Department Of Civil Engg

SOIL MECHANICS LAB MANUAL

(SCTE & VT, BPUT)

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DEPARTMENT OF CIVIL ENGINEERING

VISION OF THE DEPARTMENT:

To produce eminent, competitive and dedicated civil engineers by imparting latest technical skills and ethical values to empower the students to play a key role in the planning and execution of infrastructural & developmental activities of the nation.

MISSION OF THE DEPARTMENT:

To provide exceptional education in civil engineering through quality teaching, state-of- the-art facilities and dynamic guidance to produce civil engineering graduates, who are professionally excellent to face complex technical challenges with creativity, leadership, ethics and social consciousness.

DEPARTMENT OF CIVIL ENGINEERING

PROGRAMS: BACHELOR OF TECHNOLOGY (B. TECH)

DIPLOMA IN ENGINEERING

PROGRAM OUTCOMES

PO-1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO-2	**Problem analysis:** Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO-3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO-4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO-5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO-6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO-7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO-8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO-9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO-10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO-11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO-12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

DEPARTMENT OF CIVIL ENGINEERING

PROGRAMS: BACHELOR OF TECHNOLOGY (B. TECH)

DIPLOMA IN ENGINEERING

The Program Specific outcomes (PSO‟s) listed below were developed specifically to meet the Program Educational Objectives (PEO‟s). The focus of these PSO's is consistent with the set of required POs' identified in the NBA accreditation guidelines.

The Civil Engineering PSO's requires that graduates receiving a Bachelor of Technology in Civil Engineering degree from PKAGI demonstrate the following.

PROGRAM SPECIFIC OUTCOMES	
PSO-1	**ENGINEERING KNOWLEDGE**: Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication
PSO-2	**BROADNESS AND DIVERSITY:** Graduates will have a broad understanding of economic, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage.
PSO-3	**SELF-LEARNING AND SERVICE:** Graduates will be motivated for continuous self-learning in engineering practice and/or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.

SYLLABUS

EXPT-1	DETERMINATION OF WATER CONTENT IN SOIL SPECIMEN
EXPT-2	UNIT WEIGHT DETERMINATION OF SOIL
EXPT-3	SPECIFIC GRAVITY DETERMINATION OF SOIL
EXPT-4	GRAIN SIZE DITRIBUTION OF SOIL
EXPT-5	DETERMINATION OF ATTERBERG LIMITS OF SOIL
EXPT-6	DETERMINATION OF COEFFICIENT OF PERMABILITY OF SOIL
EXPT-7	DETERMINATION OF DENSITY BY COMPACTION TEST
EXPT-8	DETERMINATION OF CONSOLIDATION CHARACTERISTICS
EXPT-9	DETERMINATION OF SHEAR STRENGTH PARAMETER

ATTAINMENT OF PROGRAM OUTCOMES (PO's) & PROGRAM SPECIFIC OUTCOMES

EXP NO.	NAME OF THE EXPERIMENT	PO's	PSO's
EXPT-1	DETERMINATION OF WATER CONTENT IN SOIL SPECIMEN		1,3
EXPT-2	UNIT WEIGHT DETERMINATION OF SOIL		1,2
EXPT-3	SPECIFIC GRAVITY DETERMINATION OF SOIL		1,2,3
EXPT-4	GRAIN SIZE DITRIBUTION OF SOIL		1,3
EXPT-5	DETERMINATION OF ATTERBERG LIMITS OF SOIL		1,3
EXPT-6	DETERMINATION OF COEFFICIENT OF PERMABILITY OF SOIL		1,2,3
EXPT-7	DETERMINATION OF DENSITY BY COMPACTION TEST		1,2,3
EXPT-8	DETERMINATION OF CONSOLIDATION CHARACTERISTICS		1,3
EXPT-9	DETERMINATION OF SHEAR STRENGTH PARAMETER		1,3

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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.

