LABORATORY TEST # 1

GRAIN SIZE ANALYSIS (ASTM D 422)

(SIEVE ANALYSIS)

Purpose:

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

Standard Reference:

ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils

Significance:

The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

Equipment:

Balance, Set of sieves, Cleaning brush, Sieve shaker

Test Procedure:

Sieve Analysis:

(1) Write down the weight of each sieve as well as the bottom pan to be used in the analysis.

(2) Record the weight of the given dry soil sample.

(3) Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (#4 sieve at top and #200 sieve at bottom). Place the pan below #200 sieve. Carefully pour the soil sample into the top sieve and place the cap over it.

(4) Place the sieve stack in the mechanical shaker and shake for 10 minutes.

(5) Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained soil. In addition, remember to weigh and record the weight of the bottom pan with its retained fine soil.

Data Analysis:

Sieve Analysis:

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

(2) Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.

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

For example: Total mass = 500 g

Mass retained on No. 4 sieve = 9.7 g

Mass retained on No. 10 sieve = 39.5 g

For the No.4 sieve:

Quantity passing = Total mass - Mass retained

= 500 - 9.7 = 490.3 g

The percent retained is calculated as;

% retained = Mass retained/Total mass

= (9.7/500) X 100 = 1.9 %

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

For the No. 10 sieve:

Quantity passing = Mass arriving - Mass retained

= 490.3 - 39.5 = 450.8 g

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

% Passing = 100 - 1.9 - 7.9 = 90.2 %

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

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

(4) Make a semilogarithmic plot of grain size vs. percent finer.

(5) Compute C_c and C_u for the soil.

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve+Soil Retained (g)	Soil Retained (g)	Percent Retained	Percent Passing
4						
10						
20						
40						
60						
140						
200						
Pan						
			Total Weight=			

LABORATORY TEST # 2

GRAIN SIZE ANALYSIS (ASTM D 422)

(HYDROMETER ANALYSIS)

Purpose:

This test is performed to determine the percentage of different grain sizes contained within a soil. The hydrometer method is used to determine the distribution of the finer particles.

Standard Reference:

ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils

Significance:

The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

Equipment:

Mixer (blender), 152H Hydrometer, Sedimentation cylinder, Control cylinder, Thermometer, Beaker, Timing device.

Test Procedure:

Hydrometer Analysis:

(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, 60 minutes and 24 hour.

Data Analysis:

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 G_s of the soil (if not known, assume 2.65 for this lab 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 C_T from Table 3.

(6) Determine correction factor "*a*" from Table 4 using G_s.

(7) Calculate corrected hydrometer reading as follows:

$R_c = R_{ACTUAL}$ - zero correction + C_T

(8) Calculate percent finer as follows:

$$P = R_c \times \frac{a}{w_S}$$

Where W_S is the weight of the soil sample in grams.

(9) Adjusted percent fines as follows:

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

F_{200} = % finer of #200 sieve as a percent

(10) Plot the grain size curve D versus the adjusted percent finer on the semilogarithmic 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 ^{o}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 ^oC	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

LABORATORY TEST # 3

ATTERBERG LIMITS (ASTM D 4318)

(LIQUID LIMIT TEST)

Purpose:

This lab is performed to determine the plastic and liquid limits of a fine-grained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second.

Standard Reference:

ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Significance:

The Swedish soil scientist Albert Atterberg originally defined seven “limits of consistency” to classify fine-grained soils, but in current engineering practice only two of the limits, the liquid and plastic limits, are commonly used. (A third limit, called the shrinkage limit, is used occasionally.) The Atterberg limits are based on the moisture content of the soil. The liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. The shrinkage limit is the moisture content that defines where the soil volume will not reduce further if the moisture content is reduced.

A wide variety of soil engineering properties have been correlated to the liquid and plastic limits, and these Atterberg limits are also used to classify a fine-grained soil according to the Unified Soil Classification system or AASHTO system.

Equipment:

Liquid limit device, Porcelain (evaporating) dish, Flat grooving tool with gage, Eight moisture cans, Balance, Spatula, Wash bottle filled with distilled water, Drying oven set at 105°C.

