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Department of Civil and Construction Engineering

Soil Mechanics

Laboratory Manual

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Chapter-1 MOISTURE CONTENT

Moisture Content Determination by Oven Drying Method

Objective

To determine the amount of water or moisture present in the given quantity of soil in terms of its dry weight.

Need and Scope of the Experiment

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the 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.

Theory

Water content or moisture content determination is a routine laboratory test, the results of which are used in evaluation of different important engineering properties of soil. The determination of moisture content involves removing of soil moisture by oven-drying a soil sample until the weight remains constant. The moisture content is expressed in percentage and is calculated from the sample weight before and after drying.

Mathematically it can be written as;

$$\omega = \frac{W_w}{W_s} X100$$

Ww = Weight of soil water

Ws = Weight of soil solids

Apparatus

1. Moisture tins
2. Weighing balance (Least count of 0.01 g)
3. Drying oven (Temperature control at 110 ±5 ^{0}C)

Procedure

1. Take empty clean moisture tin and mark it with an identifying number or code Fig. 1.1.
2. Weight the container and record the weight as W_1 to the nearest 0.01 g

3. Take representative wet soil sample (not less than 20 g) and place it quickly in the moisture tin
4. Weight the moisture tin with wet soil sample to the nearest 0.01 g and record this weight as W_2
5. Place the moisture tin with the wet soil sample in drying oven, Fig 1.2 at constant temperature of 110 ± 5^0 C for 24 hours.
6. After 24 hours remove the moisture tin from drying oven and weight it to the nearest 0.01 g. Record this weight as W_3

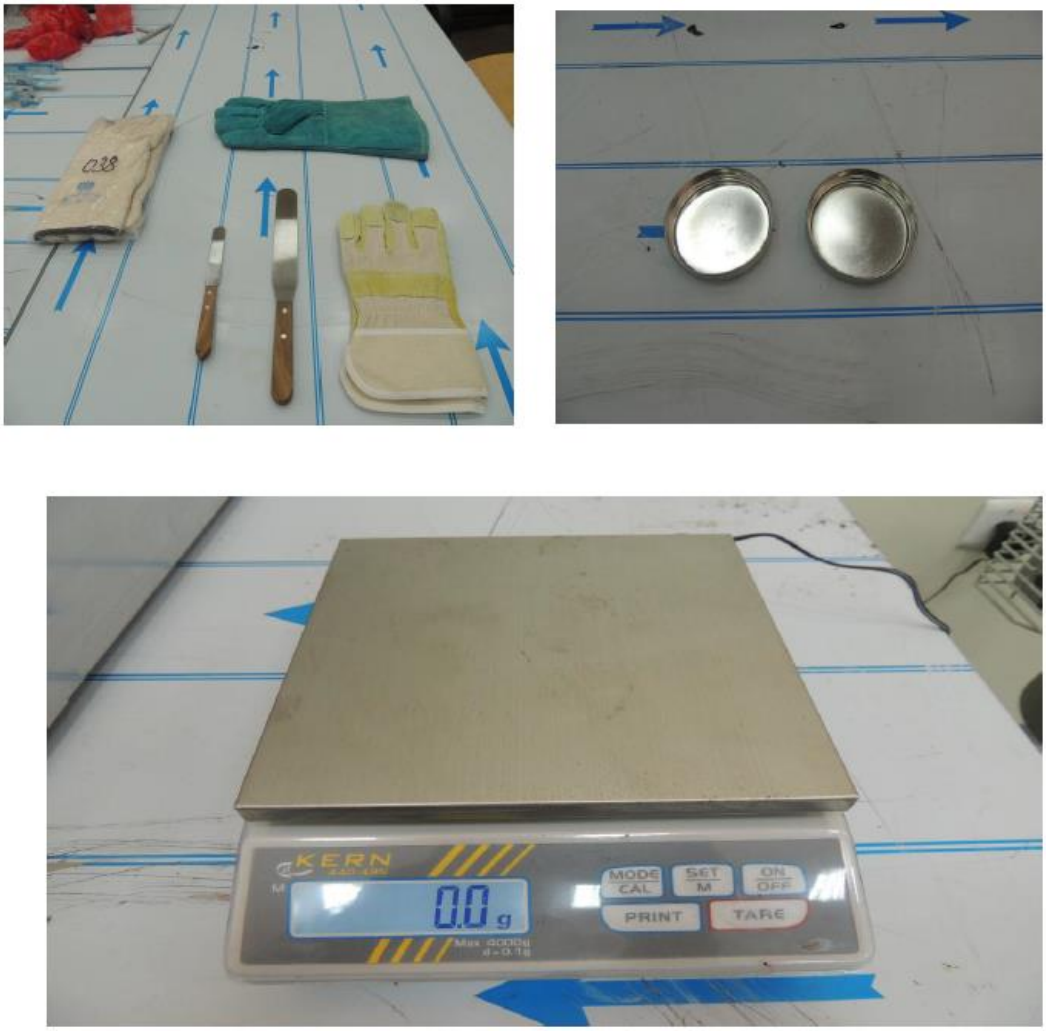


Fig 1.1: Weighing balance, Moisture tins, Gloves and Spatula

Fig 1.2: Drying oven (Temperature control at 110 ±5 °C)

Precautions

1. If it is not possible to place the container carrying wet soil sample in drying oven immediately, cover the container with led
2. If it is suspected that gypsum is present in the soil, the soil sample should not be subjected to a temperature beyond 60^0C. Otherwise gypsum will lose its water of crystallization affecting thereby the results of moisture content. Oven drying at 60^0C may, however, be continued for longer time in order to ensure complete evaporation of free water present in the sample.

Observations and Calculations

$$\omega = \frac{Ww}{Ws} X100 = \frac{W2-W3}{W3-W1} \text{X } 100$$

Where;

W_1 = Weight of tin = (g)

W_2 = Weight of moist soil + tin = (g)

W_3 = Weight of dried soil + tin = (g)

Can No.				
Wt. of wet soil + can (g) W2				
Wt. of dry soil + can (g) W3				
Wt. of can (g) W1				
Wt. of dry soil (g)				
Wt. of moisture (g)				
Water content (%)				
Depth (m)				

Moisture Content, ω =

Reference

ASTM D2216-98

Standard test method for laboratory determination of water (moisture) content of soil and rock by mass.

Comments

Moisture Content Determination by Speedy Moisture Meter

Objective

To determine the moisture content of a soil sample by speedy moisture meter.

Theory

The speedy moisture meter provides a quick, simple means of determining the moisture content of soil. It is particularly useful for field determination of moisture contents in conjunction with the field compacting testing. The speedy moisture meter is also known as calcium carbide gas moisture tester.

The basic principle behind this method is that the free moisture in the soil reacts with calcium carbide reagent to form a gas called acetylene gas eq.1. This gas exerts a pressure on the internal side of the walls of speedy moisture meter which is reflected by a pressure dial. The pressure dial is calibrated in such a way that pressure reading reflects the percent moisture by wet weight of soil directly.

The reaction which takes place inside the speedy moisture meter is as follows;

$$CaC_2 + H_2O \rightarrow CaO + C_2H_2 \quad \text{---------- (1)}$$

Since the moisture content by definition is expressed as a percentage of dry weight of soil, eq. 2. Readings obtained by speedy moisture meter are corrected using following expression;

$$\omega = \frac{\omega_{sp}}{1 - \omega_{sp}} \times 100 \quad \text{---------- (2)}$$

where

ω = Moisture content in percentage of dry weight of soil

ωsp= Moisture content as obtained by speedy moisture meter expressed as decimal fraction

Apparatus

1. Speedy moisture meter
2. Calcium carbide reagent
3. Two 1.25 inch steel balls
4. Cleaning brush and cloth
5. Scope for measuring calcium carbide reagent

Procedure

1. Weight approximately 6 g of wet soil sample on the tarred scale, and place it in the cap of the tester
2. Place three scoops of calcium carbide and two inch steel balls in the large chamber of the moisture tester Fig. 1.3
3. With the pressure vessel in an approximate horizontal position, insert the cap in the pressure vessel and seal it by tightening the clamp
4. Raise the moisture tester to a vertical position so that the soil in the cap falls into the pressure vessel
5. Shake the instrument vigorously so that all lumps are broken up to permit the calcium carbide to react with all available free moisture. The instrument should be shaken with a rotating motion so that the steel balls do not damage the instrument or cause soil particles to become embedded in the orifice leading to pressure diaphragm
6. When the needle stops moving, record the dial reading while holding the instrument in a horizontal position at eye level.
7. With the cap of the instrument pointed away from the operator, slowly release the gas pressure. Empty the pressure vessel and examine the material for lumps. If the sample is not completely pulverized, the test should be repeated using a new wet soil sample.
8. Apply correction to the dial reading to convert the moisture content in terms of dry weight of soil

Fig 1.3: Speedy moisture meter

Limitation

The speedy moisture meter can determine the moisture content only up to 20 percent. If the moisture content of the sample exceeds the limit of the pressure gauge, one half size samples must be used and dial gauge reading must be doubled.

