دليل معمل ميكانيكا التربة والاساسات

ملخص اجراء التجارب

أولاً: بيانات المعمل الأساسية

إسم المعمل:ميكانيكا التربة والاساسات

القسم العلمي: الهندسة الانشائية

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التليفون: ٠٥٠٢٢٠٢٢٤٧

الموقع بالنسبة للكلية: المعامل البحرية

مساحة المعمل:١٨٢ متر٢

ثانياً: قائمة بالأجهزة والمعدات الموجودة بالمعمل:

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ثالثاً: التجارب التي تؤدي داخل المعمل:

EXPERIMENT: 1 WATER CONTENT DETERMINATION

INTRODUCTION:

The water content (w) is also called natural water content or natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as percentage.

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

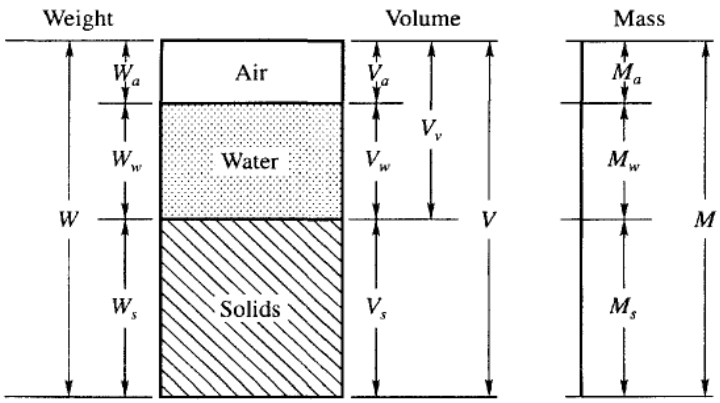
OBJECTIVE:

This test is done to determine the water content in soil by oven drying method.

THEORY:

For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil.

Soil mass is generally a three phase system. It consists of solid particles, liquid and gas. For all practical purposes, the liquid may be considered to be water (although in some cases, the water may contain some dissolved salts) and the gas as air. The phase system may be expressed in SI units either in terms of mass-volume or weight-volume relationships. The inter relationships of the different phases are important since they help to define the condition or the physical make-up of the soil.



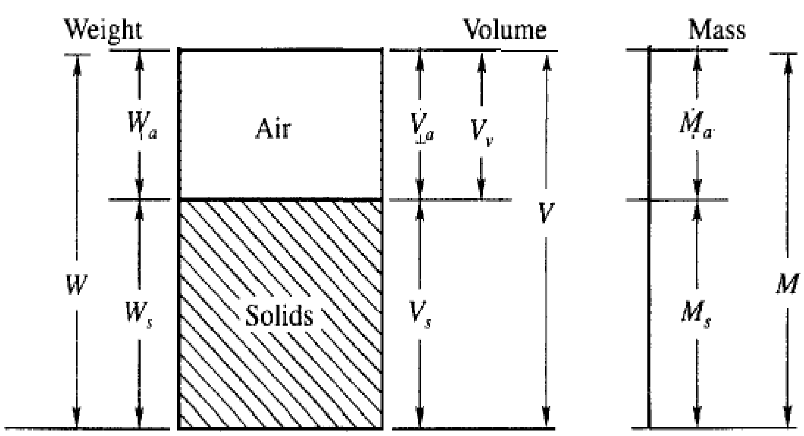
Block diagram—three phases of a soil element

W_a = *Weight of air*
W_w = *Weight of water*
W_s = *Weight of solids*
V_a = *Volume of air*
V_w = *Volume of water*
V_s = *Volume of solids*
M_a = *Mass of air*
M_w = *Mass of water*
M_s = *Mass of solids*

The water of the soil sample can be determined by the following method.

i. Oven drying method.
ii. Pycnometer method.
iii. Sand bath method.
iv. Alcohol method.
v. Calcium carbide method.
vi. Radiation method.
vii. Torsion balance method.

After complete drying the soil sample become,



Block diagram– phases of a Dry soil element

APPRATURS REQUIRED:- OVEN DRYING METHOD

i. Non-corrodible air-tight container.
ii. Electric oven, maintain the temperature between 105 C to 115 C.
iii. Desiccators
iv. Balance of sufficient sensitivity
v. Gloves
vi. Spatula

FIGURES:-

TEST PROCEDURE:-

i. Clean the containers with lid dry it and weigh it (W1). " Make sure you do this after you have tarred the balance"
ii. Take a specimen of the sample in the container and weigh with lid (W2).
iii. Keep the container in the oven with lid removed. Dry the specimen to constant weight maintaining the temperature between 105^0 C to 110^0 C for a period varying with the type of soil but usually 16 to 24 hours.
iv. Record the final constant weight (W3) of the container with dried soil sample. Peat and other organic soils are to be dried at lower temperature (say 60^0 C) possibly for a longer period.

RUNNING THE TEST AND RECORDING THE DATA:-

i. Weight of can, W_1 (g) =
ii. Weight of can + wet soil W_2 (g) =
iii. Weight of can + dry soil W_3 (g)=

The Water/Moisture content = $w(\%) = \dfrac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$

The natural moisture content of the soil sample is **________%**

Example Calculation:

Weight of can, W_1 (g) = 30.5g

Weight of can + wet soil W_2 (g) = 62.6g

Weight of can + dry soil W_3 (g) = 58.2g

The Water/Moisture content = $w\,(\%) = \dfrac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$

$$w\,(\%) = \frac{(62.6 - 58.2)}{(58.2 - 30.5)} \times 100$$

$$w\,(\%) = 15.88\%$$

OBSERVATION TABLE:-

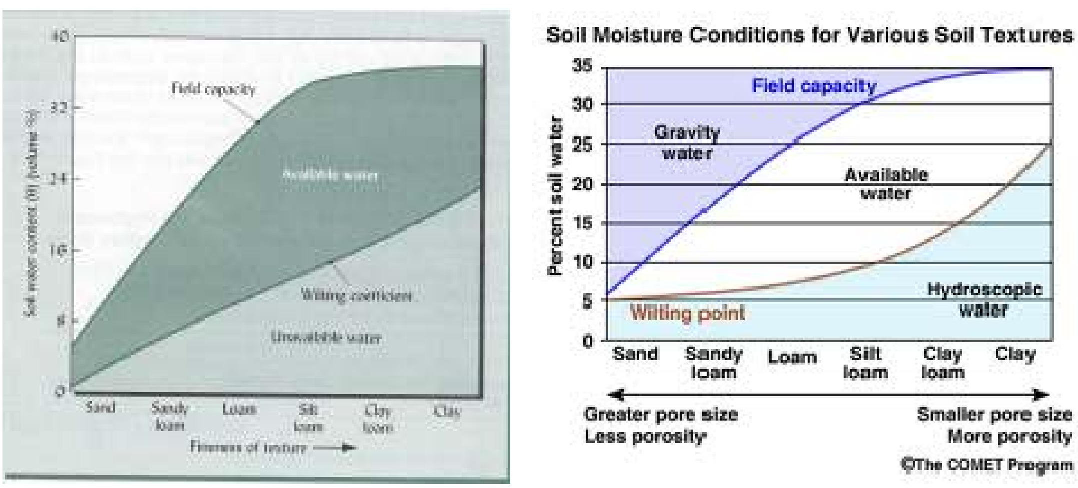
	Type 1	Type 2	Type 3	Type 4
Weight of can, W_1 (g)				
Weight of can + wet soil W_2 (g)				
Weight of can + dry soil W_3 (g)				
Water/Moisture content $w\,(\%) = \frac{(W2 - W3)}{(W3 - W1)} \times 100$				

REFERENCES:-

i. IS : 2720 (Part II) – 1973, Method of Test for soil : Part II

ii. Soil Mechanics and Foundations.

GRAPHS:-



Relationship of soil texture soil water content.

INTRODUCTION:

The particle density of a soil measures the mass in a given volume of particles. Particle density focuses on just the soil particles themselves and not the volume they occupy in the soil. Bulk density includes both the volume of the solid (mineral and organic) portion of the soil and the spaces where air and water are found.

Density is measured as mass per unit volume (mass divided by volume). Soil particle density depends on the chemical composition and structure of the minerals in the soil. Most mineral particles in soils have a particle density ranging from 2.60 to 2.75 g/cm3. However, the density can be as high as 3.0 g/cm3 for very dense mineral particles, and as low as 0.9 g/cm3 for organic particles.

Particle density is important to determine because it allows us to understand many other properties of the soil. For example, knowing the particle density allows us to know something about the relative amount of organic matter vs. mineral particles in the soil sample. Because particle density can be compared to the density of known minerals such as quartz, feldspar, and micas, or denser minerals such as magnetite, garnet, or zircon, this measurement also helps to indicate the chemical composition and structure of the soil minerals.

If we have information on both the particle density and the bulk density of the soil, we can calculate the pore space (or porosity) that is occupied by air and water. This is useful because it helps us to understand other important soil properties such as how much water can be stored in the soil, how fast water and heat will be moved through the soil, how easily roots can move through the soil, and the potential for flooding or drought in an area.

OBJECTIVE:

To determine the field or in-situ density or unit weight of soil by core cutter method

THEORY:

Field density is defined as weight of unit volume of soil present in site. That is

$$\gamma = \frac{W}{V}$$

Where, γ = Density of soil
W = Total weight of soil
V = Total volume of soil

The soil weight consists of three phase system that is solids, water and air. The voids may be filled up with both water and air, or only with air, or only with water. Consequently the soil may be dry, saturated or partially saturated.

In soils, mass of air is considered to be negligible, and therefore the saturated density is maximum, dry density is minimum and wet density is in between the two.

Dry density of the soil is calculated by using equation,

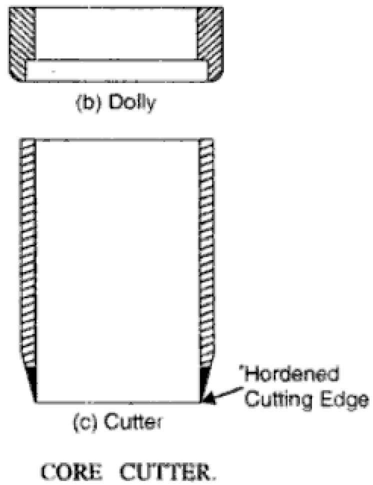
$$\gamma_d = \frac{\gamma_t}{1 + w}$$

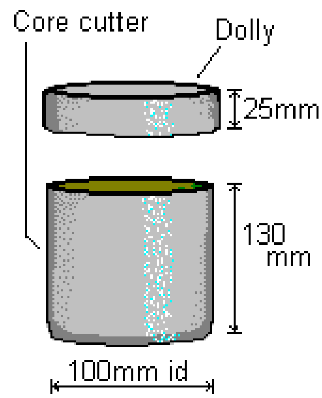
Where, γ_d = dry density of soil
γ_t = Wet density of soil
w = moisture content of soil.

Density or unit weight of soils may be determined by using the following method:

i. Core cutter method
ii. Sand replacement test
iii. Rubber balloon test
iv. Water displacement method
v. Gamma ray method

Hear we use core cutter method, the equipment arrangement is shown as fallows,





APPRATURS REQUIRED:-

a) Special:

i. Cylindrical core cutter

ii. Steel rammer

iii. Steel dolly

b) General:

i. Balance of capacity5 Kg and sensitivity 1 gm.

ii. Balance of capacity 200gms and sensitivity 0.01 gms.

iii. Scale

iv. Spade or pickaxe or crowbar

v. Trimming Knife

vi. Oven

vii. Water content containers

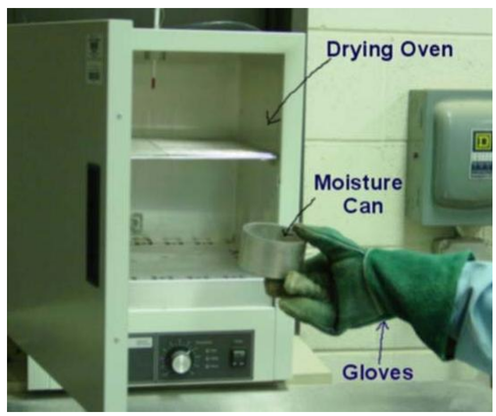
viii. Desiccator.

