LECTURE NOTES

ON

GEOTECHNICAL ENGINEERING (TH. 2)

FOR

DIPLOMA IN CIVIL ENGINEERING

(3RD SEMESTER STUDENTS)

AS PER SCTE&VT SYLLABUS

PREPARED BY:

Smt. Sushree Sangita Patel

Lecturer in Civil Engineering

Department of Civil Engineering

Government Polytechnic, Sambalpur (Rengali)

www.gpsambalpur.com

3.0 Determination Of Index Properties :—

Index properties are those properties which helps in identification and classification of soil.

3.1 Water Content

There are various methods of determining the water content of soil sample, and they are :—

i) Oven-drying method
ii) Sand bath method
iii) Alcohol Method
iv) Calcium Carbide method
v) Pycnometer method
vi) Radiation method
vii) Torsion-balance method.

i) Oven-drying Method

↳ Most accurate method of determining water content.

↳ A soil sample is kept in a clean container & put in an oven to maintain a temp. between 105°C to 110°C.

↳ The sample is kept for 24 hrs for complete drying.

↳ Mass of clean non-corrodible container is taken with its lid (M_1)

↳ Mass of moist soil in container with lid is taken as M_2.

↳ Then, container with moist soil is placed in oven after removing the lid.

↳ After drying, container is removed from oven & allowed to cool in a desiccator.

↳ The mass of dry soil, the container & lid is taken as M_3.

The water content is calculated from following expression :-

$$w = \frac{M_2 - M_3}{M_3 - M_1} \times 100$$

M_1 = Mass of container + lid

M_2 = mass of container + lid + moist soil

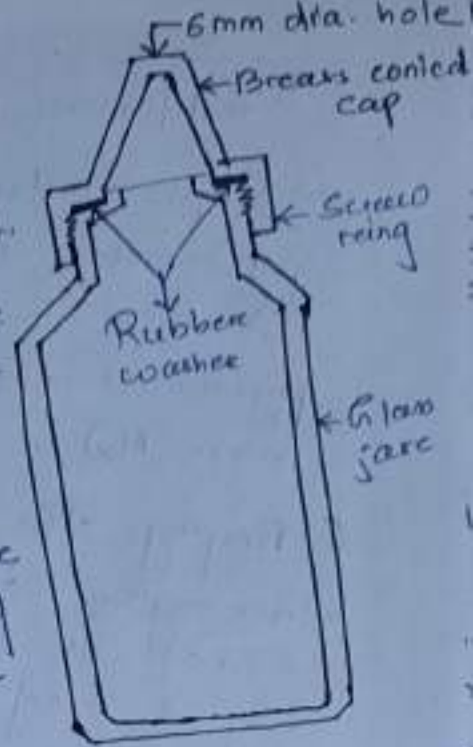
M_3 = mass of container + lid + dry soil.

ii) **Pycnometere Method**

↳ Quick method of determining watere content.

↳ Pycnometere is a large density bottle of about 900ml capacity.

↳ Conical brass cap, having 6 mm dia hole at its top is screwed to the open end of pycnometere.



↳ Rubber washere is placed between conical cap and the rim of the bottle so no leakage of watere takes place.

↳ Procedure:-

↳ Take clean, drey pycnometere and find the mass with its cap & washere (M_1).

↳ Put 200 gm to 400 gm of wet soil sample in the pycnometere and find its mass with its cap & washere (M_2).

↳ Fill the pycnometer to half its height with water & mix with glass rod.

↳ Add more water & stirr it.
↳ Replace the screw top & fill the pycnometer flush with the hole in the conical cap. Dry the pycnometer from outside. Find the mass (M_3).

↳ Empty the pycnometer, clean it thoroughly & fill it with clean water to the hole of conical cap. & find mass M_4.

Water content is calculated using following formula :-

$$w = \left[\left\{\frac{(M_2 - M_1)}{(M_3 - M_4)}\right\}\left(\frac{G-1}{G}\right) - 1\right] \times 100.$$

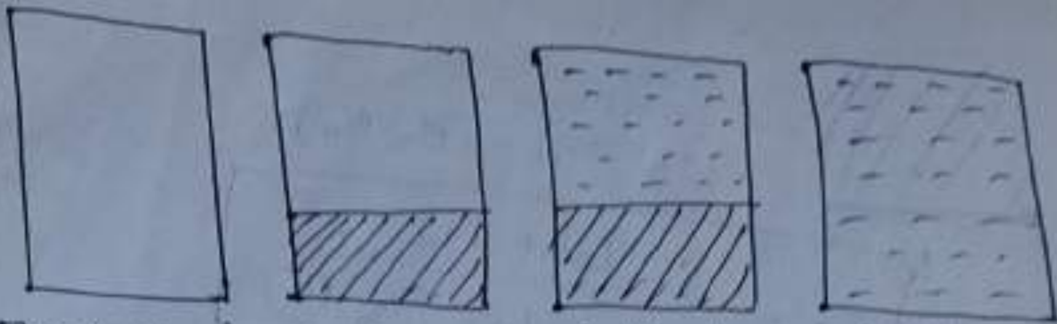
3.2 Specific Gravity

Specific gravity of soil is determined by :-

i) 50ml density bottle
ii) 500ml flask
iii) Pycnometer.

-> Density bottle is most accurate & suitable for all type of soils.

-> Flask or pycnometer is used only for coarse grained soil.



- Mass of empty dry bottle is taken as M_1.
- Sample of oven dried soil, cooled in desiccator, placed in bottle M_2.
- Bottle is filled with distilled water (or kerosene) gradually, removing the entrapped air either by applying vaccum or by shaking the bottle. The mass is taken as M_3.
- The bottle is emptied completely & thoroughly washed & clean water (or kerosene) is filled to top. The mass is taken as M_4.

Dry mass of soil = $M_2 - M_1 = M_d$.

$$G = \frac{\text{Dry mass of soil}}{\text{Mass of water of equal volume}}$$

$$= \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

$$\rightarrow G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

$$G = \frac{M_d}{M_d - (M_3 - M_4)}$$

3.3. Particle Size Distribution

- Percentage of various sizes of particles in a dry soil sample is found by particle size analysis or mechanical analysis.
- Mechanical analysis is meant for the separation of soil into different size fractions.
- Mechanical analysis is performed in two stages :-
  - i) Sieve analysis.
  - ii) Sedimentation analysis or wet mechanical analysis.
- Sieve analysis is meant for coarse grained soil & sedimentation analysis for fine grained soil.

Sieve Analysis:-

⇒ In IS, the sieves are designated by the size of aperture (openings) in mm.

⇒ Sieve analysis can be divided into two parts:-

i) Coarse analysis

ii) Fine analysis.

⇒ Soil sample is separated into two fractions by sieving through 4.75 mm IS sieve.

⇒ The sample is retained on 4.75 mm IS sieve is termed as gravel fractions & used for coarse analysis.

⇒ Set of sieves used for coarse analysis are:- 100, 63, 20, 10 & 4.75 mm

⇒ Set of sieves used for fine sieve analysis are:- 2mm, 1mm, 600µ, 425µ, 300µ, 212µ, 150µ & 75µ IS sieves.