Precautions

1. Care should be taken that no calcium carbide comes in contact with the soil until a complete seal is achieved
2. Shake the instrument by rotating the instrument in horizontal plane so that moisture tester is not damaged during shaking
3. After completion of test, slowly release the gas pressure pointing the instrument away from operator

Observations and Calculations

$$\omega = \frac{\omega_{sp}}{1 - \omega_{sp}} \times 100$$

Moisture Content, ω =

Sample no.				
ω_{sp}				
ω				

Comments

Chapter-2 SPECIFIC GRAVITY

Specific Gravity Determination

Objective

To familiarize the students with general method of obtaining the specific gravity of a mass of any type or material composed of small particles (especially soil)

Theory

A value of specific gravity is necessary to compute the void ratio of a soil, it is used in the hydrometer analysis, and it is useful to predict the unit weight of a soil. Occasionally, the specific gravity may be useful in soil mineral classification; e.g., iron minerals have large value of specific gravity than silica's.

The specific gravity of any substance is defined as the unit weight of the material divided by the unit weight of distilled water at 4^0C. Thus specific gravity of soil can be found as;

$$G_s = \frac{\gamma_{soil}}{\gamma_{water}}$$

As long as equal volume of water and soil are involved, the above stated form can be simplified as;

$$G_s = \frac{W_{soil}/V}{W_{water}/V}$$

Strictly speaking above mentioned equation is only valid if we do not consider any density change with temperature. However, a slight increase in precision to account for temperature effects on the density of water can be obtained by rewriting above stated equation as;

$$G_s = \frac{W_{soil}}{W_{water}} \times \alpha$$

Where α is the ratio of the unit weight of water at temperature T of the test and at 4^0. The value of Gs obtained at temperature T (which will be too large if T > 4^0C) is appropriately reduced.

$$\alpha = \frac{\gamma_T}{\gamma_{4^0C}}$$

Apparatus

1. Pycnometer
2. Weighing balance (Least count of 0.01 g)
3. Thermometer
4. Hot plate or Bunsen burner
5. Funnel
6. Drying oven
7. Paper towel

Procedure

1. Weigh the dry pycnometer to nearest 0.01 g and record it as W_1
2. Take about 100 g of oven dried soil and put it into the flask. Weigh the flask and dry soil to the nearest 0.01 g. Record this weight as W_2
3. Add water in the Pycnometer, Fig. 2.1 until it is about two-third full. In order to remove the entrapped air from soil and water, heat the mixture at least 2h after soil –water mixture comes to a full boil. Use only enough heat to keep the slurry boiling. Agitate the slurry as necessary to prevent any soil from sticking to or drying on to the glass above the slurry surface
4. Allow the mixture to cool, and then fill the flask with distilled water to above the calibration mark
5. Place the stopper in the bottle while removing the excess water. Be sure the entire exterior of the flask is dry. Weigh the flask to the nearest 0.01 g and record this weight as W_3
6. Empty the flask, wash it thoroughly and fill it completely with water. Dry the exterior of the flask. Weigh the flask and record it as W_4
7. Repeat the procedure three times
8. Record the temperature of soil water mixture

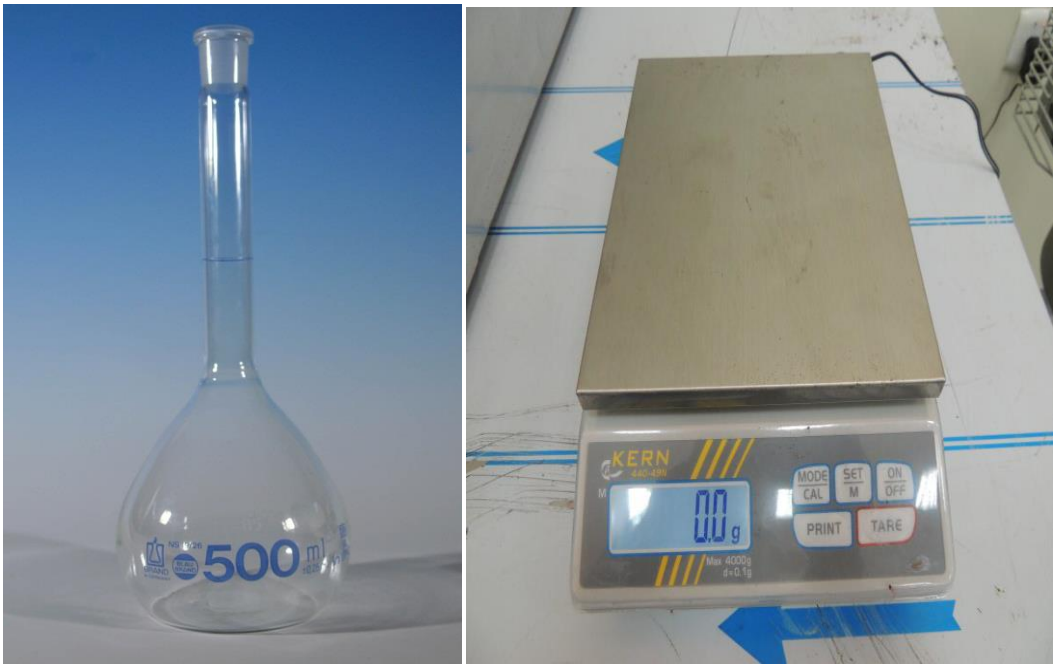


Fig 2.1: Pycnometer and Weighing balance

$$Gs = \frac{(W_2 - W_1)\alpha}{[(W_4 - W_1) - (W_3 - W_2)]}$$

Precautions

1. Make sure no air is entrapped within the soil water mixture
2. Weights should be obtained from a properly balanced weighing scale

Observations and Calculations

Test no.	1	2	3
Volume of flask			
W1 (g)			
W2 (g)			
W3 (g)			
W4 (g)			
α (Table 1)			
Gs			

Table 1. Typical values of correction factor, α;

T (^{0}C)	Correction Factor, α
4	1.0000
15	0.9999
20	0.9982
25	0.9971
30	0.9957
35	0.9941

Reference

ASTM D854-02
Standard test method for specific gravity of soil solids by water pycnometer

Comments

Chapter- 3 GRAIN SIZE ANALYSIS

Particle Size Analysis (Mechanical Analysis)

Objective

To introduce the students to the method of making a mechanical grain size analysis of a soil and presenting the resulting data

Theory

Grain size analysis is very important in the determination of engineering properties of soil e.g. suitability criteria of soils (for road, airfield, levee, dam and foundation material), soil water movement, susceptibility to frost action etc.

The grain size analysis is the attempt to determine the relative proportions of the different grain sizes which make up soil mass. For this, sample should be statically representative of the soil mass.

By carrying out mechanical analysis, particle sizes and their relative distribution can be done for the particle greater than 0.075 mm. the mechanical analysis is carried out by stacking the sieves, one on top of the other, pouring a known weight of soil into the top sieve on the stack, and shaking the sieve in a certain manner to allow the soil to fall down through the stack.

The stack of sieves is known as nest of sieves. The nest is arranged with the largest screen openings (smallest sieve number) on top, progressing to the sieve with the smallest screen opening (largest sieve number) on the bottom of the nest. A lid is placed on the top of the nest and pan is placed below the bottom sieve to catch any soil that passes through the smallest opening. The number or size of the sieves used in the nest depends on the type of the soil and the distribution of the particle sizes. Generally sieve No. 4, 10, 40, 100, 200 are used for classifying the soil.

