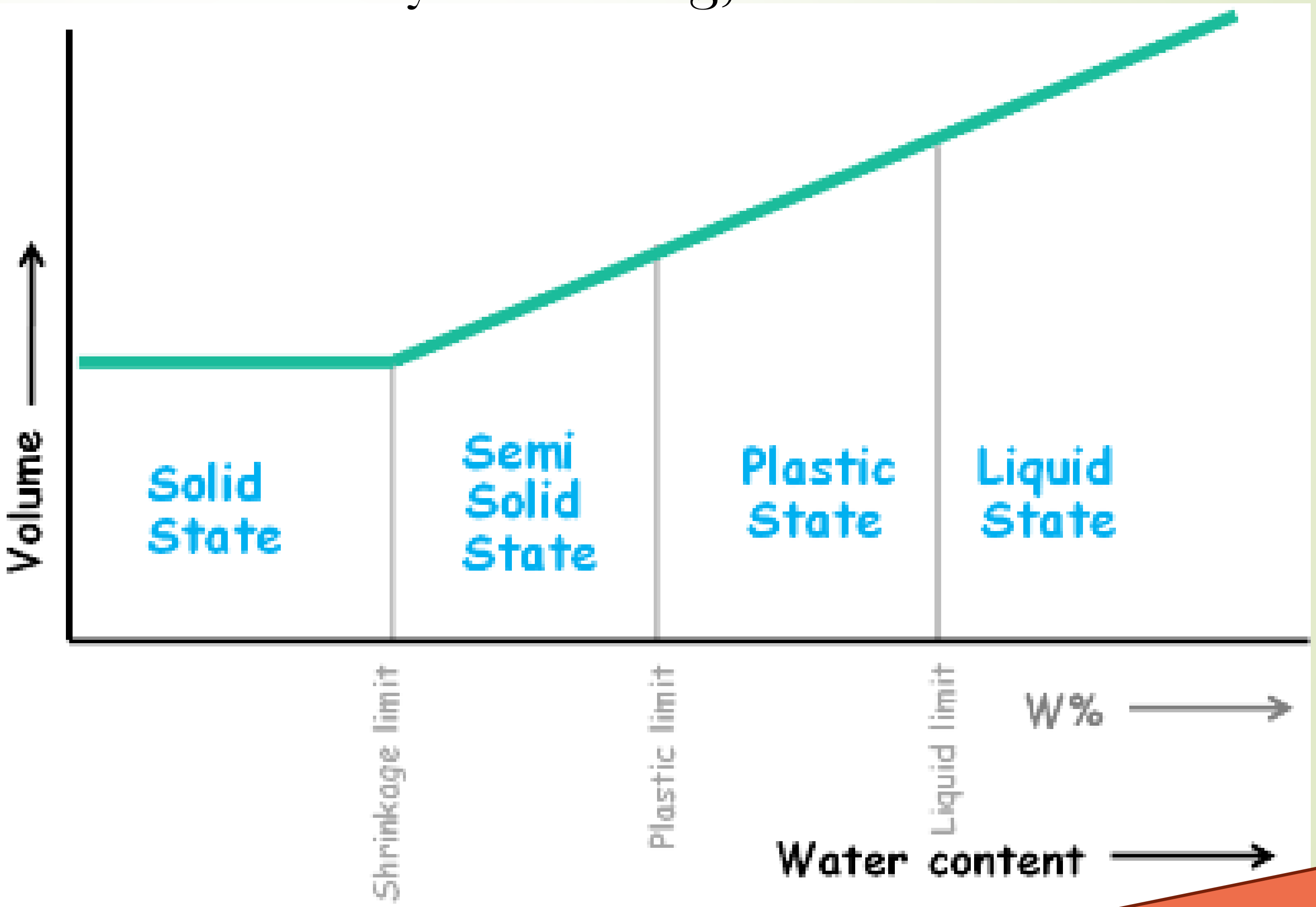
Consistency Limit:

- Three limits of moisture at which fine soil changes it's behavior is termed as consistency limit. The limits are defined by Atterberg, so also termed as Atterberg limit.

a) Liquid Limit (LL)

b) Plastic Limit (PL)

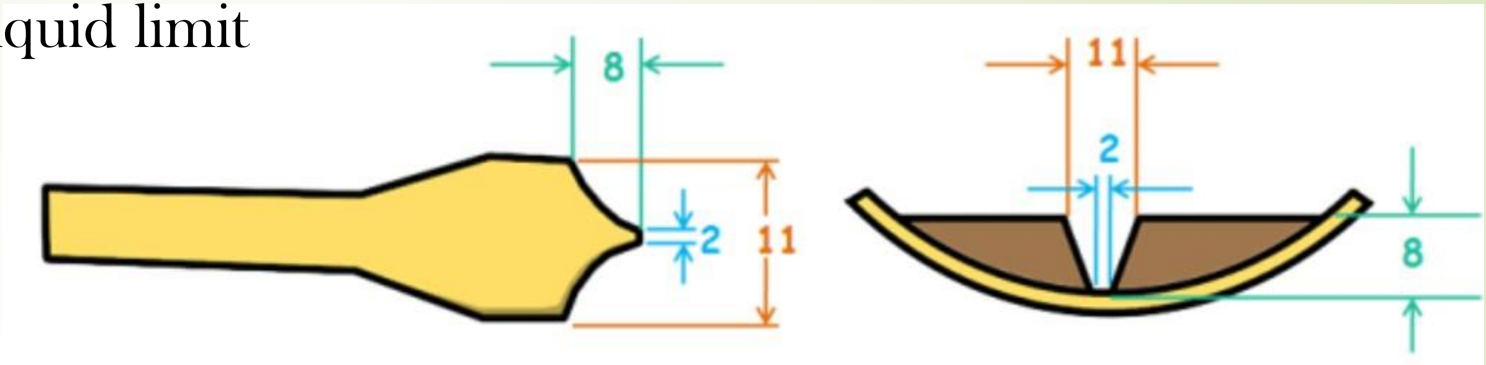
c) Shrinkage Limit (SL)