Test Procedure:

Liquid Limit:

(1) Take roughly 3/4 of the soil and place it into the porcelain dish. Assume that the soil was previously passed though a No. 40 sieve, air-dried, and then pulverized. Thoroughly mix the soil with a small amount of distilled water until it appears as a smooth uniform paste. Cover the dish with cellophane to prevent moisture from escaping.

(2) Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.

(3) Adjust the liquid limit apparatus by checking the height of drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is

10 mm high and should be used as a gage. Practice using the cup and determine the correct rate to rotate the crank so that the cup drops approximately two times per second.

(4) Place a portion of the previously mixed soil into the cup of the liquid limit apparatus at the point where the cup rests on the base. Squeeze the soil down to eliminate air pockets and spread it into the cup to a depth of about 10 mm at its deepest point. The soil pat should form an approximately horizontal surface.

(5) Use the grooving tool carefully cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Use extreme care to prevent sliding the soil relative to the surface of the cup.

(6) Make sure that the base of the apparatus below the cup and the underside of the cup is clean of soil. Turn the crank of the apparatus at a rate of approximately two drops per second and count the number of drops, N, it takes to make the two halves of the soil pat come into contact at the bottom of the groove along a distance of 13 mm (1/2 in.). If the number of drops exceeds 50, then go directly to step eight and do not record the number of drops, otherwise, record the number of drops on the data sheet.

(7) Take a sample, using the spatula, from edge to edge of the soil pat. The sample should include the soil on both sides of where the groove came into contact. Place the soil into a moisture can cover it. Immediately weigh the moisture can containing the soil, record its

mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours. Place the soil remaining in the cup into the porcelain dish. Clean and dry the cup on the apparatus and the grooving tool.

(8) Remix the entire soil specimen in the porcelain dish. Add a small amount of distilled water to increase the water content so that the number of drops required to close the groove decrease.

(9) Repeat steps six, seven, and eight for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a closure requiring 25 to 35 drops, one for closure between 20 and 30 drops, and one trial for a closure requiring 15 to 25 drops. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Analysis:

Liquid Limit:

(1) Calculate the water content of each of the liquid limit moisture cans after they have been in the oven for at least 16 hours.

(2) Plot the number of drops, N, (on the log scale) versus the water content (w). Draw the best-fit straight line through the plotted points and determine the liquid limit (LL) as the water content at 25 drops.

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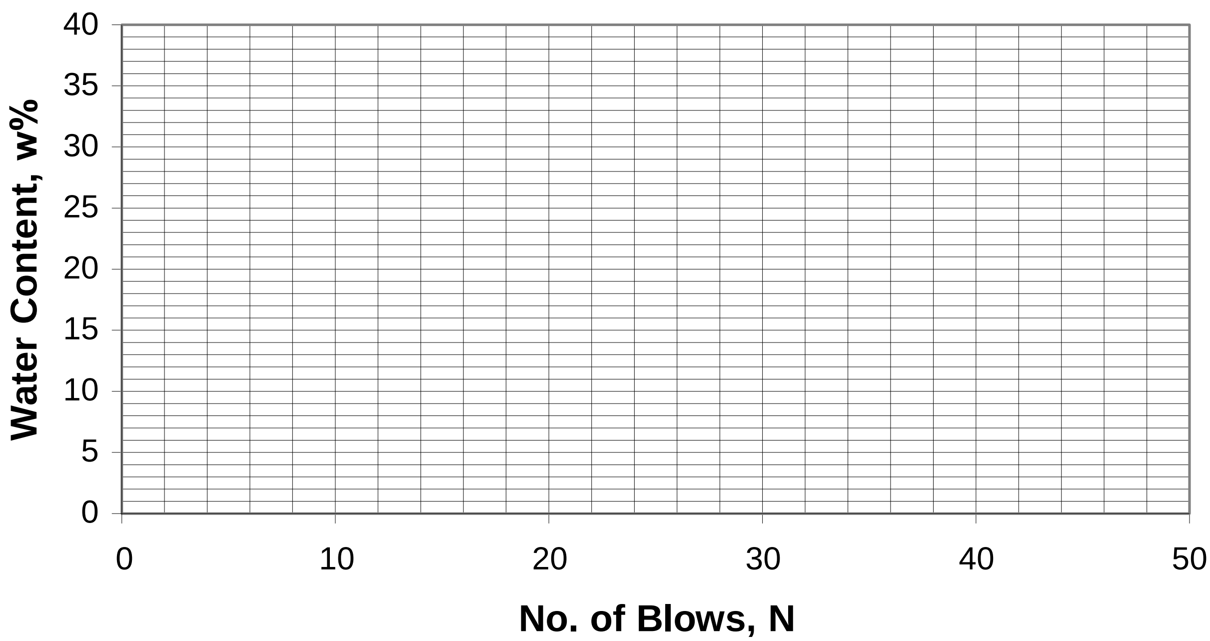
Liquid Limit Determination