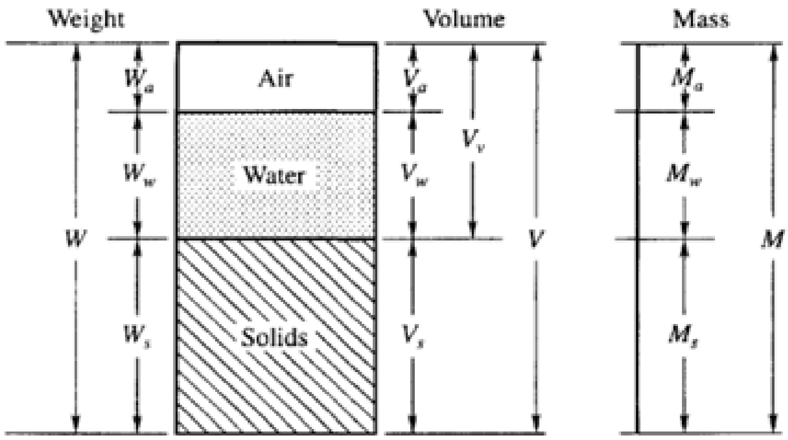
OBJECTIVE:

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.

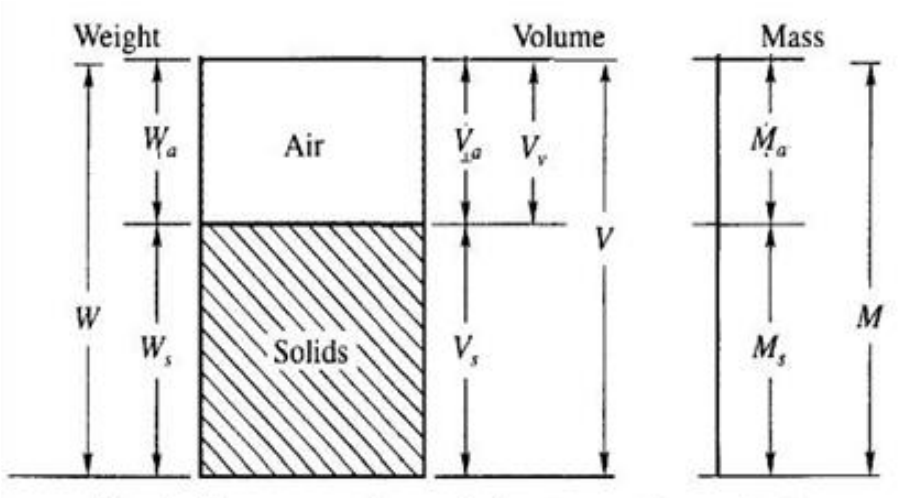
Soil mass is generally a three phase system. It consists of solid particles, liquid and gas. For all practical purposes, the liquid may be considered to be water (although in some cases, the water may contain some dissolved salts) and the gas as air. The phase system may be expressed in SI units either 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

After complete drying the soil sample becomes,



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

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 1050 C to 1100 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 600 C) possibly for a longer period.

RUNNING THE TEST AND RECORDING THE DATA: -

Weight of can, W_1 (g) =

Weight of can + wet soil W_2 (g) =

Weight of can + dry soil W_3 (g)=

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

The natural moisture content of the soil sample is _ __%

OBSERVATION TABLE: -

	Type 1	Type 2	Type 3	Type 4
Weight of can, W1 (g)				
Weight of can + wet soil W2 (g)				
Weight of can + dry soil W3 (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.

EXPERIMENT: 2 UNIT WEIGHT DETERMINATION

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, $\gamma =$ 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, Υ_d= dry density of soil

