PHYSICAL AND PLASTICITY CHARACTERISTICS

EXPERIMENTS #1 - 5

CE 3143
October 7, 2003
Group A
David Bennett

TABLE OF CONTENTS

DETERMINATION OF WATER CONTENT

EXPERIMENT # 1

CE 3143
August 26, 2003
Group A
David Bennett

TESTING OBJECTIVE:

- To determine the natural water content in a given soil sample.
- Testing conforms to ASTM D2216-90.

APPLICATIONS:

Natural moisture content is determined in almost all soil tests. Moisture content also called water content is the ratio of the weight of water to the weight of soil solids. This ration is usually expressed as a percentage. Water content will define the status of a soil sample. Natural moisture content is used in determining:

- Bearing Capacity of soil
- Settlement
- State of soil in the field

APPARATUS REQUIRED:

1. Moisture can(s):
   Moisture cans are available in various sizes.
   Example: 2-in. (50.8 mm) diameter and 7/8 in. (22.2 mm) high
   and 3.5-in. (88.9 mm) diameter and 2 in. (50..8 mm) high
2. Oven with temperature control:
   For drying, the temperature of the oven is generally kept between 105°C. A higher temperature should be avoided to prevent the burning of organic mater in the soil.
3. Balance:
   The balance should have a readability of 0.01 g for specimens having a mass of 200 g or less. If the specimen has a mass of over 200g, the readability should be 0.1 g

TEST PROCEDURE:

1. Determine the mass (g) of the empty moisture can plus its cap (W_1), and also record the number.
2. Place a sample of representative moist soil in the can. Close the can with its cap to avoid loss of moisture.
3. Determine the combined mass (g) of the closed can and moist soil (W_2).
4. Remove the cap from the top of the can and place it on the bottom (of the can).
5. Put the can (Step 4) in the oven to dry the soil to a constant weight. In most cases, 24 hours of drying is sufficient.
6. Record the final constant weight (W_3) of the dry soil sample plus the can and its cap.

TEST RESULTS:

Sample Number	1	2	3
Can Number	AE2	J22	J11
Weight of can: W_1 (g)	22.04	22.95	22.91
Weight of can + wet soil W_2 (g)	73.92	69.38	75.43
Weight of can + dry soil W_3 (g)	64.38	61.44	66.09
Water/Moisture Content: $W\% = [(W_2 - W_3)/(W_3 - W_1)] \times 100$	22.53%	20.63%	21.63%

The natural moisture content of the soil sample is **21.60%**

CLASS DATA COMPARISONS:

The natural moisture content found by all the groups in the laboratory class are:

Group A: 21.60%
Group B: 21.82%
Group C: 20.20%
Group D: 19.92%

The mean among four groups is:

Mean: $\bar{x} = \frac{\sum w_i}{n} = \frac{21.60\% + 21.82\% + 20.20\% + 19.92\%}{4} = \mathbf{20.88\%}$

The standard deviation among four groups is:

Standard Deviation: $\sigma = \sqrt{(1/n * \sum(x - w_i)^2} = \mathbf{0.8346}$

SUMMARY AND CONCLUSIONS:

All four groups ended up with fairly close values for the moisture content of the soil samples. The small variance could be a result of the moisture in the air affecting the dry soil samples. If the dry soil is not weighed immediately after being removed from the oven, moisture from the air can quickly affect the soil.

DETERMINATION OF SPECIFIC GRAVITY OF SOIL

EXPERIMENT # 2

CE 3143
September 2, 2003
Group A
David Bennett

TESTING OBJECTIVE:

Determination of the specific gravity of soil fraction passing 4.75 mm I.S. Sieve by volumetric flask.

APPLICATIONS:

Specific Gravity (G_s) is the 2nd most important parameter in soil mechanics. It is the ratio of the unit weight (or density) of soil solids to the unit weight (or density) of water. The specific gravity is required in calculation of various soil properties such as:

- Void ratio
- Degree of saturation
- Weight-volume relationships

APPARATUS REQUIRED:

1. Volumetric flask (500 ml) with stopper having pipe hole.
2. Thermometer graduated in 0.5°C division scale.
3. Balance sensitive to 0.01 g.
4. Distilled water.
5. Bunsen burner and a stand (and/or vacuum pump or aspirator)
6. Evaporating dishes
7. Spatula
8. Plastic squeeze bottle
9. Drying oven

