UNIT - II INDEX PROPERTIES OF SOILS

The properties of soils which are not of primary interest to the geotechnical engineer but which are indicative of the engineering properties are called "index properties". Simple test which are required to determine the index properties are known as classification test.

The index properties are some times divided into two categories.

1. properties of individual particles
2. properties of soil mass also known as aggregate properties.

Moisture Content :

The moisture content (m) is defined as the ratio of the mass of water to the mass of solids.

$$m = \frac{M_w}{M_s} \text{ (or) } \frac{W_w}{W_s}$$

The moisture content is also known as the water content (w). It can be expressed as percentage, but used as a decimal in computation.

The water content of the fine-grained soils, such as silts and clays is generally more than coarse grained soils.

In geology and Some other disciplines, the water Content is defined as the ratio of the mass water to total mass. Some instruments such as moisture tester, also give the water Content as a ratio of the total mass.

$$m' = \frac{M_w}{M} \times 100$$

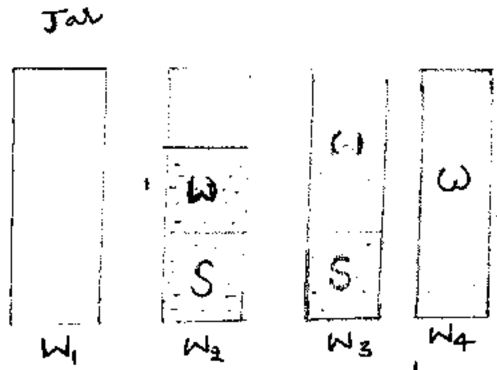
Determination of Water Content :

1. Oven dry method.
2. Pyconometer method.
3. Calcium Carbide method
4. Alcohol method
5. Torsion balance method
6. Sand bath method
7. Radiation method

1. Oven dry method :

First take the wet Sample and weigh it and put it in oven upto 24 hours and again weigh it. It gives the dry weight. By using $w = \frac{W_w}{W_s}$ we can find out the water content. If the time was less the minimum time that the Soil is be in the oven is for clayee Soil minimum 15 hours and for Sandy Soil minimum 4 hours and the maximum in 24 hours.

(2) Pyconometer method :-



The Jar was taken ded and weighted (W_1) and the moist Soil was taken in the jar and again weigh it (W_2) and the remaining space will be filled with water and weigh it (W_3). The Soil water is removed and and the jar was filled with water and weighed (W_4).

and the formula is $W = \left[\frac{W_2 - W_1}{W_3 - W_4} \left(\frac{G-1}{G} \right) - 1 \right] \times 100$

Volume of Solids $= \frac{W_s}{G}$

$$\left[\begin{aligned} W_s &= V_s \gamma_s \\ &= V_s G \gamma_w \\ &= V_s G (1) \\ W_s &= G V_s \\ V_s &= \frac{W_s}{G} \end{aligned} \right]$$

$$W_4 = W_3 - W_s + \frac{W_s}{G}$$

$$W_3 - W_4 = W_s \left(1 - \frac{1}{G}\right)$$

$$W_s = (W_3 - W_4) \left(\frac{G}{G-1}\right)$$

Weight of water in Soil Sample $W_w = (W_2 - W_1) - W_s$

we know water Content $= \frac{W_w}{W_s}$

$$\omega = \frac{(W_2 - W_1) - W_s}{W_s} = \frac{W_2 - W_1}{W_s} - 1$$

$$\omega = \left[\frac{W_2 - W_1}{W_3 - W_4} \left(\frac{G-1}{G} \right) - 1 \right]$$

③. Calcium Carbide method :-

In this method there is a Cylinder which has reading in above the Cylinder. the soil taken and calcium Carbide also taken which is equal to the Soil and mixed then thoroughly and inserted into the Cylinder. Cylinder was shaked upto 5 to 10 min. the water which the Soil is having is reacted with $CaCO_3$ and provide acetylene gas (C_2H_2) for the pressure of the gas. the Readings will be changed in the meter. It will shows the water Content of the Soil.