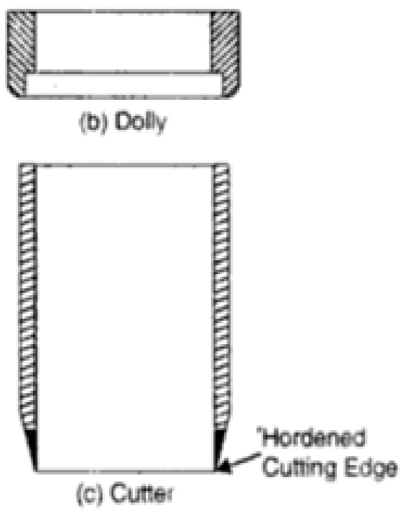
Υ_t= wet density of soil

W= water content of soil

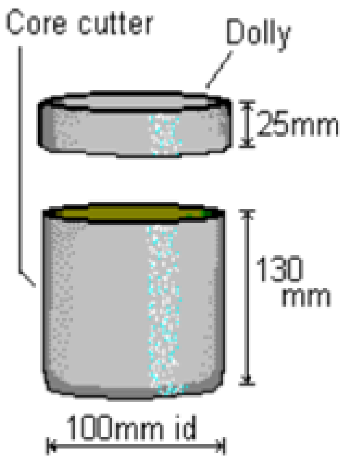
APPRATURS REQUIRED: -

Special:

i. Cylindrical core cutter
ii. Steel rammer
iii. Steel dolly



CORE CUTTER



General:

i. Balance of capacity5 Kg and sensitivity 1 gm.
ii. Balance of capacity 200gms and sensitivity 0.01 gm.
iii. Scale
iv. Spade or pickaxe or crowbar
v. Trimming Knife
vi. Oven
vii. Water content containers
viii. Desiccator

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

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/cm^3) $\gamma_t = \frac{W_2 - W_1}{V}$			
Dry density, (gm/cm^3) $\gamma_d = \frac{\gamma_t}{1 + w}$			

REFERENCES: -

i. IS: 2720 (Part II) – 1973, Method of Test for soil: Part II
ii. Soil Mechanics and Foundations.

EXPERIMENT: 3 SPECIFIC GRAVITY DETERMINATION

INTRODUCTION:

The specific gravity of a substance, designated as Gs, 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 Gs 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, Gs 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 accurate 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

TEST PROCEDURE: -

I. Clean and dry the density bottle wash the bottle with water and allow it to drain.
II. Wash it with alcohol and drain it to remove water. Wash it with ether, to remove alcohol and drain ether.
III. Weigh the empty bottle with stopper (W1)
IV. 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 (W2).
V. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.
VI. Again, fill the bottle completely with distilled water put the stopper and keep the bottle under constant temperature water baths (0).
VII. Take the bottle outside and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W3).
VIII. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W4 at temperature (24).
IX. 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 270C. So the specific gravity at 270C = K Sp. gravity at Tx0C.

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

The specific gravity of the soil particles lies within 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.

OBSERVATION TABLE:

	TEST 1	TEST 2
Pycnometer bottle number		
WP = Mass of empty, clean pycnometer (grams)		
WPS= Mass of empty pycnometer + dry soil (grams)		
WB= Mass of pycnometer + dry soil + water (grams)		
WA= Mass of pycnometer + water (grams)		
Specific gravity (GS)		

WP = _____ g, WPS = _____ g, WB = _____ g, WA = _____

Wo = _____ g

Gs =

REFERENCES: -

I. IS: 2720 (Part II) – 1973, Method of Test for soil: Part II
II. Soil Mechanics and Foundations.

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 microns.
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.