TEST PROCEDURE:

1. Clean and dry the volumetric flask.
2. Carefully fill the flask with de-aired, distilled water up to the 500 ml mark (bottom of the meniscus should be at the 500 ml mark).
3. Measure the mass of the flask and the water filled to the 500 ml mark (W_1).
4. Insert the thermometer into the flask with the water and determine the temperature of the water $T = T_1$°C.
5. Put approximately 100 grams of air dry soil into an evaporating dish.
6. In the case of cohesive soil, add water (de-aired and distilled) to the soil and mix it to the form of a smooth paste. Keep it soaked for one-half to one hour in the evaporating dish. (Note: this step is not necessary for granular, i.e., non-cohesive soils.)
7. Transfer the soil (if granular) or the soil paste (if cohesive) into the volumetric flask.
8. Add distilled water to the volumetric flask containing the soil (or the soil paste) to make it about two-thirds full.
9. Remove the air from the soil-water mixture. This can be done by applying vacuum by a vacuum pump or aspirator until all of the entrapped air is out. Notice that this is an extremely important step. Most of the errors in the results of the test are due to entrapped air, which is not removed.

10. Add de-aired, distilled water to the volumetric flask until the bottom of the meniscus touches the 500 ml mark. Dry the outside of the flask and the inside of the neck above the meniscus.
11. Determine the combined mass of the bottle plus soil plus water (W_2).
12. Pour the soil and water into an evaporating dish. Use a plastic squeeze bottle and wash the inside of the flask. Make sure that no soil is left inside.
13. Put the evaporating dish into a oven to dry to a constant weight.
14. Determine the mass of the dry soil in the evaporating dish (W_s).

TEST RESULTS:

Observation Number	1	2	3
Evaporating Dish Number	15-4	MD	ME
Weight of flask + Water filled to mark, W_1 (g)	677.60	677.30	677.30
Weight of flask + Water filled to mark + soil, W_2 (g)	739.90	739.30	739.70
Weight of dry soil W_s (g)	99.90	99.74	100.23
Water of equal volume of water as the soil solids, W_w (g) = $(W_1 + W_s) – W_2$)	37.60	37.74	37.83
G_s (T_1°C) = W_s / W_w	2.657	2.643	2.649
G_s (20°C) = G_s (T_1°C) ∗ A	2.656	2.642	2.648
Average Specific Gravity (G_s) at 20°C	-----	-----	2.649

Temperature of flask with water, T_1°C = 22°C
The temperature correction factor (A) for 22°C: A = 0.9996

Average Specific Gravity (G_s) at 20°C, **G_s = 2.649%**

CLASS DATA COMPARISONS:

The average Specific Gravity (G_s) found by all the groups in the laboratory class:
Group A: 2.65
Group B: 2.66
Group C: 2.63
Group D: 2.66

Mean: $\bar{x} = \frac{\sum w_i}{n} = \frac{2.65 + 2.66 + 2.63 + 2.66}{4} = \mathbf{2.65\%}$

Standard Deviation: $\sigma = \sqrt{(1/n * \sum(x - w_i)^2} = \mathbf{0.0122}$

SUMMARY AND CONCLUSIONS:

The specific gravity of most common minerals found in soils fall within a range of 2.6 to 2.9. The specific gravity of sandy soil, which is mostly made of quartz, may be estimated to be about 2.65, whereas for clayey and silty soils, it may vary from 2.6 to 2.9. Soils containing organic mater and porous particles may have specific gravity values below 2.0, while soils having heavy substances may have values above 3.0.

All four groups ended up with specific gravity values very close to 2.65. These values fall into the average specific value range for most soils.

GRAIN SIZE DISTRIBUTION
SIEVE ANALYSIS

EXPERIMENT # 3

CE 3143
September 9, 2003
Group A
David Bennett

TESTING OBJECTIVE:

- To determine the grain size distribution of a given soil sample by performing a sieve analysis test.
- The data from this test will be represented in graphical form to determine whether the soil is course grained or fine-grained.
- From the graphical data, uniformity and gradation calculations will be performed to determine if the soil sample is poorly, gap, or well graded.