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

LIQUID LIMIT CHART



LABORATORY TEST # 4

ATTERBERG LIMITS (ASTM D 4318)

(PLASTIC LIMIT TEST)

Purpose:

This lab is performed to determine the plastic and liquid limits of a fine-grained soil. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

Standard Reference:

ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Significance:

The Swedish soil scientist Albert Atterberg originally defined seven "limits of consistency" to classify fine-grained soils, but in current engineering practice only two of the limits, the liquid and plastic limits, are commonly used. (A third limit, called the shrinkage limit, is used occasionally.) The Atterberg limits are based on the moisture content of the soil. The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic (flexible) state.
A wide variety of soil engineering properties have been correlated to the liquid and plastic limits, and these Atterberg limits are also used to classify a fine-grained soil according to the Unified Soil Classification system or AASHTO system.

Equipment:

Porcelain (evaporating) dish, , Eight moisture cans, Balance, Glass plate, Spatula, Wash bottle filled with distilled water, Drying oven set at 105°C.

Test Procedure:

Plastic Limit:

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

(2) Take the remaining 1/4 of the original soil sample and add distilled water until the soil is at a consistency where it can be rolled without sticking to the hands.

(3) Form the soil into an ellipsoidal mass. 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.

(4) When the diameter of the thread reaches the correct diameter, break the thread into several pieces. Knead and reform the pieces into ellipsoidal masses and re-roll them. Continue this alternate rolling,

gathering together, kneading and re-rolling until the thread crumbles under the pressure required for rolling and can no longer be rolled into a 3.2 mm diameter thread.

(5) Gather the portions of the crumbled thread together and place the soil into a moisture can, then cover it. If the can does not contain at least 6 grams of soil, add soil to the can from the next trial (See Step 6). Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours.

(6) Repeat steps three, four, and five at least two more times. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Analysis:

Plastic Limit:

(1) Calculate the water content of each of the plastic limit moisture cans after they have been in the oven for at least 16 hours.

(2) Compute the average of the water contents to determine the plastic limit, PL. Check to see if the difference between the water contents is greater than the acceptable range of two results (2.6 %).

(3) Calculate the plasticity index, PI=LL-PL.
Report the liquid limit, plastic limit, and plasticity index.

Plastic Limit Determination

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

Plastic Limit (PL)= Average w %

LABORATORY TEST # 5

STANDARD PROCTOR COMPACTION TEST (ASTM D 698)

Purpose:

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort. The compactive effort is the amount of mechanical energy that is applied to the soil mass. Several different methods are used to compact soil in the field, and some examples include tamping, kneading, vibration, and static load compaction. The test is also known as the Proctor test.