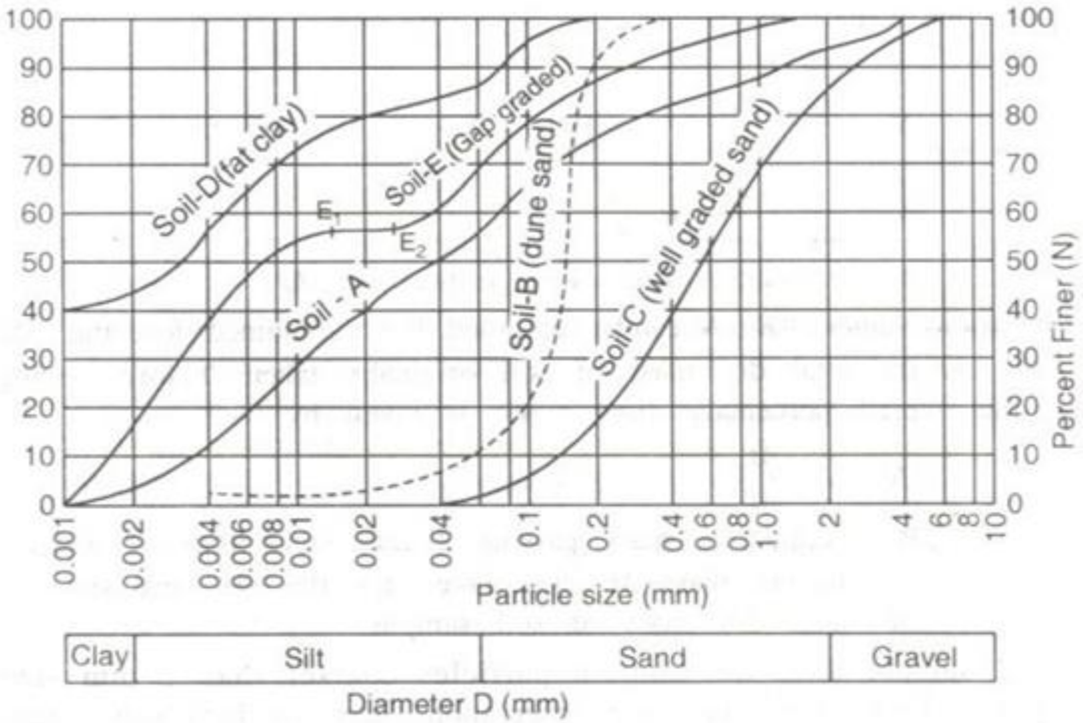
SP: Poorly Graded Sand.

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 microns passing between 5 to 12%.

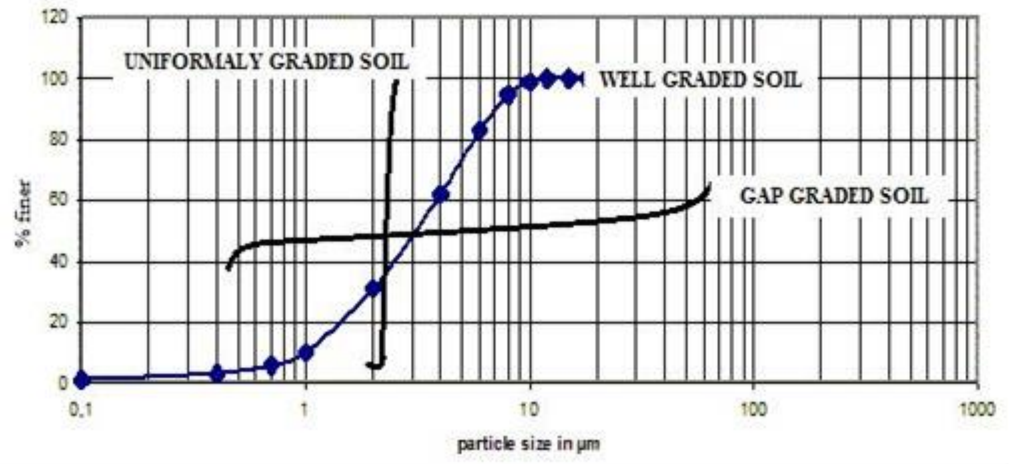
Dry sieve is performed for cohesion less soils if fines are less than 5%. Wet sieve analysis is carried out if fines are more than 5% and of cohesive nature.

We can analysis from foiling,



PARTICLE SIZE DISTRIBUTION CURVE

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



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 (Cc) may be estimated as:

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

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

Uniformity coefficient (Cu) is given by:

$$C_{\mathrm{u}} = \frac{D_{60}}{D_{10}}$$

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

Where, D60 = particle size at 60% finer.

D30 = particle size at 30% finer.

D10 = particle size at 10% finer.

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 equalling 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.

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 fractions.