APPLICATIONS:

- Dam seepage problems – Seepage problems in dams are usually caused by improperly graded soils. An earth embankment dam is usually constructed with core of fine grained soil surrounded by a shoulder of coarse grained soil.
- Pavement design – Poorly graded soil under a roadway can cause the pavement to fail prematurely. If the soil is expansive, heaving and swelling of the soil under the pavement will occur. Cracks in the road shoulders may develop allowing water to penetrate under the pavement surface. Swell pressure will then cause damage to the pavement.

APPARATUS REQUIRED:

10. Sieves, a bottom pan, and a cover. *Note*: Sieve numbers 4, 10, 20, 40, 60, 140, and 200 are generally used for most standard sieve analysis work.
11. Balance sensitive to 0.01 g.
12. Mortar and rubber-tipped pestle
13. Oven
14. Mechanical sieve shaker

TEST PROCEDURE:

15. Collect a representative oven dry soil sample. Samples having largest particles of the size of No. 4 sieve openings (4.75 mm) should be about 500 grams. For soils having largest particles of size greater than 4.75 mm, larger weights are needed.
16. Break the soil sample into individual particles using a mortar and a rubber-tipped pestle. (*Note:* The idea is to break up the soil into individual particles, not to break the particles themselves.)
17. Determine the mass of the sample accurately to 0.1 g (W).
18. Prepare a stack of sieves. A sieve with larger openings is placed above a sieve with smaller openings. The sieve at the bottom should be No. 200. A bottom pan should be placed under sieve No. 200. As mentioned before, the sieves that are generally used in a stack are Nos. 4, 10, 20, 40, 60, 140, and 200; however, more sieves can be placed in between.
19. Pour the soil prepared in Step 2 into the stack of sieves from the top.
20. Place the cover on the top of the stack of sieves.
21. Run the stack of sieves through a sieve shaker for about 10 to 15 minutes.

22. Stop the sieve shaker and remove the stack of sieves.
23. Weigh the amount of soil retained on each sieve and the bottom pan.
24. If a considerable amount of soil with silty and clayey fractions is retained on the No. 200 sieve, it has to be washed. Washing is done by taking the No. 200 sieve with the soil retained on it and pouring water through the sieve from a tap in the laboratory. When the water passing through the sieve is clean, stop the flow of water. Transfer the soil retained on the sieve at the end of washing to a porcelain evaporating dish by back washing. Put it in the oven to dry to a constant weight. (*Note:* This step is not necessary if the amount of soil retained on the No. 200 sieve is small.) Determine the mass of the dry soil retained on No. 200 sieve. The difference between this mass and that retained on no. 200 sieve determined in Step 9 is the mass of soil that has washed through.

TEST RESULTS:

Sieve No.	Sieve opening (mm)	Mass of sieve + soil retained (g)	Mass of sieve (g)	Mass of soil retained on each sieve, W_n (g)	Percent of mass ret. on each sieve, R_n	Cumulative percent retained, $\sum R_n$	Percent finer, $100 - \sum R_n$
4	4.750	609.90	515.54	94.36	15.73%	15.73%	84.27%
8	2.360	547.60	492.92	54.68	9.11%	24.84%	75.16%
16	1.180	506.92	452.72	54.20	9.03%	33.88%	66.12%
30	0.600	536.66	431.43	105.23	17.54%	51.42%	48.58%
40	0.425	410.38	345.25	65.13	10.86%	62.27%	37.73%
50	0.300	427.15	357.89	69.26	11.54%	73.82%	26.18%
100	0.150	456.66	348.85	107.81	17.97%	91.79%	8.21%
200	0.075	378.28	347.50	30.78	5.13%	96.92%	3.08%
Pan	-----	409.18	390.69	18.49	3.08%	100.00%	0.00%

Calculations:

1. % Retained on n[th] sieve, $R_n = \dfrac{\text{mass retained, } W_n}{\text{total mass, } W} * 100$