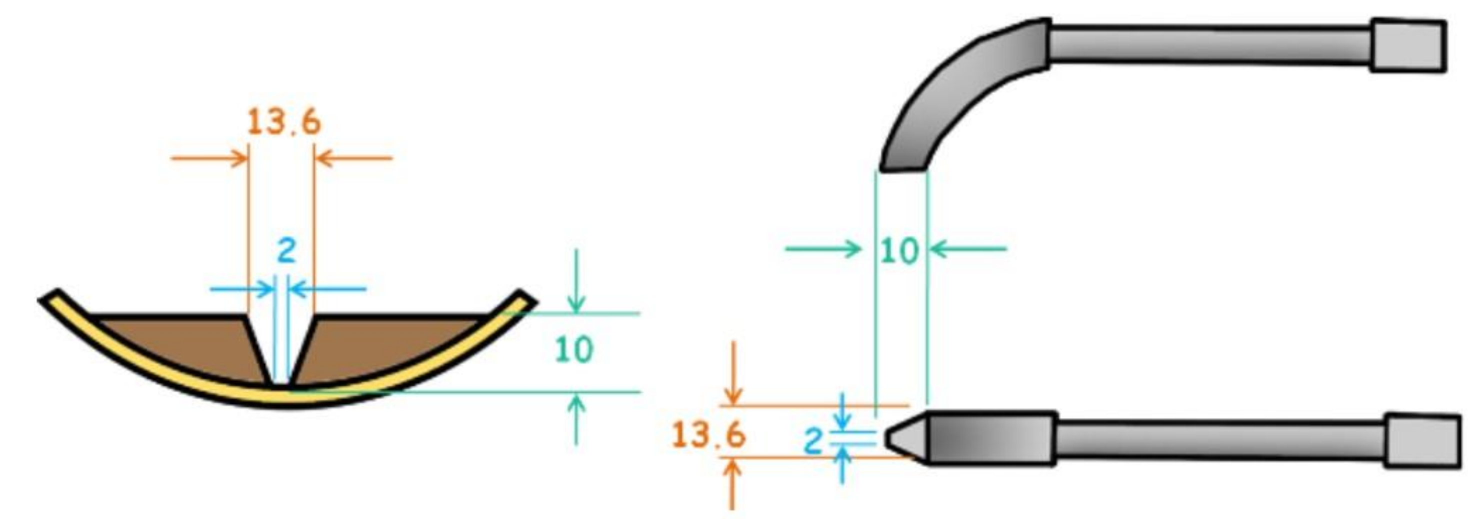
Liquid Limit Test: Casagrande's Method

Materials and Equipment: Mechanical liquid limit

Casagrande Tool, ASTM tool



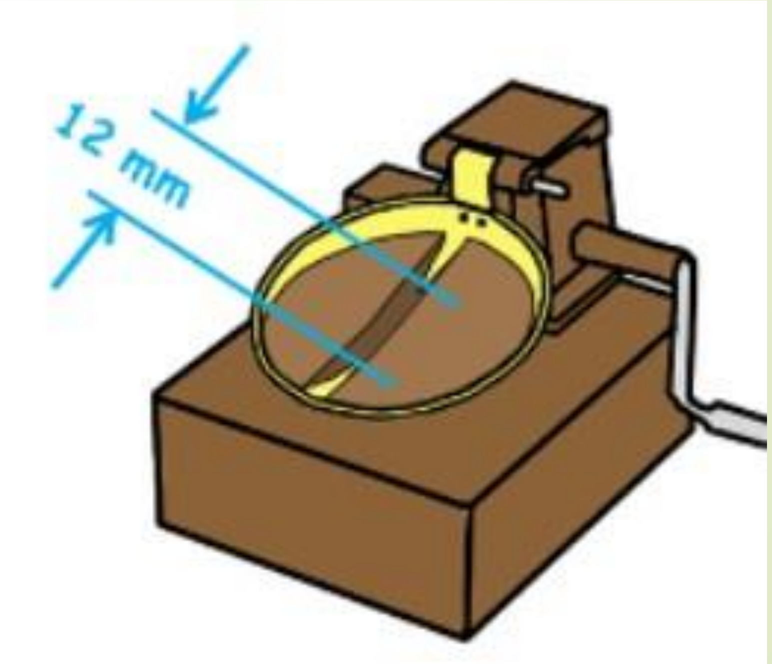
Casagrande Grooving Tool



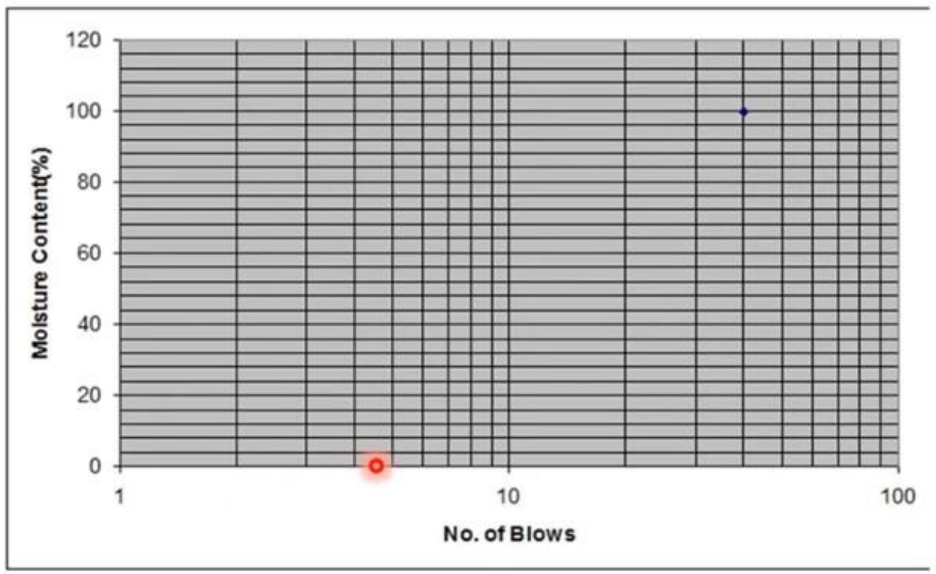
ASTM Grooving Tool

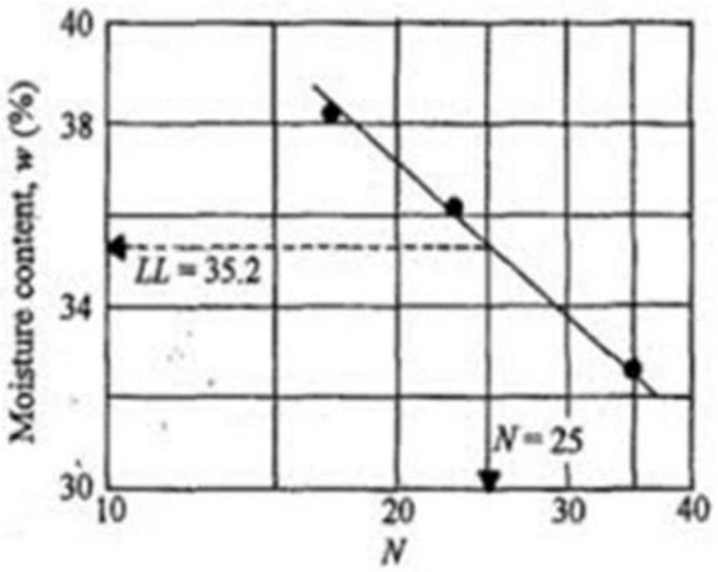
Liquid Limit Test: Casagrande's Method

test	No of Blow(N)	Moisture content (W)
1	N1	W1
2	N2	W2
3	N3	W3



Liquid Limit Test: Casagrande's Method





- **Flow index (I_F)**

It indicates the shear strength variation with water content. It is slope of the **flow curve** obtained from liquid limit test. If N_1 and N_2 be number of blows required to close the groove at water content W_1 and W_2 respectively, flow index is given by:

$$I_f = \frac{W_1 - W_2}{\log(^{N_2}/_{N_1})}$$

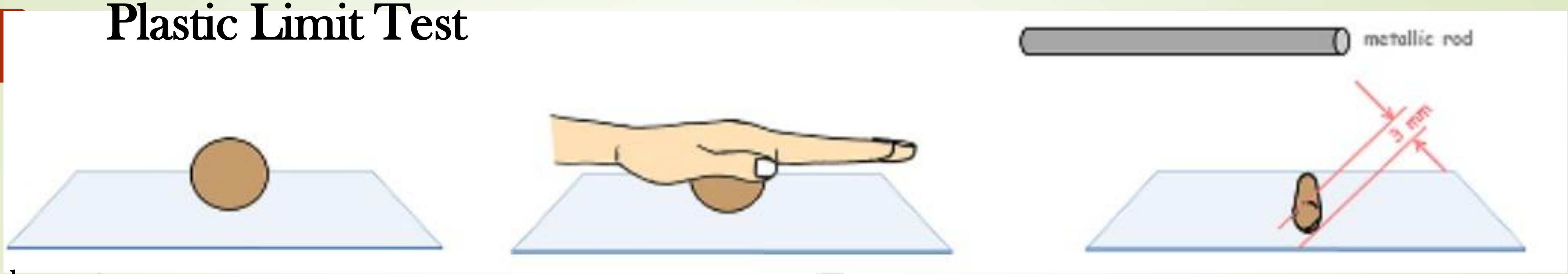
Liquid Limit Test: Casagrande's Method

Test Procedure:

1. Adjust the height through which the cup is lifted and dropped, so that falls through 1cm in one revolution.
2. 120g of **specimen, passing 420 micron IS Sieve**, mix with distilled water
3. Take a portion of paste with the spatula and place it in the center of the cup so that it is almost half filled. Level off the top of the wet soil symmetrically with the spatula, so that it is parallel to the rubber base and the maximum depth of the soil is 1cm.
4. Grooving tool "Casagrande type" cut V-shape, **In case of sandy soils tool it does not form a neat groove and hence ASTM Tool is used.**
5. Turn the handle, at the rate of 2 revolutions per second, until the **two parts of the soil come in contact with the bottom of the groove along a distance of 12mm.**
6. Record the number of blows, either by adding more water or leaving the soil paste to dry.
7. Repeat the same for 3 times, such that number of blow be within 25$\pm$ 10.