⇒ The sieves are arranged one over the other by keeping the largest opening sieve at the top & smallest opening sieve at the bottom.

⇒ A receiver is kept at bottom &

a cover is kept at the top.
→ The sample is placed on the top sieve, and the whole assembly is fitted on sieve shaking machine.
→ 10 mins. of shaking is desirable for soils with small particles.
→ The soil sample retained on each sieve is weighed.
→ Percentage of soil retained on each sieve is calculated on the basis of total mass of soil sample taken.
→ It is advisable to wash the soil portion passing through 4.75mm sieve over 75μ sieve so that silt & clay particles sticking to sand will be washed off.
→ The fraction retained on 75μ sieve is dried in the oven.
→ The dried portion is then re-sieved through 2mm, 1mm, 600μ, 425μ, 300μ, 212μ, 150μ & 75μ.
→ If the portion passing 75μ size is substantial or considerable, wet analysis is done for further sub-division of particle size distribution

Sedimentation Analysis

In wet mechanical analysis or sedimentation analysis, the soil fraction finer than 75μ size is kept in suspension in a liquid medium.

→ This analysis is based on Stoke's law.

→ Stoke's law states that the velocity at which the grains settle out of suspension, all other factors being equal, is dependent upon the shape, weight & size of grains.

→ It is assumed that the soil particles are spherical & have same sp. gravity.

→ The coarser particles settle more quickly than the finer ones.

so, $v = \frac{2}{9} r^2 \frac{\gamma_s - \gamma_w}{\eta}$

$= \frac{1}{18} D^2 \frac{\gamma_s - \gamma_w}{\eta}$

v = terminal velocity of sinking spherical particle (m/s)

r = radius of spherical particle (m)

D = diameter " " (m)

γ_s = unit wt of particles (KN/m^3)

γ_w = " " " water/liquid (KN/m^3)

η = viscosity of water / liquid ($KN \cdot s/m^2$)

$\eta = \frac{\mu}{g}$.

μ = viscosity in poise.

g = acceleration due to gravity.

⇒ Sedimentation analysis is done by :-

i) Hydrometer ii) Pipette.

→ In both the methods, a suitable amount of oven dried soil sample, finer than 75 μ size, is mixed with a given volume v of distilled water.

→ The analysis is based on the assumption that :-

i) Soil particles are spherical

ii) Particles settle independent of other particles.

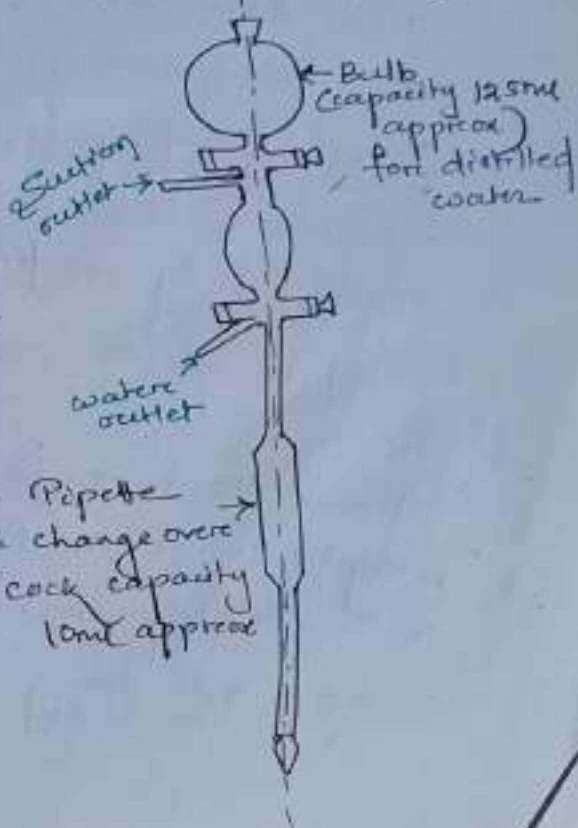
iii) Wall of jar, in which suspension is kept, also donot affect the settlement.

i) <u>Hydrometer Method</u>

→ The principle of the test is same in both hydrometer & pipette method.

i) Pipette Method

- It is a standard sedimentation method used in laboratory.
- The equipment consists of a pipette, jar and a no. of sampling bottle.
- A boiling tube of 500ml capacity is used in place of a jar.
- The pipette consists of
  - i) a 125ml bulb with stop cock, for keeping distilled water.
  - ii) a three way stop cock.
  - iii) Suction & waste water outlet.
  - iv) Sampling pipette of 10ml capacity.
- The method consist in drawing off samples of soil suspension, 10ml in volume, by means of pipette from a depth of 10 cm at various time intervals after commencement of test.



→ The pipette should be inserted in the boiling tube about 25 sec before the selected time interval & time taken for sucking the sample should not be more than 10 to 20 sec.

→ Each sample is transferred into suitable sampling bottle & dried in an oven.

⇒ M_D (mass of solids) per ml of suspension is then found by taking the dry mass & dividing it by 10.

→ The time intervals are ½ min, 1 min, 2 min, 4 min, 8 min, 15 min & 30 min & 1 hr, 2 hr, 4 hr, 8 hr, 16 hr, 24 hr from the commencement of the test.

(i) Method of preparing soil suspension

↳ Particles finer than 75 µ size are included in sedimentation analysis.

↳ Soil sample is washed through 75 µ sieve.

↳ About 12 to 30 gm of oven dried sample is accurately weighed & mixed with distilled water in a dish or beaker to form smooth paste

⇒ For proper dispersion of soil, a dispersing agent is added to the soil.

⇒ Some dispersing agents are sodium oxalate, sodium silicate & sodium polyphosphate compounds.

⇒ A dispersing solution containing 33 gm of sodium hexametaphosphate & 7 gm of sodium carbonate in distilled water to make 1 lit of solution.

⇒ 25 ml of this solution is added to the dish (~~mix~~ having soil & distilled water & mixture is warmed up gently for 10 mins.

⇒ The contents are transferred to a mechanical mixer.

⇒ Soil suspension is mixed or stirred for 15 mins or longer for highly clayey soil.

⇒ The suspension is washed through 75 μ sieve & suspension which has passed through the sieve is transferred to 500 ml capacity boiling tube.

⇒ The tube is then put in a constant temperature water bath.

→ When temp. in the tube has been stabilized to the temp. of the bath, the soil suspension is thoroughly shaken by inverting the tube & replacing in the bath.

→ Stop watch is started & soil sample are collected at various intervals with help of pipette.

→ The soil which contains organic matter & calcium compounds are pretreated before dispersing agents are mixed since these contents act as cementing agent & cause particles to settle as aggregation of particles instead of individuals.

→ Process of removing these organic matters & calcium compounds is known as pretreatment.

→ Soil is first treated with hydrogen peroxide solution to remove the organic matter by oxidation. The mixture of soil & hydrogen peroxide is kept warm at a temp. not exceeding 60°C, till no further evolution of gas takes place

→ The remaining hydrogen peroxide in the solution is then decomposed by boiling the solution.

→ To remove calcium compounds, the cooled mixture of soil is then treated with 0.2 N hydrochloric acid.

HYDROMETER METHOD

→ It is another method of sedimentation analysis.