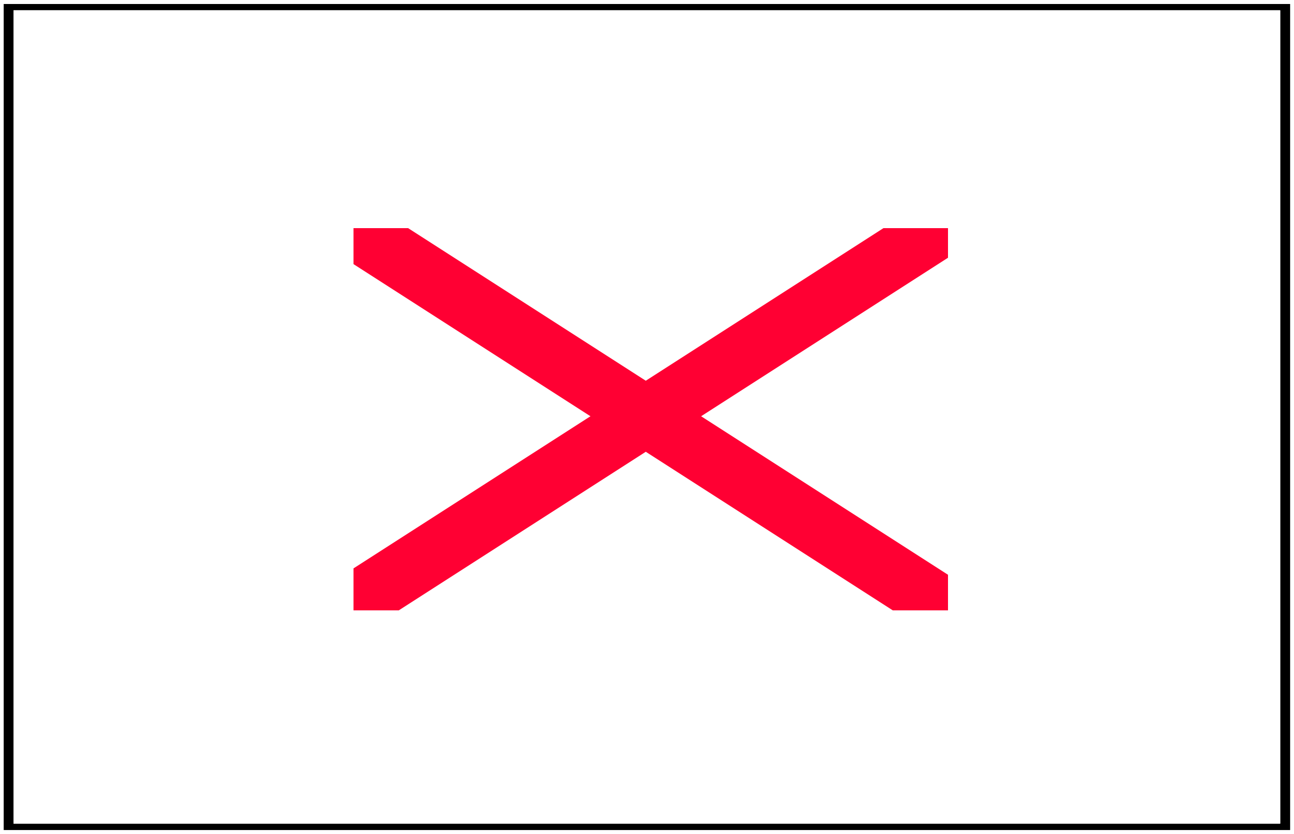
2. Cumulative % retained on n[th] sieve = $\sum_{i=1}^{i=n} R_n$

3. Cumulative % passing through n[th] sieve, % finer = $100 - \sum_{i=1}^{i=n} R_n$

Mass of oven dry sample, W = 600.03 g

Sum of mass of soil retained on each sieve, $\sum$ = 599.94 g = W_1

% Mass Loss = $\dfrac{W - W_1}{W} * 100 = \dfrac{600.03 - 599.94}{600.93} * 100 =$ **0.015%** (OK if less than 2%)



From the graph, the percents finer of 10%, 30%, and 60%, which are respectively, the diameters D_{10}, D_{30}, and D_{60} are:

$D_{10} = 0.17$
$D_{30} = 0.35$
$D_{60} = 0.90$

Uniformity Coefficient (C_u) = $D_{60} / D_{10} = 0.90 / 0.17 =$ **5.29**

Coefficient of Gradation (C_c) = $D_{30}^2 / (D_{60} * D_{10}) = (0.35)^2 / (0.90 * 0.17) =$ **0.801**

CLASS DATA COMPARISONS:

D_{10}	0.17	0.18	0.19	0.17
D_{30}	0.35	0.38	0.37	0.33
D_{60}	0.90	1.20	0.90	0.98

Mean: $x = \frac{\sum w_i}{n} =$

D_{10} = 0.178
D_{30} = 0.358
D_{60} = 0.995

Standard Deviation: $\sigma = \sqrt{(1/n * \sum(x - \underline{w_i})^2}$
D_{10} = 0.008290
D_{30} = 0.01920
D_{60} = 0.1228

<u>SUMMARY AND CONCLUSIONS</u>:

The most basic classification of soil is whether it is fine-grained (cohesive), or coarse-grained (non-cohesive). Soils offer two types of resistance, plasticity (c) and friction (ϕ). For fine-grained soils, the resistance comes from plasticity which is when the particles in a soil stick together. Resistance in coarse-grained soils comes from friction. An ideal soil is a well-graded soil with the qualities of both fine and coarse-grained soils.

The method of soil gradation or grain size distribution for coarse-grained soils is the sieve analysis test. For fine-grained soils, the hydrometer test is used.

From the sieve analysis test, over 80% of the soil sample is sand, while some 15% is gravel, and 3% is fines (silt and clay). With the majority soil sample consisting of sandy particles, the soil type can be classified as sand with some fines (silt and clay).

Three numerical values were read directly from the particle-size distribution curve; the diameters, D_{10}, D_{30}, and D_{60}. The diameter D_{10} is generally referred to as the effective size. From these values the Uniformity Coefficient (C_u) and the Coefficient of Gradation (C_c) can be calculated.

The Uniformity Coefficient (C_u) is a parameter which indicates the range of distribution of grain sizes in a given soil sample. For well-graded soils C_u is large, usually greater than 6 for sandy soils. Poorly graded soils have C_u that is nearly equal to 1, which means that the soil particles are approximately equal in size.

The Coefficient of Gradation (C_c) is a parameter that is also referred to as the coefficient of curvature. For soil to be considered well-graded C_c is usually between 1 and 3.

The soil sample tested with the sieve analysis test in the laboratory has properties that come very close to the general requirements and properties of a well-graded soil.
The Uniformity Coefficient (C_u) was found to be 5.29, which is close to 6 for sandy soils. The Coefficient of Gradation (C_c) was found to be 0.801, which is close to 1 for sandy soils. The graph of the sieve analysis particle-size distribution curve closely resembles an example of a well-graded soil. From the calculated and graphical data it can be determined that the soil sample is a well-graded sandy soil with some fines.

GRAIN SIZE DISTRIBUTION HYDROMETER ANALYSIS

EXPERIMENT # 4

CE 3143
September 16, 2003
Group A
David Bennett

TESTING OBJECTIVE:

- To determine the particle-size distribution of a given soil sample for the fraction that is finer than No. 200 sieve size (0.075 mm). The lower limit of the particle-size determined by this procedure is about 0.001 mm.
- In hydrometer analysis, a soil specimen is dispersed in water. In a dispersed state in the water, the soil particles will settle at different velocities over time.
- The hydrometer will measure the specific gravity of the soil-water suspension.
- Hydrometer readings will be taken at specific time intervals to measure the percentage of soil still in suspension at time t.
- From this data the percentage of soil by weight finer and the diameters (D) of the soil particles at their respective time readings can be calculated.
- A graph of the diameter (D) vs. percent finer can be plotted to develop a particle-size distribution curve.

APPLICATIONS:

- In many cases, the results of the sieve analysis and hydrometer analysis of a given soil sample are combined on one graph. When these results are combined on one graph, a discontinuity occurs because soil particles are generally irregular in shape.
- Hydrometer test is used to determine what type of clay is predominant in a given soil sample (Ex: kaoloinite, illite, montmorillonite, etc…)

APPARATUS REQUIRED:

15. ASTM 152-H hydrometer
16. Mixer
17. Two 100-cc graduated cylinders
18. Thermometer
19. Constant temperature bath
20. Deflocculating agent
21. Spatula
22. Beaker
23. Balance
24. Plastic squeeze bottle
25. Distilled water
26. No. 12 rubber stopper

TEST PROCEDURE:

Note: This procedure is used when more than 90 percent of the soil is finer than No. 200 sieve.