Apparatus

1. A set of sieves
2. Mechanical soil pulverizer
3. Weighing balance (least count 0.01 g)
4. Mechanical sieve shaker

Procedure

1. Obtain 500 g of soil sample which has already been pulverized by placing it on sieve no. 200 and then oven dried
2. Arrange a nest of sieves including sieves no. 4, 10, 40, 100, 200, Fig. 3.1.
3. Place the set of sieves in the mechanical sieve shaker and sieve it for 5 to 10 mint. Note that if the entire set of sieves does not fit into the shaker perform a hand shaking operation until the

top few sieves can be removed from the stack and then place the remainder of the stack in the mechanical shaker

4. Remove the nest of sieves from the shaker and obtained the weight of the material retained on each sieve. Sum these weights and compare with the actual weight taken. A loss of more than 2 % by the weight of the residual material is considered unsatisfactory and the test should be replaced
5. Compute the % retained on each sieve by dividing the weight retained on each sieve by the original sample weight
6. Compute the % passing by starting with 100 % and subtracting the cumulative % retained for that sieve

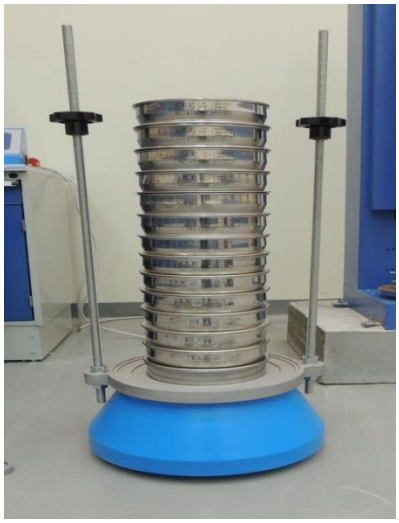


Fig 3.1: Set of sieves and mechanical sieve shaker

Observations and Calculations

Weight of sample = (g)

Sieve No. 1	Diameter (mm) 2	Weight of Soil Retained (g) 3	% Weight Retained 4	Cumulative Percent Retained (%) 5	Percent Passing (%) 6

Colum (5) = Colum (4) + Colum (5) of previous line

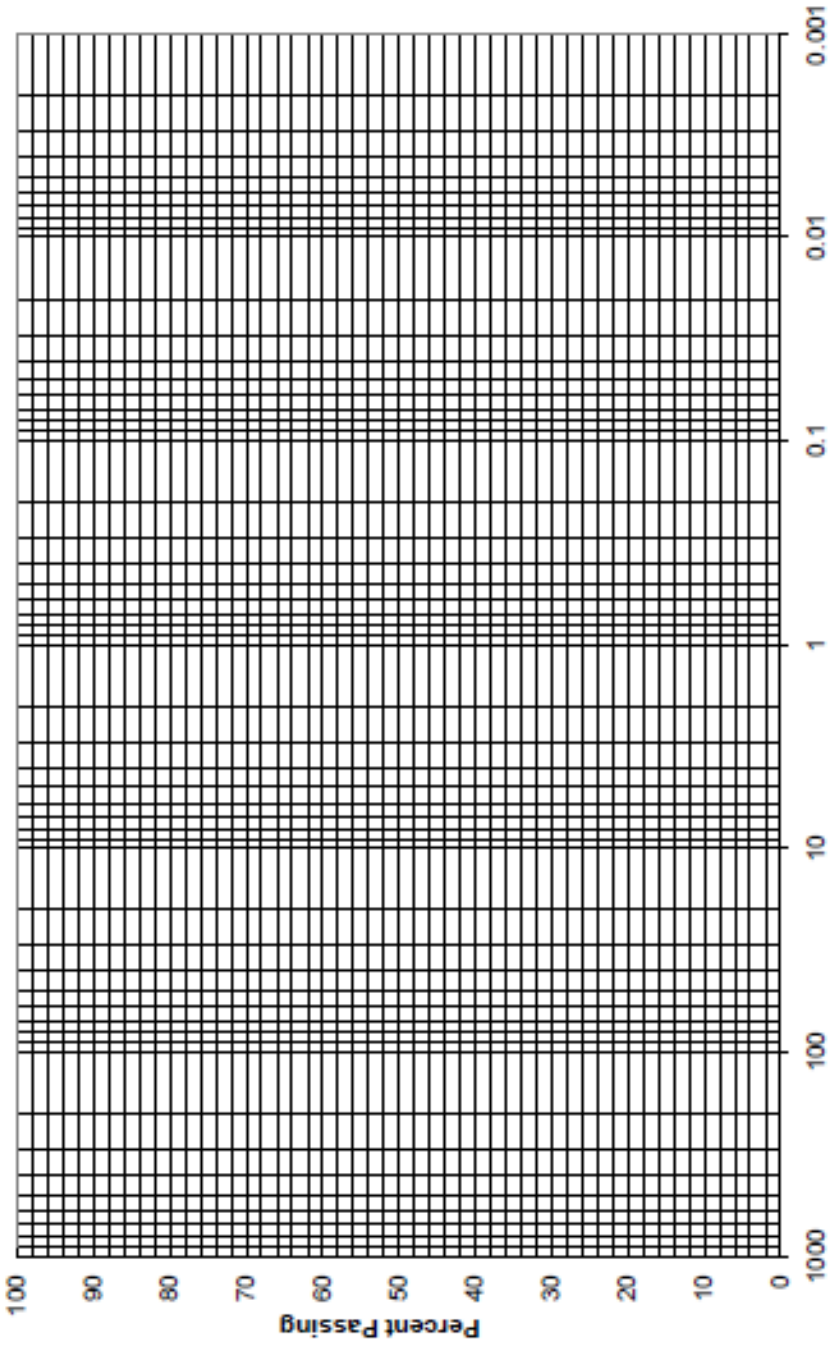
Colum (4) = (Colum (3)/ Total Weigh) × 100

Colum (6) = 100 - Colum (5)

D10= D30= D60=

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

$$\boldsymbol{C_c = \frac{(D_{30})^2}{(D_{10}) \times (D_{60})} =}$$



Note: You can plot your data on this graph or generate similar graph using any graphics program (e.g., excel)

Precautions

1) Particles that appear to be stuck in the sieve screen should never be forced on through the mesh. There are two reasons for not doing this
    - The particles would have passed the screen on their own had they been smaller than the mesh opening. Forcing these particles through the screen to be retained on the next size would distort the grain size results
    - Secondly forcing the particles through the mesh can damage the screen and necessitate its replacement

Particles caught in the screen should be removed by brushing with the proper sieve brush. Brushing should be done from the undesired of the screen in order that the particles can be brushed out of the screen in the direction from which it entered in the screen opening. Stubborn (obstinate) particles that cannot be removed by rushing should be left in place.

2) Lumps of soil must have broken down into their individual particles in order for the grain size analysis to be valid. This is accomplished in two ways. The first is to break up lumps with a rubber-tipped pestle in ceramic mortar. It has been found that the rubber-tipped pestles will not grind or crush the individual particles while a ceramic or metal-tipped pestle will. The second is to wet-sieve the soil. Washing the particles that are retained on the No.200 sieve with water and this will accomplish two things.
    - It separates those small lumps that might not have been broken up with the rubber tipped pestle into individual particles
    - It washes the “Dust Size” particles and through the No.200 sieve
3) A 10 minute shaking period is suggested in procedure. A large sample is requires longer shaking. Similarly a sample comprising primarily of fine grained material will require a longer shaking period than a coarse grained sample of equal weight

Reference

ASTM D22
Standard test method for particle-size analysis of soils

Comments

Particle Size Analysis (Hydrometer Analysis)

Objective

The hydrometer method is used to approximate the particle size distribution for particles that passes sieve No.200. The hydrometer test is held as an extension to the sieve analysis to make us able to classify the soil.

Apparatus

1. Sedimentation cylinder (1,000 cu-cm cylinder) also termed a hydrometer jar
2. Hydrometer (152H)
3. Soil-dispersion device (malt mixer)
4. Dispersion agent (sodium hexametaphosphate $NaPO_3$), trade name calgon, or sodium silicate (Na_2Sio_3) also called water glass
5. thermometer

Procedure

1. Take the fine soil from the bottom pan of the sieve set, place it into a beaker, and add 125 mL of the dispersing agent (sodium hexametaphosphate (40 g/L)) solution. Stir the mixture until the soil is thoroughly wet. Let the soil soak for at least ten minutes.
2. While the soil is soaking, add 125mL of dispersing agent into the control cylinder and fill it with distilled water to the mark. Take the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction. This reading is called the zero correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1). Shake the control cylinder in such a way that the contents are mixed thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature respectively.
3. Transfer the soil slurry into a mixer by adding more distilled water, if necessary, until mixing cup is at least half full. Then mix the solution for a period of two minutes.
4. Immediately transfer the soil slurry into the empty sedimentation cylinder. Add distilled water up to the mark.
5. Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Then turn the cylinder upside down and back upright for a period of one minute. (The cylinder should be inverted approximately 30 times during the minute.)
6. Set the cylinder down and record the time. Remove the stopper from the cylinder. After an elapsed time of one minute and forty seconds, very slowly and carefully insert the hydrometer for the first reading. (Note: It should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing).
7. The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer is removed slowly and placed back into the control cylinder. Very gently spin it in control cylinder to remove any particles that may have adhered.
8. Take hydrometer readings after elapsed time of 2 and 5, 8, 15, 30, 60minutes and 24 hour

Hydrometer Analysis

1. Apply meniscus correction to the actual hydrometer reading
2. From Table 1, obtain the effective hydrometer depth L in cm (for meniscus corrected reading)
3. For known Gs of the soil (if not known, assume 2.65 for this purpose), obtain the value of K from Table 2
4. Calculate the equivalent particle diameter by using the following formula:

$$D = K\sqrt{\frac{L}{t}}$$

   Where t is in minutes, and D is given in mm.
5. Determine the temperature correction CT from Table 3.
6. Determine correction factor "a" from Table 4 using Gs.
7. Observations and Calculations Calculate corrected hydrometer reading as follows:
   Rc = RACTUAL - zero correction + CT
8. Calculate percent finer as follows:

$$P_A = \frac{R_c}{W_s} \times a \times 100$$

   Where WS is the weight of the soil sample (g)
9. Adjusted percent fines as follows:

$$P_A = \frac{F_{200}}{100} \times P$$

   F200 = % finer of #200 sieve as a percent
10. Plot the grain size curve D versus the adjusted percent finer on the semi logarithmic sheet.