→ The principle of the test is same in both the pipette & hydrometer method.

→ In pipette method, Mass M_D per ml of suspension is found directly by collecting 10 ml sample of soil suspension from sampling depth H_e.

→ In hydrometer method, M_D is computed indirectly by reading the density of soil suspension at the depth H_e at various time interval.

→ In pipette method, sampling depth (H_e) is constant (10 cm) but in hydrometer method, the sampling depth increases as the particle settle with the increase in the time interval.

→ Calibration of the hydrometer and sedimentation jar is required before starting sedimentation test.

→ For the hydrometer, the reading on the stem gives the density of soil suspension situated at center of bulb at any time.

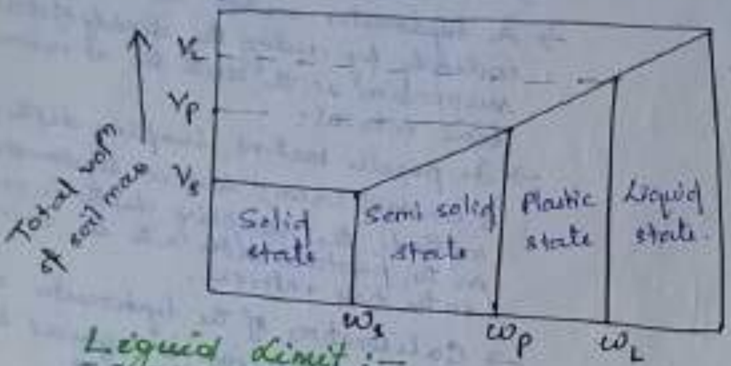
→ Hydrometer reading are recorded after subtracting & multiplying the remaining digits by 1000. It is designated as R_h.

→ The hydrometer reading R_h increase in the downward direction towards the hydrometer bulb.

→ Let H be the ht in cm between any hydrometer reading R_h and the neck & the h as ht of bulb.

→ Sedimentation jar contain soil suspension.
→ When hydrometer is immersed in the jar water level aa rises to a₀a₀. The rise is equal to V_h of the hydrometer divided by interval area of cross section A of jar.
→ Similarly the level bb rises to b_1b_1, where bb is the level, situated at a depth He below the top level a.a

3.4 CONSISTENCY OF SOIL :-
→ Consistency is the relative ease with which soil can be deformed.
→ Atterberg divided various stages of consistency from liquid to solid state in to 4 stages.
i) Liquid state
ii) plastic state.
iii) Semi solid state
→ There are certain limits known as consistency limit & atterberg limit depending up to water content.
→ For Engg purpose the atterberg limits are :- Liquid limit, plastic limit & Srinkage limit.



Liquid Limit :-
→ It is the water content corresponding to the limit between liquid & plastic state of consistency of soil.
→ It is the minimum water content at which the soil is still in the liquid state, but has shearing strength against flowing.
→ It is the minimum water content at which a part of soil is cut by a groove of standard dimension will flow together from a distance of 12mm under an impact of 25 blows in the device.

Plastic Limit (W_P) :-

→ It is the water content corresponding to the limit between plastic & semi solid state of consistency of soil.

→ It is the min water content at which an soil will just begin to crumble when rolled in to a thread of 3mm in dia.

Shrinkage Limit (W_s) :-

It is the maximum water content at which a reduction in water content will not causes a decrease in the volume of a soil mass.

Plastic Index (I_P) :-

It is defined as the numerical difference between the liquid limit and the plastic limit of the soil.

$$I_P = W_L - W_P$$

Plasticity :-

It is the property of a soil which allows it to deform rapidly with out vol. change.

Consistency Index (I_c) :-

It is the ratio of the liquid limit minus the natural water content to the plasticity index of soil.

$$I_c = \frac{W_L - W}{I_P}$$

Liquidity Index (I_L) :-

It is the ratio of natural water content of the soil minus its plastic limit to its plasticity index.

$$I_L = \frac{W - W_P}{I_P}$$

Determination of Liquid Limit :-

→ Liquid limit is determined by an apparatus designed by casagranda named as Casagranda liquid limit apparatus.

→ It is consist of hard rubber base, over which a brass cup is placed which can be raised and lowered with the help of a handle.

→ Height of fall can be adjusted with the help of adjusting screw & before conducting the test, ht. of fall is adjusted to 1 cm.

→ Two types of grooving tools are used:-
i) Casagrande tool
ii) ASTM tool

→ Casagrande tool cut a groove of 2mm wide at bottom, 11 mm wide at top and 8 mm high.

→ ASTM tool cut a groove 2 mm wide at bottom 13.6 mm at top & 10 mm deep.

Procedure

↳ About 100 gm of soil sample passing through 425μ IS sieve is taken in a porcelain dish. Some quantity of water is added to it & thoroughly mixed to form a soil paste of uniform colour.

↳ The height of fall of cup of the liquid limit device is adjusted to be 1 cm.

↳ A portion of soil paste in porcelain dish is placed in the liquid limit device & levelled by means of spatula.

↳ Using standard grooving tool, a groove is cut in the soil.

↳ Cup is given blows by rotating the handle at 2 revolution per second.

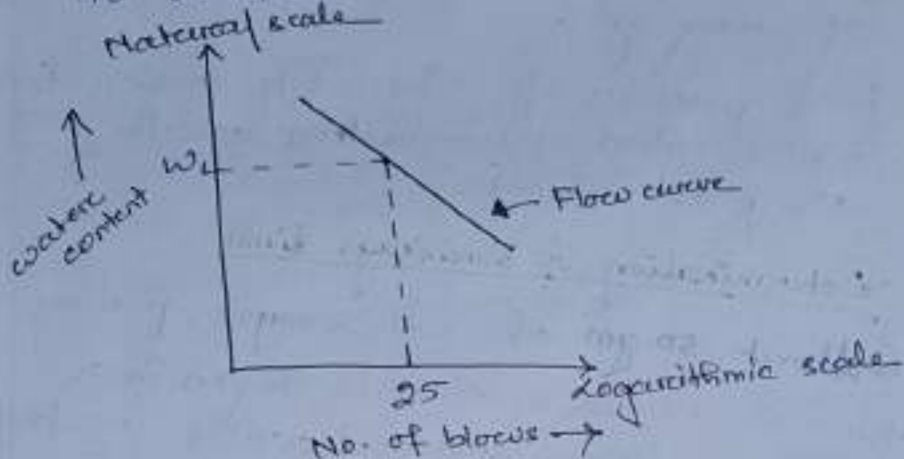
↳ The number of blows required to close the groove for a distance of 13 mm is noted down.

↳ The above steps are repeated to get at least 4 concurrent sets of number of blows & water content.

↳ It is convinient to increase the water content in successive steps and obtain blows count near about 40, 30, 20 & 10.

↳ The water content values are plotted as ordinate on natural scale against number of blows as abscissa on logarithmic scale to obtain straight line, which is known as flow curve.

↳ From this plot the liquid limit is obtained as water content corresponding to 25 blows.



Determination of plastic limit

↳ About 30 gms of soil sample passing through 425 μ IS sieve is taken & some quantity of water is added & thoroughly mixed to form a soil paste which can be rolled into balls between palm of ~~hands~~ hands.