APPLICATION:

Field density is used in calculating the stress in the soil due to its overburden pressure it is needed in estimating the bearing capacity of soil foundation system, settlement of footing earth pressures behind the retaining walls and embankments. Stability of natural slopes, dams, embankments and cuts is checked with the help of density of those soils. It is the density that controls the field compaction of soils. Permeability of soils depends upon its density. Relative density of cohesionless soils is determined by knowing the dry density of soil in natural, loosest and densest states. Void ratio, porosity and degree of saturation need the help of density of soil.

Core cutter method in particular, is suitable for soft to medium cohesive soils, in which the cutter can be driven. It is not possible to drive the cutter into hard, boulder or murrumy soils. In such case other methods are adopted.

FIGURES:-



TEST PROCEDURE:-

i. Measure the height and internal diameter of the core cutter.
ii. Weight the clean core cutter.
iii. Clean and level the ground where the density is to be determined.
iv. Press the cylindrical cutter into the soil to its full depth with the help of steel rammer.
v. Remove the soil around the cutter by spade.
vi. Lift up the cutter.
vii. Trim the top and bottom surfaces of the sample carefully.
viii. Clean the outside surface of the cutter.
ix. Weight the core cutter with the soil.
x. Remove the soil core from the cutter and take the representative sample in the water content containers to determine the moisture content

PRECAUTIONS:

i. Steel dolly should be placed on the top of the cutter before ramming it down into the ground.
ii. Core cutter should not be used for gravels, boulders or any hard ground.
iii. Before removing the cutter, soil should be removed around the cutter to minimize the disturbances.
iv. While lifting the cutter, no soil should drop down

Water/Moisture content determination:

	sample 1	sample 2	sample 3
Weight of can, W_1 (g)			
Weight of can + wet soil W_2 (g)			
Weight of can + dry soil W_3 (g)			
Water/Moisture content $w\ (\%) = \frac{(W_2 - W_3)}{(W_3 - W_1)}\ \text{x}\ 100$			

Calculation Table:

	sample 1	sample 2	sample 3
Mass of core cutter, W_1 (gm)			
Mass of cutter + soil from field, W_2 (gm)			
Wet density, (gm/cm3) $\gamma_t = \frac{W_2 - W_1}{V}$			
Dry density , (gm/cm3) $\gamma_d = \frac{\gamma_t}{1 + w}$			

INTRODUCTION:

The specific gravity of a substance, designated as G_S, is defined as the ratio of the density of that substance to the density of distilled water at a specified temperature. Since it is a ratio, the value of G_S does not depend on the system of units used and is a numerical value having no units. In soil mechanics, the specific gravity of soil solids is an important parameter and is a factor in many equations involving weight-volume relationships. Remember that the specific gravity of soil solids refers only to the solid phase of the three phase soil system, it does not include the water and air phases present in the void space. For soil solids, G_S may be written as:

$$G_s = \frac{density\ of\ the\ soil\ solids}{density\ of\ water} = \frac{mass\ of\ soil\ solids}{mass\ of\ an\ equal\ volume\ of\ water}$$

OBJECTIVE:

Determine the specific gravity of soil fraction passing 4.75 mm I.S sieve by density bottle.

THEORY:

The specific gravity of soil solids is determined by either (a) density bottle or (b) specific gravity flask or (c) pycnometer. The density bottle is suitable for all types of soil and it is the accrutate method. Whereas the specific gravity flask or pycnometer methods are only suitable for coarse grained soils.

APPRATURS REQUIRED:-

i. Density bottle of 50 ml with stopper having capillary hole.
ii. Balance to weigh the materials (accuracy 10gm).
iii. Wash bottle with distilled water.
iv. Alcohol and ether.
v. Constant temperature water bath

FIGURES:-

TEST PROCEDURE:-

1. Clean and dry the density bottle

   a. wash the bottle with water and allow it to drain.
   b. Wash it with alcohol and drain it to remove water.
   c. Wash it with ether, to remove alcohol and drain ether.

2. Weigh the empty bottle with stopper (W_1)

3. Take about 10 to 20 gm of oven soil sample which is cooled in a desiccator. Transfer it to the bottle. Find the weight of the bottle and soil (W_2).

4. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.

5. Again fill the bottle completely with distilled water put the stopper and keep the bottle under constant temperature water baths (T_x^0).

6. Take the bottle outside and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W_3).

7. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W_4 at temperature (T_x^0 C).

8. Repeat the same process for 2 to 3 times, to take the average reading of it.

CALCULATIONS

$$\textit{Specific gravity of soil} = \frac{\text{Density of water at 27 C}}{\text{Weight of water of equal volume}}$$

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

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

INTERPRETATION AND REPORTING

Unless or otherwise specified specific gravity values reported shall be based on water at 27^0C. So the specific gravity at 27^0C = K Sp. gravity at $T_x{}^0$C.

$$\textit{where} \quad K = \frac{\text{Density of water at tempera ture } T_x^0 C}{\text{Density of water at tempera ture } T_x^0 C}$$

The specific gravity of the soil particles lie with in the range of 2.65 to 2.85. Soils containing organic matter and porous particles may have specific gravity values below 2.0. Soils having heavy substances may have values above 3.0.

Sample Calculation:

Specimen number	1	2
Pycnometer bottle number	**96**	**37**
W_P = Mass of empty, clean pycnometer (grams)	**37.40**	**54.51**
W_{PS}= Mass of empty pycnometer + dry soil (grams)	**63.49**	**74.07**
W_B= Mass of pycnometer + dry soil + water (grams)	**153.61**	**165.76**
W_A= Mass of pycnometer + water (grams)	**137.37**	**153.70**
Specific gravity (G_S)	**2.65**	**2.61**

W_P = 37.40 g, W_{PS} = 63.49 g, W_B = 153.61 g, W_A = 137.37

W_o = 63.49 – 37.40 = 26.09 g

G_s = (26.09) / [26.09 + (137.37 -153.61)] = 2.65

Empty Table:

Specimen number		
Pycnometer bottle number		
W_P = Mass of empty, clean pycnometer (grams)		
W_{PS}= Mass of empty pycnometer + dry soil (grams)		
W_B= Mass of pycnometer + dry soil + water (grams)		
W_A= Mass of pycnometer + water (grams)		
Specific gravity (G_S)		

W_P = _____ g, W_{PS} = _____ g, W_B = _____ g, W_A = _____

W_o = _____ g

G_s =

EXPERIMENT: 4 GRAIN SIZE DISTRIBUTION

AIM OF THE EXPERIMENT:-

To determine the percentage of various size particles in a soil sample, and to classify the coarse grained soil.

APPARATUS REQUIRED:-

i. 1st set of sieves of size 300 mm, 80 mm, 40 mm, 20 mm, 10 mm, and 4.75 mm.
ii. 2nd set of sieves of sizes 2mm, 850 micron, 425 micron, 150 micron, and 75 micron.
iii. Balances of 0.1 g sensitivity, along with weights and weight box.
iv. Brush.

THEORY:-

Soils having particle larger than 0.075mm size are termed as coarse grained soils. In these soils more than 50% of the total material by mass is larger 75 micron. Coarse grained soil may have boulder, cobble, gravel and sand.

The following particle classification names are given depending on the size of the particle:

i. BOULDER: particle size is more than 300mm.
ii. COBBLE: particle size in range 80mm to 300mm.
iii. GRAVE (G): particle size in range 4.75mm to 80mm.
    a. Coarse Gravel: 20 to 80mm.
    b. Fine Gravel: 4.75mm to 20mm.
iv. SAND (S): particle size in range 0.075mm to 4.75mm.
    a. Coarse sand: 2.0mm to 4.75mm
    b. Medium Sand: 0.075mm to 0.425mm.
    c. Fine Sand: 0.075mm to o.425mm.

Name of the soil is given depending on the maximum percentage of the above components.

Soils having less than 5% particle of size smaller than 0.075mm are designated by the symbols, Example:

GP: Poorly Graded Gravel.

GW: Well Graded Gravel.

SW: Well Graded Sand.

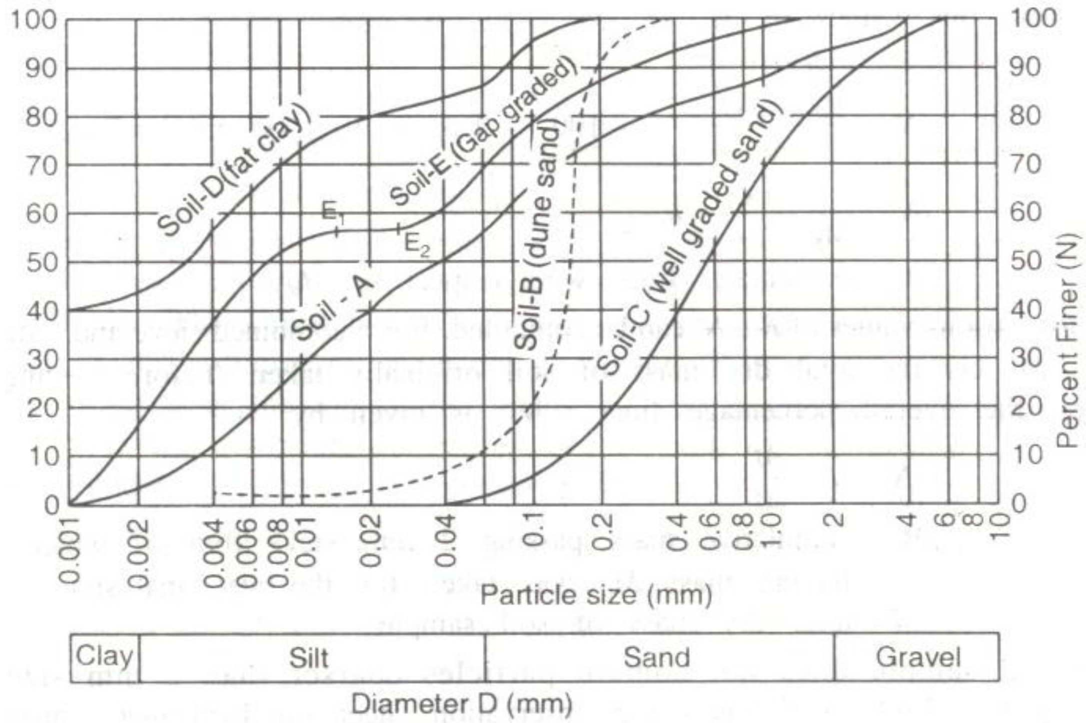
SP: Poorly Graded Sand.

Soils having greater than 12% of particle of size smaller than 0.075mm are designated by the following symbols:

Dual symbols are used for the soils having 75 micron passing between 5 to 12%.

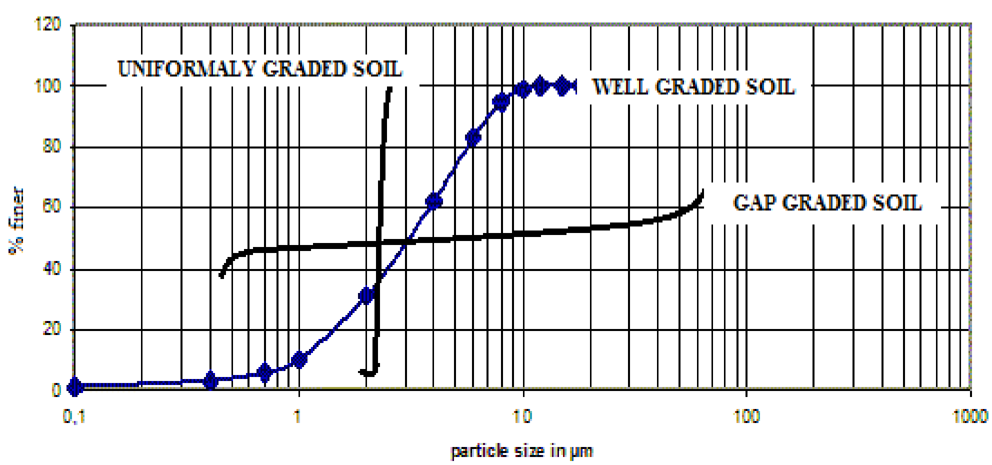
Dry sieve is performed for cohesion less soils if fines are less than 5%. Wet sieve analysis is carried out if fines are more than 5% and of cohesive nature.