25. Take 50 g of oven-dry, well-pulverized soil in a beaker.
26. Prepare a deflocculating agent. Usually a 4% solution of sodium hexametaphosphate (Calgon) is used. This can be prepared by adding 40 g of Calgon in 1000 cc of distilled water and mixing it thoroughly.
27. Take 125 cc of the mixture prepared in Step 2 and add it to the soil taken in Step 1. This should be allowed to soak for about 8 to 12 hours.
28. Take a 1000-cc graduated cylinder and add 875 cc of distilled water pluts 125 cc of deflocculating agent in it. Mix the solution well.
29. Put the cylinder (from Step 4) in a constant temperature bath. Record the temperature of the bath, T (in °C).
30. Put the hydrometer in the cylinder (Step 5). Record the reading. (*Note:* The top of the meniscus should be read.) This is the zero correction (F_z), which can be +ve or -ve. Also observe the meniscus correction (F_m).
31. Using a spatula, thoroughly mix the soil prepared in Step 3. Pour it into the mixer5 cup. *Note:* During this process, some soil may stick to the side of the beaker. Using the plastic squeeze bottle filled with distilled water, wash all the remaining soil in the beaker into the mixer cup.
32. Add distilled water to the cup to make it about two-thirds full. Mix it for about two minutes using the mixer.
33. Pour the mix into the second graduated 1000-cc cylinder. Make sure that all of the soil solids are washed out of the mixer cup. Fill the graduated cylinder with distilled water to bring the water level up to the 1000-cc mark.
34. Secure a No. 12 rubber stopper on the top of the cylinder (Step 9). Mix the soil-water well by turning the soil cylinder upside down several times.
35. Put the cylinder into the constant temperature bath next to the cylinder described in Step 5. Record the time immediately. This is cumulative time t=0. Insert the hydrometer into the cylinder containing the soil-water suspension.
36. Take hydrometer readings at cumulative times t=0.25 min., 0.5 min., 1 min., and 2 min. Always read the upper level of the meniscus.
37. Take the hydrometer out after two minutes and put it in the cylinder next to it(Step 5)
38. Hydrometer readings are to be taken at time t=4 min., 8 min., 15 min., 30 min., 1 hr., 2 hr., 4 hr., 8 hr., 24 hr., and 48 hr. For each reading, insert the hydrometer into the cylinder containing the soil-water suspension about 30 seconds before the reading is due. After the reading is taken, remove the hydrometer and put it back into the cylinder next to it (Step 5).

TEST RESULTS:

Hydrometer Analysis

Description of soil Brown silty clay Sample No. 1.
Location Geotech Lab - B20, Nedderman Hall.
G_s 2.71 Hydrometer type ASTM 152-H.
Dry weight of soil, W_s 40 g Temperature of test, T = 22 °C.
Meniscus correction, F_m 1 Zero correction, F_z 4 Temperature correction, F_T 0.65.
Tested by Group A Date 09/09/2003.

Time (min)	Hydrometer reading, *R*	R_{cp}	*Percent finer,* $\frac{a \times R_{cp} \times 100}{40}$	R_{cL}	Effective depth L (cm)	A	D (mm)
0.25	31.0	27.65	68.43%	32.0	11.10	0.0131	0.0873
0.5	24.0	20.65	51.11%	25.0	12.20	0.0131	0.0647
1	18.0	14.65	36.26%	19.0	13.20	0.0131	0.0476
2	12.0	8.65	21.41%	13.0	14.20	0.0131	0.0349
4	9.5	6.15	15.22%	10.5	14.60	0.0131	0.0250
8	9.0	5.65	13.98%	10.0	14.70	0.0131	0.0178
15	7.5	4.15	10.27%	8.5	14.90	0.0131	0.0131
30	6.5	3.15	7.80%	7.5	15.10	0.0131	0.0093
60	7.0	3.65	9.03%	8.0	15.00	0.0131	0.0066
120	6.5	3.15	7.80%	7.5	15.10	0.0131	0.0046
240	6.5	3.15	7.80%	7.5	15.10	0.0131	0.0033
1440	6.5	3.15	7.80%	7.5	15.10	0.0131	0.0013
2880	6.5	3.15	7.80%	7.5	15.10	0.0131	0.0009

Calculations:

1. Corrected hydrometer reading (R_{cp}) = $R + F_T - F_z$
   Temperature correction (F_T) = $-4.85 + 0.25T$ = $-4.85+0.25(22°C)$ = **0.65**
   Zero correction (F_z) = 4