OBSERVATION AND CALCULATION TABLE:

Sieve size (mm)	Mass of soil Retained (gm)	% of soil retained (%) =(x/M)	Cumulative % of soil retained (%)	% finer =(100 – p)
80				
40				
20				
10				
4.75				
2.0				
0.850				
0.425				
0.150				
0.075				
pan				

Coefficient of curvature (Cc) may be estimated as:

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

Uniformity coefficient (Cu) is given by:

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

EXPERIMENT: 5 ATTERBERG LIMITS

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 behaviour 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 behaviour. 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 Casagrande 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 behaviour. 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) 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 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.

TEST PROCEDURE: -

Liquid Limit:

I. Take roughly 3/4 of the soil and place it into the porcelain dish. Assume that the soil was previously passed through 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.
II. Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.
III. 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.
IV. 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.
V. Use the grooving tool carefully cut a clean straight groove down the centre 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.

VI. 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.). 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.

VII. 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.

VIII. 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.

IX. 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:

I. Weigh the remaining empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.

II. 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.

III. Form the soil into an ellipsoidal mass. Roll the mass between the palm or the fingers and the glass plate. 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.

IV. 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.

V. 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.

VI. 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.

OBSERVATION TABLE: -

Liquid Limit Determination

Sample No.	1	2	3	4
Moisture can and lid number				
Mc = Mass of empty, clean can + lid (grams)				
MCMS = Mass of can, lid, and moist soil (grams)				
MCDS = Mass of can, lid, and dry soil (grams)				
MS = Mass of soil solids (grams)				
MW = Mass of pore water (grams)				
w = Water content, w%				
No. of drops (N)				

Plastic Limit Determination

Sample No.	1	2	3	4
Moisture can and lid number				
Mc = Mass of empty, clean can + lid (grams)				
MCMS = Mass of can, lid, and moist soil (grams)				
MCDS = Mass of can, lid, and dry soil (grams)				
MS = Mass of soil solids (grams)				
MW = Mass of pore water (grams)				
w = Water content, w%				
Moisture can and lid number				

REFERENCES: -

I. IS: 2720 (Part II) – 1973, Method of Test for soil: Part II
II. Soil Mechanics and Foundations.

EXPERIMENT: 6 PERMEABILITY TESTS

AIM OF THE EXPERIMENT:

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

APPARATUS REQUIRED:

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.

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.

Laboratory method:

I. Variable head test.
II. Constant head test.

Field method:

I. Pumping out test.
II. Pumping in test.

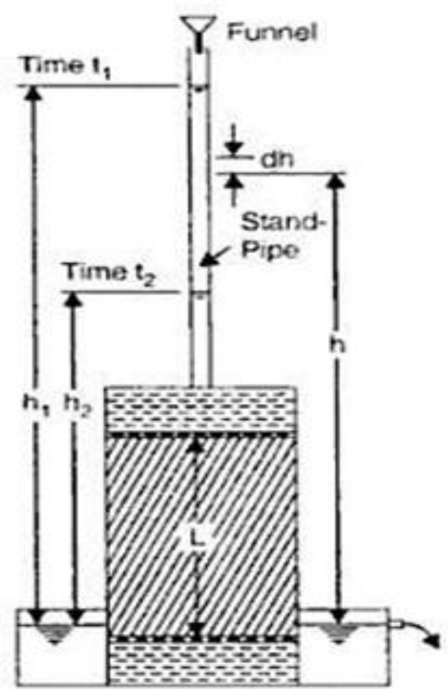
Indirect test:

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.

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:

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

Where,

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

a = Cross Sectional area of stand pipe (cm^2).

L = Length of soil specimen (cm)

A = Cross-sectional area of soil sample inside the mould (cm^2)