We can analysis from foiling,



PARTICLE SIZE DISTRIBUTION CURVE

In simpler way we can show the above particle size distribution curve for course grain soil as fallows,



Gravels and sands may be either poorly graded (Uniformly graded) or well graded depending on the value of coefficient of curvature and uniformity coefficient.

Coefficient of curvature (C_c) may be estimated as:

$$C_c = \frac{{D_{30}}^2}{D_{10} \text{ x } D_{60}}$$

Coefficient of curvature (C_c) should lie between 1 and 3 for well grade gravel and sand.

Uniformity coefficient (C_u) is given by:

$$C_u = \frac{D_{60}}{D_{10}}$$

Its value should be more than 4 for well graded gravel and more than 6 for well graded sand.

Were, D_{60} = particle size at 60% finer.

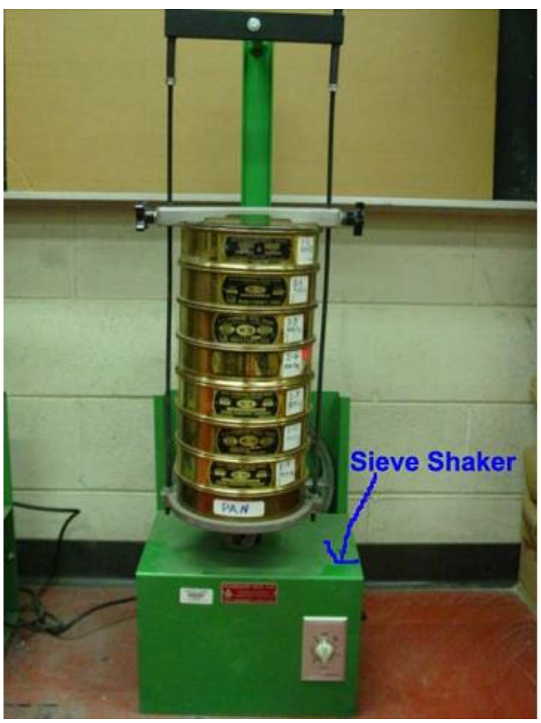
D_{30} = particle size at 30% finer.

D_{10} = particle size at 10% finer.

FIGURES:


Set of Sieves
Soil Specimen
PAN
Balance


PAN


Sieve Shaker
PAN


Adventurer

APPLICATION:

The percentage of different size of soil particles coarser than 75 micron is determined. Coarse soils are mainly classified by sieve analysis. The grain size distribution curve gives an idea regarding the gradation of the soil, that is, it is possible to identify whether the soil is well graded or poorly graded. In mechanical soil stabilization, the main principle is to mix a few selected soils in such a proportion that a desired grain size distribution is obtained for the design mix. Hence for proportioning the selected soils, the grain size distribution of each soil is to be first known.

PROCEDURE:

i. Weight accurately about 200gms of oven dried soil sample. If the soil has a large fraction greater than 4.75mm size, then greater quantity of soil, that is, about 5.0 Kg should be taken. For soil containing some particle greater than 4.75 mm size, the weight of the soil sample for grain size analysis should be taken as 0.5 Kg to 1.0 Kg.
ii. Clean the sieves and pan with brush and weigh them upto 0.1 gm accuracy. Arrange the sieves in the order as shown in Table. The first set shall consist of sieves of size 300 mm, 80mm, 40mm, 20mm, 10mm, and 4.75 mm. While the second set shall consist of sieves of sizes 2mm, 850 micron, 425 micron, 150 micron, and 75 micron.
iii. Keep the required quantity of soil sample on the top sieve and shake it with mechanical sieve shaker for about 5 to 10 minutes. Care should be taken to tightly fit the lid cover on the top sieve.
iv. After shaking the soil on the sieve shaker, weigh the soil retained on each sieve. The sum of the retained soil must tally with the original weight of soil taken.

DATA ANALYSIS:

i. Obtain the mass of soil retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve + retained soil, and record this mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals the initial mass of the soil sample. A loss of more than two percent is unsatisfactory.

ii. Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.

iii. Calculate the percent passing (or percent finer) by starting with 100 percent and subtracting the percent retained on each sieve as a cumulative procedure.

For example: Total mass = 500 g

Mass retained on No. 4 sieve = 9.7 g

Mass retained on No. 10 sieve = 39.5 g

For the No.4 sieve:

Quantity passing = Total mass - Mass retained

= 500 - 9.7 = 490.3 g

The percent retained is calculated as;

% retained = Mass retained/Total mass

= (9.7/500) X 100 = 1.9 %

From this, the % passing = 100 - 1.9 = 98.1 %

For the No. 10 sieve:

Quantity passing = Mass arriving - Mass retained

= 490.3 - 39.5 = 450.8 g

% Retained = (39.5/500) X 100 = 7.9 %

% Passing = 100 - 1.9 - 7.9 = 90.2 %

(Alternatively, use % passing = % Arriving - % Retained

For No. 10 sieve = 98.1 - 7.9 = 90.2 %)

iv. Make a semilogarithmic plot of grain size vs. percent finer.

v. Compute C_u and C_c for the soil.

PRECAUTIONS:

i. During shaking the lid on the topmost sieve should be kept tight to prevent escape of soils.

ii. While drying the soil, the temperature of the oven should not be more than 105 c because higher temperature may cause some permanent change in the 75 fraction.

OBSERVATION AND CALCULATION TABLE:

Mass of soil Sample taken for Analysis = __M____

Sieve size (mm)	**Mass of soil Retained (gms)**	**% of soil retained (%) =(x/M)**	**Cumulative % of soil retained (%)**	**% finer =(100 – p)**
80	x1	y1	p1=y1	n1=100-p1
40	x2	y2	p2=y1+y2	n2=100-p2
20	x3	y3	p3=y1+y2+y3+....	n3=100=p3
10				
4.75				
2.0				
0.850				
0.425				
0.150				
0.075				
pan				

Coefficient of curvature (C_c) may be estimated as:

$$C_c = \frac{{D_{30}}^2}{D_{10} \text{ x } D_{60}}$$

Uniformity coefficient (C_u) is given by:

$$C_u = \frac{D_{60}}{D_{10}}$$

Example 1:

Weight of Container: 198.5 gm

Wt. Container + Dry Soil: 722.3 gm

Wt. of Dry Sample: 523.8 gm

Sieve Number	Diameter (mm)	Mass of Empty Sieve (gm)	Mass of Sieve + Soil Retained (gm)	Soil retained (gm)	Percent Retained	Percent Passing
4	4.75	116.23	166.13	49.9	9.5	90.5
10	2	99.27	135.77	36.5	7	83.5
20	0.84	97.58	139.68	42.1	8	75.5
40	0.425	98.96	138.96	40	7.6	67.8
60	0.25	91.46	114.46	23	4.4	63.4
140	0.106	93.15	184.15	91	17.4	46.1
200	0.075	90.92	101.12	10.2	1.9	44.1
Pan	---	70.19	301.19	231	44.1	0
			Total Weight	523.7		

*Percent passing=100-cumulative percent retained.

From Grain Size Distribution Curve:

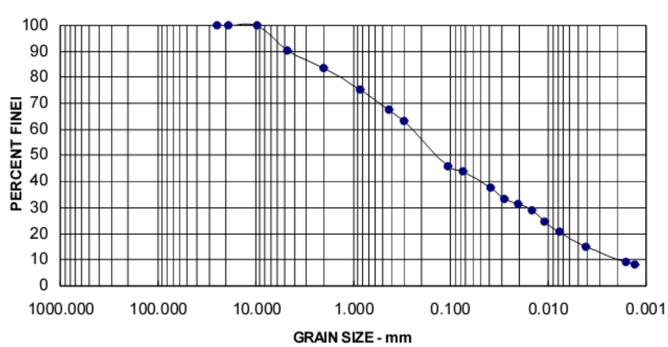
% Gravel = 9.5 D_{10} = 0.002 mm

% Sand = 46.4 D_{30} = 0.017 mm

% Fines = 44.1 D_{60} = 0.25 mm

$C_u = 0.25/0.002 = 125$

$C_c = (0.017)^2 / (0.025 \times 0.002) = 0.58$



INTRODUCTION:

The Atterberg limits are a basic measure of the nature of a fine-grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state the consistency and behavior of a soil is different and thus so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg limits can be used to distinguish between silt and clay, and it can distinguish between different types of silts and clays. These limits were created by Albert Atterberg, a Swedish chemist.[1] They were later refined by Arthur Casagrande.

OBJECTIVE:

To determine the liquid and plastic limits of the given soil sample.

THEORY:

The definitions of the consistency limits proposed by Atterberg are not, by themselves, adequate for the determination of their numerical values in the laboratory, especially in view of the arbitrary nature of these definitions. In view of this, Arthur Casagrade and others suggested more practical definitions with special reference to the laboratory devices and methods developed for the purpose of the determination of the consistency limits. In this sub-section, the laboratory methods for determination of the liquid limit, plastic limit, shrinkage limit, and other related concepts and indices will be studied, as standardized and accepted by the Indian Standard Institution and incorporated in the codes or practice.

Shrinkage limit:

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid limit and the plastic limit.

Plastic limit:

The plastic limit (PL) is the water content where soil starts to exhibit plastic behavior. A thread of soil is at its plastic limit when it is rolled to a diameter of 3 mm or begins to crumble. To improve consistency, a 3 mm diameter rod is often used to gauge the thickness of the thread when conducting the test. (AKA Soil Snake Test).

Liquid limit:

'Liquid limit' (LL or w_L) is defined as the arbitrary limit of water content at which the soil is just about to pass from the plastic state into the liquid state. At this limit, the soil possesses a small value of shear strength, losing its ability to flow as a liquid.In other words, the liquid limit is the minimum moisture content at which the soil tends to flow as a liquid.

TERMS:

PLATICITY INDEX:

'Plasticity index' (PI or I_p) is the range of water content within which the soil exhibits plastic properties; that is, it is the difference between liquid and plastic limits.

PI (or I_p) = (LL - PL) = ($W_L - W_p$)

When the plastic limit cannot be determined, the material is said to be non-plastic (NP).

Plasticity index for sands is zero.

For proper evaluation of the plasticity properties of a soil, it has been found desirable to use both the liquid limit and the plasticity index values.

SHRINKAGE INDEX:

'Shrinkage index' (SI OR I_S) is defined as the difference between the plastic and shrinkage limits of a soil; in other words, it is the range of water content within which a soil is in a semisolid state of consistency.

SI (or I_S) = (SL OR I_S) = ($W_p - W_S$)

CONSISTENCY INDEX:

'Consistency index' or 'Relative consistency' (CI OR I_C) is defined as the ratio of the difference between liquid limit and the natural water content to the plasticity index of a soil:

CI OR I_C = (LL - w) / PI = ($w_L - w$) / I_P

Where w = natural water content of the soil (water content of a soil in the undisturbed condition in the ground).

If I_C = 0, *w* = LL

I_C = 1, *w* = PL

I_C> 1, the soil is in semi-solid state and is stiff.

I_C< 0, the natural water content is greater than LL, and the soil behaves like a liquid.

LIQUIDITY INDEX:

'Liquidity index (LI OR IL) or 'Water-plasticity ratio' is the ratio of the difference between the natural water content and the plastic limit to the plasticity index:

LI or (I_L) = (w - PL) / PI or (I_P) = (w - w_P) / I_p

If I_L = 0, *w* = PL

I_L= 1, *w* = LL

I_L> 1, the soil is in liquid state.