Two types of compaction tests are routinely performed: (1) The Standard Proctor Test, and (2) The Modified Proctor Test. Each of these tests can be performed in three different methods as outlined in the attached Table 1. In the Standard Proctor Test, the soil is compacted by a 5.5 lb hammer falling a distance of one foot into a soil filled mold. The mold is filled with three equal layers of soil, and each layer is subjected to 25 drops of the hammer. The Modified Proctor Test is identical to the Standard Proctor Test except it employs, a 10 lb hammer falling a distance of 18 inches, and uses five equal layers of soil instead of three. There are two types of compaction molds used for testing. The smaller type is 4 inches in diameter and has a volume of about 1/30 ft^3 (944 cm^3), and the larger type is 6 inches in diameter and has a volume of about 1/13.333 ft^3 (2123 cm^3). If the larger mold is used each soil layer must receive 56 blows instead of 25 (See Table 1).

Table 1 Alternative Proctor Test Methods

	Standard Proctor ASTM 698			Modified Proctor ASTM 1557		
	Method A	Method B	Method C	Method A	Method B	Method C
Material	δ 20% Retained on No.4 Sieve	>20% Retained on No.4 δ 20% Retained on 3/8" Sieve	>20% Retained on No.3/8" <30% Retained on 3/4" Sieve	δ 20% Retained on No.4 Sieve	>20% Retained on No.4 δ 20% Retained on 3/8" Sieve	>20% Retained on No.3/8" <30% Retained on 3/4" Sieve
For test sample, use soil passing	Sieve No.4	3/8" Sieve	¾" Sieve	Sieve No.4	3/8" Sieve	¾" Sieve
Mold	4" DIA	4" DIA	6" DIA	4" DIA	4" DIA	6" DIA
No. of Layers	3	3	3	5	5	5
No. of blows/layer	25	25	56	25	25	56

Note: Volume of 4" diameter mold = 944 cm^3 , Volume of 6" diameter mold = 2123 cm^3
(verify these values prior to testing)

Standard Reference:

ASTM D 698 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbs/ft^3 (600 KN-m/m^3))

ASTM D 1557 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbs/ft^3 (2,700 KN-m/m^3))

Significance:

Mechanical compaction is one of the most common and cost effective means of stabilizing soils. An extremely important task of geotechnical engineers is the performance and analysis of field control tests to assure that compacted fills are meeting the prescribed design specifications. Design specifications usually state the required density (as a percentage of the “maximum” density measured in a standard laboratory test), and the water content. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density.

The optimum water content is the water content that results in the greatest density for a specified compactive effort. Compacting at water contents higher than (wet of) the optimum water content results in a relatively dispersed soil structure (parallel particle orientations) that is weaker, more ductile, less pervious, softer, more susceptible to shrinking, and less susceptible to swelling than soil compacted dry of optimum to the same density. The soil compacted lower than (dry of) the optimum water content typically results in a flocculated soil structure (random particle orientations) that has the opposite characteristics of the soil compacted wet of the optimum water content to the same density.

Equipment:

Molds, Manual rammer, Extruder, Balance, Drying oven, Mixing pan, Trowel, #4 sieve, Moisture cans, Graduated cylinder, Straight Edge.

Test Procedure:

(1) Depending on the type of mold you are using obtain a sufficient quantity of air-dried soil in large mixing pan. For the 4-inch mold take approximately 10 lbs, and for the 6-inch mold take roughly 15 lbs. Pulverize the soil and run it through the # 4 sieve.

(2) Determine the weight of the soil sample as well as the weight of the compaction mold with its base (without the collar) by using the balance and record the weights.

(3) Compute the amount of initial water to add by the following method:

(a) Assume water content for the first test to be 8 percent.

(b) Compute water to add from the following equation:

$$Water\ to\ add\ (in\ ml) = \frac{(Soil\ mass\ in\ grams) * 8}{100}$$

Where “water to add” and the “soil mass” are in grams. Remember that a gram of water is equal to approximately one milliliter of water.

(4) Measure out the water, add it to the soil, and then mix it thoroughly into the soil using the trowel until the soil gets a uniform color.

(5) Assemble the compaction mold to the base, place some soil in the mold and compact the soil in the number of equal layers specified by the type of compaction method employed.
The number of drops of the rammer per layer is also dependent upon the type of mold used (See Table 1). The drops should be applied at a uniform rate not exceeding around 1.5 seconds per drop, and the rammer should provide uniform coverage of the specimen surface. Try to avoid rebound of the rammer from the top of the guide sleeve.