↳ A small portion of the ball is then rolled on a smooth plate into a thread of 3 mm diameter & the thread is looked for signs of cracking.

↳ If no cracks are seen, the thread is picked up and again rolled into a ball between palms to reduce water content.

↳ The ball is then rolled on smooth plate a into a thread of 3 mm dia.

↳ The steps are repeated until a 3 mm diameter thread first shows signs of cracking.

↳ A portion of thread is taken for water content determination, which gives the plastic limit.

Determination of shrinkage limit

↳ About 50 gm of soil sample passing through IS 425 μ sieve is taken in a porcelain dish, distilled water is added to it, and mixed thoroughly to form a soil paste of slightly flowing consistency.

↳ The shrinkage dish (cup of 45 mm dia and 15 mm ht) is weighed after coating inner side of the cup with a thin layer of grease or oil. ~~The~~

↳ shrinkage cup is filled with the soil paste in 3 layers, the cup ~~being~~ being gently tapped on a cushioned surface after filling with each layer to ensure expulsion of air bubbles.

↳ The surface of soil is levelled & outer side of cup is cleaned. The mass of shrinkage cup with wet soil pat is found & this is deducted from mass of shrinkage cup to get mass of wet soil pat (M_1).

↳ The wet soil is allowed to dry in air for some time, then kept in oven & dried for 24 hrs at 105 to 110°C.

↳ Then mass of dry soil (M_d) is found.

↳ The volume of dry soil (V_d) is found by mercury displacement method.

↳ The volume of wet soil (V_1) is equal to volume of shrinkage dish which is found by filling it with mercury & finding mass of mercury required to fill it after removing convex portion at the top by pressing with a flat plate.

↳ Volume is obtained by dividing mass by density of mercury.

4.0 Classification Of Soil

4.1 General

⇒ Soil is classified into various groups depending on engg. properties and characteristics.

⇒ From engg. point of view, soil is classified with the objective of finding the suitability of soil for construction of dam, highway, foundation & other engg. structures.

⇒ The soil may be classified to following systems :-

i> Particle size classification

ii> Textural classification.

iii> Highway research Board (HRB) classification.

iv> Unified soil classification.

v> Soil Classification.

i) Particle Size Classification

↳ Soil is arranged according to grain size

↳ Gravel, sand, silt & clay are used to indicate grain size.

↳ They designate the particle size,

naturally occurring soil have mixture of particles of different sizes.

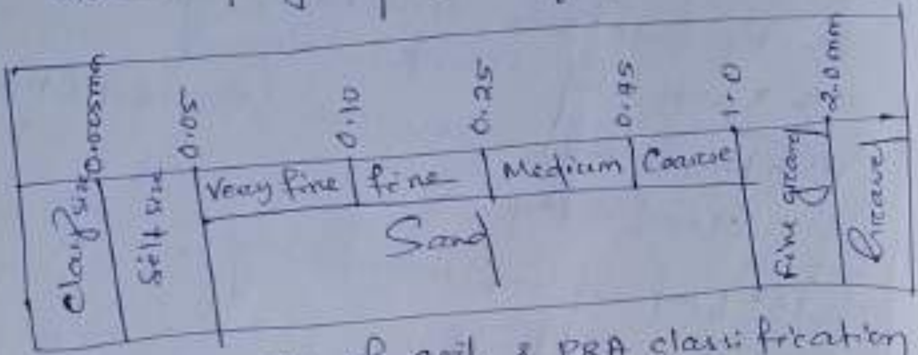
↳ Silt size & clay size are mostly used word in place of simply silt or clay in this system.

→ Three such systems which have been widely used are :-

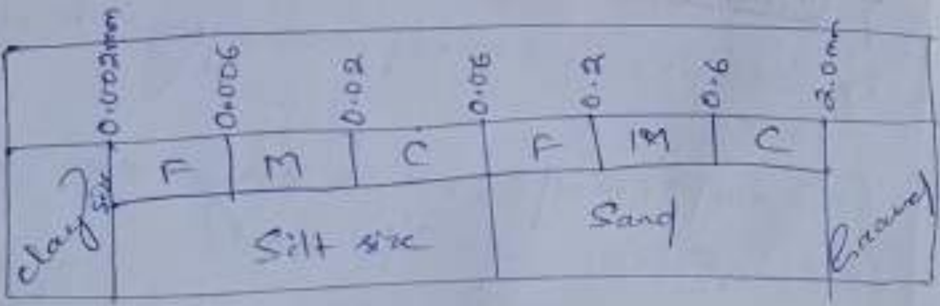
(a) U.S Bureau of soil & Public Roads Administration (PRA) classification system.

(b) M.I.T. classification system.

(c) Indian standard particle size classification system (based on M.I.T. system)

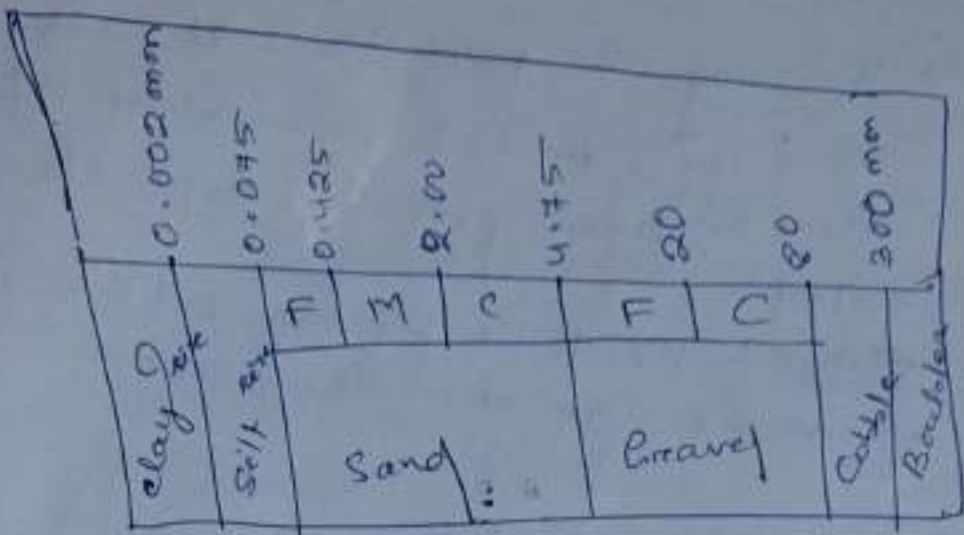


(a) U.S. Bureau of soil & PRA classification system.



(b) M.I.T. classification

P-4.2



(c) I S classification.

ii) Textural Classification

→ Naturally occurring soil compose of sand, silt & clay.

→ Soil classification of composite soil based on particle size distribution is known as textural classification.

→ It is a triangular classification & it is suitable for coarse grained soil.