I_L< 0, the soil is in semi-solid state and is stiff.

Obviously, CI + LI = 1

APPARATUS:

1. FOR LIQUID LIMIT DETERMINATION:

The apparatus required are the mechanical liquid limit device, grooving tool, porcelain evaporating dish, flat glass plate, spatula, palette knives, balance, oven wash bottle with distilled water and containers.

2. FOR PLASTIC LIMIT DETERMINATION:

The apparatus consists of a porcelain evaporating dish, about 12 cm in diameter (or a flat glass plate, 10 mm thick and about 45 cm square), spatula, about 8 cm long and 2 cm wide (or palette knives, with the blade about 20 cm long and 3 cm wide, for use with flat glass plate for mixing soil and water), a ground-glass plate, about 20×15 cm, for a surface for rolling, balance, oven, containers, and a rod, 3 mm in diameter and about 10 cm long.

STANDARD REFERENCE:

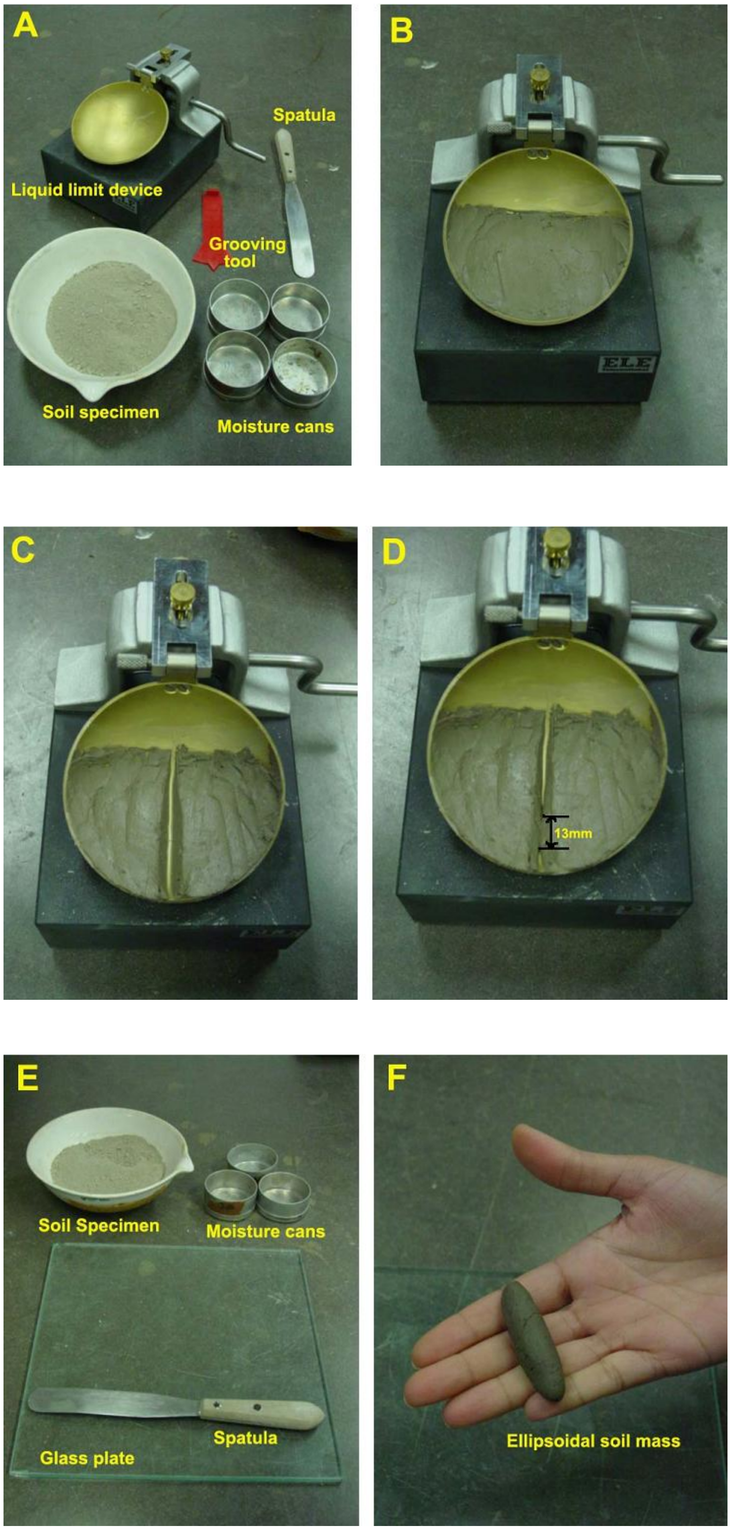
FOR LIQUID LIMIT:

The liquid limit is determined in the laboratory with the aid of the standard mechanical liquid limit device, designed by Arthur Casagrande and adopted by the ISI, as given in IS:2720(Part V)–1985.

FOR PLASTIC LIMIT:

IS: 2720, Part V–1985.

FIGURES:-


A
Spatula
Liquid limit device
Grooving
tool
Soil specimen
Moisture cans
B
C
D
13mm
E
Soil Specimen
Moisture cans
Spatula
Glass plate
F
Ellipsoidal soil mass

TEST PROCEDURE:-

Liquid Limit:

1. Take roughly 3/4 of the soil and place it into the porcelain dish. Assume that the soil was previously passed though a No. 40 sieve, air-dried, and then pulverized. Thoroughly mix the soil with a small amount of distilled water until it appears as a smooth uniform paste. Cover the dish with cellophane to prevent moisture from escaping.
2. Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.
3. Adjust the liquid limit apparatus by checking the height of drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is 10 mm high and should be used as a gage. Practice using the cup and determine the correct rate to rotate the crank so that the cup drops approximately two times per second.
4. Place a portion of the previously mixed soil into the cup of the liquid limit apparatus at the point where the cup rests on the base. Squeeze the soil down to eliminate air pockets and spread it into the cup to a depth of about 10 mm at

its deepest point. The soil pat should form an approximately horizontal surface (See Photo B).

5. Use the grooving tool carefully cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Use extreme care to prevent sliding the soil relative to the surface of the cup (See Photo C).
6. Make sure that the base of the apparatus below the cup and the underside of the cup is clean of soil. Turn the crank of the apparatus at a rate of approximately two drops per second and count the number of drops, N, it takes to make the two halves of the soil pat come into contact at the bottom of the groove along a distance of 13 mm (1/2 in.) (See Photo D). If the number of drops exceeds 50, then go directly to step eight and do not record the number of drops, otherwise, record the number of drops on the data sheet.
7. Take a sample, using the spatula, from edge to edge of the soil pat. The sample should include the soil on both sides of where the groove came into contact. Place the soil into a moisture can cover it. Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours. Place the soil remaining in the cup into the porcelain dish. Clean and dry the cup on the apparatus and the grooving tool.
8. Remix the entire soil specimen in the porcelain dish. Add a small amount of distilled water to increase the water content so that the number of drops required to close the groove decrease.
9. Repeat steps six, seven, and eight for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a closure requiring 25 to 35 drops, one for closure between 20 and 30 drops, and one trial for a closure requiring 15 to 25 drops. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Plastic Limit:

1. Weigh the remaining empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.
2. Take the remaining 1/4 of the original soil sample and add distilled water until the soil is at a consistency where it can be rolled without sticking to the hands.
3. Form the soil into an ellipsoidal mass (See Photo F). Roll the mass between the palm or the fingers and the glass plate (See Photo G). Use sufficient pressure to roll the mass into a thread of uniform diameter by using about 90 strokes per minute. (A stroke is one complete motion of the hand forward and back to the starting position.) The thread shall be deformed so that its diameter reaches 3.2 mm (1/8 in.), taking no more than two minutes.
4. When the diameter of the thread reaches the correct diameter, break the thread into several pieces. Knead and reform the pieces into ellipsoidal masses and re-roll them. Continue this alternate rolling, gathering together, kneading and re-rolling until the thread crumbles under the pressure required for rolling and can no longer be rolled into a 3.2 mm diameter thread (See Photo H).
5. Gather the portions of the crumbled thread together and place the soil into a moisture can, then cover it. If the can does not contain at least 6 grams of soil, add soil to the can from the next trial (See Step 6). Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours.
6. Repeat steps three, four, and five at least two more times. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Different Classification Systems Followed in Classification of Soils:

FOR ENGINEERING PURPOSE:

Engineers, typically Geotechnical engineers, classify soils according to their engineering properties as they relate to use for foundation support or building material. Modern engineering classification systems are designed to allow an easy transition from field observations to basic predictions of soil engineering properties and behaviors.

The most common engineering classification system for soils in North America is the Unified Soil Classification System (USCS). The USCS has three major classification groups:

1. Coarse-grained soil (e.g. sands and gravels).
2. Fine-grained soils (e.g. silts and clays).
3. Highly organic soils (mainly referred to as "peat").

The USCS further subdivides the three major soil classes for clarification.

Other engineering soil classification systems in the States include the AASHTO Soil Classification System and the Modified Burmister A full geotechnical engineering soil description will also include other properties of the soil including color, in-situ moisture content, in-situ strength, and somewhat more detail about the material properties of the soil than is provided by the USCS code.

SOIL SCIENCE:

For soil resources, experience has shown that a natural system approach to classification, i.e. grouping soils by their intrinsic property (soil morphology), behaviour, or genesis, results in classes that can be interpreted for many diverse uses. Differing concepts of pedogenesis, and differences in the significance of morphological features to various land uses can affect the classification approach. Despite these differences, in a well-constructed system, classification criteria group similar concepts so that interpretations do not vary widely. This is in contrast to a technical system approach to soil classification, where soils are grouped according to their fitness for a specific use and theiredaphic characteristics.

Natural system approaches to soil classification, such as the French Soil Reference System (Référentiel pédologique français) are based on presumed soil genesis. Systems have developed, such as USDA soil taxonomy and the World Reference Base for Soil Resources, which use taxonomic criteria involving soil morphology and laboratory tests to inform and refine hierarchical classes.

Another approach is numerical classification, also called ordination, where soil individuals are grouped by multivariate statistical methods such as cluster analysis. This produces natural groupings without requiring any inference about soil genesis.

In soil survey, as practiced in the United States, soil classification usually means criteria based on soil morphology in addition to characteristics developed during soil formation. Criteria are designed to guide choices in land use and soil management. As indicated, this is a hierarchical system that is a hybrid of both *natural* and objective criteria. USDA soil taxonomy provides the core criteria for differentiating soil map units. This is a substantial revision of the 1938 USDA soil taxonomy which was a strictly natural system. Soil taxonomy based soil map units are additionally sorted into classes based on technical classification systems. Land Capability Classes, hydric soil, and prime farmland are some examples.

In addition to scientific soil classification systems, there are also vernacular soil classification systems. Folk taxonomies have been used for millennia, while scientifically based systems are relatively recent developments.