(6) The soil should completely fill the cylinder and the last compacted layer must extend slightly above the collar joint. If the soil is below the collar joint at the completion of the drops, the test point must be repeated. (Note: For the last layer, watch carefully, and add more soil after about 10 drops if it appears that the soil will be compacted below the collar joint.)

(7) Carefully remove the collar and trim off the compacted soil so that it is completely even with the top of the mold using the trowel. Replace small bits of soil that may fall out during the trimming process.

(8) Weigh the compacted soil while it's in the mold and to the base, and record the mass. Determine the wet mass of the soil by subtracting the weight of the mold and base.

(9) Remove the soil from the mold using a mechanical extruder and take soil moisture content samples from the top and bottom of the specimen. Fill the moisture cans with soil and determine the water content.

(10) Place the soil specimen in the large tray and break up the soil until it appears visually as if it will pass through the # 4 sieve, add 2 percent more water based on the original sample mass, and re-mix as in step 4. Repeat steps 5 through 9 until, based on wet mass, a peak value is reached followed by two slightly lesser compacted soil masses.

Analysis:

(1) Calculate the moisture content of each compacted soil specimen by using the average of the two water contents.

(2) Compute the wet density in grams per cm^3 of the compacted soil sample by dividing the wet mass by the volume of the mold used.

(3) Compute the dry density using the wet density and the water content

determined in step 1. Use the following formula:

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

where: w = moisture content in percent divided by 100, and ρ = wet density in grams per cm^3.

(4) Plot the dry density values on the y-axis and the moisture contents on the x-axis. Draw a smooth curve connecting the plotted points.

(5) On the same graph draw a curve of complete saturation or “zero air voids curve”. The values of dry density and corresponding moisture contents for plotting the curve can be computed from the following equation:

$$W_{sat} = \left(\frac{\rho_w}{\rho_d} - \frac{1}{G_s}\right) \times 100$$

or

$$\rho_d = \frac{\rho_w}{\left(\frac{w}{100} + \frac{1}{G_s}\right)}$$

where:

ρ_d = dry density of soil grams per cm^3

G_s = specific gravity of the soil being tested (assume 2.70 if not given)

ρ_w = density of water in grams per cm^3 (approximately1 g/cm^3)

w_{sat} = moisture content in percent for complete saturation.

Example Calculations:

G_s=2.7 (assumed)

ρ_w = 1.0 g/cm^3

Assumed w_{sat}%	Calculated ρ_d (g/cm^3)
8	2.22
10	2.13
12	2.04
14	1.96
16	1.89
18	1.82

(6) Identify and report the optimum moisture content and the maximum dry density.

Water Content Determination:

Compacted Soil - Sample no.						
Water content - Sample no.						
Moisture can number - Lid number						
M_C = Mass of empty, clean can + lid (grams)						
M_{CMS} = Mass of can, lid, and moist soil (grams)						
M_{CDS} = Mass of can, lid, and dry soil (grams)						
M_S = Mass of soil solids (grams)						
M_W = Mass of pore water (grams)						
w = Water content, w%						