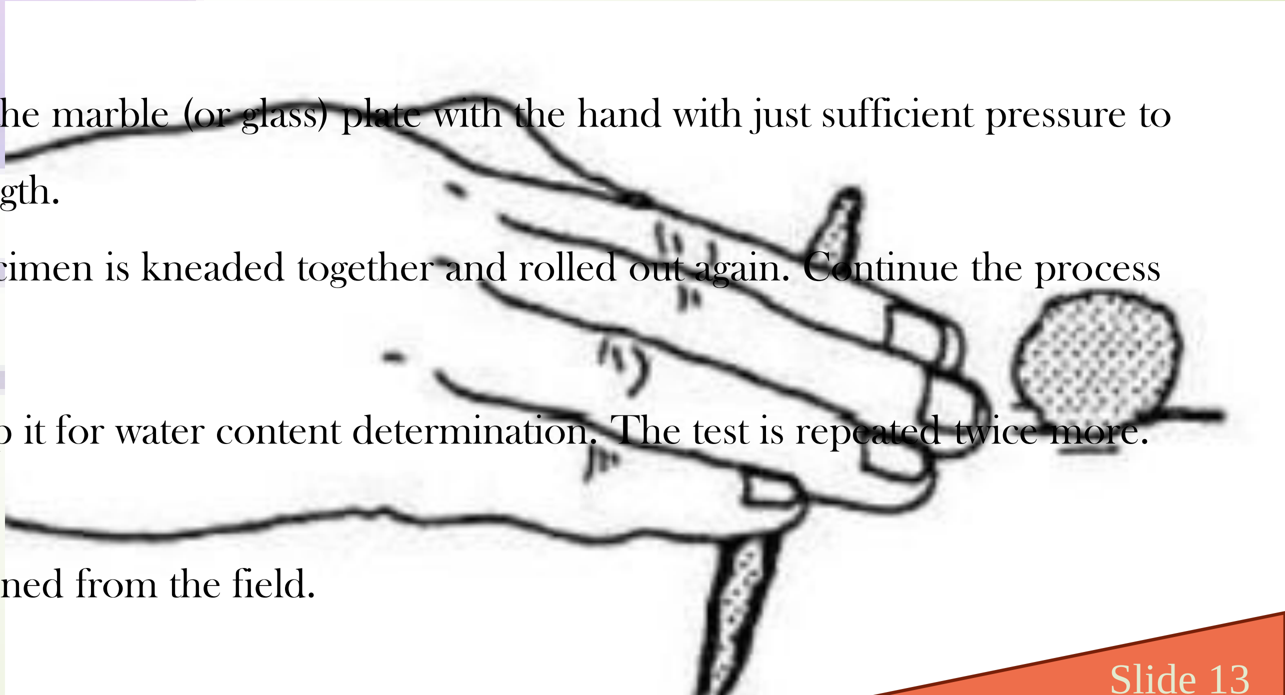
2.4: DETERMINATION OF VARIOUS INDEX PROPERTIES

Plastic Limit Test

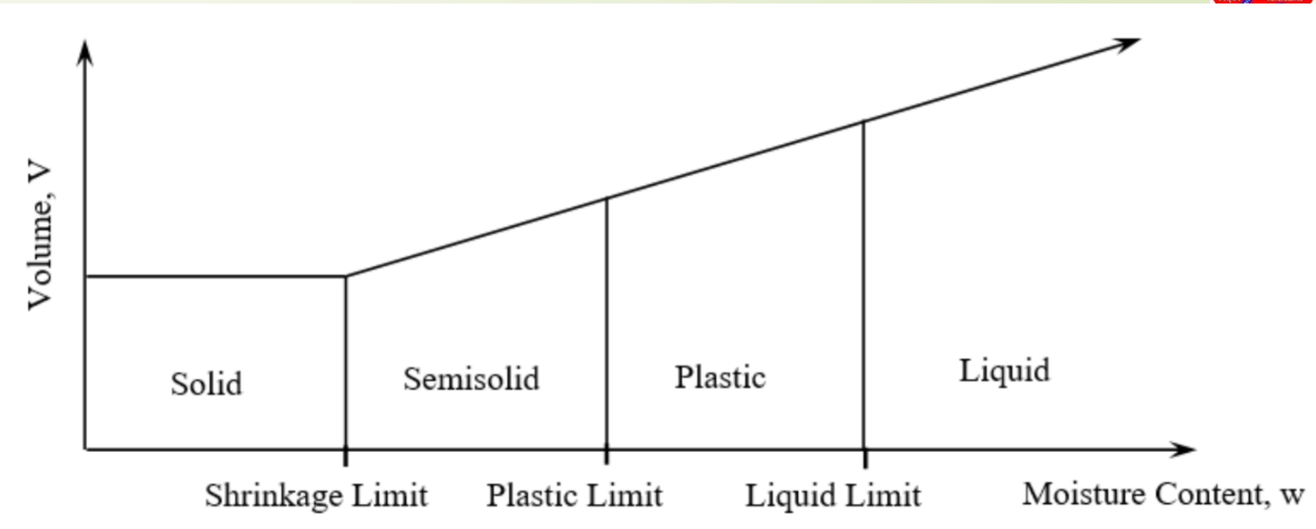


Test Procedure:

1. Take about 20g of **air dried soil, passing 420 micron IS sieve.**
2. Mix it on the marble plate with sufficient distilled water to make it plastic enough to be shaped into a ball.
3. Leave the plastic soil mass for some time to mature.
4. Take about 8 g of the plastic soil, make a ball of it, and roll it on the marble (or glass) plate with the hand with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length.
5. When the diameter of the thread has decreased to 3mm, the specimen is kneaded together and rolled out again. Continue the process until **thread just crumbles at 3mm diameter.**
6. Collect the crumbled soil thread in the airtight container and keep it for water content determination. The test is repeated twice more. Thus three readings are obtained for the determination.
7. Also, determine the natural water content of the soil sample obtained from the field.



- As shown in the given figure, liquid limit represents the boundary between liquid and plastic state of soil, plastic limit represents the boundary between plastic and semi solid states of the soil and so on. Some related terms are discussed here.



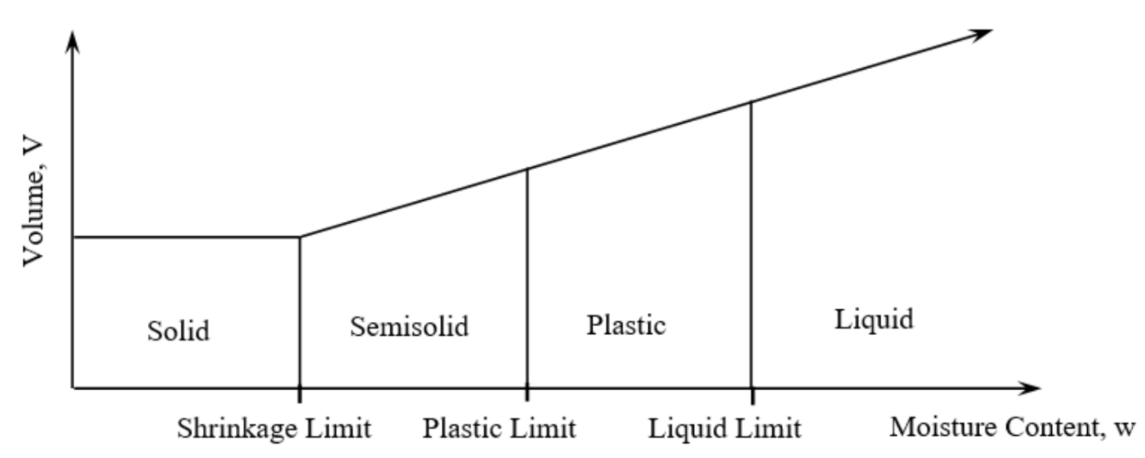
- **Plasticity of soils**: It is the property of soil which allows it to be deformed rapidly without any rupture, elastic rebound or volume change. Fine grained soils have high plasticity (specially clays). Silts have little or no plasticity.
- **Plasticity Index (I_P):**

It is the difference between liquid limit (LL) and plastic limit (PL). It is the range of water content at which the soil behaves plastic. Hence, soils of high plasticity index are called plastic soils like clay. Clean sand is non-plastic material. Plasticity index is zero, when plastic limit is more than or equal to liquid limits.

$$I_P = W_L - W_P$$

- **Shrinkage index (S.I)**

It is the difference between plastic limit and shrinkage limit. It is indicator for the amount of clay.



- **Consistency index or relative consistency (I_C)**

$$I_C = \frac{Liquid\ limit - Water\ Content}{Plasticity\ Index} = \frac{W_L - w}{W_L - W_P}$$

$I_C = 0$, indicates, soil is at its liquid limit
$I_C = 1$, indicates, soil is at its plastic limit
$I_C > 1$, indicates, soil is in a semi solid state, and is stiff.
$I_C < 0$, soil behaves as a liquid.

- **Liquidity index (I_L):**

$$I_L = \frac{Natural\ water\ Content - Plastic\ Limit}{Plasticity\ Index} = \frac{w - W_P}{W_L - W_P}$$

$I_L = 0$, indicates, soil is at its plastic limit
$I_L = 1$, indicates, soil is at its liquid limit
$I_L > 1$, indicates, soil is in liquid state.
$I_L < 0$, soil behaves as semi solid state, and is stiff.

Obviously, $I_L + I_C = 1$.

- **Flow index (I_F)**

It indicates the **shear strength variation with water content**. It is slope of the flow curve obtained from liquid limit test. If N_1 and N_2 be number of blows required to close the groove at water content W_1 and W_2 respectively, flow index is given by:

$$I_f = \frac{W_1 - W_2}{\log\left({}^{N_2}/_{N_1}\right)}$$

- **Toughness index (I_t)**

It is the ratio of plasticity index to flow index.

- **Activity of clay** (A_K)

It is the ratio of plasticity index to the clay fraction, (or percentage of clay sizes). The presence of even the small amount of clay particles can be found with the help of Activity ratio.

Activity (A_K)	Classification
<0.75	Inactive
0.75 to 1.25	Normal
>1.25	Active

- **Sensitivity of clay**

$$Sensitivity = \frac{\text{Unconfined compressive strength of the natural or undisturbed soil}}{\text{Unconfined compressive strength of soil in remolded state}}$$

The sensitivity of most clays is 1 to 8, for normal clays its value ranges from 2 to 4.