Table 1. Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specific Sizes

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L (cm)	Actual Hydrometer Reading	Effective Depth, L (cm)	Actual Hydrometer Reading	Effective Depth, L (cm)
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5	36	10.4
1.006	14.7	6	15.3	37	10.2
1.007	14.4	7	15.2	38	10.1
1.008	14.2	8	15.0	39	9.9
1.009	13.9	9	14.8	40	9.7
1.010	13.7	10	14.7	41	9.6
1.011	13.4	11	14.5	42	9.4
1.012	13.1	12	14.3	43	9.2
1.013	12.9	13	14.2	44	9.1
1.014	12.6	14	14.0	45	8.9
1.015	12.3	15	13.8	46	8.8
1.016	12.1	16	13.7	47	8.6
1.017	11.8	17	13.5	48	8.4
1.018	11.5	18	13.3	49	8.3
1.019	11.3	19	13.2	50	8.1
1.020	11.0	20	13.0	51	7.9
1.021	10.7	21	12.9	52	7.8
1.022	10.5	22	12.7	53	7.6
1.023	10.2	23	12.5	54	7.4
1.024	10.0	24	12.4	55	7.3
1.025	9.7	25	12.2	56	7.1
1.026	9.4	26	12.0	57	7.0
1.027	9.2	27	11.9	58	6.8
1.028	8.9	28	11.7	59	6.6
1.029	8.6	29	11.5	60	6.5
1.030	8.4	30	11.4		
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				
1.039	5.9				

Table 2. Values of k for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.0394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01269	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

Table 3. Temperature Correction Factors C_T

Temperature ^0C	Factor C_T
15	1.10
16	-0.90
17	-0.70
18	-0.50
19	-0.30
20	0.00
21	+0.20
22	+0.40
23	+0.70
24	+1.00
25	+1.30
26	+1.65
27	+2.00
28	+2.50
29	+3.05
30	+3.80

Table 4 Correction Factors a for Unit Weight of Solids

Unit Weight of Soil Solids, (g/cm^3)	Correction factor a
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.04

Hydrometer Analysis

Observation and Calculations

Test Date: _____

Tested By: _____

Hydrometer Number (if known): _____

Specific Gravity of Solids: _____

Dispersing Agent: _____

Weight of Soil Sample: (g) _____

Zero Correction: _____

Meniscus Correction: _____

Observations and Calculations

Date					
Time					
Elapsed Time (min)					
Temp. (^{O}C)					
Actual Hydro. Rdg. Ra					
Hyd. Corr. for Meniscus					
L from Table 1					
K from Table 2					
D (mm)					
CT from Table 3					
a from Table 4					
a from Table 4					
% Finer P					
% Adjusted Finer PA					

Precautions

1. It is usual to leave the hydrometer in the soil suspension for the first 4 min. remove it and reinsert it each time for all additional readings. Little error will be caused if the hydrometer is left in the jar for all 4 of the readings as compensating errors of the fluid disturbance will tend to offset errors due to soil participating on the hydrometer bulb.
2. When placing the hydrometer in the soil suspension for a reading proceed slowly enough that it takes about 10 sec. for the operation (the insertion time should not exceed approximately 5 to 6 second)
3. Consistent readings indicate a uniform mixture of soil water suspension
4. Time beyond first 2 hr. of readings are approximate and are set to give reasonable spread of plotted points for the percent finer vs grain size (diameter) curve

Reference

ASTM D422
Standard test method for particle-size analysis of soils

Comments

Chapter-4 ATTERBERG LIMITS

Determination Atterberg's Limits
(Liquid Limit and Plastic Limit)

Objective
To introduce the students to the procedure for determining the liquid and plastic limit

Theory
The liquid and plastic limits are two of the five "limits" proposed by A. Atterberg, a Swedish agricultural scientist. These limits are;

1. **Cohesion Limit –** that moisture content at which soil crumbs just stick together
2. **Sticky Limit –** that moisture content at which soil just sticks to a metal surface such as spatula blade. This would have some significance to the agricultural engineer since it is related to soil sticking to the moldboard of a plow or disc in cultivating soil
3. **Shrinkage Limit –** that moisture content below which no further soil volume reduction (shrinkage) occurs
4. **Plastic Limit –** moisture content below which soil is non-plastic
5. **Liquid Limit –** moisture content below which the soil behaves as plastic material. At this moisture content, the soil is on the verge of becoming a viscous fluid

The liquid and plastic limits have been widely used all over the world, primarily for soil identification and classification. The shrinkage limit is useful in certain geographical areas where soil undergo large volume changes when going through wet and dry cycles. The cohesion and sticky limits are used very little worldwide.

Apparatus
1. Liquid limit device with Casagrande grooving tool (cuts a groove of size 2 mm wide at the bottom, 11 mm wide at the top and 8 mm high)
2. No.40 ASTM sieve
3. Water content equipment
4. Spatula
5. Glass plate
6. 1/8 inch diameter brass rod
7. containers

Procedure for Liquid Limit Determination

1. Pulverize a sufficient quantity of air-dried soil to obtain about 250 g of representative sample passing through No.40 sieve
2. Adjust the height of fall of the liquid limit device to exactly 1 cm. Use the 1 cm calibration block at the end of the grooving tool for making this adjustment
3. Place about 250 g of soil in a glass plate, (or container). Add distilled water very slowly and using spatula mix the soil thoroughly until it becomes a thick, homogeneous paste. Be careful not to add too much water. Add approximately that much water in the soil to make it such consistent that a blow count of 30 to 40 blows to close the standard groove of ½ inch is obtained.
4. Place a portion of the soil paste in the brass cup, Fig. 4.1, of liquid limit device and by means of spatula, level and smooth the surface of soil.
5. Cut a clean, straight groove in the soil by drawing the grooving tool along the diameter through center of the hinge which separates the soil into two parts.
6. Turn the crank of the liquid limit device at the rate of two revolutions per second and count the number of blows (drops) until two parts of the soil come into contact at the bottom of the groove along a distance ½ inch.
7. Take about 20-40 g of sample of soil from the closed part of the groove for subsequent water content determination and put it in a pre-weighted moisture content container. Remove the remaining soil from the brass cup and return it to the container. Wash and dry the cup.
8. Repeat steps 4, 5, 6 and 7 at least four times using the same soil samples to which further small increments of distilled water have been added. The amount of water added must be such that the blows (drops) count range between 10 and 50
9. The test should always proceed from the drier to the wetter conditions. If it should occur that too much water was added to the soil must never be dried by adding additional dry soil. The proper procedure is to thinly spread the wet soil on the glass plate and let it air dry to the desired consistency. Continuous mixing and fanning of wet soil is permitted to expedite the drying process
10. Weight the moisture containers and place them in the oven to dry overnight
11. The U.S army Corps of Engineers found from an investigation conducted with 767 liquid limit determinations that the liquid limit of soil could be reliably obtained by conducting only one trial and using the following correlation equation;

$$L.L = W_n(N/25)^{0.121}$$

N = Number of blows required to close the standard groove for distance of ½ inch

W_n= moisture content of the soil which closed after N blows

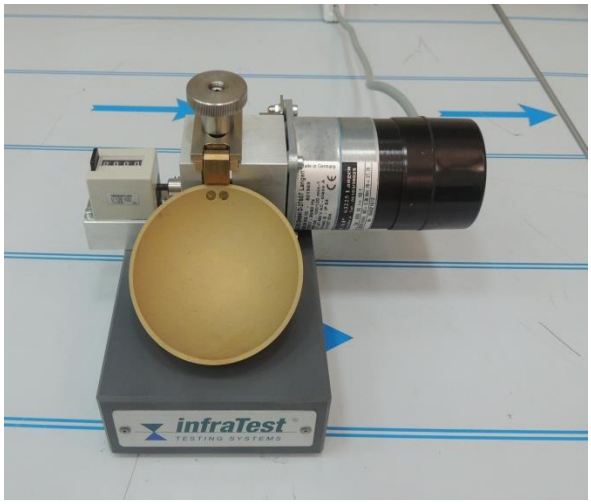


Fig 4.1: Casagrande apparatus

Observations and Calculations

Can No.	1	2	3	4
Wt. of wet soil + can (g)				
Wt. of dry soil + can (g)				
Wt. of can (g)				
Wt. of dry soil (g)				
Wt. of moisture (g)				
Water content %				
No. of blows				