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$

Specific gravity :-

The Specific gravity of Solid particles (G) is defined as the ratio of the mass of a given volume of Solids to the mass of an equal volume of water at 4°c. Thus, the Specific gravity is given by

$$G = \frac{\rho_s}{\rho_w}$$

The mass density of water ρ_w at 4°c is one gm/mL, 1000 kg/m³ (or) 1 mg/m³

The Specific gravity of Solids for most natural soil falls in the general range of 2.65 to 2.80.

Specific gravity of Solids is an important parameter. It is used for determination of void ratio and particle size.

Typical Values of Sp. gravity

1. Gravel	—	2.65 – 2.68
2. Sand	—	2.65 – 2.68
3. Silty Sands	—	2.66 – 2.70
4. Inorganic Clays	—	2.68 – 2.80
5. Silt	—	2.66 – 2.70
6. Organic Soils	—	Variable may fall below 2.00

In addition to the Standard term of Specific gravity as defined, the following two terms related with the Specific gravity are also occasionally used.

1. Mass Specific gravity (G_m)
2. Absolute Specific gravity (G_a)

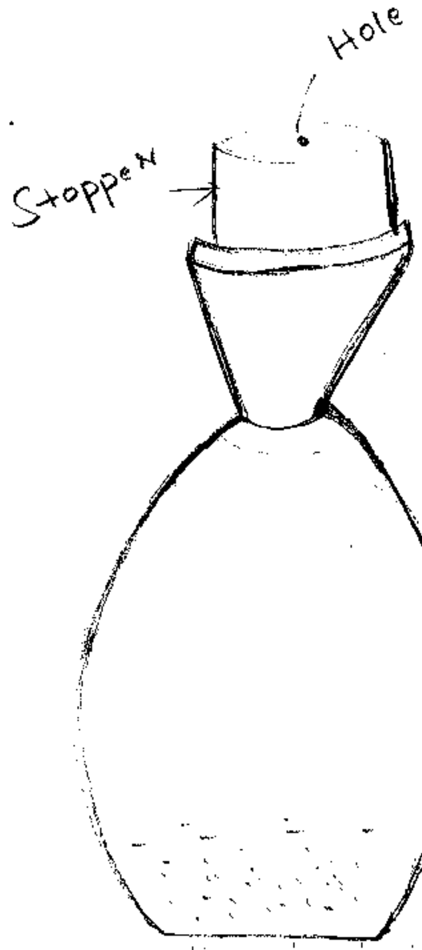
→ Refer I-unit ←

Specific gravity determination

The Specific gravity of Solid particles is determined in the laboratory using the following methods.

1. Density bottle method.
2. Gas Jar method.
3. pyconometer method.
4. measuring flask method.
5. shrinkage limit method.

1. Density Bottle method :-



(i) Take a clean and dry density bottle and weigh it with Stopper. let the weight be w_1.

(ii) Take about 10-20 gm of an oven dried Soil Sample into it and fixed the weight of the bottle and the Soil with stopper, let it be w_2.

(iii) Add distilled water so that the bottle is half full, remove the entrapped air by Connecting it to Vaccum source.

(iv) Fill the bottle Completely with distilled water, put the stopper and wipe it clean. Determine the weight of the bottle and its Content 'w_3'

(V) Empty the bottle and clean it thoroughly. Fill it with distilled water, put the stopper and wipe the bottle dry on outside. Find its weight 'W_4'

(VI) Repeat the steps 2 to 5 on more samples of the given soil and find the result by using below formulae.

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

W_1 = weight of empty density bottle with stopper

W_2 = weight of bottle with stopper + dry soil

W_3 = weight of bottle with stopper + soil + water

W_4 = weight of bottle with stopper + water

2. Pyconometer method:-

This method is similar to the density bottle method. As the capacity of the pyconometer is larger about 200 - 300g of oven-dry soil is required for the test. The method can be used for all types of soils, but is more suitable for medium grained soils, with more than 90% passing a 20mm IS sieve and for coarse grained soils with more than 90% passing a 40mm IS sieve.