- **Thixotropy of clay** (phenomenon of strength lose and strength gain): It is the property of soil which enables to regain its strength lost on remolding in a short time, without change in water content.

Borehole Log Interpretation

Bore hole data hence should be as correctly interpreted as possible so that following conditions are met.

- No interpretation of folded strata as straight strata.
- Case of weaker soil layer laying below stronger layer should be properly studied. For this, deeper bore hole as specified in codes should be provided.
- Possibility of formation of sink holes or any other such structures underground surface should be clearly illustrated.
- It is recommended to check any dips if existing, to prevent foundation overloading and subsequent failure.
- Higher number of boreholes are drilled to eliminate the possibility of misrepresentation of bed rock. When a large boulder is reached at shallow depth, it may be misrepresented as a bed rock.
- Presence of Faults if any should be precisely studied. Rock strata would be improperly studied if the presence of faults is not taken care of.
- Soil profile and water table should be interpreted clearly.

Layer id	Depth(m)	Strip log	Lithology description
01	2.00		Quaternary surface soil...
02	10.00		Completely weathred basalt ...
03	20.00		Highly weathred basalt...
04	30.00		Moderately weathred basalt ... Slightly weathred basalt...
05	50.00		Fresh basalt, bedrock...

DACDB

11. Liquid limit and plastic limit exist in:
    a. Sand
    b. Silt
    c. Gravel
    d. Clay
12. The ratio of the unconfined compressive strength of undisturbed soil to the unconfined compressive strength of soil in remolded state is called:
    a. Sensitivity
    b. Thixotropy
    c. Relative Density
    d. Bulk Density
13. The property of a soil which enables to regain its strength lost on remoulding in a short time, without change in moisture content, is called:
    a. Unconfined compressive strength
    b. Sensitivity
    c. Thixotropy
    d. Relative Density
14. The maximum water content of a saturated soil at which a reduction in its moisture does not cause a decrease in volume of the soil, is called:
    a. Liquid Limit
    b. Plastic Limit
    c. Elastic Limit
    d. Shrinkage Limit
15. Toughness index is the ratio of:
    a. Flow index and plasticity index
    b. Plasticity Index and Flow Index
    c. Liquidity Index and Flow Index
    d. Flow index and liquidity Index

BDBDA

16. The consistency index is given by:
    a. $\frac{w_p - w}{I_P}$
    b. $\frac{w_l - w}{I_P}$
    c. $\frac{w_l - w_p}{I_P}$
    d. $\frac{w - w_p}{I_P}$
17. The Liquidity index is given by: (same option as 16)
18. Liquid limit minus plastic limit is termed as:
    a. Flow Index
    b. Plasticity Index
    c. Shrinkage Index
    d. Liquidity Index
19. The flow index in soil indicates:
    a. Ratio of liquid limit to plastic limit
    b. Variation of liquid limit
    c. Variation of Plastic limit
    d. Shear Strength variation with water content
20. Consistency index , $I_C = 1$, indicates, soil is at its
    a. plastic limit
    b. Liquid limit
    c. Shrinkage limit
    d. None of the above

SOIL CLASSIFICATION

Field Identification

Textural Classification

Indian Standard Soil Classification System (ISSCS)

MIT System of Classification

Unified Soil Classification System

Basic Requirement of Soil Classification

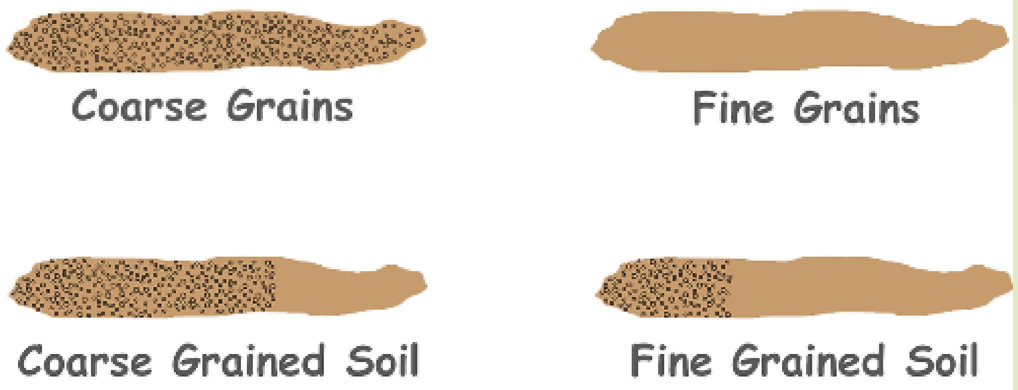
- Should have limited number of groups
- Should provide probable **engineering behavior** of soil
- Should grade the soil for its suitability for a specific engineering project
- Should be simple and should use the terms which are easily understood

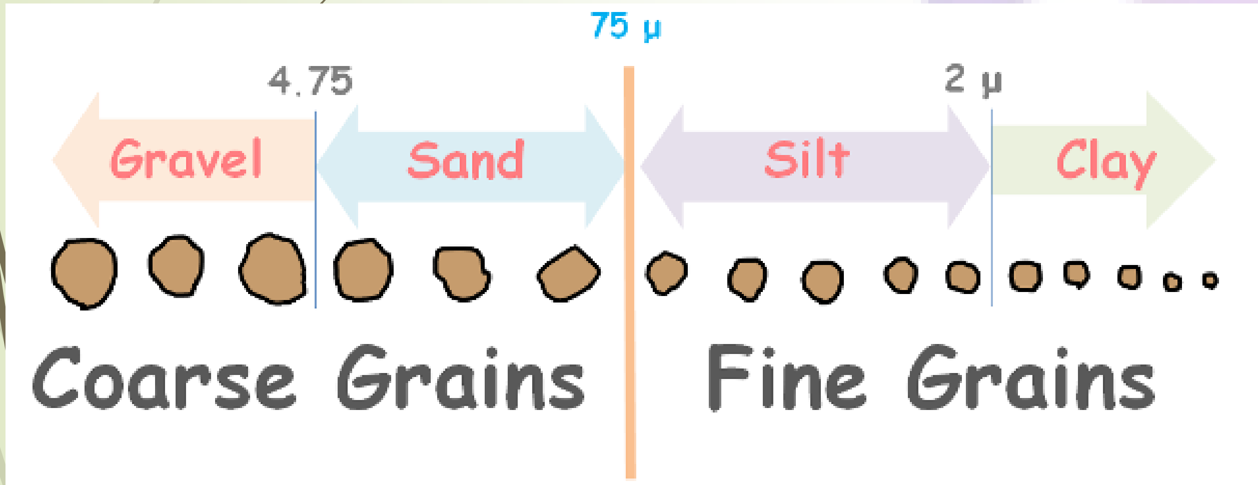
3.2: FIELD IDENTIFICATION OF SOIL

Coarse Soil Vs. Fine Soil

Visual Inspection

- The fine soil (smaller than 0.075mm) is not visible to the necked eye
- If visible particles are greater than 50%, then coarse soil otherwise fine soil