Example Data

Liquid Limit Determination

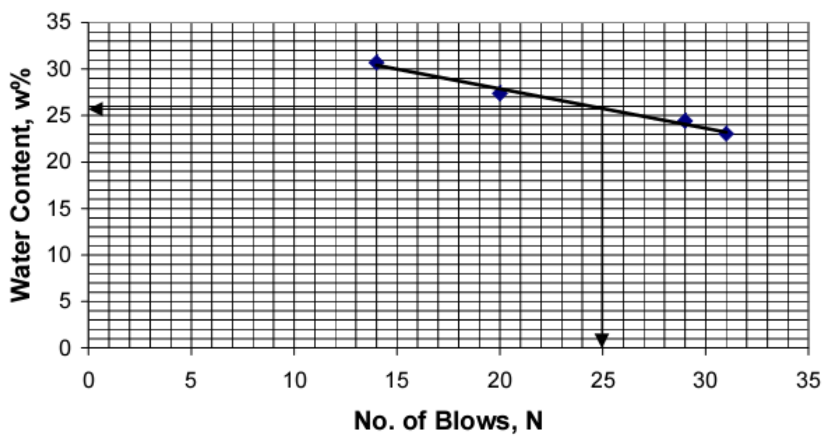
Sample No.	1	2	3	4
Moisture can and lid number	*A1*	*A2*	*A3*	*A4*
M_c = *Mass of empty, clean can + lid (grams)*	*22.23*	*23.31*	*21.87*	*22.58*
M_{CMS} = *Mass of can, lid, and moist soil (grams)*	*28.56*	*29.27*	*25.73*	*25.22*
M_{CDS} = *Mass of can, lid, and dry soil (grams)*	*27.40*	*28.10*	*24.90*	*24.60*
M_S = *Mass of soil solids (grams)*	*5.03*	*4.79*	*3.03*	*2.02*
M_W = *Mass of pore water (grams)*	*1.16*	*1.17*	*0.83*	*0.62*
w = Water content, w%	*23.06*	*24.43*	*27.39*	*30.69*
No. of drops (N)	*31*	*29*	*20*	*14*

Plastic Limit Determination

Sample No.	1	2	3
Moisture can and lid number	*A6*	*A7*	*A8*
M_c = *Mass of empty, clean can + lid (grams)*	*7.78*	*7.83*	*15.16*
M_{CMS} = *Mass of can, lid, and moist soil (grams)*	*16.39*	*13.43*	*21.23*
M_{CDS} = *Mass of can, lid, and dry soil (grams)*	*15.28*	*12.69*	*20.43*
M_S = *Mass of soil solids (grams)*	*7.5*	*4.86*	*5.27*
M_W = *Mass of pore water (grams)*	*1.11*	*0.74*	*0.8*
w = Water content, w%	*14.8*	*15.2*	*15.1*

Plastic Limit (PL)= Average w % = (14.8+15.2+15.1)/3 = 15.0

Liquid Limit Chart:



From the above graph, liquid limit = 26

Results:

Liquid Limit = 26 Plastic Limit = 15 Plasticity Index =11

OBSERVATION TABLE:-

Liquid Limit Determination

Sample No.	**1**	**2**	**3**	**4**
Moisture can and lid number				
M_c = *Mass of empty, clean can + lid (grams)*				
M_{CMS} = *Mass of can, lid, and moist soil (grams)*				
M_{CDS} = *Mass of can, lid, and dry soil (grams)*				
M_S = *Mass of soil solids (grams)*				
M_W = *Mass of pore water (grams)*				
w = *Water content, w%*				
No. of drops (N)				

Plastic Limit Determination

Sample No.	**1**	**2**	**3**
Moisture can and lid number			
M_c = *Mass of empty, clean can + lid (grams)*			
M_{CMS} = *Mass of can, lid, and moist soil (grams)*			
M_{CDS} = *Mass of can, lid, and dry soil (grams)*			
M_S = *Mass of soil solids (grams)*			
M_W = *Mass of pore water (grams)*			
w = *Water content, w%*			

Liquid Limit =
Plastic Limit =
Plasticity Index =

AIM OF THE EXPERIMENT:

To determine the coefficient of permeability of a given soil sample by Variable head permeability test.

APPARATUS REQUIRED:

a) Special:
   i. Jodhpur permeameter frame consisting of sand pipe graduated scale, rubber tubing connected to permeameter mould.
   ii. Permeameter mould.
   iii. Accessories of permeameter mould including the cover, base, detachable collar, porous stones, dummy plate etc.
   iv. Round filter paper.
   v. Dynamic compaction device.

b) General:
   i. Stop watch.
   ii. De-aired water.
   iii. IS 4.75 mm sieve
   iv. Grease.

THEORY:-

Permeability is defined as the property of porous material which permits the passage or seepage of water through its interconnected voids. The coefficient of permeability is finding out following method.

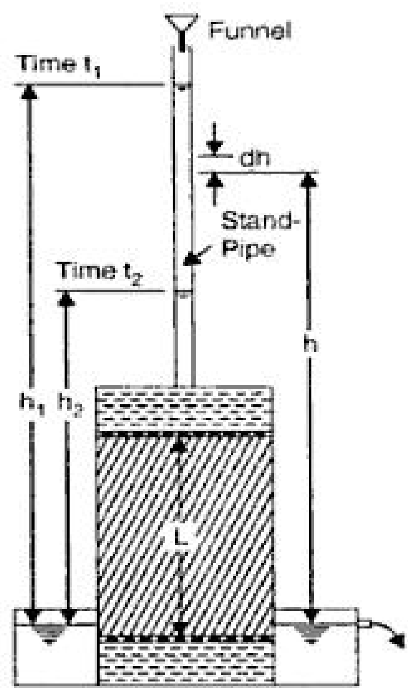
a) Laboratory method:
   i. Variable head test.
   ii. Constant head test.

b) Field method:
   i. Pumping out test.
   ii. Pumping in test.
c) Indirect test:
   i. Computation from grain size or specific surface.
   ii. Horizontal capillarity test.
   iii. Consolidation test data.

The derivation of the coefficient of permeability is based on the assumption of the validity of the Darcy's law to the flow of water in soil. The term coefficient of permeability implies the velocity of flow of water through the soil under unit hydraulic gradient, and consequently has the same units as that of velocity.

A. Variable head test:

   The variable head test is used for fine grained soils like silts and silty clays.



FALLING HEAD TEST.

For the Variable head test the following formula is applicable:

$$k = 2.203 \frac{a * L}{A * t} log_{10} (\frac{h_1}{h_2})$$

Where, k = Coefficient of permeability at T^o C (cm/sec).

a = Cross Sectional area of stand pipe (cm2).

L = Length of soil specimen (cm)

A = Cross-sectional area of soil sample inside the mould (cm2)

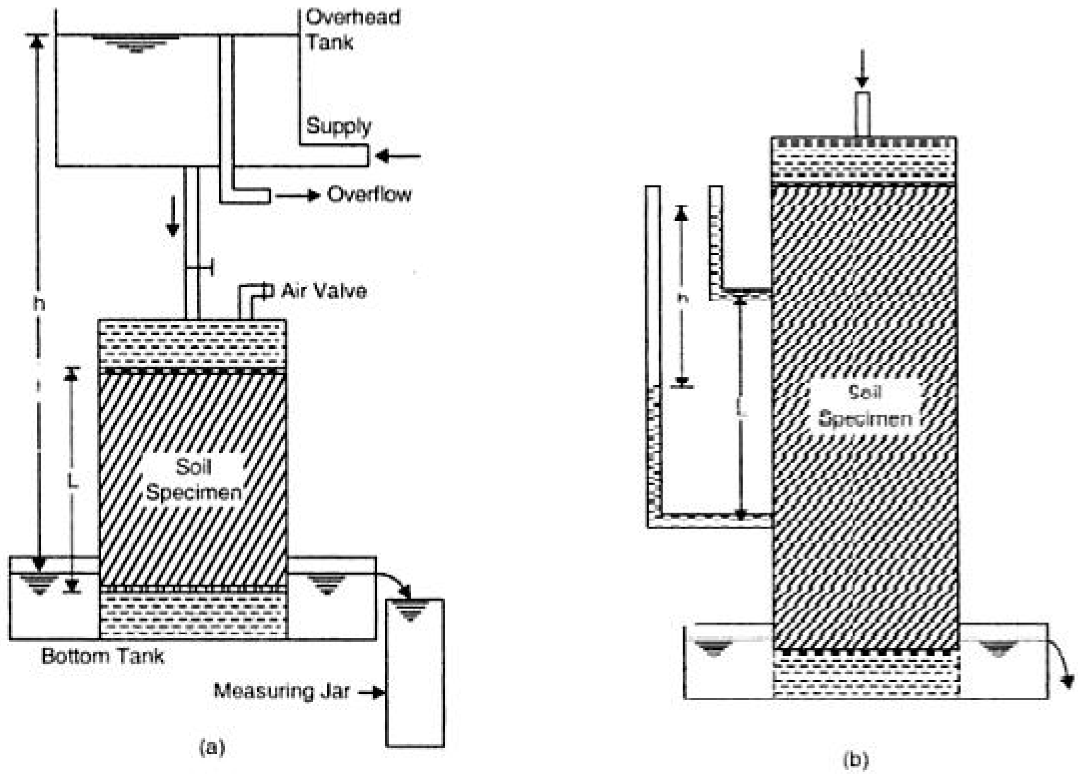
t = (t1 – t2) = Time interval for the head to fall from h1 to h2.

h1 = Initial head of water at time t1 in the pipe, measured above the outlet.

h_2 = Final head of water at time t2 in the pipe, measured above the outlet.

B. Constant head test:

The Constant head test is suitable for coarse grained soils like sands, sandy silts.



CONSTANT HEAD TEST.

For the Constant head test the following formula is applicable:

if Q is the total quantity of flow in a time interval t, we have from Darcy's low,

$$q = \frac{Q}{t} = k\ i\ A$$

$$k = \frac{Q}{t}\frac{1}{i\ A} = \frac{Q}{t}\frac{L}{h}\frac{1}{A}$$

Where, k = Coefficient of permeability at T° C (cm/sec).

L = Length of soil specimen (cm)

A = Total cross-sectional area of soil sample (cm2)

i = hydraulic gradients.

Q = Quantity of water collected in measuring jar.

t = total time required for collecting ‘Q’ quantity of water.

h = Difference in the water levels of the overhead and bottom tank.

APPLICATION:

Water flowing through soil exerts considerable seepage force which has direct effect on the safety of hydraulic structures.
The rate of settlement of compressible clay layer under load depends on its permeability. The quantity of water escaping through and beneath the earthen dam depends on the permeability of the embankments and its foundations respectively. The rate of discharge through wells and excavated foundation pits depends on the coefficient of permeability of the soils. Shear strength of soils also depends indirectly on its permeability, because dissipation of pore pressure is controlled by its permeability.

The table below gives rough values of the coefficient of permeability of various soils:

Type of soil	**Value of permeability (cm/sec)**
Gravel	10^3 to 1.0
Sand	1.0 to 10^{-3}
Silt	10^{-3} to 10^{-6}
Clay	less than 10^{-3}

According to U.S Bureau of Reclamations, soil are classified as follows:

Impervious	k less than 10^{-6} cm/sec
Semi-pervious	k between 10^{-6} to 10^{-4} cm/sec
Pervious	k greater than 10^{-4} cm/sec

PROCEDURE:

a) Preparation of remoulded soil specimen:

i. Weight the required quantity of oven dried soil sample. Evenly sprinkle the calculated quantity of water corresponding to the OMC. Mix the soil sample thoroughly.
ii. Clean the mould and apply a small portion of grease inside the mould and around the porous stones in the base plate. Weight the mould and attach the collar to it. Fix the mould on the compaction base plate. Keep the apparatus on solid base.
iii. The soil sample is placed inside the mould, and is compacted by the standard Proctor compaction tools, to achieve a dry density equal to the pre-determine3d MDD. Weight the mould along with the compacted soil.
iv. Saturate the porous stones. Place the filter papers on both ends of the soil specimen in the mould. Attach the mould with the drainage base and cap having saturated porous stones.

b) Saturation of soil specimen:

i. Connect the water reservoir to the outlet at the bottom of the mould and allow the water to flow in the soil. Wait till the water has been able to travel up and saturate the sample. Allow about 1 cm depth of free water to collect on the top of the sample.
ii. Fill the remaining portion of cylinder with de-aired water without disturbing the surface of soil.
iii. Fix the cover plate over the collar and tighten the nuts in the rods.

c) Constant head test:

i. Place the mould assembly in the bottom tank and fill the bottom tank with water up to the outlet.
ii. Connect the outlet tube with constant head tank to the inlet nozzle of the permeameter, after removing the air in flexible rubber tubing connecting the tube.
iii. Adjust the hydraulic head by either adjusting the relative hight of the permeameter mould and constant head tank or by rising or lowering the air intake tube with in the head tank.

iv. Start the stop watch and at the same time put a bucket under the outlet of the bottom tank, run the test for same convenient time interval and measure.
v. Repeat the test twice more, under the same head and for the same time interval.

d) Variable head permeability test method:

i. Disconnect the water reservoir from the outlet at the bottom and connect the stand pipe to the inlet at the top plate.
ii. Fill the stand pipe with water. Open the stop cock at the top and allow water to flow out so that all the air in the cylinder is removed.
iii. Fix the height h1 and h2 on the stand pipe from the centre of the outlet such that (h1 – h2) is about 30 cm to 40 cm.
iv. When all the air has escaped, close the stop clock and allow the water from the pipe to flow through the soil and establish a steady flow.
v. Record the time interval, t, for the head to drop from h1 to h2.
vi. Take about five such observations by changing the values of h1 and h2.
vii. Measure the temperature of water.