3. Measuring Flask method :-

A measuring flask is of 250 ml (or) (500 ml) Capacity. with a graduation mark at the level. It is fitted with an adapter for Connecting it to a Vaccum line for removing entrapped air. This method is similar to the density bottle method. About 80 to 100 g of oven dry Soil is required in this case. this method is Suitable for fine grained and medium grained Soils.

4. Gas jar method :-

In this method, a gas jar of about 1 Lt Capacity is used. The jar is fitted with a rubber bung. the gas jar Serve as a pyconometer. This method is Similar to the pyconometer method.

CONSISTENCY LIMITS

"The water Contents at which the soil changes from one state to the other are known as Consistency limits or Atterberg's Limits"

We have three types of Consistency limits. They are

1. Liquid limit
2. plastic limit
3. shrinkage limit

1. Liquid Limit :-

"The liquid limit is the water Content at which the Soil changes from the liquid state to plastic state.

At the liquid state, the Clay is practically Like a liquid, but possesses a Small shearing strength. the liquid limit of Soil depends upon the clay mineral present in the Soil.

The liquid limit is determined in the laboratory either by Casagrande's apparatus or by cone-penetration method. the device used in the Casagrande method Consists of a brass cup which drops through a height of 1 cm from the hard base.

Procedure :-

1. Adjust the cup of the liquid limit apparatus with the help of grooving tool gauge and adjustment plate to give a drop of exactly 1 cm on the point of Contact on base.

2. Take about 120 gms of air-dried Sample passing 425 μ Sieve.

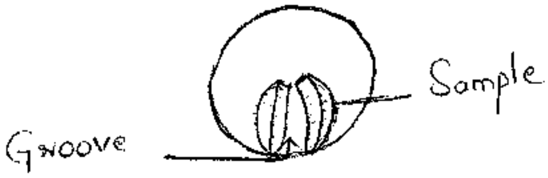
3. Mix it thoroughly with quantity of distilled water to form a uniform paste.

4. place a portion of the paste in the Cup. Smooth the Surface with Spatula to a minimum depth of 1 cm. Draw grooving tool through the Sample along the Symmetrical axis of the cup. holding the tool perpendicular to the cup.

5. Turn the handle at a rate of 2 revolutions per Second and Count blows until the two parts of the Sample Come in Contact at the bottom of the groove.

6. Transfer the remaining Soil in the Cup to the main Soil Sample and mix thoroughly after adding a Small amount of water.

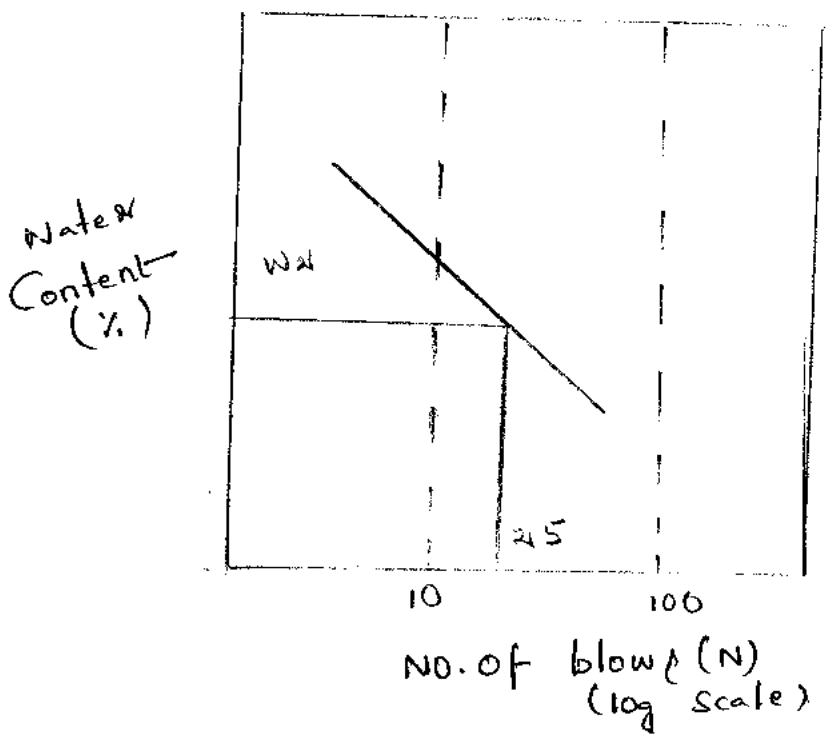
7. Repeat the Steps 4, 5 and 6. Obtain at least five Sets of reading in the range of 10 to 50 blows.