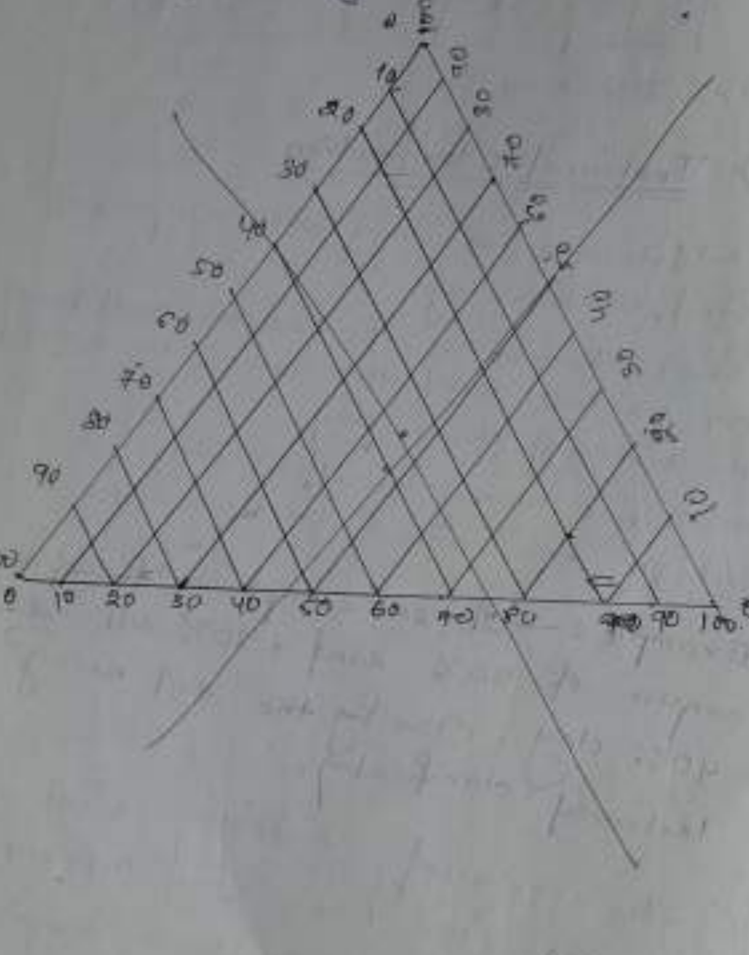
Example :— A soil sample is found to consist of 30% sand, 30% silt & 40% clay. Classify the soil using textural classification.

→ The textural classification chart of U.S.P.R.A (U.S. Public Road Administration) has been developed to classify composite soil.

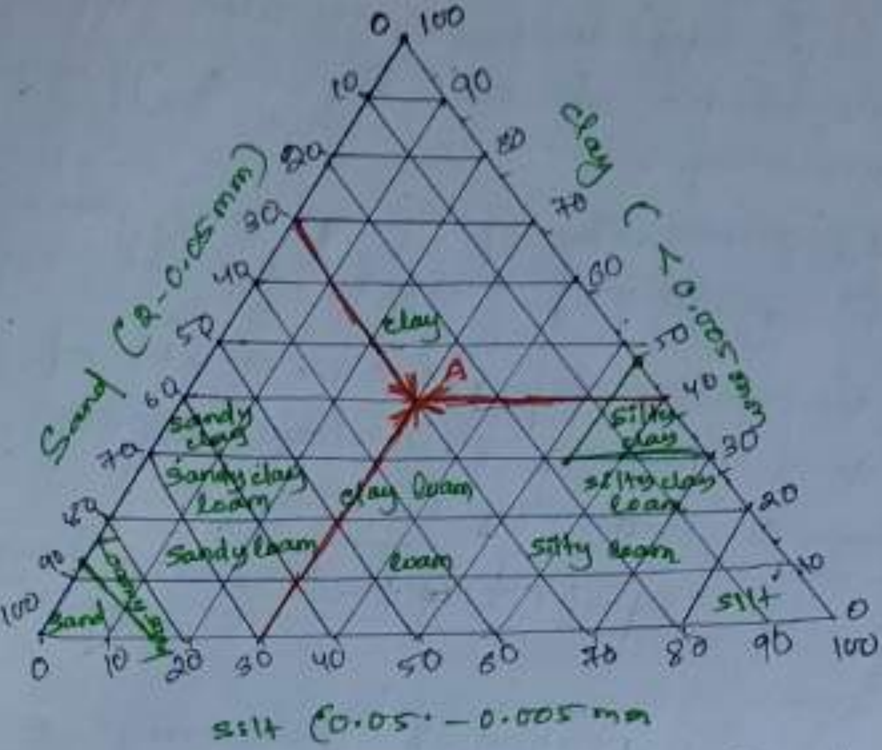
S-2011

↳ Knowing the percentage of sand, silt & clay, lines of intersection of the 3 lines gives the type of soiled.

Note: – The chart ignores soil fract of gr-size greater than 2.00 mm.



P-4.4



From respective points on 3 sides, intersects at point A, which lies in the region marked as clay. Hence the soil can be classified as clay.

(iii) Highway Research Board (HRB) classifn

- It is also known as Public Road Administration (PRA) classification.
- It is used for pavement construction.
- Soil is divided into 7 primary groups, named as A-1, A-2 ------ A7.
- Group A-1 is divided into two sub-groups and group A-2 is divided

into 4 sub-groups.

→ Group index used to describe the performance of soil when used in pavement construction.

→ Higher the value of group index, poorer the quality of material.

→ Group index depends on amount of material passing #75μ sieve, liquid limit & plastic limit.

$$\text{Group Index (GI)} = 0.2a + 0.005ac + 0.01bd$$

where,

a = that portion of percentage passing #75μ sieve greater than 35 & not exceeding 75 expressed as whole no. (0 to 40)

b = that portion of percentage passing #75μ sieve, greater than 15 & not exceeding 55 expressed as a whole number (0 to 40).

c = that portion of numerical liquid limit greater than 40 & not exceeding 60 expressed as a positive whole number (0 to 40) d - that portion of numerical plasticity index greater than 10 & not exceeding 30 expressed as positive whole number (0 to 20).

(iv) Unified Soil Classification System

↳ This system is used for the construction of foundation, earth dam, canal, earth slopes etc.

↳ The coarse grained soils are classified on the basis of grading size distribution while the fine grained soils are classified on the basis of their plasticity.

↳ The soil is first classified into 2 groups

(a) Coarse grained soil

(b) Fine grained soil

(a) Coarse grained soil

↳ If the soil retained on 75 μ is more than 50%, then the soil is coarse grained soil.

↳ A coarse grained soil is called gravel (G) when 50% or more of coarse fraction is retained on 4.75 mm sieve otherwise termed as sand (S).

↳ Coarse grained soil containing less than

5% fines, are designated as GW & SW if they are well graded and designated as GP & SP if they are poorly graded.