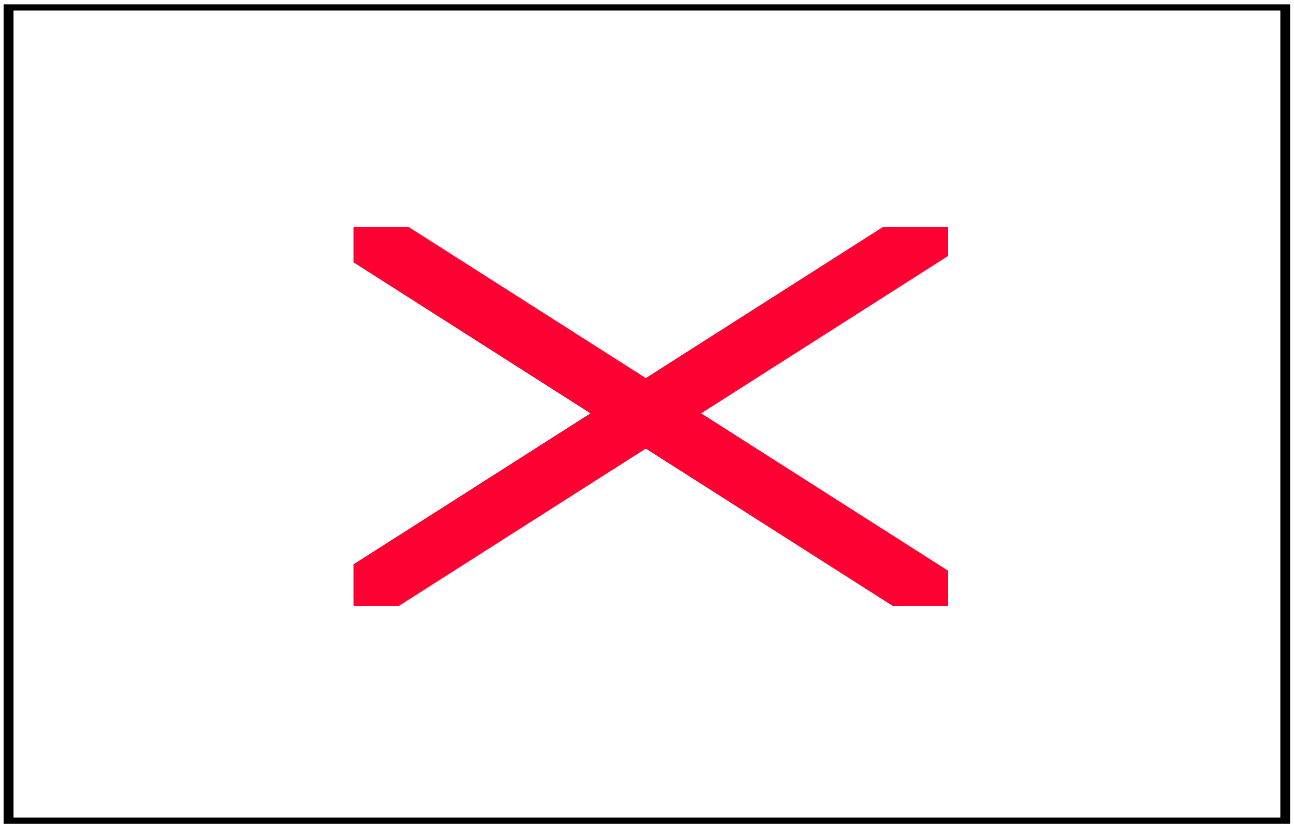
2. Percent finer = (a ∗ R_{cp}) / W_s ∗ 100
   a = correction for specific gravity (values of a given in Table A-3; See Appendix)
   a = **0.99**

3. Corrected reading for effective length (R_{cl}) = $R + F_m$
   Meniscus correction (F_m) = **1**

4. Effective Length (L) = (values of L given in Table A-1; See Appendix)

5. Variation of (A) with Gs and T°C = (values of A given in Table A-2; See Appendix)

6. Particle Diameter D (mm) = $A\sqrt{(L(cm) / t\ (min))}$



<u>SUMMARY AND CONCLUSIONS</u>:

The hydrometer test for the given soil sample produced results for very small particles as expected. The particle size distribution curve shows values ranging from 0.085mm (close to No. 200 sieve) to 0.00095mm. There is however, a variation in the curve at around 0.02 mm. This is likely because the hydrometer reading at 1 hr. was 0.5 higher than the reading before it at 30 min. and the reading after it at 2 hr.