Exp:-

S.NO	Amount of water added (ml)	Moisture Content (%)	No. of blows.
1	30	30%	4
2	29	29%	10
3	28	28%	15

plot a Straight line graph between no. of blows and water Content. Read the water Content at 25 blows, which is the value of liquid limit.



2. plastic limit :-

plastic limit is the water content below which the soil stops behaving as a plastic material

(or)

The moisture content at which soil has the smallest plasticity is called the plastic limit.

Procedure :-

1. Take about 30 gm of air dried sample passing though 425 micron sieve.
2. Mix thoroughly with distilled water on the glass plate until it is plastic enough to be shaped into small ball.
3. Take about 10 gm of the plastic soil mass and roll it between the hand and the glass-plate to form the soil mass into a thread. if the diameter of thread becomes less than 3 mm without cracks, shows that water is more than its plastic plastic limit, hence the soil is kneaded further and rolled into thread again.
4. Repeat this rolling and remoulding process untill the thread starts just crumbling at the diameter of 3 mm.
5. If crumbling starts before 3 mm diameter thread, it shows that water added is less than the plastic limit of the soil, hence some more

water should be added and mixed to a uniform mass and rolled again, until the thread starts crumbling at a diameter of 3mm.

6. Collect the pieces of crumbled soil thread at 3mm diameter in an air tight container and determine moisture content

7. Repeat this procedure for two more samples.

SHRINKAGE LIMIT :

Shrinkage limit is defined as the maximum water content at which a reduction in water content will not cause a decrease in the volume of a soil mass. It is the lowest water content at which a soil can still be completely saturated.

$$\text{Shrinkage limit } W_s = \left[W_1 - \frac{V - V_d}{W_d}\right]$$

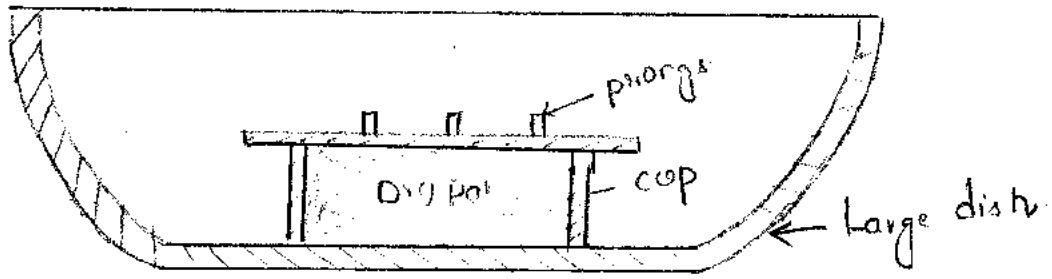
Where

W_1 = moisture content

V = Volume of wet soil = Volume of dry soil

V_d = Volume of dry soil pat

W_d = weight of the dry soil pat.



Procedure for Shrinkage limit test:-

1. Take about 100 gm of Soil Sample passing through 425 μ IS Sieve.
2. place about 30gm of the Soil in evapourating dish and mix it thoroughly with distilled water such that water added will Completely fill the Voids in the Soil and make the Soil pasty enough to be readily worked out into the shrinkage dish without entrapping air.
3. Weigh a clean and dry shrinkage dish.
4. place the Shrinkage dish in Evapourating dish fill it with mercury. Remove the excess mercury, clean the dish and find the weight of mercury in the shrinkage dish. Volume of shrinkage dish will be obtained by dividing the weight of mercury by its unit weight volume of the wet Soil pat will be equal to the Volume of shrinkage dish.

5. Apply a thin Coat of grease on the inside of the shrinkage dish.

6. place the Soil paste at the Centre of the dish and tap it on firm Surface and allow the paste to flow towards edges. Continue the tapping till the Soil is Compacted. and entrapped air is removed. Repeat the process till the dish is Completly filled with Soil.