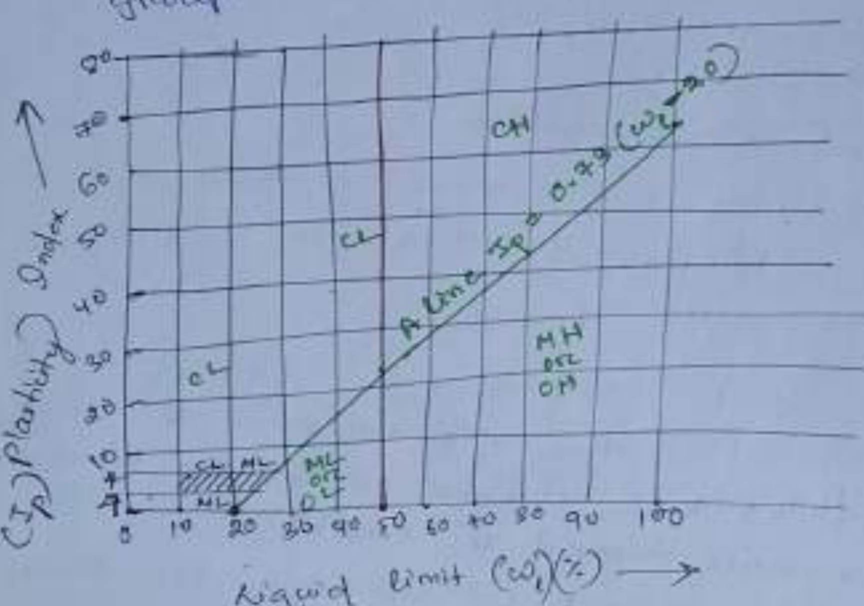
↳ If percent of fines lie between 5 to 12%, coarse grained soil are designated as GW - GM or SP - SM

(b) **Fine grained soil**

↳ A soil is termed as fine grained if soil sample passes more than 50% of soil through 75μ sieve

↳ Fine grained soil is such, divided into silt (M) & clay (C) based on liquid limit & plasticity index.

↳ Organic soils are also included in this group



P-4.8

75μ IS sieve size.

ii) Fine grained soil :- when more than half of the material by mass is smaller than 75 μ IS sieve size.

iii) Highly organic soil & other miscellaneous soil material :- It contains organic matter, like peat & decomposed vegetable matter.

1) Coarse Grained Soil :-
It is divided into sub divisions :-

(a) Gravel (G) :-
when more than half of coarse fraction (75μ) is larger than 4.75 mm IS sieve size.
It is designated by G.

(b) Sands (S) :-
when more than half of coarse fraction (75μ) is smaller than 4.75 mm IS sieve size. It includes sands & sandy soils.

→ Gravel & Sand are further sub divided into 4 groups depending upon grading :-
W = well graded, clean.
C = well graded with clay binder
P = poorly graded, fairly clean
M = containing fine materials not covered in other groups.

↳ The A-line in the chart has equation
$I_p = 0.73(w_L - 20)$

↳ The A-line separates clay like materials from silty & organic soil materials.

↳ Fine grained soils are further sub-divided into soil possessing low (L) or High (H) plasticity when liquid limit is less than 50% or more than 50%.

↳ When plasticity index & liquid limit plot lies in the hatched portion of plasticity chart, the soil is given dual symbol 'CL-ML'

↳ When soil having characteristics of more than one group are termed as boundary soil & gives dual group symbols.
For eg:- GW-GC means well graded gravel with clay fines.

↳ Organic silts (OL or OH) & inorganic soils (ML or MH) are also plotted on plasticity chart.

↳ Soils having liquid limit about 30% or less is known as organic (OL or OH). If liquid limit is higher, it is known as inorganic (ML or MH).

(V) <u>Indian Standard Classification System</u>

↳ The soil is broadly divided into 3 divisions:-

i) <u>Coarse grained soil</u> :- when more than half of the material by mass is larger than

These symbols are used in combination to designate the type of coarse grained soil.
ex:- GC means clayey gravel.

2) **Fine Grained Soil:-**
It is divided into 3 sub-divisions:-
i) Inorganic silts & very fine sand (M)
ii) Inorganic clays (C)
3) **Organic silts & clay & organic matter (O)**
Fine grained soil is further divided into groups depending upon liquid limit which is good index of compressibility :-
i) Silt & clay of low compressibility having liquid limit less than 35 & represented by L.
ii) Silt & clay of medium compressibility having liquid limit greater than 35 & less than 50 & represented by I.
iii) Silt & clay of high compressibility having liquid limit greater than 50 & represented by H.
Combination of these symbol indicates the type of fine grained soil. Ex:- ML means inorganic silt with low to medium compressibility.

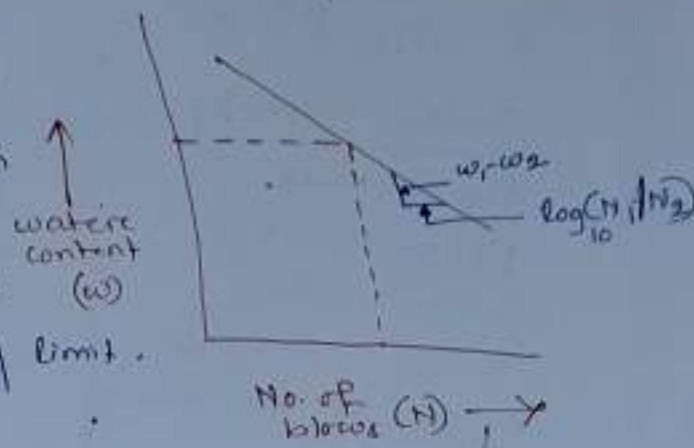
i.e A-line, dividing inorganic clay from silt & organic soil has following equation:-

$$I_p = 0.73 (w_L - 20)$$

P-4.12

Flow Index

Flow index (I_f) is the slope of the flow curve obtained between number of blows & the water content in Casagrande's method of determination of liquid limit.



From fig.,

$$\text{Flow index } I_f = \frac{w_1 - w_2}{\log_{10}(N_2/N_1)}$$

N_1 = no. of blows at water content w_1
N_2 = " " " " " w_2.

$\log_{10}(N_2/N_1) = 1$ when $N_2/N_1 = 10$.

as $\log_{10} 10 = 1$.

Toughness Index

It is $$I_t = \frac{I_p}{I_f}$$

I_p = Plasticity index = $w_l - w_p$

I_f = flow index.

Q:- Following index properties were determined for 2 soils A & B.

Index Property	A	B
Liquid limit	65	35
Plastic limit	25	20
water content	35	25
Sp. gr. of solids	2.7	2.65
Degree of saturation	100 %	100%

which have (1) greater bulk density (2) greater dry density (3) greater void ratio.

	A	B
Plasticity index $I_p = \omega_L - \omega_p$	$65-25 = 40\%$	$35-20 = 15\%$
Void ratio $e = \omega G$	$0.35 \times 2.7 = 0.945$	$0.25 \times 2.65 = 0.663$
Dry density $\rho_d = \frac{G\rho_w}{1+e}$	$\frac{2.7 \times 1}{1.945} = 1.388$	$\frac{2.65 \times 1}{1.663}$
Bulk density $\rho = \rho_d (1+\omega)$	$1.388 \times 1.35 = 1.874$ g/ml	$= 1.594 \times 1.25 = 1.992$ g/ml.

As plasticity index of A is more, A has more clay particles.

6.0 COMPACTION & CONSOLIDATION

6.1 Compaction

It is the process by which the soil particles are artificially arranged & packed together into a closer state of contact by mechanical means in order to decrease the porosity of soil & increase the dry density.