PRECAUTIONS:

i. All possible leakage of joints must be eliminated.
ii. Porous stones must be saturated before being put to use.
iii. De-aired and distilled water should be used to prevent choking of flowing water.
iv. Soil sample must be carefully saturated before taking the observations.
v. Use of high heads, which result in turbulent flows, should be avoided.

OBSERVATION AND CALCULATION TABLE FOR CONSTANT HEAD PERMIABILITY TEST:

S No	OBSERVATION	1	2	3
1	Diameter of stand pipe (cm) ‘d’	1.0	1.1	1.2
2	c/s area of stand pipe ‘a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen ‘A = $\pi D^2/4$			

5	Height of soil specimen, L			
6	Hydraulic head ‘h’ (cm)			
7	Time interval ‘t’ (sec)			
8	Coefficient of permeability (cm/sec) $k = \frac{Q}{t}\frac{L}{h}\frac{1}{A}$			

Avg. Coefficient of permeability (cm/sec) = _____________

OBSERVATION AND CALCULATION TABLE FOR FOLLOWING HEAD PERMIABILITY TEST:

Table 1:

Sr no.	Observation	1	2	3
1	Diameter of stand pipe (cm) ‘d’	1.0	1.1	1.2
2	c/s area of stand pipe ‘a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen ‘A = $\pi D^2/4$			
5	Height of soil specimen, L			

Table 2:

Sr. No.	Initial Head (h_1) cm	Final Head (h_2) cm	Time required (t) sec	Permeability, $k = 2.203 \frac{a*L}{A*t} log_{10}(\frac{h_1}{h_2})$
1				
2				
3				

AIM OF THE EXPERIMENT:

To determine the Optimum moisture content and maximum dry density of a soil by standard proctor compaction test.

APPARATUS REQUIRED:

a) Special:

  i. Proctor mould (capacity 1000.0 cc, internal diameter 100mm, and effective height 127.3 mm.
  ii. Rammer for light compaction (2.6Kg, with free drop of 310 mm).
  iii. Mould accessories including detachable base plate, removable Collar.
  iv. I.S. sieve 4.75 mm.

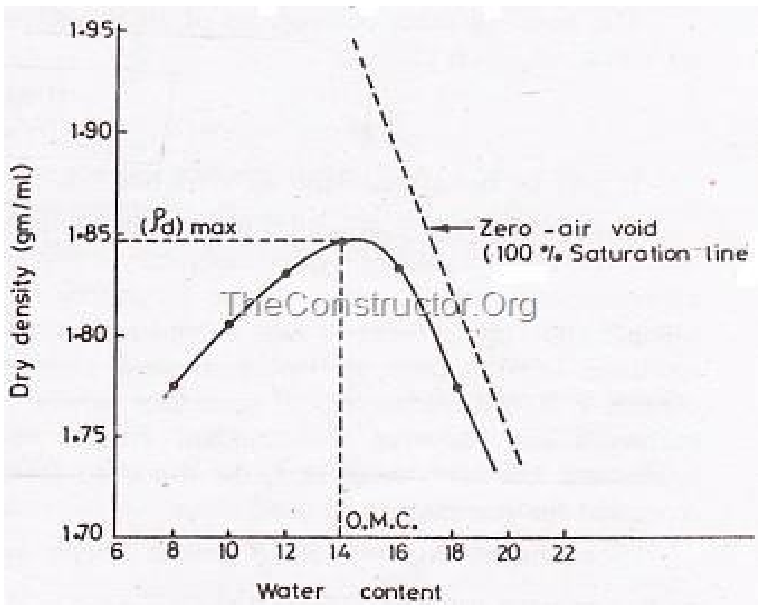
b) General:

  i. Balance of capacity 10 kg, and sensitivity of 1 gm.
  ii. Balance of capacity 200 gms and sensitivity of 0.01 gm.
  iii. Drying oven.
  iv. Desiccators.
  v. Containers for water content.
  vi. Graduated Jar.
  vii. Trimming knife.
  viii. Large mixing tray.

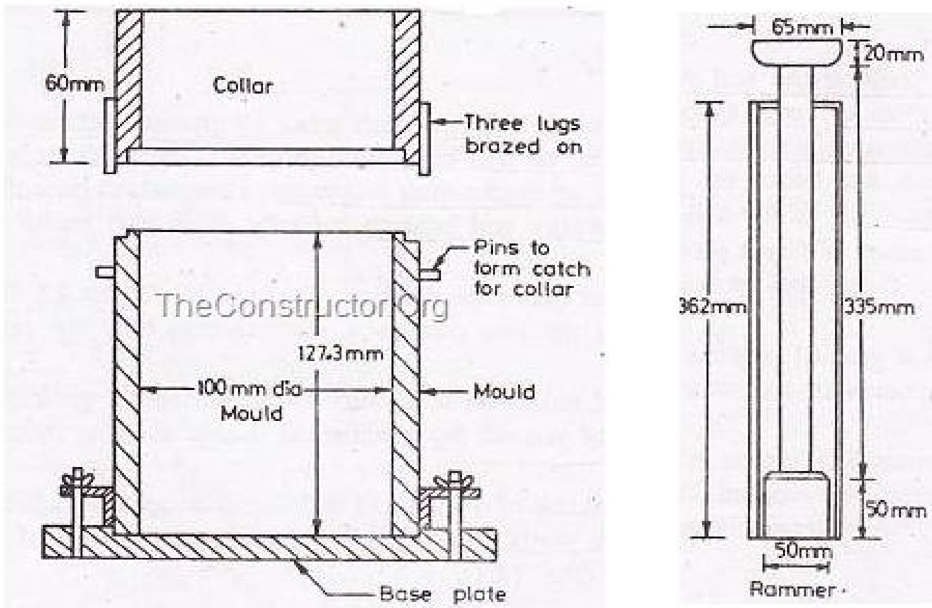
THEORY:

Compaction is the process of densification of soil mass by reducing air voids. The purpose of laboratory compaction test is so determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum, the amount of water is thus called the Optimum Moisture Content (OMC). In the laboratory different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.

For example



The standard equipment shown below,



standard proctor test apparatus

The wet density of the compacted soil is calculated as below,

$$\gamma_t = \frac{w_1 - w_2}{V}$$

Where, w_1 = Weight of mould with moist compacted soil.

w_2 = Weight of empty mould.

V = Volume of mould.

The dry density of the soil shall be calculated as follows,

$$\gamma_d = \frac{\gamma_t}{1 + w}$$

Where, γt = wet density of the compacted soil.

w = moisture content

APPLICATION:

Compaction of soil increases the density, shear strength, bearing capacity, thus reducing the voids, settlement and permeability. The results of this are useful in the stability of field problems like earthen dams, embankments, roads and airfield. In such compacted in the field is controlled by the value of the OMC determined by laboratory compaction test. The compaction energy to be given by a compaction unit is also controlled by the maximum dry density determined in the laboratory. In other words, the laboratory compaction tests results are used to write the compaction specification for field compaction of the soil.

PROCEDURE:

i. Take about 20 kg of soil and sieve it through 20 mm and 4.75 mm.
ii. A 100 mm diameter Proctor mould is to be used if the soil fraction that passes 4.75 mm sieve is greater than 80% by weight.
iii. Take about 2.25 kg of the soil sample and add water to get the moisture content round 8%. Leave the mix to mature for few minutes.
iv. Clean and grease gently the inside surface of the mould, and the base plate.
v. Take the weight of empty mould with the base plate.
vi. Fir the collar and place the mould on a solid base.
vii. Place first batch of soil inside the mould and apply 25 blows of Standard rammer, so that the compacted layer thickness is about one-third height of the mould Scratch the top of the compacted soil before the second layer is placed Place the second batch of wet soil and follow the same procedure In all the soil is compacted in three layers, each given 25 blows of the standard rammer weighing 2.6 Kg and having a drop of 310 mm.
viii. Remove the collar, and trim of the excess soil with trimming knife. Clean the mould, and weight the mould with the compacted soil and the base plate.
ix. Take a representative sample from the mould and determine its water content.
x. Repeat the above procedure for water content values of 13%, 17%, 20%, 22% and 25%.

PRECAUTIONS:

i. Adequate period is allowed to mature the soil after it is mixed with water.
ii. The rammer blows should be uniformly distributed over the surface with spatula before next layer is placed.
iii. To avoid stratification each compacted layer should be scratched with spatula before next layer is placed.
iv. At the end of compaction test, the soil should not penetrate more than 5mm into the collar.

OBSERVATION AND CALCULATION TABLE:

i. Diameter of mould, D (cm): __ _ _ _ _ _ _
ii. Height of mould, h (cm) : _ _ _ _ _ _ _ _ _
iii. Volume of mould, V (cc) : _ _ _ _ _ _ _ _ _

Weight of empty mould + Base plate (w_1) ,kg					
Weight of compacted soil + Base plate (w_2) ,kg					
Bulk unit weight of compacted soil γ (gm/cc)					
Water content (w)					
Dry unit weight $\gamma_d = \gamma / (1 + w)$, (gm/cc)					

AIM OF THE EXPERIMENT:

To determine the settlements due to primary consolidation of soil by conducting one dimensional test to determine:

i. Rate of consolidation under normal load.
ii. Degree of consolidation at any time.
iii. Pressure-void ratio relationship.
iv. Coefficient of consolidation at various pressures.
v. Compression index.

APPARATUS REQUIRED:

i. Consolidometer consisting essentially;
   a. A ring of diameter = 60mm and height = 20mm
   b. Two porous plates or stones of silicon carbide, aluminium oxide or porous metal.
   c. Guide ring.
   d. Outer ring.
   e. Water jacket with base.
   f. Pressure pad.
   g. Rubber basket.
ii. Loading device consisting of frame, lever system, loading yoke dial gauge fixing device and weights.
iii. Dial gauge to read to an accuracy of 0.002mm.
iv. Thermostatically controlled oven.
v. Stopwatch to read seconds.
vi. Sample extractor.
vii. Miscellaneous items like balance, soil trimming tools, spatula, filter papers, sample containers.