Procedure for Plastic Limit Determination

1. Take about 20 g of air dried soil from the thoroughly mixed portion of the material passing No.40 sieve. Mix it on the glass plate with sufficient distilled water to make it plastic enough to be shaped into a ball. Leave the plastic soil mass for some time to mature
2. Take about 8 g of the plastic soil, make a ball of it, and roll it between the fingers and glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length, Fig. 4.2. When the diameter of the thread has decreased to 1/8 inch. The specimen is kneaded together and rolled out again. Continue the process until the thread just crumbled at 1/8 inch diameter, Fig. 4.3.
3. Collect the crumbled soil thread in the container for water content determination

4. Repeat the test for three to four times and take average value of these readings

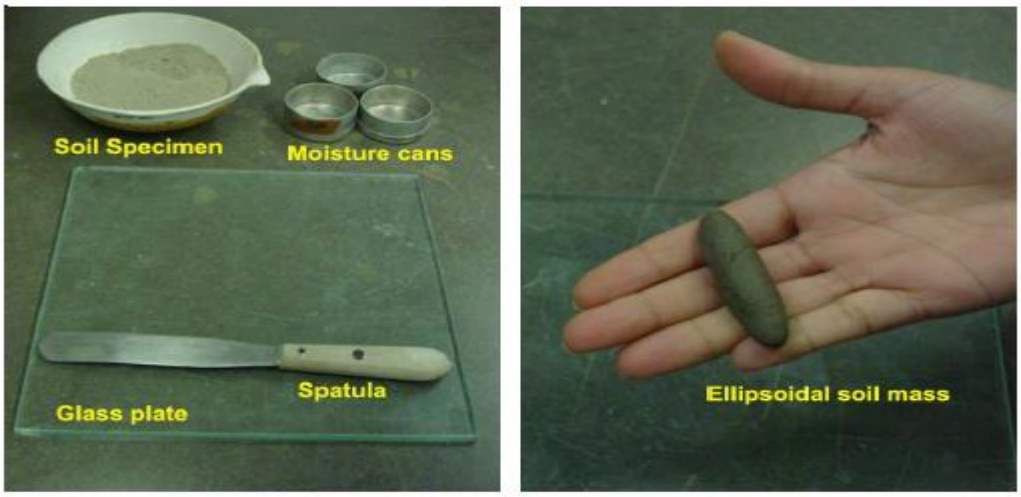


Fig 4.2: Spatula, glass plate cans and ellipsoidal soil sample

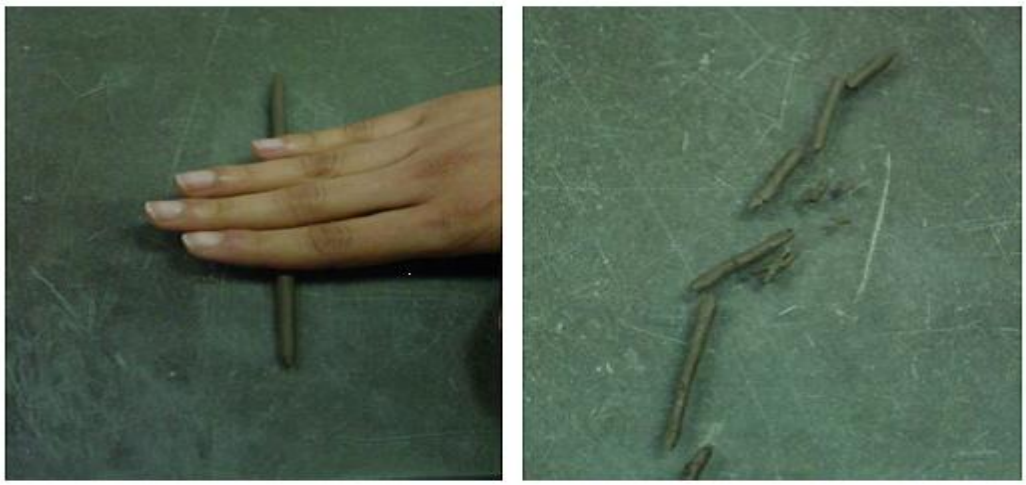


Fig 4.3: Plastic Limit Determination

Observations and Calculations

Can No.	1	2	3	4
Wt. of wet soil + can (g)				
Wt. of dry soil + can (g)				
Wt. of can (g)				
Wt. of dry soil (g)				
Wt. of moisture (g)				
Water content %				

Precautions

Make sure that the liquid limit test should always proceed from the drier to the wetter conditions. Otherwise, drying of soil sample may cause wastage of time.

Reference

ASTM D4318

Standard test method for liquid limit, plastic limit and plasticity index of soils.

Comments

Chapter-5 FIELD DETERMINATION OF DENSITY

Core-Cutter Method

Objective

Core cutter is used for finding field density of cohesive/clayey soils placed as fill. It is a rapid method conducted in the field. It cannot be applied to coarse grained soil as the penetration of core cutter becomes difficult due to increased resistance at the tip of core cutter leading to damage to core cutter

Apparatus

1. Cylindrical core cutter of seamless steep tube, 130 mm long and 10 cm internal diameter with wall thickness of 3mm, beveled at one end; giving a volume of 1000 cm^3.
2. Steel dolly, 2.5 cm high and 10 cm internal diameter with wall thickness of 7.5 mm with a lip to enable it to be fitted on top of the core cutter.
3. Steel rammer with solid mild steel foot 14 cm diameter and 7.5 cm height with a concentrically screwed 2.5 cm diameter solid mild steel staff.
4. Balance
5. Palette knife having blade approximately 20 cm long and 3 cm wide.
6. Steel ruler.
7. Container for determination of water content

Procedure

1. Calculate internal volume of the core cutter.
2. Weigh the empty core cutter and record its weight.
3. Apply oil on inner surface of the core cutter.
4. Place the core cutter on a freshly prepared plain ground with dolly on it; and gently hammer it so that the cutter will get pushed in the soil completely.
5. Remove the side material and take out the filled up core cutter gently and properly trim the top and bottom surfaces and weigh it.
6. Remove soil from the core cutter and preserve a representative sample in an air tight container to determine water content.

Observations and Calculations

Dry Density Determination:

a) Determination of bulk and dry density of soil

Determination No.	**1**	**2**	**3**
Mass of empty core cutter, M_1 (g)			
Mass of core cutter + wet soil, M_2 (g)			
Mass of wet soil, (M_2-M_1) (g)			
Volume of core cutter ,V, (cm^3)			
Bulk Density $\rho_b = \frac{M_2 - M_1}{V}$ (g/cm^3)			
Dry density of soil $\rho_d = \frac{\rho_b}{1+w}$ (g/cm^3)			

b) Determination of water content of soil

Container No.	**1**	**2**	**3**
Mass of empty container with lid, M_1 , (g)			
Mass of container with lid and wet soil, M_2 ,(g)			
Mass of container with lid and dry soil, M_3, (g)			
Water content, $w = \frac{M_w}{M_d} = \frac{M_2 - M_3}{M_3 - M_1} \times 100\,(\%)$			

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Sand Replacement Method

Objective

These test methods are used to determine the in-place density of compacted materials in construction of earth embankments, road fills, and structure backfill. For construction control, these test methods are often used as the basis for acceptance of material compacted to a specified density or to a percentage of a maximum unit weight determined by a standard laboratory test method. This test method covers determination of the in-place density and unit weight of soil using a pouring device and calibrated sand to determine the volume of a test pit.