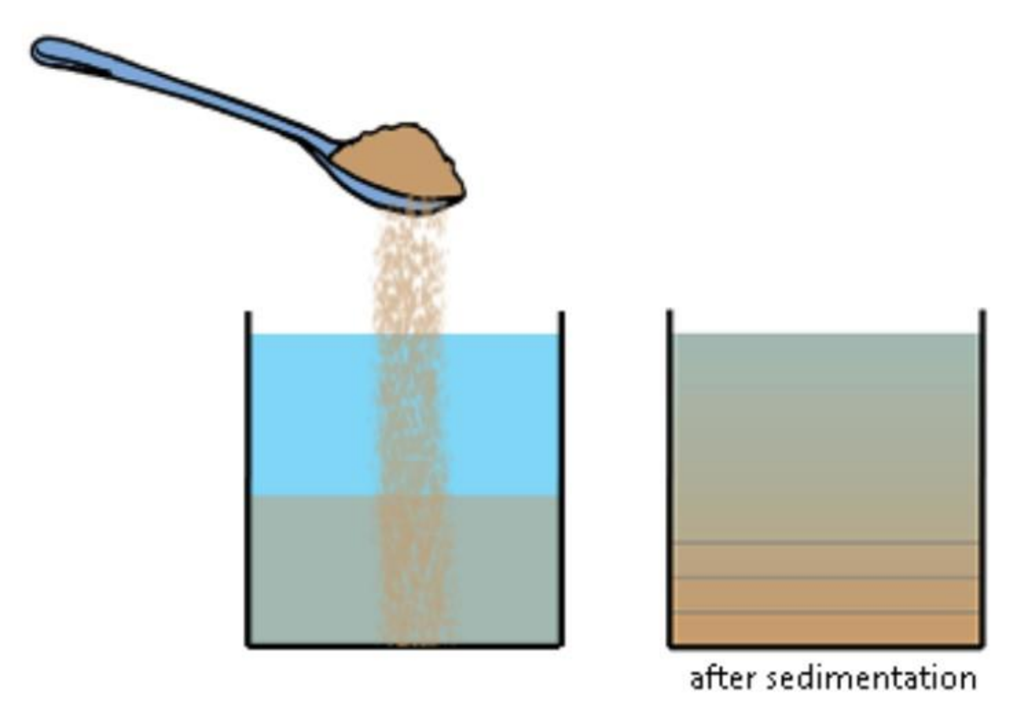




Gravel Vs. Sand

- The particles greater than 4.75mm are gravel and 0.075mm to 4.75mm are sand.
- If particles larger than 4.75mm are greater than 50%, soil is termed as gravel otherwise sand.

Fine Sand Vs. Silt



Dispersion test

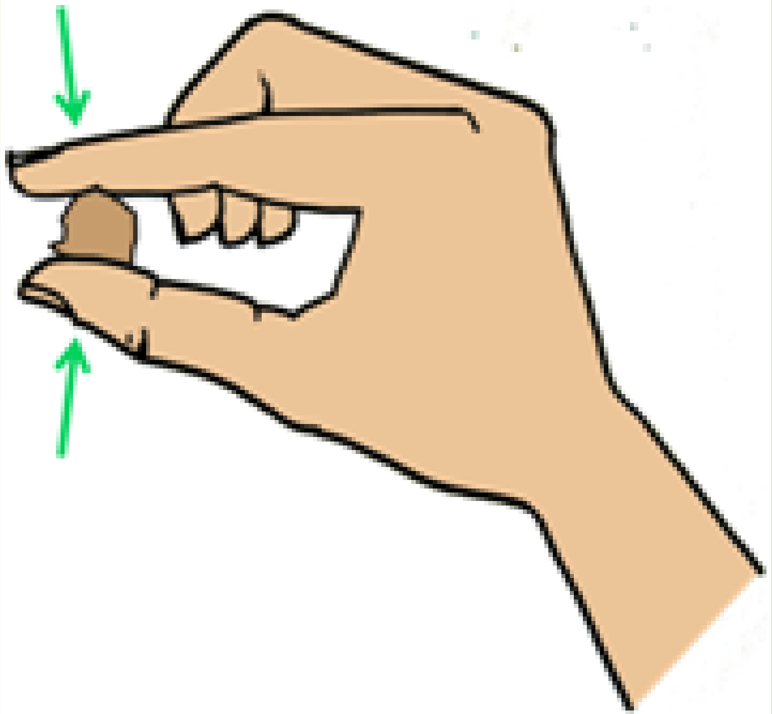
- By putting soil in water in glass the sand settle fast than silt.
- Pouring a spoonful of sample in a jar of water, sand will settle down in a minute or two, but if it is silt it may takes 15 minute to 1 hour. Clay remains in suspension.

Silt Vs. Clay

Dilatancy or Shaking test

- If silt, water will rise quickly to the surface and give it a shiny glistening appearance.
- If clay the water cannot move easily and hence it continues to look dark.
- Percentage of silt and clay can be estimated by rate of reaction.

Silt Vs. Clay



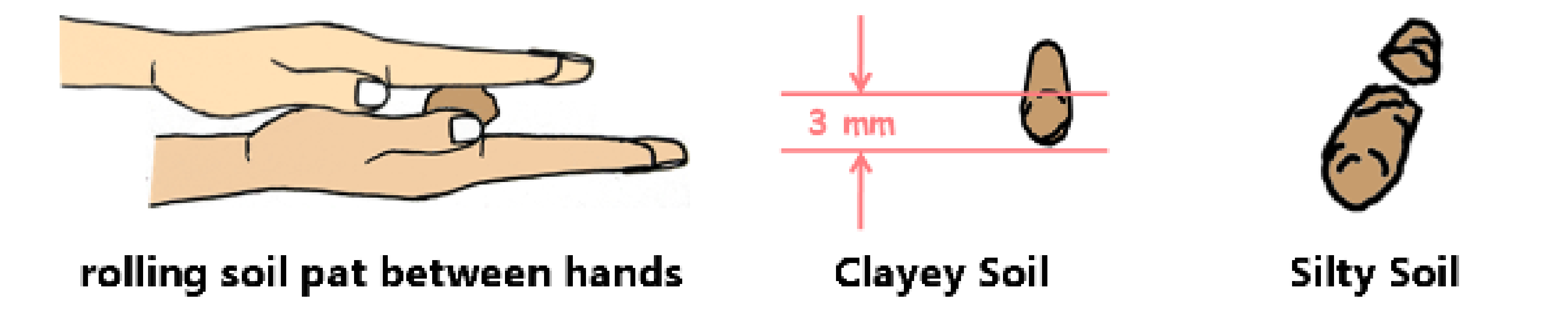
Dry Strength Test

- Dry piece of clay is hard to crumble than Silt.