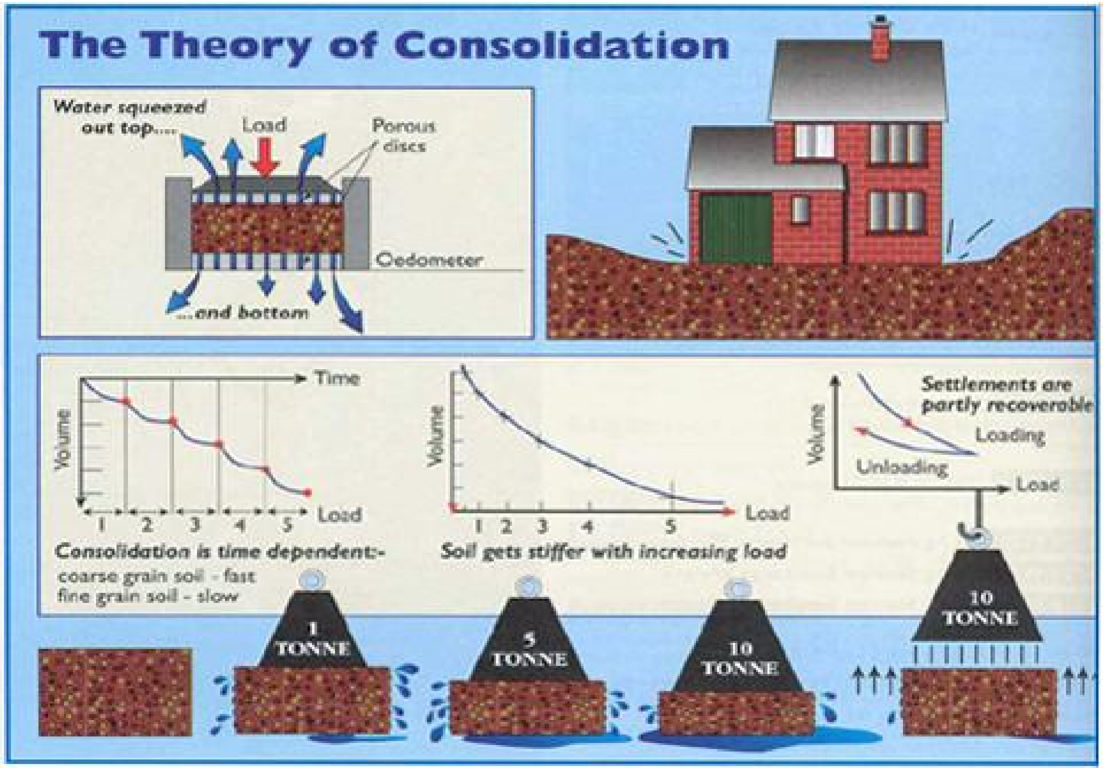
THEORY:

When a compressive load is applied to soil mass, a decrease in its volume takes place, the decrease in volume of soil mass under stress is known as compression and the property of soil mass pertaining to its tendency to decrease in volume under pressure is known as compressibility. In a saturated soil mass having its void 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 a long time static load and the consequent escape of pore water is termed as consolidation.

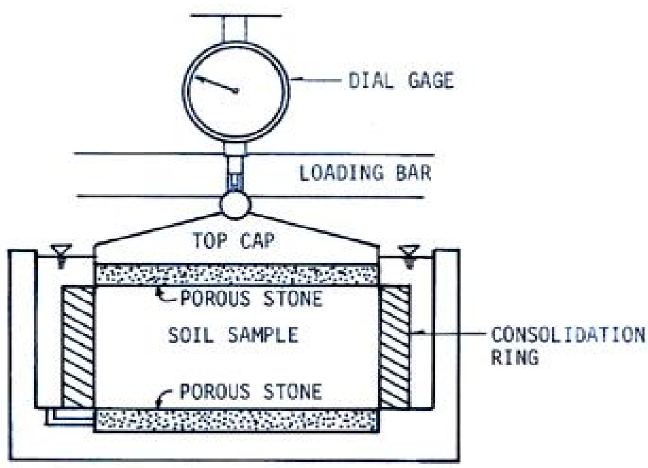
Then the load is applied on the saturated soil mass, the entire load is carried by pore water in the beginning. As the water starts escaping from the voids, the hydrostatic pressure in water gets gradually dissipated and the load is shifted to the soil solids which increases effective on them, as a result the soil mass decrease in volume. The rate of escape of water depends on the permeability of the soil.

Major problem in the soil is the soil subsidence caused by pressure or weight of construction trucks on the surface, which may be divided into three categories.

1. Elastic Deformation
2. Primary Consolidation
3. Secondary Consolidation



The equipment arrangement is as fallows;



CONSOLIDOMETER

APPLICATION:

The test is conducted to determine the settlement due to primary consolidation. To determine:

i. Rate of consolidation under normal load.
ii. Degree of consolidation at any time.
iii. Pressure-void ratio relationship.
iv. Coefficient of consolidation at various pressures.
v. Compression index.

From the above information it will be possible for us to predict the time rate and extent of settlement of structures founded on fine-grained soils. It is also helpful in analyzing the stress history of soil. Since the settlement analysis of the foundation depends mainly on the values determined by the test, this test is very important for foundation design.

PROCEDURE:

i. Preparation of the soil specimen:
   a. From undisturbed soil sample:

      From the sample tube, eject the sample into the consolidation ring. The sample should project about one cm from outer ring. Trim the sample smooth and flush with top and bottom of the ring by using a knife. Clean the ring from outside and keep it ready from weighing.
   b. From remoulded or disturb sample :
      - Choose the density and water content at which sample has to be compacted from the moisture density relationship.
      - Calculate the quantity of soil and water required to mix and compact.
      - Compact the specimen in compaction mould in three layers using the standard rammers.
      - Eject the specimen from the mould using the sample extractor.

ii. Saturate two porous stones either by boiling in distilled water about 15 minute or by keeping them submerged in the distilled water for 4 to 8 hrs. Wipe away excess water. Fittings of the consolidometer which is to be enclosed shall be moistened.

iii. Assemble the consolidometer, with the soil specimen and porous stones at top and bottom of specimen, providing a filter paper between the soil specimen and porous stone. Position the pressure pad centrally on the top porous stone.
iv. Mount the mould assembly on the loading frame, and center it such that the load applied is axial.
v. Position the dial gauge to measure the vertical compression of the specimen. The dial gauge holder should be set so that the dial gauge is in the begging of its releases run, allowing sufficient margin for the swelling of the soil, if any.
vi. Connect the mould assembly to the water reservoir and the sample is allowed to saturate. The level of the water in the reservoir should be at about the same level as the soil specimen.
vii. Apply an initial load to the assembly. The magnitude of this load should be chosen by trial, such that there is no swelling. It should be not less than 50 g/cm^2 (5 kN/m$^{2)}$ for ordinary soils & 25 g/cm^2 (2.5 kN/m^2) for very soft soils. The load should be allowed to stand until there is no change in dial gauge readings for two consecutive hours or for a maximum of 24 hours.
viii. Note the final dial reading under the initial load. Apply first load of intensity 0.1 kg/cm^2 (10 kN/m^2) start the stop watch simultaneously. Record the dial gauge readings at various time intervals (and fill in the table). The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation is gradually reached within 24 hrs.
ix. At the end of the period, specified above take the dial reading and time reading. Double the load intensity and take the dial readings at various time intervals. Repeat this procedure fir successive load increments.
x. The usual loading intensity are as follows: 0.1, 0.2, 0.5, 1, 2, 4 and 8 kg/cm^2
xi. After the last loading is completed, reduce the load to half (1/2) of the value of the last load and allow it to stand for 24 hrs. Reduce the load further in steps of 1/4th the previous intensity till an intensity of 0.1 kg/cm^2 is reached. Take the final reading of the dial gauge.
xii. Reduce the load to the initial load, keep it for 24 hrs and note the final readings of the dial gauge.
xiii. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen in oven, note the dry weight of it.

PRECAUTIONS:

i. While preparing the specimen, attempts has to be made to have the soil strata orientated in the same direction in the consolidation apparatus.

ii. During trimming care should be taken in handling the soil specimen with least pressure.

iii. Smaller increments of sequential loading have to be adopted for soft soils.

OBSERVATION AND CALCULATION TABLE:

Pressure Intensity (Kg/cm^2)	**0.1**	**0.2**	**0.5**	**1**	**2**	**4**	**8**
Elapsed Time	Dial gauge reading						
0.25 min							
1 min							
2.5 min							
4 min							
6.25 min							
9 min							
16 min							
25 min							
30 min							
1 hr							
2 hrs							
4 hrs							
8 hrs							
24 hrs							

Observation Sheet for Pressure Voids Ratio:

Applied pressure σ' (kg/cm^2)	Final dial reading	Dial change ΔH	Specimen height $H = H_1 \pm \Delta H$	Height solids $H_s = \frac{M_d}{G\,A\,\rho_w}$	Height of voids $H - H_s$	Void ration $e = \frac{H - H_s}{H_s}$
0.1						
0.2						
0.5						
1						
2						
4						
8						
0.0						

CALCULATION:

1. **Height of solids** (H_S) is calculated from the equation,

$$H_s = \frac{M_d}{G\,A\,\rho_w}$$

2. **Void ratio.** Voids ratio at the end of various pressures are calculated from equation

$$e = \frac{H - H_s}{H_s}$$

3. **Coefficient of consolidation**:

   The Coefficient of consolidation at each pressures increment is calculated by using the following equations:

   i. $C_v = 0.197\, d^2/t_{50}$ (Log fitting method)

      In the log fitting method, a plot is made between dial readings and logarithmic of time, the time corresponding to 50% consolidation is determined

   ii. $C_v = 0.848\, d^2/t_{90}$ (Square fitting method)

In the square root fitting method, a plot is made between dial readings and square root of time and the time corresponding to 90% consolidation is determined.

The values of C_v are recorded in table II.

4. **Compression Index:**

   To determine the compression index, a plot of voids ratio (e) V_s log t is made. The initial compression curve would be a straight line and the slope of this line would give the compression index C_c.

5. **Coefficient of compressibility:** It is calculated as follows

   a_v = 0.435 C_c/Avg. pressure for the increment

   Where C_c = Coefficient of compressibility

6. **Coefficient of permeability.** It is calculated as follows

   K = $C_v.a_v$ *(unit weight of water)/(1+e).

AIM OF THE EXPERIMENT:

To determine shear strength parameters of the given soil sample by Direct Shear Test.

APPARATUS REQUIRED:

a) Special:

i. Shear test frame housing the motor, loading yoke, etc.

ii. Shear box of internal dimension 60 mm x 60 mm x 25 mm.

iii. Water jacket for shear box.

iv. Metallic Grid plates.

v. Base plate

vi. Porous stones

vii. Loading pad.

viii. Proving ring of capacity 200 Kgf.

ix. Slotted weights to impart appropriate normal stress on soil sample.

b) General:

i. Balance of capacity 1 Kg and sensitivity 0.1 gms.

ii. Scale.

iii. Dial Gauge of sensitivity 0.01 mm

THEORY:

Shear strength of a soil is the maximum resistance to shearing stress at failure on the failure plane.

Shear strength is composed of:

i. Internal friction which is the resistance due to friction between individual particles at their contact points and interlocking of particles. This interlocking strength is indicated through parameter φ.
ii. Cohesion which resistance due to inter-particle force which tend hold the particles together in a soil mass. The indicative parameter is called Cohesion intercept (c).

Coulomb has represented the shear strength of soil by the equation:

$$\tau_{\mathrm{f}} = c + \sigma_{\mathrm{n}} \tan \varphi$$

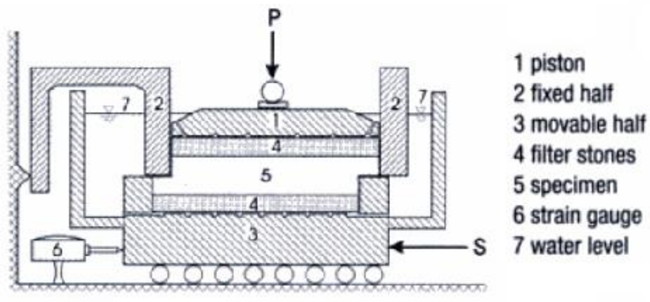
Where, $\tau_{\mathrm{f}} =$ shear strength of soil = shear stress at failure.

c = Cohesion intercepts.

$\sigma_{\mathrm{n}} =$ Total normal stress on the failure plane

$\varphi =$ Angle of internal friction or shearing resistance

The graphical representation of the above equation gives a straight line called Failure envelope.