Apparatus

1. Sand-Cone Density Apparatus—It consists of a capacity cylinder with attached one separated by a shutter and base plate.
2. Cylindrical calibrating container
3. Metal Template—A square or circular template to serve as a pattern for the excavation.
4. Balance—A balance accurate to 0.01 g.
5. Drying Oven— thermostatically controlled oven, capable of maintaining a uniform temperature of 110 + 5°C throughout the drying chamber.
6. Tools for excavating hole.
7. Sieve—No. 4 (4.75 mm) conforming to the requirements of Specification E 11.
8. Sand—the sand must be clean, dry, uniform, un cemented, durable and free flowing. The maximum particle size may be No. 4 (4.75 mm) sieve

Procedure

(I) Calibration of the cylinder:

1. Measure the internal dimensions of the calibrating container and find its volume.
2. Fill the clean uniformly graded standard sand in the sand pouring cylinder up to a height of 1cm below the top with the shutter closed. Find out initial mass of the sand, (M0). This mass should be maintained constant throughout the test for which the calibration is used.
3. Allow the sand of volume equal to that of the calibrating container to run out of the cylinder by opening the shutter. Close the shutter.

4. Place the sand cone-pouring cylinder on a paper placed on a horizontal table. Open the shutter again and allow the sand to flow and fill the cone.
5. Close the shutter. Find the mass of sand on paper, (M1)
6. Repeat steps 2-4 at least thrice and fine the mean mass, (M1).

(II) Determination of bulk density of sand:

7. Place the sand-pouring cylinder concentrically on the top of the calibrating container with the shutter closed making sure that constant mass (M0) is maintained.
8. Open the shutter of cylinder and allow the sand to move into the container. When no further movement is seen, close the shutter and find the mass of sand left in the cylinder, (M2).
9. Repeat steps 2-3 at least thrice and fine the mean mass (M2).

(III) Determination of field density of soil

10. Level surface of the soil in the open field.
11. Place metal tray on the surface having a circular hole at the center. Dig a hole of the same diameter up to about 15 cm depth. Collect all the excavated soil in a tray and find the mass of excavated soil, (M).
12. Remove the tray and place the sand–pouring cylinder concentrically on the hole. Open the shutter and allow the sand to run into the hole till no further movement of sand is noticed. Close the shutter and determine mass of sand which is left in the cylinder, (M3).
13. The representative sample is taken from the excavated soil for determination of water content.

Observations and Calculations

Dry Density Determination:

A) Determination of Mass of sand in the cone

1. Volume of calibrating container, V_c, (ml)			
2. Mass of sand in cylinder before pouring, M_0, (g)			
3. Mean mass of sand in cone , M_1, (g)			

B) *Determination of bulk density of sand*

1. Mean mass of sand left in cylinder after pouring, M_2, (g)			
2. Mass of sand filling calibrating container, $M_C = M_0-M_1-M_2$ (g)			
3.Bulk density of sand ρ_s = M_C/ V_C (g/cm^3)			

C) Bulk density and unit weight of soil

1. Mass of wet soil from the hole (M)			
2. Mass of sand in cylinder after pouring in the hole, M_3, (g)			
3. Mass of sand in the hole, $M_S = M_1 - M_3$ (g)			
4. Bulk density of soil, $\rho = \frac{M}{M_S} \times \rho_S$ (g/cm^3)			
5. Dry density of soil, $\rho_d = \frac{\rho}{1+w}$			

D) *Determination of water content soil*

Container No.	1	2	3
Mass of empty container with lid, m_1, (g)			
Mass of container with lid and wet soil, m_2, (g)			
Mass of container with lid and dry soil, m_3, (g)			
Mass of dry soil, $m_d = m_3-m_1$, (g)			
Mass of water, $m_w = m_2-m_3$, (g)			
Water content, w = $\frac{m_w}{m_d} = \frac{m_2 - m_3}{m_3 - m_1} \times 100$ (%)			

Reference

ASTM D1556-00

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Chapter-6 COMPACTION

Standard AASHTO Method

Objective

Determination of the relationship between water content and dry density of soil using Standard Proctor Test

Need and Scope of the Experiment

It is required to compact the in-situ soil to produce a strong, settlement free, water-resistant mass. This test serves as a guide and a basis of comparison for field compaction.

These test methods covers laboratory compaction methods used to determine the relationship between water content and dry unit weight of soils (compaction curve) compacted in a 4 or 6-in. (101.6 or 152.4-mm) diameter mold with a 5.5-lbf (24.4-N) rammer dropped from a height of 12 in. (305 mm) producing a compacting effort of 12,400 ft-lbf/ft^3 (600 kN-m/m^3).

Theory

Dry density of soil (or dry unit weight) is defined as the weight of oven dry soil per unit volume of soil mass. Water content (or moisture content) is expressed as percentage of weight of water in a given soil mass to the weight of solid particles under a specified testing condition. Optimum water content is the water content of which a soil can be compacted to the maximum dry unit weight by a given compacting effort.

Apparatus

1. Proctor mould with a detachable collar assembly and base plate.
2. Manual rammer weighing 2.5 kg and equipped to provide a height of drop to a free fall of 30 cm.
3. Sample Extruder.
4. A balance accurate to 0.01 g.
5. Straight edge.
6. Squeeze bottle
7. Mixing tools such as mixing pan, spoon, trowel, spatula etc.
8. Moisture cans.
9. Thermostatically controlled oven, capable of maintaining a uniform temperature of 110 $\pm$ 5°C throughout the drying chamber.

Fig 6.1: Proctor mould and Manual rammer

Procedure

1. Obtain approximately 10 lb. (4.5 kg) of air-dried soil in the mixing pan, break all the lumps so that it passes No. 4 sieve.
2. Add approximate amount of water to increase the moisture content by about 5%.
3. Determine the weight of empty proctor mould without the base plate and the collar. M_4 (g).
4. Fix the collar and base plate.
5. Place the first portion of the soil in the Proctor mould, Fig. 6.1 as explained in the class and compact the layer applying 25 blows.
6. Scratch the layer with a spatula forming a grid to ensure uniformity in distribution of compaction energy to the subsequent layer. Place the second layer, apply 25 blows, place the last portion and apply 25 blows.
7. The final layer should ensure that the compacted soil is just above the rim of the compaction mould when the collar is still attached.
8. Detach the collar carefully without disturbing the compacted soil inside the mould and using a straight edge trim the excess soil leveling to the mould.
9. Determine the weight of the mould with the moist soil M_5 (g). Extrude the sample and break it to collect the sample for water content determination preferably from the middle of the specimen.
10. Weigh an empty moisture can, M_1 (g) and weigh again with the moist soil obtained from the extruded sample in step9, M_2 (g). Keep this can in the oven for water content determination.

11. Break the rest of the compacted soil with hand (visually ensure that it passes US Sieve No.4). Add more water to increase the moisture content by 2%.
12. Repeat steps 4 to 11. During this process the weight W_2 increases for some time with the increase in moisture and drops suddenly. Take two moisture increments after the weights starts reducing. Obtain at least 4 points to plot the dry unit weight, moisture content variation.
13. After 24 hrs. recover the sample in the oven and determine the weight M_3 (g).

Observations and Calculations

Compaction Test

Diameter of mould D =_____ (cm)

Height of mould H =_____ (cm)

Volume of mould V =_____ (cm)

	1	2	3
Moisture can number			
Mass of moisture can, M_1, (g)			
Mass of can + moist soil, M_2, (g)			
Mass of can + dry soil, M_3, (g)			
Moisture content: $w(\%)= [(M_2-M_3)/(M_3-M_1)] \times 100$			
Mass of the mold without the base and collar, M_4, (g)			
Mass of the mold + moist soil, M_5(g)			
Mass of the compacted soil, $M=M_5-M_4$, (g)			
Wet Density, $\gamma = [(M_5-M_4)/V]$, (kN/m^3)			
Dry unit weight of compaction: γ_d (lb/ft^3) = $\gamma/[1+(w/100)]$			

Graph

Determine optimum water content and the corresponding maximum dry density of soil by drawing a graph between water content at X-axis and dry density at Y-axis.

Reference

ASTM D698-00

Comments

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Modified AASHTO Method

Objective

Determination of the relationship between water content and dry density of soil using Modified Proctor Test

Need and Scope of the Experiment

Soil placed as engineering fill (embankments, foundation pads, road bases) is compacted to a dense state to obtain satisfactory engineering properties such as, shear strength, compressibility, or permeability. Also, foundation soils are often compacted to improve their engineering properties. Laboratory compaction tests provide the basis for determining the percent compaction and water content needed to achieve the required engineering properties, and for controlling construction to assure that the required compaction and water contents are achieved.