7. Weigh the shrinkage dish with wet Soil.

8. Keep the dish in air till the Colour turns from dark to light and there keep it in oven for 24 hours at Constant temparature of 105°c

9. cool the dish and weigh it immediately.

10. Determine the Volume of dry Soil pat by immersing it in mercury and measuring the volume of mercury displaced.

11. Repeat the procedure for two more Samples.

1. Plasticity Index :- (I_p (or) PI)

I_p is the range of water Content over which the Soil remains in the plastic state. It is equal to the differance between the liquid limit (w_l) and plastic limit (w_p).

$$I_p = w_l - w_p$$

if the plastic limit is greater than the liquid limit. the plasticity index is reported at zero (and not -ve)

2. Liquidity Index :-

Liquidity index (I_l or LI) is defined as.

$$I_l = \frac{w - w_p}{I_p} \times 100$$

Where. w = water content of the soil in natural condition.

The liquidity index of a soil indicates the nearness of its water content to its liquid limit. when the soil is liquid limit. its liquidity index is 100%. and it becomes and behaves as a liquid. when the soil is at the plastic limit. its liquidity index is zero.

Consistency Index :-

$$I_c = \frac{w_l - w}{I_p} \times 100$$

4. Shrinkage Index :- The Shrinkage index (I_s) is the numerical differance between the liquid limit (w_l) and the shrinkage limit (w_s).

$$I_s = w_l - w_s$$

5. Shrinkage Ratio :-

The Shrinkage Ratio (SR) is defined as the ratio of given volume change, expressed as the percentage of dry volume to the Corresponding change in water Content.

$$SR = \frac{(V_1 - V_2) * V_d}{(w_1 - w_2)} \times 100$$

Where, V_1, V_2 = Volume of Soil at w_1, w_2.

V_d = Volume of dry Soil mass.

6. Volumetric Shrinkage :-

The Volumetric Shrinkage (VS) (or) Volumetric change is defined as the change in volume expressed as percentage of the dry volume. when the water content is reduced from a given Value to the shrinkage limit. That.

$$V_s = \left[\frac{V_1 - V_d}{V_d} \right] * 100.$$

Indian standard classification of Soils :-

The System uses particle Size analysis and plasticity chart for the classification of the Soil. in the System the Soils are Classified into 18 groups.

The Soil first Classified into three Categories.

(1) Coarse grained soils
(2) Fine - grained Soils
(3) High organic Soils (peat)

(1) Coarse grained Soils :-

Coarse grained Soils are Sub-divided into gravel and Sand. The Soil is termed gravel (CG) when more than 50% of Coarse fraction is retained on 4.75 mm IS Sieve and termed sand (CS), if more than 50% of the Coarse fraction is Smaller than 4.75 mm. IS Sieve. Coarse grained Soils are further sub-divided as given as the table no: 01.

(2) Fine grained Soils :-

the fine grained Soils are further divided into three Sub-divisions, depending upon the Values of the liquid limit.

(a) silts and clays of low Compressibility :- These soils have a liquid limit less than 35