Direct shear box

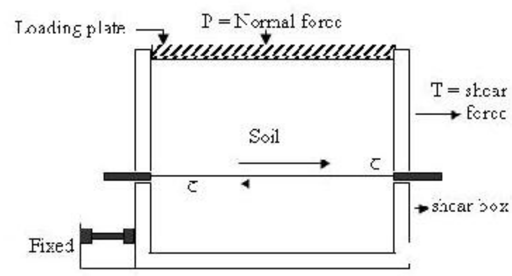
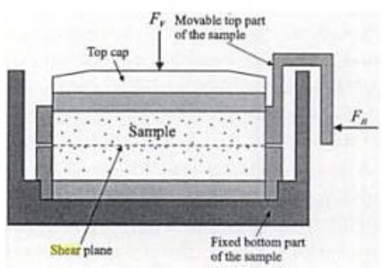
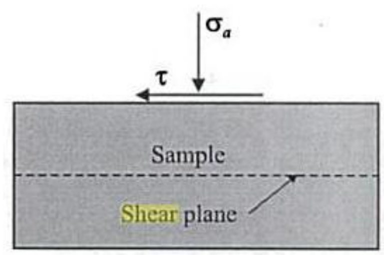


Diagram of direct shear arrangement



Schematic presentation of a direct shear box apparatus



Stresses acting on a sample in a direct shear box

The parameters c and are not constant for a given type of soil but depends in its degree of saturation, drainage conditions and the condition of laboratory testing.

In direct shear test, the sample is sheared along the horizontal plane. This indicates that the failure plane is horizontal. The normal stress, on this plane is the external vertical load divided by the corrected area of the soil sample. The shear stress at failure is the external lateral load divided by the corrected of soil sample.

APPLICATION:

The purpose of direct shear test is to get the ultimate shear resistance, peak shear resistance, cohesion, angle of shearing resistance and stress-strain characteristics of the soils.

Shear parameters are used in the design of earthen dams and embankments. These are used in calculating the bearing capacity of soil-foundation systems. These parameter help in estimating the earth pressures behind the retaining walls. The values of these parameters are also used in checking the stability to natural slopes, cuts and fills.

PROCEDURE:

i. Prepare a soil specimen of size 60 mm * 60mm* 25 mm either from undisturbed soil sample or from compacted or remoulded sample. Soil specimen may also be directly prepared in the box by compaction.
ii. Fix the upper part of the box to the lower box by fixing screws. Attach the base plate to the lower part.
iii. Place the porous stone in the box.
iv. Transfer the soil specimen prepared into the box.
v. Place the upper grid, porous stone, and loading pad in the order on soil specimen.
vi. Place the box inside the container and mount it on loading frame.
vii. Bring the upper half of the box in contact with the proving ring assembly. Contact is observed by the slight movement of proving ring dial gauge needle.
viii. Mount the loading yoke on the ball placed on the loading pad.
ix. Put the weight on the loading yoke to apply a given value of normal stress intensity. Add the weight of the yoke also in the estimation of normal stress intensity.
x. Remove the fixing screws from the box and raise slightly the upper box with the help of the spacing screws. Remove the spacing screws also.
xi. Adjust the entire dial gauge to read zero.
xii. Shear load is applied at constant rate of strain.
xiii. Record the readings of proving ring and dial readings at a fixed interval.
xiv. Continue the observations till the specimen fails.
xv. Repeat the test on the identical specimen under increasing normal stress and record the corresponding reading.

PRECAUTIONS:

i. Before starting the test, the upper half of the box should be brought in proper contact with the proving ring.
ii. Before subjecting the specimen to shear, the fixing screws should take out.
iii. Spacing screws should also be removed before shearing the specimen.
iv. No vibrations should be transmitted to the specimen during the test.

v. Do not forget to add the self weight of the loading yoke in the vertical loads.

OBSERVATION AND CALCULATION TABLE:

1. Size of Soil sample = Internal Dimensions of the Box
2. Weight of yoke, w_1=0.775 Kg.
3. Weight of Loading pad, w2=0.620 Kg.
4. Lever Ratio = 1:5
5. Proving ring Number=
6. Proving ring Constant (K): 1 Division = Kg.
7. Rate of strain for Horizontal Shear = 1.25 mm/min.

Load on yoke (w) (kg)					
Normal load on soil sample(N) (kg)=$(W+w_1)x5+w_2$					
Normal stress σ_n (kg/cm^2) σ_n = N/(6x6)					
Proving ring division at failure (D)					
Shear force at failure (S) =D x k					
Shear resistance at failure (τ_f) =S/(6x6)					

AIM OF THE EXPERIMENT:

To find the shear of the soil by Undrained Triaxial Test.

APPARATUS REQUIRED:

a) Special:

i. A constant rate of strain compression machine of which the following is a brief description of one is in common use.

- A loading frame in which the load is applied by yoke acting through an elastic dynamometer, more commonly called a proving ring which used to measure the load. The frame is operated at a constant rate by a geared screw jack. It is preferable for the machine to be motor driven, by a small electric motor.
- A hydraulic pressure apparatus including an air compressor and water reservoir in which air under pressure acting on the water raises it to the required pressure, together with the necessary control valves and pressure dials.

ii. A triaxial cell to take 3.8 cm dia and 7.6 cm long samples, in which the sample can be subjected to an all round hydrostatic pressure, together with a vertical compression load acting through a piston. The vertical load from the piston acts on a pressure cap. The cell is usually designed with a non-ferrous metal top and base connected by tension rods and with walls formed of Perspex.

b) General:

i. 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.

ii. Rubber ring.

iii. An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.

iv. Stop clock.

v. Moisture content test apparatus.

vi. A balance of 250 gm capacity and accurate to 0.01 gm.

THEORY:

Triaxial test is more reliable because we can measure both drained and untrained shear strength.

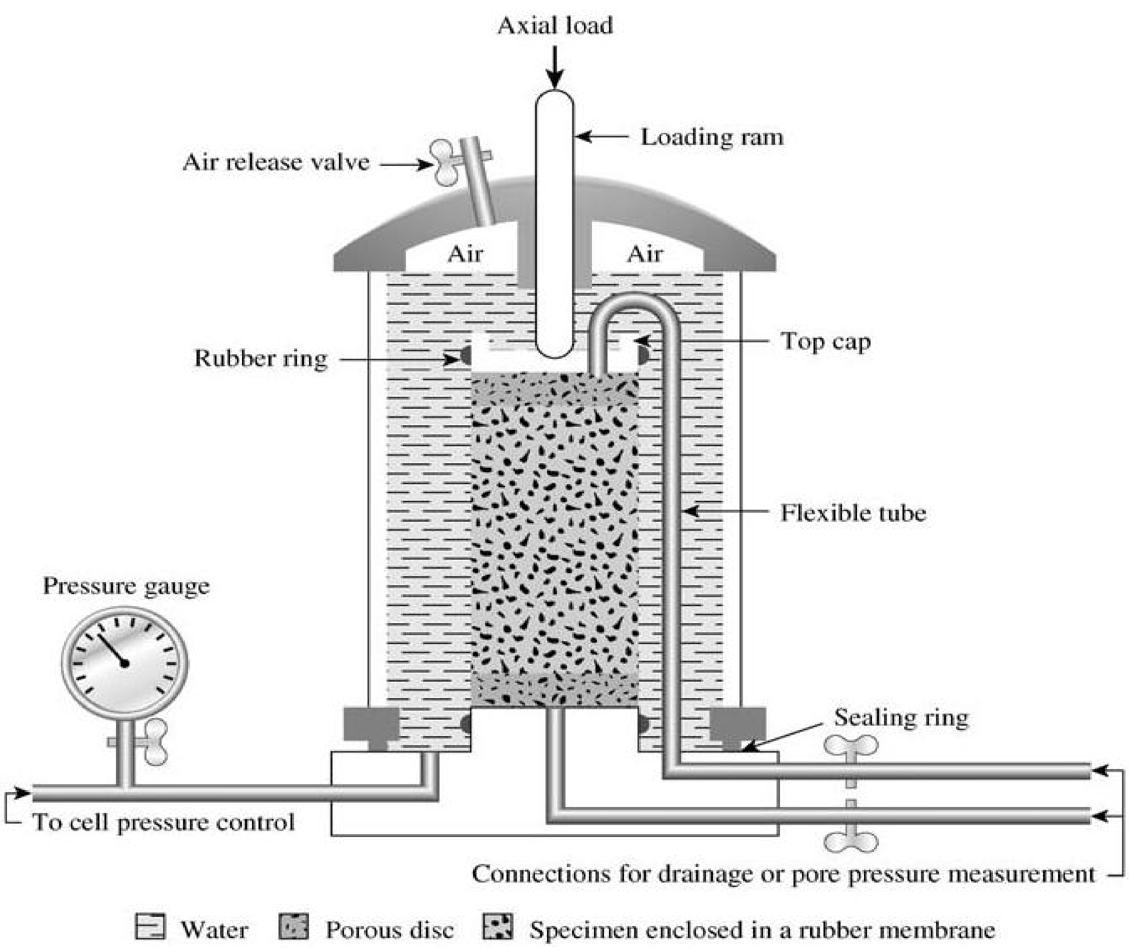


Diagram of triaxial test equipment

Generally 1.4” diameter (3” tall) or 2.8” diameter (6” tall) specimen is used. Specimen is encased by a thin rubber membrane and set into a plastic cylindrical chamber. Cell pressure is applied in the chamber (which represents σ3’) by pressurizing the cell fluid (generally water).

Vertical stress is increased by loading the specimen (by raising the platen in strain controlled test and by adding loads directly in stress controlled test, but strain controlled test is more common) until shear failure occurs. Total vertical stress, which is σ1’ is equal to the sum of σ3’ and deviator stress (σd). Measurement of σd, axial deformation, pore pressure, and sample volume change are recorded.

Depending on the nature of loading and drainage condition, triaxial tests are conducted in three different ways.

i. UU Triaxial test
ii. CU Triaxial test
iii. CD Triaxial test

APPLICATION:

UU triaxial test gives shear strength of soil at different confining stresses. Shear strength is important in all types of geotechnical designs and analyses.

PROCEDURE:

i. The sample is placed in the compression machine and a pressure plate is placed on the top. Care must be taken to prevent any part of the machine or cell from jogging the sample while it is being setup, for example, by knocking against this bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.
ii. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.

iii. When the sample is setup water is admitted and the cell is fitted under water escapes from the beed valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.
iv. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.
v. The handle wheel of the screw jack is rotated until the underside of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.
vi. The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the begging of the test.

PRECAUTIONS:

OBSERVATION AND CALCULATION TABLE:

The machine is set in motion (or if hand operated the hand wheel is turned at a constant rate) to give a rate of strain 2% per minute. The strain dial gauge reading is then taken and the corresponding proving ring reading is taken the corresponding proving ring chart. The load applied is known. The experiment is stopped at the strain dial gauge reading for 15% length of the sample or 15% strain.

i. Size of specimen :
ii. Length :
iii. Proving ring constant :
iv. Diameter : 3.81 cm
v. Initial area L:
vi. Initial Volume :
vii. Strain dial least count (const) :

Sample No.	Wet bulk density gm/cc	Cell pressure kg/cm^2	Compressive stress at failure	Strain at failure	Moisture content	Shear strength (kg/cm^2)	Angle of shearing resistance
1							
2							
3							

Cell pressure kg/cm^2	Strain dial	Proving ring reading	Load on sample kg	Corrected area cm^2	Deviator stress
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				

GENERAL REMARKS:

i. It is assumed that the volume of the sample remains constant and that the area of the sample increases uniformly as the length decreases. The calculation of the stress is based on this new area at failure, by direct calculation, using the proving ring constant and the new area of the sample. By constructing a chart relating strains readings, from the proving ring, directly to the corresponding stress.

ii. The strain and corresponding stress is plotted with stress abscissa and curve is drawn. The maximum compressive stress at failure and the corresponding strain and cell pressure are found out.

iii. The stress results of the series of triaxial tests at increasing cell pressure are plotted on a mohr stress diagram. In this diagram a semicircle is plotted with normal stress as abscissa shear stress as ordinate.

iv. The condition of the failure of the sample is generally approximated to by a straight line drawn as a tangent to the circles, the equation of which is t = C + a tan f. The value of cohesion 'C' is read of the shear stress axis, where it is cut by the tangent to the mohr circles, and the angle of shearing resistance (f) is angle between the tangent and a line parallel to the shear stress.