These test methods cover laboratory compaction methods used to determine the relationship between water content and dry unit weight of soils (compaction curve) compacted in a 4- or 6-in. (101.6 or 152.4 mm) diameter mold with a 10-lbf. (44.5-N) rammer dropped from a height of 18 in. (457 mm) producing a compacting effort of 56,000 ft-lbf/ft^3 (2,700 kN-m/m^3).

Theory

Apparatus

1. Proctor mold with a detachable collar assembly and base plate.
2. Manual rammer weighing 4.5 kg and equipped to provide a height of drop to a free fall of 45.7 cm.
3. Sample Extruder.
4. A balance accurate to 0.01 g.
5. Straight edge.
6. Squeeze bottle
7. Mixing tools such as mixing pan, spoon, trowel, spatula etc.
8. Moisture cans.
9. Thermostatically controlled oven, capable of maintaining a uniform temperature of 110 $\pm$ 5°C throughout the drying chamber.

Procedure

1. Obtain approximately 10 lb. (4.5 kg) of air-dried soil in the mixing pan, break all the lumps so that it passes No. 4 sieve.
1. Add approximate amount of water to increase the moisture content by about 5%.
2. Determine the weight of empty proctor mold without the base plate and the collar. M_4 (g).
3. Fix the collar and base plate.
4. Place the first portion of the soil in the Proctor mold as explained in the class and compact the layer applying 25 blows.
5. Scratch the layer with a spatula forming a grid to ensure uniformity in distribution of compaction energy to the subsequent layer. Place the second layer, apply 25 blows, place the last portion and apply 25 blows.
6. The final layer should ensure that the compacted soil is just above the rim of the compaction mold when the collar is still attached.
7. Detach the collar carefully without disturbing the compacted soil inside the mold and using a straight edge trim the excess soil leveling to the mold.
8. Determine the weight of the mold with the moist soil M_5 (g). Extrude the sample and break it to collect the sample for water content determination preferably from the middle of the specimen.
9. Weigh an empty moisture can, M_1 (g) and weigh again with the moist soil obtained from the extruded sample in step9, M_2 (g). Keep this can in the oven for water content determination.
10. Break the rest of the compacted soil with hand (visually ensure that it passes US Sieve No.4). Add more water to increase the moisture content by 2%.
11. Repeat steps 4 to 11. During this process the weight W_2 increases for some time with the increase in moisture and drops suddenly. Take two moisture increments after the weights starts reducing. Obtain at least 4 points to plot the dry unit weight, moisture content variation.
12. After 24 hrs recover the sample in the oven and determine the weight M_3 (g).

Observations and Calculations

Compaction Test

Diameter of mold D =_____ (cm)

Height of mold H =_____ (cm)

Volume of mold V =_____ (cm)

Observations and Calculations

No.	1	2	3
Moisture can number			
Mass of moisture can, M_1, (g)			
Mass of can + moist soil, M_2, (g)			
Mass of can + dry soil, M_3, (g)			
Moisture content: $w(\%)= [(M_2-M_3)/(M_3-M_1)] \times 100$			
Mass of the mold without the base and collar, M_4, (g)			
Mass of the mold + moist soil, M_5(g)			
Mass of the compacted soil, $M=M_5-M_4$, (g)			
Wet Density, $\gamma = [(M_5-M_4)/V]$, (kN/m^3)			
Dry unit weight of compaction: γ_d (lb/ft^3) = $\gamma/[1+(w/100)]$			

Graph

Determine optimum water content and the corresponding maximum dry density of soil by drawing a graph between water content at X-axis and dry density at Y-axis

Reference

ASTM D1557-02

Comments

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Chapter-7 PERMEABILITY

Constant Head Permeameter
Variable Head Permeameter

Permeability refers to the porosity of a material to allow a fluid to move through its pores. In soil mechanics, permeability generally refers to the porosity of a soil to allow water to move through its void spaces.

Two general laboratory methods are available for determining the coefficient of permeability of a soil. There are constant head method and the falling head method. Both methods use Darcy's Law which is expressed as;

$$q = Ki\ A$$

Where

q = Quantity of fluid flow in a given time (vol/time)

K = Coefficient of permeability (length/time)

I = Hydraulic gradient

A = Cross-sectional area of soil mass

Neither the constant head nor the falling head laboratory method provided a reliable value for coefficient of permeability of a soil. Reasons for this are varied, but the major ones are as follow;

- The soil in the permeability device in never in the same state as in the field- it is always disturbed to some extent
- Orientation of the in situ stratum to the flow of water is probably not duplicated
- Boundary conditions are not the same in the laboratory. The smooth walls of the permeability mold make for better flow paths than if they were rough. If the soil is stratified vertically, the flow in the different strata will be different and this boundary condition may be impossible to duplicate
- The hydraulic head 'h' may be different (often much larger) in the laboratory, causing a wash-out of fine material to the boundary with a possible reduction of K
- The effect of entrapped air on the laboratory sample will be large even for small air bubbles since the sample is small

Fig 7.1: Permeability Apparatus

Constant Head Permeameter

Objective

To determine the co-efficient of permeability of a granular soil by constant head permeameter.

Apparatus

1. Constant head permeameter device or apparatus
2. Constant elevation reservoir with water supply
3. Thermometer (nearest to 1^0C or 1^0F)
4. 1000 ml beaker
5. Balance, sensitive to nearest 0.01 g
6. Mater stick
7. Plastic tubing
8. stopwatch

Procedure

1. Measure the inside diameter of the permeameter and record as D, Fig. 7.1.
2. Measure the length 'L' of the permeameter, between the centers of the two piezometric tubes
3. Calculate the volume of the specimen needed for length L
4. For the given bulk-density and moisture content calculate the weight of the soil needed for the volume in step 3
5. Place the specimen in the permeameter and allow water to flow through the sample for at least 10 min in order to saturate it. Longer periods are sometimes required to ensure complete saturation of the sample. Bubbles that appear (entrapped air) should be removed by tapping gently on the permeameter or using other means
6. When constant flow conditions have been achieved, measure the hydraulic head 'h' across the sample
7. Using a 500 or 1000 cu-cm container (preferably 1000 cu-cm), record the time 't' required to collect 1000 cu-cm of water. Repeat two or three additional times until two runs agree reasonably well
8. Measure and record the temperature of the test water as T^0C
9. Compute the K value at test temperature, also compute K_{20} (co-efficient of permeability at 20^0C)

Observations and Calculations

Internal

Dia. of the permeameter , D = (cm)
Area of the specimen, $A= (\pi/4)D^2$ (cm^2)
Bulk-density of the soil, γ_b= (gm/cm^3)
Dry density of the soil, γ_d= (gm/cm^3)

Length of specimen, L= (cm)
Volume of the specimen, V= AxL = (cm^3)
Natural moisture content of the soil, w = (%)
Weight of the specimen needed for volume V = W= (gm)

Test No.	h_1 (cm)	h_2 (cm)	$h = h_1h_2$ (cm)	t (sec)	Vol. of water collected (V) (cm^3)	Q = V/ t Cm^3/sec	T (^0C)	K_T= Q.L/ A.h	$K_{20}= K_T (\eta T/\eta_{20})$

Variable Head Permeameter

Objective

To determine the coefficient of permeability of a fine-grained soil (such as fine sand, silt and clay) by falling head permeameter.

Apparatus

1. Falling head permeameter device or apparatus
2. Stand pipe or graduated device or apparatus
3. Plastic tubing
4. Thermometer (nearest to 1^0C to 1^0F)
5. Meter stick
6. Stop watch

Procedure

1. Measure the inside diameter of the specimen of the permeameter and record as D
2. Measure the length of the soil specimen and record as L
3. Weight the permeameter mold and record as W_1
4. Take undisturbed soil sample in the mold and record the weight of the mold with soil sample as W_2
5. Calculate the weight of the soil sample as $W_3 = (W_2-W_1)$
6. Attach the permeameter with the water supply and allow water to flow. This pretest flow period should be permitted to continue until the specimen is saturated
7. Once the soil is saturated close the stand pipe valve. Measure the height of the water in the stand pipe with respect to some convenient datum and record as 'h_1'
8. Open the stand valve and start the stopwatch simultaneously
9. After a reasonable period, or after a reasonable quantity of water has flowed out of the stand pipe, close the stand pipe valve and record the time as 't'. Measure the height to the stand pipe water level from the same datum used in step 7 and record as 'h_2'
10. Measure and record the water temperature as T^0C
11. Compute the K value at test temperature, also compute K_{20} (co-efficient of permeability at 20^0C)

Observations and Calculations

Variable Head:

Internal dia. of the mold, D, (cm)
Internal height of mold, L, (cm)
Int. area of the mold, A, $(\pi/4)\ D^2$ (cm)
Int. volume of mold, V, AxL, (cm^3)
Wt. of empty mold, W_1, (gm)
Wt. of empty mold + soil, W_2, (gm)

Wt. of soil sample, W_3, $\{W_2 - W_1\}$ (gm)
Dia. Of stand pipe, d, (cm)

Test no.	h_1 (cm)	h_2 (cm)	t (sec)	T (^{0}C)	$K_T = (2.3\ a.L / (A.t))\ Log\ (h_1/h_2)$ (cm/sec)	$K_{20} = K_T \eta_T / \eta_{20}$

Chapter-8 TRIAXIAL TEST

Triaxial Test

Scope of the test

The measurement of the effective shear strength parameters for cylindrical specimens of saturated soil which have been subjected to isotropic consolidation and then sheared in compression, under a constant confining pressure, by increasing the axial strain.