6.1.1 Light & Heavy Compaction Test

The test equipment consist of :—

i) Cylindrical metal mould having internal dia of 4 inches (10.15 cm), internal effective height of 4.6 inches (11.7 cm) & a capacity of 0.945 lt. (1000 ml).

ii) detachable base plate

iii) Collar of 2 inches (5 cm) effective height

iv) Rammer of 2.5 kg in mass.

Procedure :—

↳ 5 kg of soil is taken & water is added to it of different percentages

↳ The mould with base plate is weighed as M_1. The exterior collar is to be attached with the mould.

↳ The moist soil in the mould is compacted by ~~letting~~ dropping the rammer ~~fall~~ through a height of 30.5 cm.

↳ The above compaction is done by gi... 25 blows on ~~layers~~ soil layers & the cyllinder is filled by filling soil in different layers, each layer being comp... in above manner.

↳ The extension collar is then removed & the compacted soil is levelled off carefully to the top of the mould by means of straight edge.

↳ Then the mould & soil is weighed as M_2.

↳ Soil is removed from the mould & a small sample of soil is taken for water content determination.

↳ This process is repeated after adding suitable amount of water to the soil in an increasing order.

↳ Then Bulk density ρ, at each compaction is calculated as follows: –

$$\rho = \frac{M_2 - M_1}{V_m}$$

$M_2 - M_1$ = Mass of compacted soil

V_m = Volume of soil

= Volume of mould

↳ Dry density ρ_d is calculated from the relation:-

$$\rho_d = \frac{\rho}{1+w}$$

w = moisture content of soil in %.

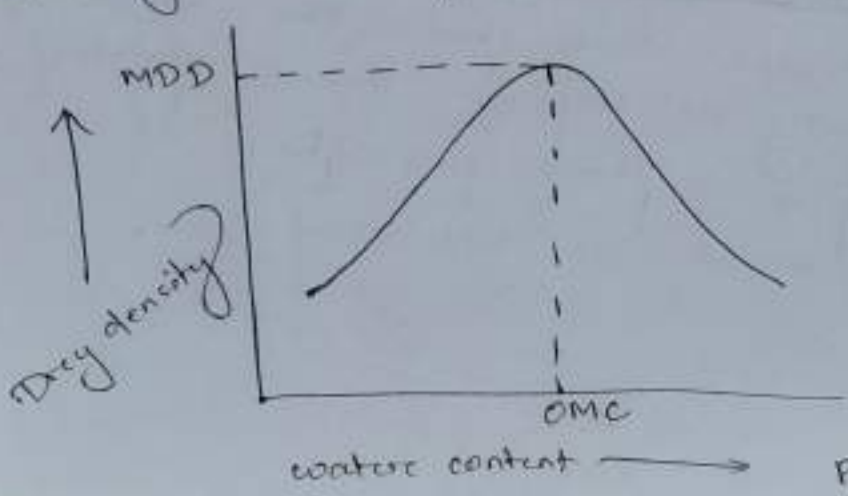
6.1.2 OMC & MDD

↳ As, a number of times, the above test is repeated, a no. of dry densities at corresponding water contents are obtained.

↳ A smooth curve or compaction curve is plotted between water content as abscissa & dry densities as ordinate.

↳ The dry density goes on increasing as the water content is increased, till the maximum density is reached.

↳ The water content corresponding to max. density is called optimum moisture content (OMC)



↳ The maximum or peak point of comp... curve is called maximum dry density. DD

↳ Light compaction method is also known as <u>Standard Proctor Test</u>.

↳ The equipments required for light & heavy compaction tests are same, except:—

— in heavy compaction test:—

(i) rammer is of 4.9 kg & it's height of fall is 450 mm.

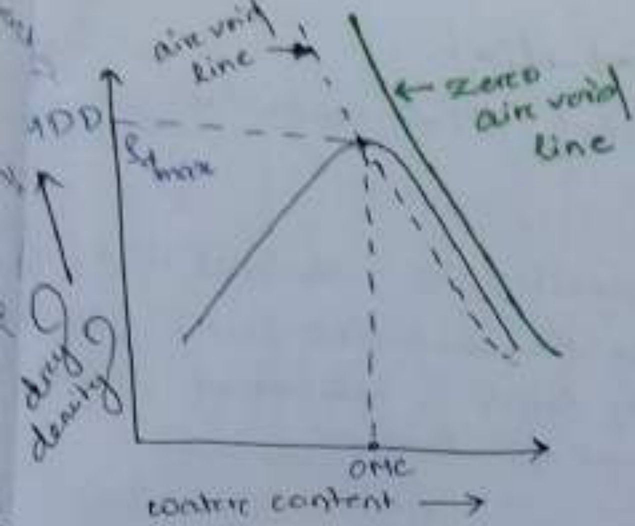
(ii) The soil is compacted in 5 equal layers instead of 3.

(iii) Each layer is given 25 blows of rammer if 1000 ml mould is used & 55 blows if 2250 ml mould is used.

↳ So, Heavy compaction method is also known as <u>Modified Proctor Test</u>.

6.1.3 Zero air void line:-

A line which shows the water content dry density relation for the compacted soil containing a constant percentage of air voids is known as air void line.



$$\rho_d = \frac{(1-n_a)\, G \rho_w}{1+wG}$$

n_a = % air void

ρ_d = dry density

w = water content of compacted soil

G = sp. gravity

ρ_w = density of water.

↳ The theoritical maximum compaction for any given water content corresponds to zero air voids condition ($n_a = 0$). The line showing dry density for soil containing no air voids is called zero air void line or saturation line, with eq

$$\rho_d = \frac{G \rho_w}{1+wG}$$

↳ Alternatively, a line showing the relation between water content & dry density for a constant degree of saturation S,

$$\rho_d = \frac{G \rho_w}{1+\frac{wG}{S}}$$

6.2. Factors Affecting Compaction:-

The various factors which affect compaction are as follow:-

(i) Water Content:-

From laboratory experiments, it is observed that the water content increases, the compacted density goes increasing, till a maximum dry density is achieved after which further addition of water decreases the density.

(ii) Amount of Compaction:-

Amount of compaction greatly affects the maximum dry density & optimum water content of a given soil. The effect of increasing the compactive energy results in an increase in max. dry density and decrease in optimum water content.