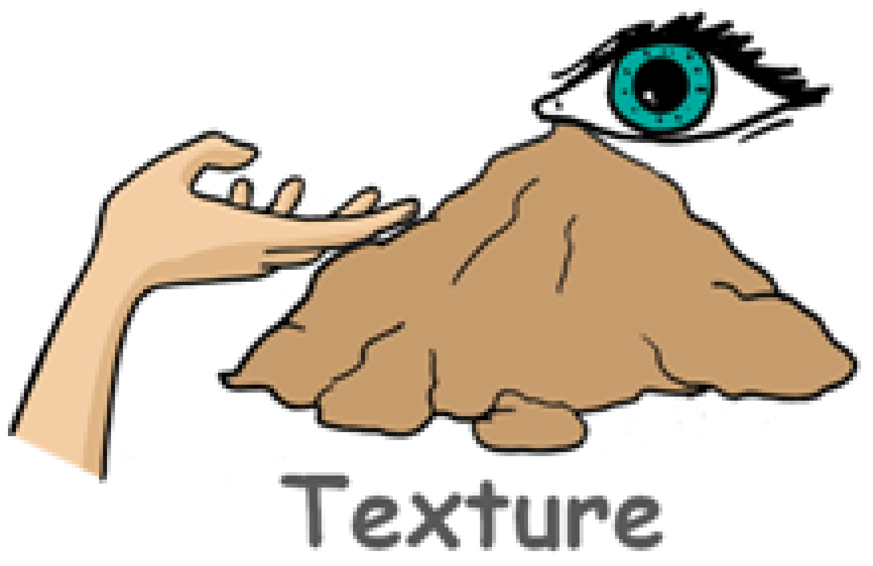
- The silt gives soapy feel.

Silt Vs. Clay

Plasticity Test



TEXTURAL CLASSIFICATION

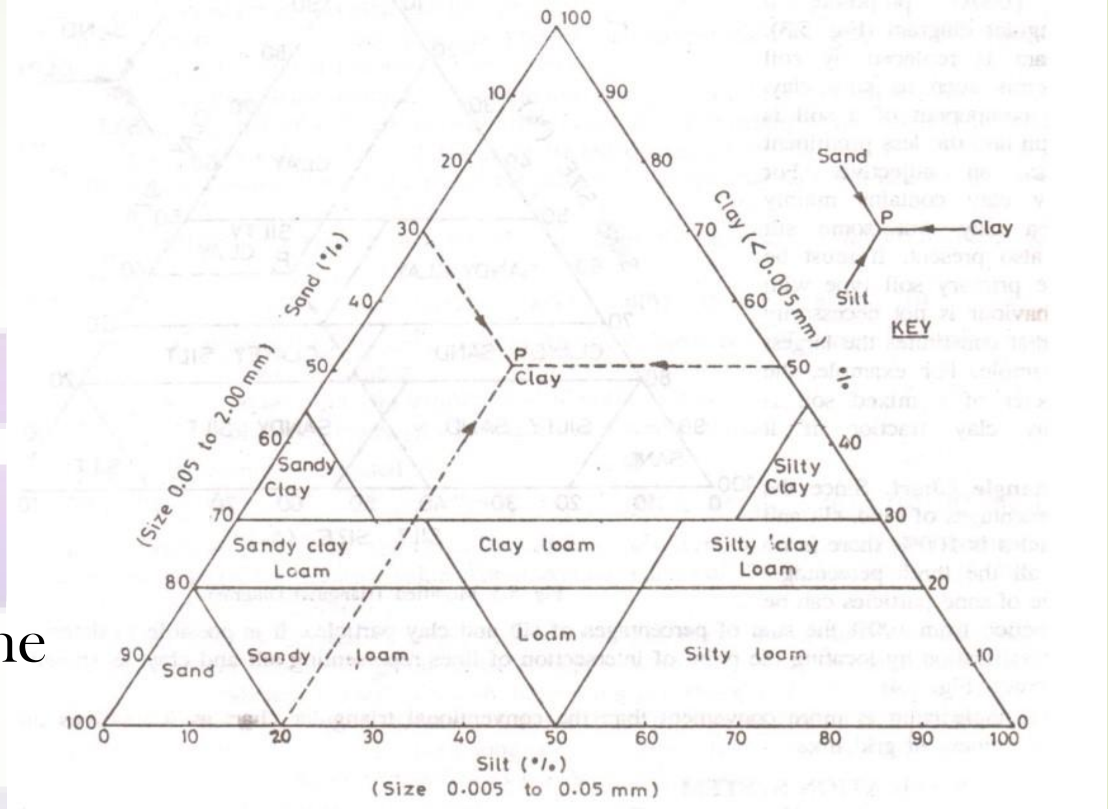


- Soil are classified based on their texture.
- Texture of a soil means how a soil visually appear and feels.
- Texture is influenced by the size, shape and gradation of soil particles in soil.

Preferred in Agriculture.

TEXTURAL CLASSIFICATION

- The first step in the classification of soil is to determine the percentage of sand, silt and clay size material in a given sample by mechanical analysis.
- This method does not reveal any properties of the soil other than grain-size distribution.