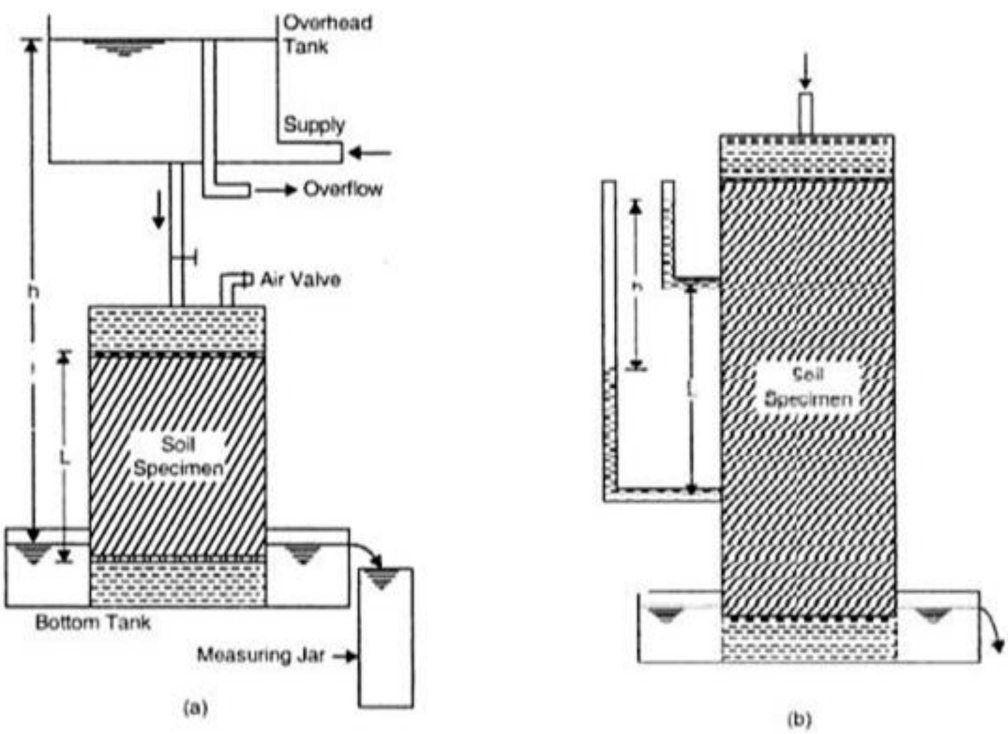
t = ($t_1 - t_2$) = Time interval for the head to fall from h_1 to h_2.

h_1 = Initial head of water at time t_1 in the pipe, measured above the outlet.

h_2 = Final head of water at time t_2 in the pipe, measured above the outlet.

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 (cm^2)

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.

PROCEDURE:

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.

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.

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 raising 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.

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:

Sl no.	OBSERVATION	1	2	3
1	Diameter of stand pipe (cm) 'd'			
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)			

OBSERVATION AND CALCULATION TABLE FOR FOLLOWING HEAD PERMIABILITY TEST:

Table 1:

SLNO.	OBSERVATION	1	2	3
1	Diameter of stand pipe (cm) ‘d’			
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:

SL 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				

EXPERIMENT: 7 COMPACTION TEST

AIM OF THE EXPERIMENT:

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

APPARATUS REQUIRED:

Special:

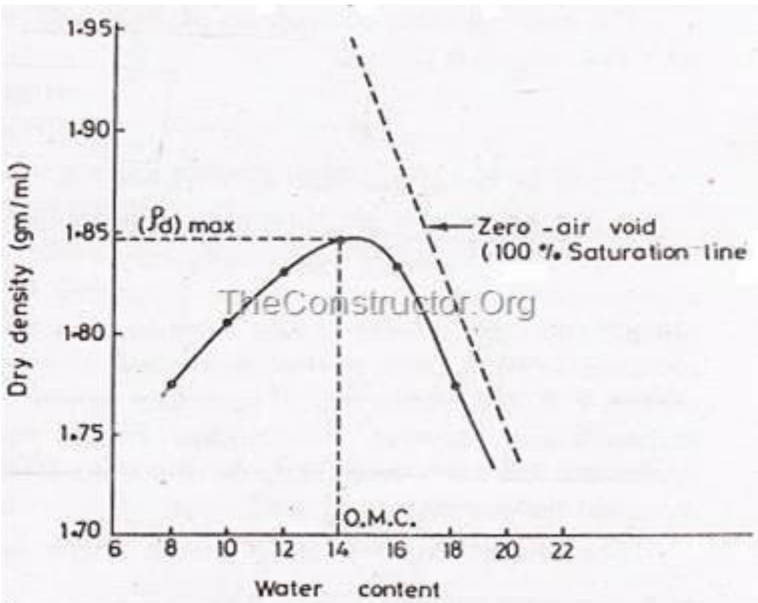
I. Proctor mould (capacity 1000.0 cc, internal diameter 100mm, and effective height 127.3 mm.
II. Rammer for light compaction (2.6Kg, with free drop of 310 mm).
III. Mould accessories including detachable base plate, removable Collar.
IV. I.S. sieve 4.75 mm.