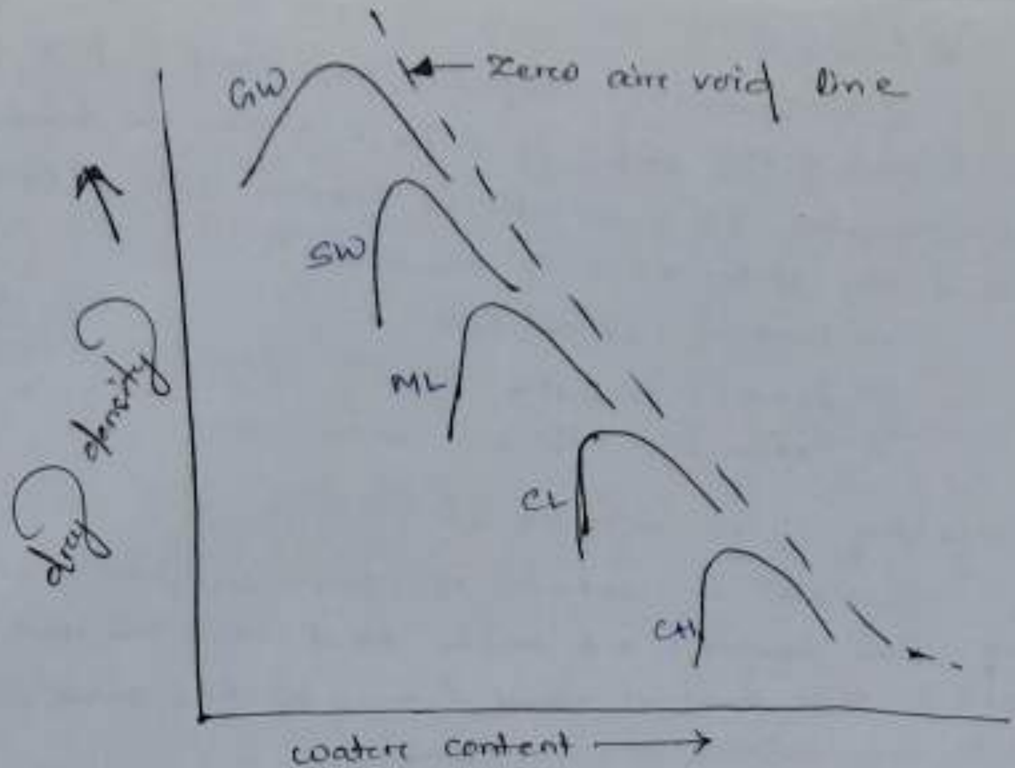
(iii) Method of compaction:-

Type of compaction or the manner in which the compactive effort is applied affects density. The weight of compacting equipment, manner of operation such as dynamic or impact, static, kneading or rolling and time & area of contact between the compacting element & soil plays role.

(iv) Types of soil:-

The maximum dry density achieved by the soil largely depends upon the type of soil. Well graded coarse grained soil attain a much higher density and lower optimum water content than fine grained soil which require more water for lubrication because of greater specific surface.

Figure shows the water content & dry density curve for a range of soil types. The coarse grained soils can be compacted to higher dry densities than fine grained soil.



(v) Addition of Admixture :-

The compaction characteristics of a soil can be modified by a number of admixtures. these admixtures can be used in construction of stabilised soil.

Field Compaction Methods :-

There are various types of compacting equipments. Use of these compacting machines depends on soil type and moisture condition.

The soil compaction equipments can be divided into two conditions groups :-

(i) Light soil compacting equipment.
(ii) Heavy soil compacting equipment.

(i) Light soil compacting equipment :-

These equipments are used for soil compacting of small areas only and where the compacting effort needed is less.

Some of the equipments are :-

a) Rammer
b) Vibrating equipment.

a) Rammer :-

It is used for compacting small areas by providing impact load to the soil. It is light & can be hand machine operated. It is suitable for compacting cohesive soils well as other soils. It is of three types :-

→ Dropping weight type.

→ Internal combustion type.

→ Pneumatic type.

b) Vibrating Plate compactors :-

It is used for compaction of coarse soil with 4 to 8% fines. These equipments are used for small areas. The usual weights of these machines varies from 100 kg to 2 tonnes with plate area between 0.16 m² & 1.6 m².

Vibro Tampers :-

It is used for compaction of small areas in confined space. This machine is suitable for compaction of all types of soil by vibration set up in a base plate through a spring activated by an engine driven reciprocating mechanism. They are usually manually guided & weigh between 50 & 100 kg.

(ii) Heavy Soil Compaction Equipments :-

These equipments are used for large areas & Different types of soils, Following are different types of these equipments -

a) Smooth wheeled Rollers :-

It is of two types :-

→ Static smooth wheeled roller

→ Vibrating smooth wheeled roller.

The most suitable soils for these roller type are well graded sand, gravel, crushed rock, asphalt etc. where crushing is required. These are used on soils which does not require great pressure for compaction. These rollers are

generally used for finishing the upper surface of soil.
These roller are used for compaction of uniform sands.

The performance of smooth wheeled rollers depend on load per cm width it transfers to the soil & diameter of the drum. the load per cm width is derived from the gross weight of drum.

The smooth wheeled roller consist of one large steel drum in front & two steel drum on the rear. the gross weight of these rollers is in the range of 8-10 tonnes the other type of smooth wheel roller is called Tandem roller, which weigh between 6-8 tonnes.

→ Vibrating smooth wheel rollers:-

These rollers are helpful from several consideration:-

(i) Higher compaction level can be achieved with maximum work.
(ii) Compaction can be done up to greater depths.
(iii) Output is many times more than conventional rollers

These rollers are expensive but in the long run the cost becomes economical due to their outputs & improved performance. the latest work specifications for excavation recommends the use of vibratory rollers due to their advantage over static smooth wheeled rollers

b) Sheepfoot Roller :-

→ These are used for compacting fine grained soil such as heavy clay & silty clay. These are used for compaction of soil in dams, embankments, subgrade, layer in pavement & rail road construction projects.

→ They are static & vibrating types. Vibratory types rollers are used for compaction of all fine grained soil.

→ It consist of steel drum on which projecting legs are fixed & can apply a pressure upto 19 kg/cm^2 or more. The weight of drum can be increased by ballasting with water or wet sand.

→ The compaction of soil is mainly due to foots ~~pen~~ penetrating & exerting pressure on the soil. The pressure is maximum when foot is vertical.

c) Pneumatic tyred roller :-

→ These are also known as rubber tyred rollers. It is used for compaction of coarse grained soil with some fines. These are least suitable for uniform coarse soils & rocks.

→ These rollers have wheels on both axels. The wheels are staggered for ~~staggered for~~ compaction of soil layers with uniform pressure throughout the width of rollers.

d) Grid Rollers :-

It is used for compaction of weathered rocks, well graded coarse soils. It is not suitable for clayey soils, silty clays & uniform soils. The main use of these rollers are in subgrade & sub-base in road construction.

The roller have a cylindrical heavy steel surface containing a network of steel bars forming a grid with square holes. The wt. of these roller can be increased by ballasting with concrete block.

e) Pad foot / Tamping Rollers :-

It is similar to sheep foot roller with legs of larger area than sheep foot rollers. These rollers are more preferred than sheepfoot rollers due to high production capacity & they are replacing sheepfoot rollers.

The degree of compaction achieved is more than sheepfoot roller. They operate at high speed & are capable to break large lumps. It is best suitable for compacting cohesive soil.

6.4 CONSOLIDATION

→ In a soil sample, there are voids which are either filled with air, or water or both.

→ When the voids are filled with air alone compression of soil occurs rapidly, because air is compressible & can escape easily from voids.

→ When saturated soil have it's voids filled with incompressible water, decrease in volume or compression can take place when water is expelled out of the voids. Such a compression resulting from long term & escape of pore water is termed as consolidation.

→ According to Terzaghi, every process involving a decrease in water content of saturated soil without replacement of water by air is called consolidation.

Distinction Between Compaction & Consolidation

Compaction	Consolidation
→ Compaction is the compression of soil by expulsion of air from the voids of soil.	→ Consolidation is the compression of soil by expulsion of water from voids of soil.
→ It is a quick process	→ It is slow process.