Apparatus

Fig 8.1: Triaxial Test Apparatus

The triaxial test apparatus consist of the following parts as shown in figures;

1- Triaxial cell

2- Upper Drainage Valve

3- Lower Drainage Valve

4- Cell pressure Control Valve

5- Proving ring

6- Pressure controller

7- Pressure Gauge

8- Bladder for air control

9- Bladder for water pressure control

Procedure

1- Place the triaxial cell Fig. 8.1 (with the specimen inside it) on the platform of the compression machine.

2- Make proper adjustments so that the piston of the triaxial cell just rests on the top platen of the specimen

3- Fill the chamber of the triaxial cell with water. Apply a hydrostatic pressure, σ3 to the specimen through the chamber fluid.

4- All drainage valves should be closed so that drainage from the specimen does not occur.

5- Check for proper contact between the piston and the top platen on the specimen. Zero the dial gauge of the proving ring and the gauge used for measurement of the vertical compression of the specimen. Set the compression machine for a strain rate of about 0.5% per minute, and tum the switch on.

6- Take initial proving ring dial readings for vertical compression intervals of 0.01 in. This interval can be increase to 0.02 in. or more later when the rate of increase of load on the specimen decreases. The proving ring readings will increase to a peak value and then may decrease or remain approximately constant. Take about four to five readings after the peak point.

7- After completion of the test, reverse the compression machine; lower the triaxial cell, and then tum off the machine. Release the chamber pressure and drain the water in the triaxial cell. Then remove the specimen and determine its moisture content.

Application

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

Calculations

Description of Soil._____ Specimen No. _____

Location. _____

Tested By._____ Date. _____

Table 1. Triaxial Test Preliminary Data

Serial No	Items	Quantity
1	**Moist mass of specimen (end of test), W1**	
2	**Dry mass of specimen, W2**	
3	**Moisture content (end of test), w (%)**	
4	**Initial average length of specimen, Lo**	
5	**Initial average diameter of specimen, Do**	
6	**Initial area, Ao**	
7	**Specific gravity of soil solids, Gs**	
8	**Final degree of saturation**	
9	**Cell confining pressure, σ_3**	

Table 2.Triaxial Test Axial Stress-Strain Calculation

Axial Deformation (ΔL)	Axial Load (P)	Axial Strain ($\varepsilon = \Delta L / L_o$)	Corrected Area ($A = A_o/(1-\varepsilon)$)	Deviator Stress ($\Delta\sigma = P/A$)

Chapter-9 CONSOLIDATION

CONSOLIDATION TEST

Objective

This test is performed to determine the magnitude and rate of volume decrease that a laterally confined soil specimen undergoes when subjected to different vertical pressures.

Need and Scope of the Experiment

The One-dimensional Consolidation test is used to determine the consolidation characteristics of soils of low permeability. Tests are carried out on specimens prepared from undisturbed samples. Data obtained from these tests, together with classification data and knowledge of the soils loading history, enables estimates to be made of the behavior of foundations under load.

Theory

All soils are compressible so deformation will occur whenever stress is applied to soils. Soil minerals and water are both incompressible. Therefore, when saturated soils are loaded, the load first acts on the pore water causing pore water pressures that are in excess of the hydrostatic pressures. The excess pore water pressures are largest near the application of load and decrease with distance from the loading. The variations in excess pore water pressure cause total head gradients in the soil which, according to Darcy's Law, will induce water to flow from locations of high total head to low total head. The excess pore water pressures dissipate as water flows from the soil and, to compensate for the applied stress, the stress is transferred to the soil minerals resulting in higher effective soil stress. The flow of water from the soil also causes reductions in the soil volume and settlements at the ground surface. Fine-grained soils have very low permeability so they can require substantial periods of time before the excess pore water pressures fully dissipate. This process of time-dependent settlement is referred to as consolidation. Terzaghi's theory for one-dimensional consolidation provided the means to calculate the total amount of consolidation settlement and the consolidation settlement rate. In practice, engineers obtain representative soil samples, conduct consolidation tests and use Terzaghi's consolidation theory to predict the total settlement and time rate of settlement for embankments and foundations.

Apparatus

- Consolidation device (including ring, porous stones, water reservoir, and load plate)
- Dial gauge (0.0001 inch = 1.0 on dial)
- Sample trimming device
- Glass plate
- Metal straight edge
- Clock
- Moisture can
- Filter paper

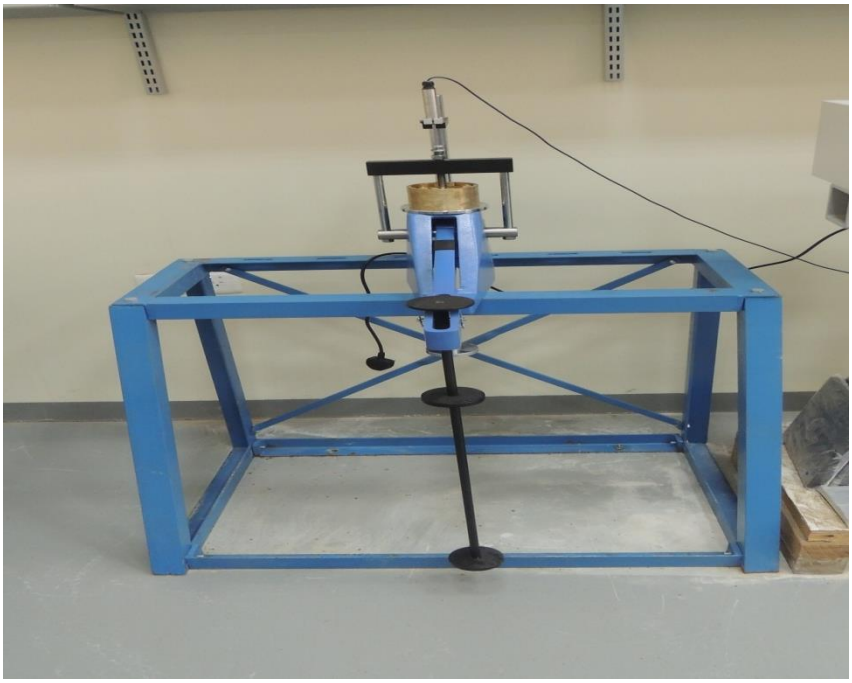

Fig 9.1: Consolidation Apparatus

Procedure

A. Sample Preparation (several days before test)

Moist fine-grained soil from the laboratory was placed in the consolidation ring and statically compacted using several layers. Excess soil from the top of the ring was carefully trimmed level with the top of the ring.

B. Test Preparation (several days before test)

1) The height, diameter and mass of the consolidation ring were measured, Fig. 9.1. The initial wet mass of the soil sample and ring and the height of the soil sample were measured. The trimmings were used for a water content determination.

2) The test specimen in the consolidation ring was placed in the consolidometer, Fig. 9.1 and the consolidometer was placed in the loading device. The deformation gage was adjusted and an initial reading obtained. Loads were applied and removed incrementally in order to preconsolidate the test specimen. Water was added to the consolidometer periodically to saturate the soil.

C. Consolidation Test

1) Apply increments of total stress to the soil specimen. The duration of each increment should be sufficient to define the characteristic curve obtained by a graph of deformation versus either the square root of time or the log of time.

2) The standard loading schedule is determined using a load increment ratio (LIR) of one, obtained by doubling the total stress on the soil. The load values should be 17.1, 34.2, 68.3, 136.7, 273.3, 546.7 kPa.

3) For each load increment, record the dial readings at time intervals of approximately 0.09, 0.25, 0.49, 1, 4, 9, 16, 25, 36, 49, 64, 81 and 100 minutes to obtain the deformations, d.

4) After completion of all load increments, remove the soil from the consolidometer and determine the final water content.

Reference

ASTM D 2435 - Standard Test Method for One-Dimensional Consolidation Properties of Soils.

Comments