General:

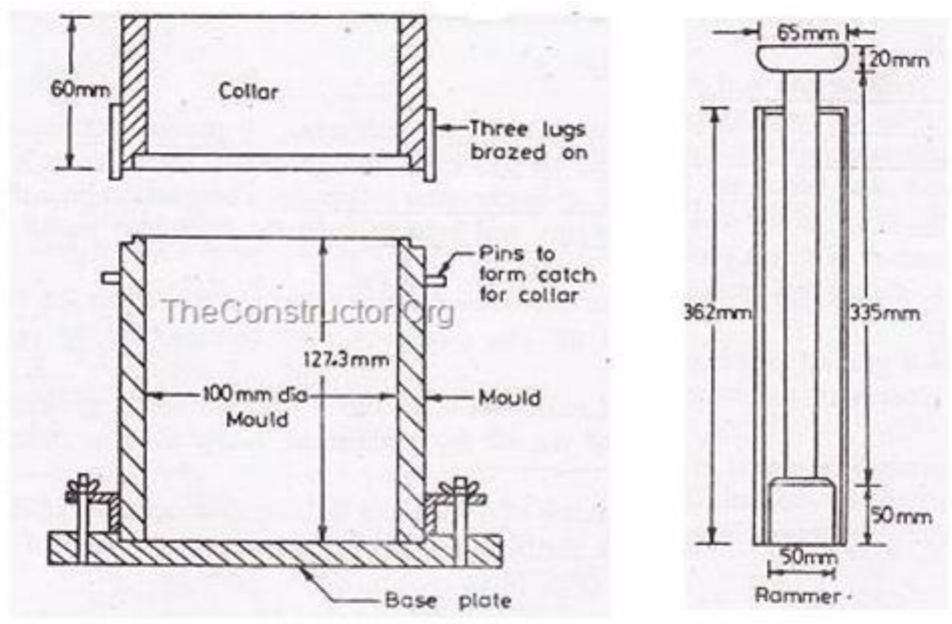
I. Balance of capacity 10 kg, and sensitivity of 1 gm.
II. Balance of capacity 200 gms and sensitivity of 0.01 gm.
III. Drying oven.
IV. Desiccators.
V. Containers for water content.
VI. Graduated Jar.
VII. Trimming knife.
VIII. Large mixing tray.

THEORY:

Compaction is the process of densification of soil mass by reducing air voids. The purpose of laboratory compaction test is so determining 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.



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,

w1 = Weight of mould with moist compacted soil.

w2 = Weight of empty mould.

V = Volume of mould.

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

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

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. First 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	1	2	3	4	5
Weight of compacted soil + Base plate (w_2), kg					
Bulk unit weight of compacted soil γ (gm/cc)					
Water content					
Dry unit weight $\gamma d = \gamma / (1 + w)$, (gm/cc)					

EXPERIMENT: 8 CONSOLIDATION TEST

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.

I. Elastic Deformation
II. Primary Consolidation
III. Secondary Consolidation

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/cm2 (5 kN/m2) for ordinary soils & 25 g/cm2 (2.5 kN/m2) 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/cm2 (10 kN/m2) 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/cm2

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/cm2 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 hr							
4 hr							
8 hr							
24 hr							

OBSERVATION SHEET FOR PRESSURE VOIDS RATIO:

Applied pressure σ′ (kg/cm^2)	Final dial reading	Dial change ΔH	Specimen height H=H1+ΔH	Height Solids $H_s = \frac{M_d}{G A \rho_w}$	Height of voids H – Hs	Void Ratio $e = \frac{H - H_s}{H_s}$
0.1						
0.2						
0.5						
1						
2						
4						
8						
0.0						

CALCULATION:

I. Height of solids (HS) is calculated from the equation,

   i. $H_s = \frac{M_d}{G A \rho_w}$

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

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

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

a) $C_v = 0.197\ d^2/t50$ (Log fitting method)

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

c) $C_v = 0.848\ d^2/t90$ (Square fitting method)

d) 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.