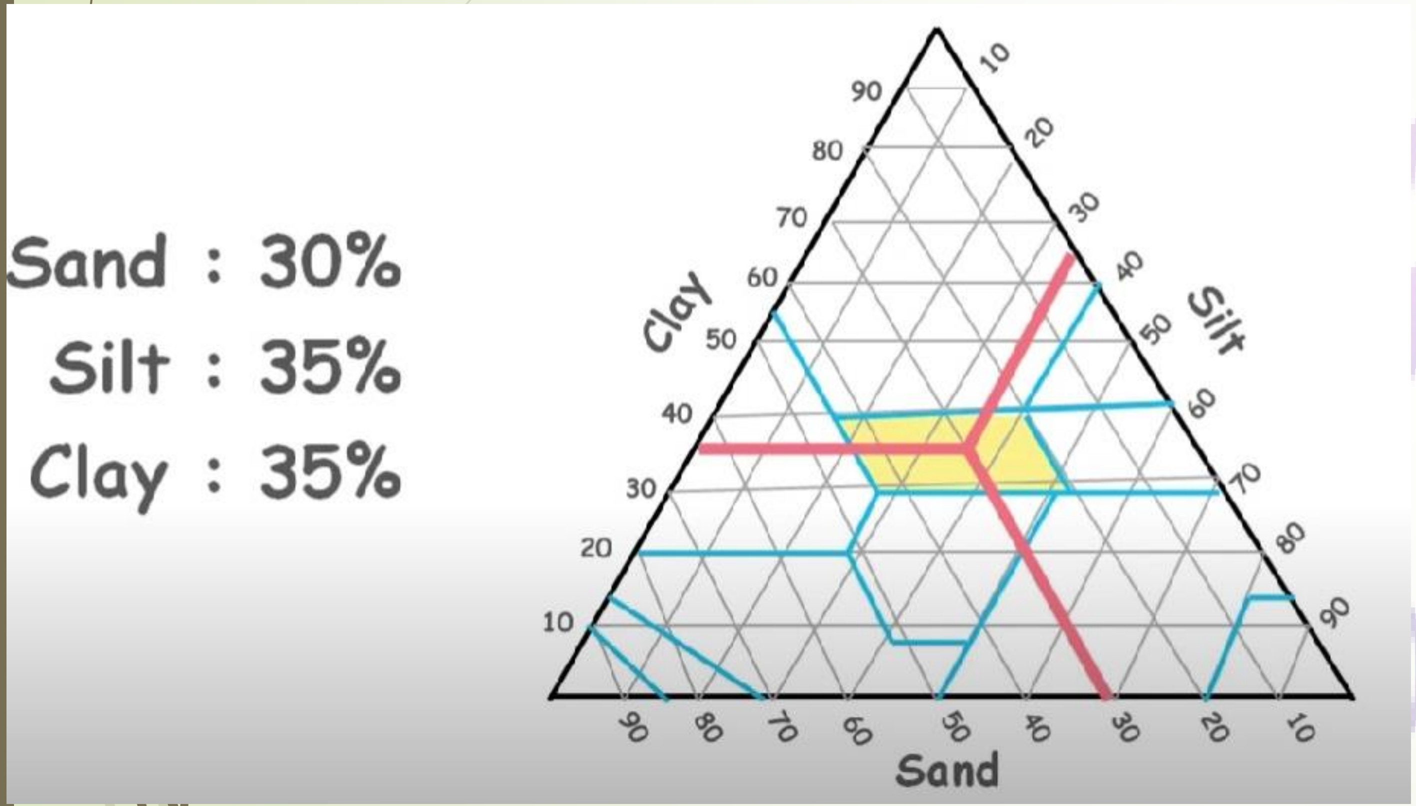


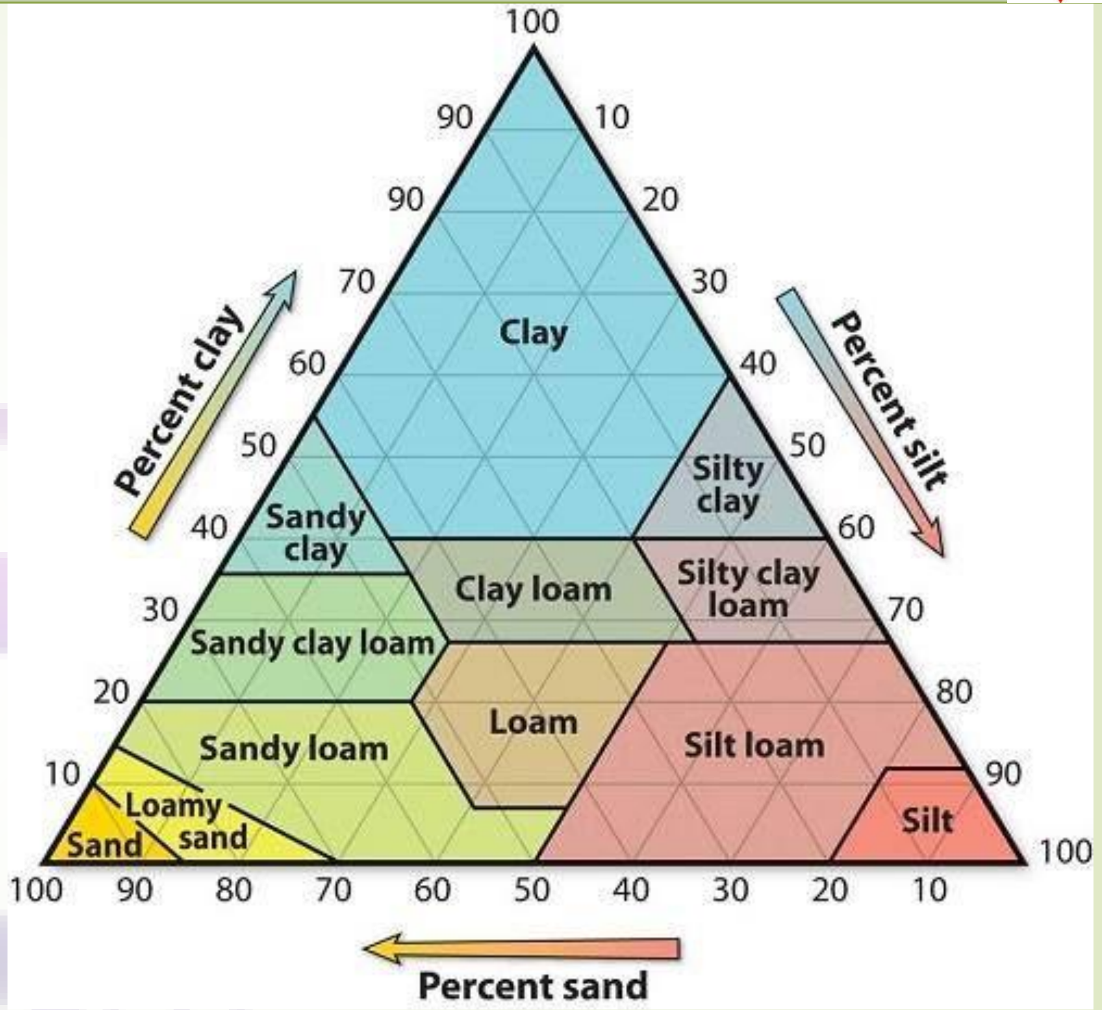
Sand, particle size between 0.06mm to 2mm

Silt, particle size between 0.002mm to 0.06 mm

Clay, particle size smaller than 0.002mm

TEXTURAL CLASSIFICATION





Modified Textural classification

12 zones in triangle and each represents different type of soil.

MIT SYSTEM OF CLASSIFICATION

Developed by: Prof. G. Giloby,

Massachusetts Institute of Technology, USA