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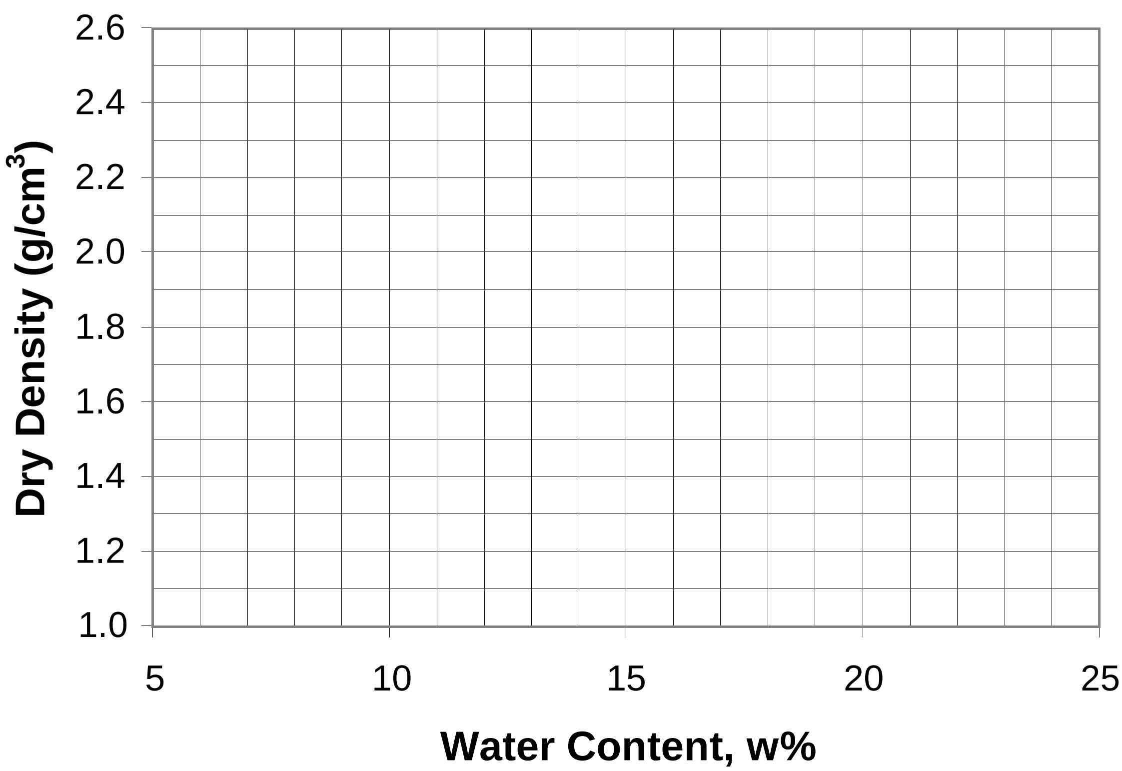
Density Determination:

Mold Volume=944 cm^3

Compacted Soil - Sample no.						
Water content - Sample no.						
Moisture can number - Lid number						
M_C = Mass of empty, clean can + lid (grams)						
M_{CMS} = Mass of can, lid, and moist soil (grams)						
M_{CDS} = Mass of can, lid, and dry soil (grams)						
M_S = Mass of soil solids (grams)						
M_W = Mass of pore water (grams)						
W = Water content, w%						



Optimum Moisture Content = __________________ %

Maximum Dry Density = ____________________ g/cm^3

LABORATORY TEST # 6

PERMEABILITY TEST BY THE CONSTANT HEAD METHOD (ASTM D 2434)

Purpose:

The purpose of this test is to determine the permeability (hydraulic conductivity) of a sandy soil by the constant head test method. There are two general types of permeability test methods that are routinely performed in the laboratory: (1) the constant head test method, and (2) the falling head test method. The constant head test method is used for permeable soils ($k>10^{-4}$ cm/s) and the falling head test is mainly used for less permeable soils ($k<10^{-4}$ cm/s).

Standard Reference:

ASTM D 2434 - Standard Test Method for Permeability of Granular Soils (Constant Head) (Note: The Falling Head Test Method is not standardized)

Significance:

Permeability (or hydraulic conductivity) refers to the ease with which water can flow through a soil. This property is necessary for the calculation of seepage through earth dams or under sheet pile walls, the calculation of the seepage rate from waste storage facilities (landfills, ponds, etc.), and the calculation of the rate of settlement of clayey soil deposits.

Equipment:

Permeameter, Tamper, Balance, Scoop, 1000 mL Graduated cylinders, Watch (or Stopwatch), Thermometer, Filter paper.

Test Procedure:

(1) Measure the initial mass of the pan along with the dry soil (M_1).

(2) Remove the cap and upper chamber of the permeameter by unscrewing the knurled cap nuts and lifting them off the tie rods. Measure the inside diameter of upper and lower chambers. Calculate the average inside diameter of the permeameter (D).

(3) Place one porous stone on the inner support ring in the base of the chamber then place a filter paper on top of the porous stone.