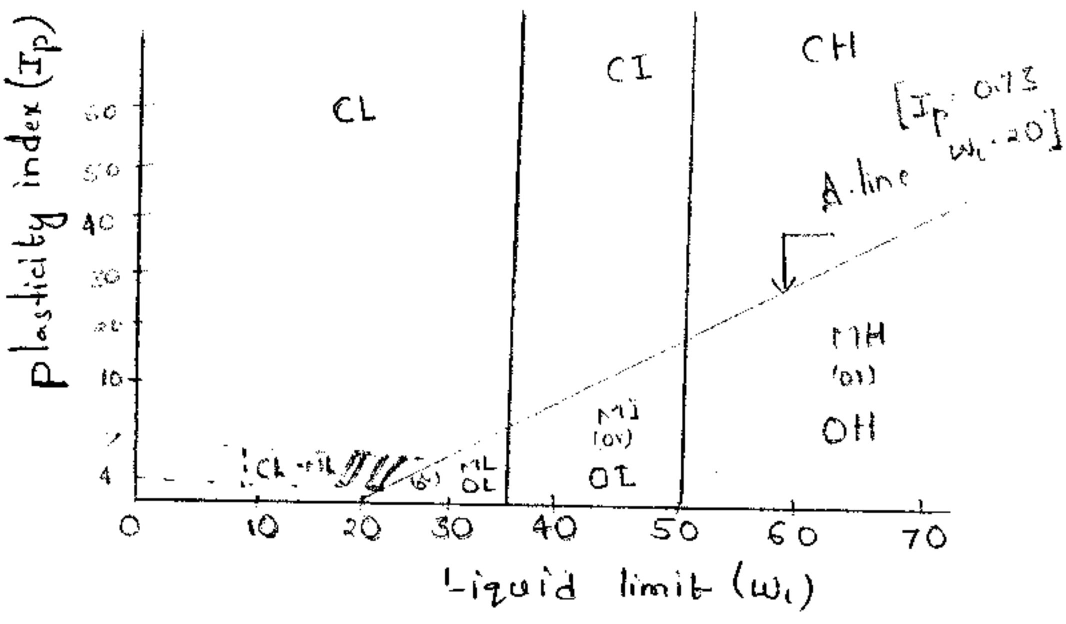
(b). silts and clays of Medium Compressibility:-
These Soils have a liquid limit greater than 35 but less than 50 (symbol is I)

(c). Silts and Clays of high Compressibility:-
These Soils have a liquid limit greater than 50.

Fine-grained Soils are further Sub-divided into 9 groups in table no: 02.

(3). High organic Soils:-
If the Soil is highly organic and Contains a large percentage of organic matter and particles of decomposed Vegetation. it is kept in a Seperate Category marked peat (Pt)

Plasticity Chart



problems

1. Determine the liquid limit, plasticity index, liquidity index from following data.

Water Content(W)	55	46	32	22	15
No. of blows (N)	24	30	35	41	49

The plastic limit is 24% and Natural water Content is 32%

$w_p = 24\%$

$w = 32\%$

liquid limit = 53.5%

plasticity index = Liquid limit - plastic limit

= 53.5 - 24

= 29.5%

liquidity index = $I_l = \frac{w - w_p}{I_p} \times 100$

$= \frac{32-24}{29.5} \times 100$

= 27.1%

2. An undisturbed Saturated Specimen of clay has a volume of 18.9 cm^3 and a mass of 30.2 gm on oven drying the mass reduces to 18 gm. The volume of dry specimen is 9.9 cm^3. Determine shrinkage limit, specific gravity of solids, shrinkage ratio and volumetric shrinkage?

$W_1 = 30.2\ gm$, $W_s = 18\ gm$

V_d (or) $V_2 = 9.9\ cm^3$ $V_1 = 18.9\ cm^3$

$\gamma_w = 1\ g/cc$

$$w_s = \left[w - \frac{(V_1 - V_2)\gamma_w}{W_s} \right] \times 100 \qquad \left\{ w = \frac{W_1 - W_s}{W_s} \times 100 \right\}$$

$$= \left[\frac{W_1 - W_s}{W_s} - \frac{(V_1 - V_2)\gamma_w}{W_s} \right] \times 100$$

$$= \left[\frac{30.2 - 18}{18} - \frac{(18.9 - 9.97) * 1}{18} \right] \times 100$$

$$= [0.678 - 0.5] \times 100$$

$$= 17.8\%$$

$$G = \frac{W_s}{V_1\gamma_w - (W_1 - W_s)} = \frac{18}{18.9 \times 1 - (30.2 - 18)} = 2.69$$

$$S.R = \frac{\gamma_d}{\gamma_w} = \frac{W_s}{V\gamma_w} = \frac{18}{9.9 \times 1} = 1.818$$

$$V_s = \frac{V_1 - V_d}{V_d} \times 100 = \frac{18.9 - 9.9}{9.9} \times 100 = 91\%$$

(or) $\left\{ V_d = \frac{W_s}{V} \right\}$

$$V_s = SR / (w_1 - w_s)$$

$$= (67.8 - 17.8) * 1.82$$

$$= 91\%$$