IV. The values of Cv are recorded in table II.

V. Compression Index: To determine the compression index, a plot of voids ratio (e) Vs log t is made. The initial compression curve would be a straight line and the slope of this line would give the compression index Cc.

VI. Coefficient of compressibility: It is calculated as follows
av = 0.435 Cc/Avg. pressure for the increment
Where Cc = Coefficient of compressibility

VII. Coefficient of permeability. It is calculated as follows K = Cv.av *(unit weight of water)/(1+e).

EXPERIMENT: 9 DIREST SHEAR TEST

AIM OF THE EXPERIMENT:

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

APPARATUS REQUIRED:

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.

General:

I. Balance of capacity 1 Kg and sensitivity 0.1 gm.
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:

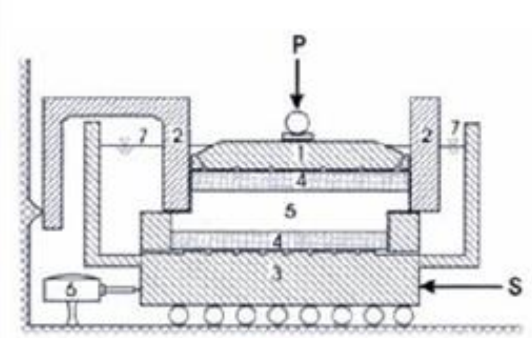
I. Internal friction which is the resistance due to friction between individual particles at their contact points and interlocking of particles. This interlocking strength is indicated through parameter ϕ.

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:

$$\tau_f = c + \sigma_n \tan \varphi$$

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



Direct shear box

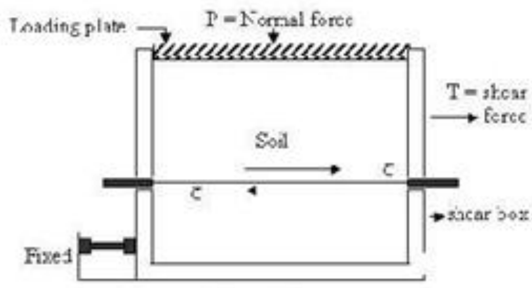
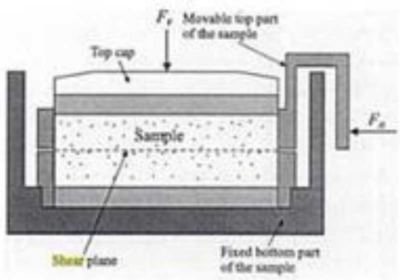
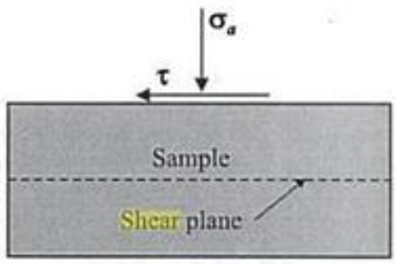


Diagram of direct shear arrangement



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.

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.

OBSERVATION AND CALCULATION TABLE:

I. Size of Soil sample = Internal Dimensions of the Box
II. Weight of yoke, w1=0.775 Kg.
III. Weight of Loading pad, w2=0.620 Kg.
IV. Lever Ratio = 1:5
V. Proving ring Number=
VI. Proving ring Constant (K): 1 Division = Kg.
VII. Rate of strain for Horizontal Shear = 1.25 mm/min.

Load on yoke (w) (kg)					
Normal load on soil sample(N) (kg)=(W+w1) x5+w2					
Normal stress (kg/cm2) = N/(6x6)					
Proving ring division at failure (D)					
Shear force at failure (S) =D x k					
Shear resistance at failure =S/(6x6)					