(4) Mix the soil with a sufficient quantity of distilled water to prevent the segregation of particle sizes during placement into the permeameter. Enough water should be added so that the mixture may flow freely.

(5) Using a scoop, pour the prepared soil into the lower chamber using a circular motion to fill it to a depth of 1.5 cm. A uniform layer should be formed.

(6) Use the tamping device to compact the layer of soil. Use approximately ten rams of the tamper per layer and provide uniform coverage of the soil surface. Repeat the compaction procedure until the soil is within 2 cm. of the top of the lower chamber section.

(7) Replace the upper chamber section, and don't forget the rubber gasket that goes between the chamber sections. Be careful not to disturb the soil that has already been compacted. Continue the placement operation until the level of the soil is about 2 cm. below the rim of the upper chamber. Level the top surface of the soil and place a filter paper and then the upper porous stone on it.

(8) Place the compression spring on the porous stone and replace the chamber cap and its sealing gasket. Secure the cap firmly with the cap nuts.

(9) Measure the sample length at four locations around the circumference of the permeameter and compute the average length. Record it as the sample length.

(10) Keep the pan with remaining soil in the drying oven.

(11) Adjust the level of the funnel to allow the constant water level in it to remain a few inches above the top of the soil.

(12) Connect the flexible tube from the tail of the funnel to the bottom outlet of the permeameter and keep the valves on the top of the permeameter open.

(13) Place tubing from the top outlet to the sink to collect any water that may come out.

(14) Open the bottom valve and allow the water to flow into the permeameter.

(15) As soon as the water begins to flow out of the top control (deairing) valve, close the control valve, letting water flow out of the outlet for some time.

(16) Close the bottom outlet valve and disconnect the tubing at the bottom. Connect the funnel tubing to the top side port.

(17) Open the bottom outlet valve and raise the funnel to a convenient height to get a reasonable steady flow of water.

(18) Allow adequate time for the flow pattern to stabilize.

(19) Measure the time it takes to fill a volume of 750 - 1000 mL using the graduated cylinder, and then measure the temperature of the water. Repeat this process three times and compute the average time, average volume, and average temperature. Record the values as t, Q, and T, respectively.

(20) Measure the vertical distance between the funnel head level and the chamber outflow level, and record the distance as h.

(21) Repeat step 17 and 18 with different vertical distances.

(22) Remove the pan from the drying oven and measure the final mass of

the pan along with the dry soil (M_2).

Analysis:

(1) Calculate the permeability, using the following equation:

$$K_T = \frac{QL}{Ath}$$

Where:

K_T = coefficient of permeability at temperature T, cm/sec.

L = length of specimen in centimeters

t = time for discharge in seconds

Q = volume of discharge in cm^3 (assume 1 mL = 1 cm^3)

A = cross-sectional area of permeameter (= $\frac{\pi}{4}D^2$, D= inside diameter of the permeameter)

h = hydraulic head difference across length L, in cm of water; or it is equal to the vertical distance between the constant funnel head level and the chamber overflow level.

(2) The viscosity of the water changes with temperature. As temperature increases viscosity decreases and the permeability increases. The coefficient of permeability is standardized at 20°C, and the permeability at any temperature T is related to K_{20} by the following ratio:

$$K_{20} = K_T \frac{\eta_T}{\eta_{20}}$$

Where:

η_T and η_{20} are the viscosities at the temperature T of the test and at 20°C, respectively. From Table 1 obtain the viscosities and compute K_{20}.

(3) Compute the volume of soil used from: V = LA.

(4) Compute the mass of dry soil used in permeameter (M) = initial mass - final mass:

$$M = M_1 - M_2$$

(5) Compute the dry density (ρ_d) of soil:

$$\rho_d = \frac{M}{V}$$

Initial Dry Mass of Soil + Pan (M_1) = ____________________g
Length of Soil Specimen, L = ___________________cm
Diameter of the Soil Specimen (Permeameter), D = ______________cm
Final Dry Mass of Soil + Pan (M_2) = ___________________g Dry
Mass of Soil Specimen (M) = ___________________________g
The dry density (ρd) of soil:
Volume of Soil Specimen (V) = _____________________cm^3

Trial Number	Constant Head, h (cm)	Elapsed Time, t (seconds)	Outflow Volume, Q (cm^3)	Water Temp., T (°C)	K_T	K_{20}
1						
2						
3						
4						

Average K_{20}= _________________________cm/sec

1. What is the main difference between the K lab and K field?
2. What is the expected value of K in the following temperatures, T=30, and T=28?
3. List some engineering applications of this test?

Table 1. Properties of Distilled Water (η = absolute)

Temperature ^{o}C	Density (g/cm^3)	Viscosity (Poise*)
4	1.00000	0.01567
16	0.99897	0.01111
17	0.99880	0.01083
18	0.99862	0.01056
19	0.99844	0.01030
20	0.99823	0.01005
21	0.99802	0.00981
22	0.99780	0.00958
23	0.99757	0.00936
24	0.99733	0.00914
25	0.99708	0.00894
26	0.99682	0.00874
27	0.99655	0.00855
28	0.99627	0.00836
29	0. 99598	0.00818
30	0. 99568	0.00801

LABORATORY TEST # 7

CONSOLIDATION TEST (ASTM D 2435)

Purpose:

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. From the measured data, the consolidation curve (pressure-void ratio relationship) can be plotted. This data is useful in determining the compression index, the recompression index and the preconsolidation pressure (or maximum past pressure) of the soi. In addition, the data obtained can also be used to determine the coefficient of consolidation and the coefficient of secondary compression of the soil.

Standard Reference:

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

Significance:

The consolidation properties determined from the consolidation test are used to estimate the magnitude and the rate of both primary and secondary consolidation settlement of a structure or an earthfill. Estimates of this type are of key importance in the design of engineered structures and
the evaluation of their performance.

Please adhere to the following in your report:

- For which type of soils the consolidation is considered more significant?
- Elaborate more on the following consolidation parameters using clear Figures, and equations?
  - Coefficient of consolidation.
  - Coefficient of volume compressibility.
  - Compression index.
  - Coefficient of volume change.
  - Degree of consolidation.
  - The rate of consolidation.
  - Time factor.
- List the assumptions made by Terzaghi in studying the one dimensional consolidation?
- What is the difference between the following with respect to stress history?
  - Normally consolidated soil .
  - Over consolidated soil (pre consolidated ,and under consolidated) .
- What is the difference between the following?
  - Initial settlement.
  - Primary settlement (consolidation).
  - Secondary settlement .
- Suppose that the time required for 50 % consolidation of 25 mm thickness clay sample (drained form top and bottom in the laboratory is 2 min and 20 seconds .How long in days will it take for a 3 m thickness clay layer (of the same clay) in the field under the same pressure increment to reach 50 % consolidation. In the field there is a rock layer at the bottom of the clay.
  - Hint : You may use the following formula :$T_{layer} = T_{sample}\left(\frac{d_{layer}}{d_{sample}}\right)^2$
- The co-ordinates of two points on a virgin compression curve are as follows;
  - $e_1 = 1.82$, $e_2 = 1.54$, $\sigma'_1 = 200\ kN/m2$, $\sigma'_2 = 400\ kN/m2$
  - Determine the coefficient of volume compressibility for the pressure range stated above.

- Consolidation test results of a settlement versus time at a certain effective normal stress is shown in the following table. Determine the value of the Coefficient of consolidation CV for that clay sample using (a) the log-time method, (b) the square root time method.
- Take the thickness of the specimen H = 14.80 cm

Time (mins)	0	0.25	0.5	1	2.25	4	9	16	25
Settlement (mm)	0.33	0.38	0.47	0.59	0.72	0.99	1.25	1.5	0.33
$\sqrt{t}$									
$\log t$									

Time (mins)	36	49	64	81	100	200	400	1440
Settlement (mm)	1.72	1.85	1.94	2	2.04	2.16	2.24	2.39
$\sqrt{t}$								
$\log t$								