APPENDICES:

Table A-1: Variation of L with Hydrometer Reading
ASTM 152-H hydrometer

Hydrometer reading	L (cm)	Hydrometer reading	L (cm)	Hydrometer reading	L (cm)	Hydrometer reading	L (cm)
0	16.3	13	14.2	26	12.0	39	9.9
1	16.1	14	14.0	27	11.9	40	9.7
2	16.0	15	13.8	28	11.7	41	9.6
3	15.8	16	13.7	29	11.5	42	9.4
4	15.6	17	13.5	30	11.4	43	9.2
5	15.5	18	13.3	31	11.2	44	9.1
6	15.3	19	13.2	32	11.1	45	8.9
7	15.2	20	13.0	33	10.9	46	8.8
8	15.0	21	12.9	34	10.7	47	8.6
9	14.8	22	12.7	35	10.6	48	8.4
10	14.7	23	12.5	36	10.4	49	8.3
11	14.5	24	12.4	37	10.2	50	8.1
12	14.3	25	12.2	38	10.1	51	7.9

Table A-2: Variation of A with G_s

Temp. (C)	Specific Gravity (G_s)						
	2.50	2.55	2.60	2.65	2.70	2.75	2.80
17	0.0149	0.0146	0.0144	0.0142	0.0140	0.0138	0.0136
18	0.0147	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134
19	0.0145	0.0143	0.0140	0.0138	0.0136	0.0134	0.0132
20	0.0143	0.0141	0.0139	0.0137	0.0134	0.0133	0.0131
21	0.0141	0.0139	0.0137	0.0135	0.0133	0.0131	0.0129
22	0.0140	0.0137	0.0135	0.0133	**0.0131**	0.0129	0.0128
23	0.0138	0.0136	0.0134	0.0132	0.0130	0.0128	0.0126
24	0.0137	0.0134	0.0132	0.0130	0.0128	0.0126	0.0125
25	0.0135	0.0133	0.0131	0.0129	0.0127	0.0125	0.0123
26	0.0133	0.0131	0.0129	0.0127	0.0125	0.0124	0.0122
27	0.0132	0.0130	0.0128	0.0126	0.0124	0.0122	0.0120
28	0.0130	0.0128	0.0126	0.0124	0.0123	0.0121	0.0119
29	0.0129	0.0127	0.0125	0.0123	0.0121	0.0120	0.0118
30	0.0128	0.0126	0.0124	0.0122	0.0120	0.0118	0.0117

Table A-2: Variation of a with G_s

G_s	A
2.50	1.04
2.55	1.02
2.60	1.01
2.65	1.00
2.70	**0.99**
2.75	0.98
2.80	0.97

ATTERBERG LIMIT TESTS LIQUID LIMIT & PLASTIC LIMIT

EXPERIMENT # 5

CE 3143
September 25, 2003
Group A
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TESTING OBJECTIVE:

- To determine the Atterberg Limits/Consistency Limits and classify the soil from the plasticity chart. The Atterberg Limits are a method to describe the consistency of fine-grained soils. Two of these limits are the *Plastic Limit* and the *Liquid Limit*. From these values the *Plasticity Index* may be calculated.
- *Plastic Limit (PL)* - the moisture content of a soil at the point of transition from semisolid to plastic state.
- *Liquid Limit (LL)* - the moisture content of a soil at the point of transition from plastic to liquid state.
- *Plasticity Index (PI)* – the difference between the *Liquid Limit* and the *Plastic Limit*. *PI = LL - PL.*

APPLICATIONS:

- Consistency limits (*LL* and *PL*) are significant to understand the stress history and general properties of the soil met with construction. An estimate of *Plasticity Index* is important to classify the soils particularly in highly expansive clays.
- High *PI* soils are more difficult to compact. The sometimes need to be stabilized by chemicals.
- Low *PI* soils make construction difficult, because adding only a little water turns the soil to liquid (*LL).*

A) LIQUID LIMIT TEST

APPARATUS REQUIRED:

27. Casagrande liquid limit device
28. Grooving tool
29. Mixing dishes
30. Spatula
31. Balance Sensitive up to 0.01 g
32. Electric Oven

TEST PROCEDURE:

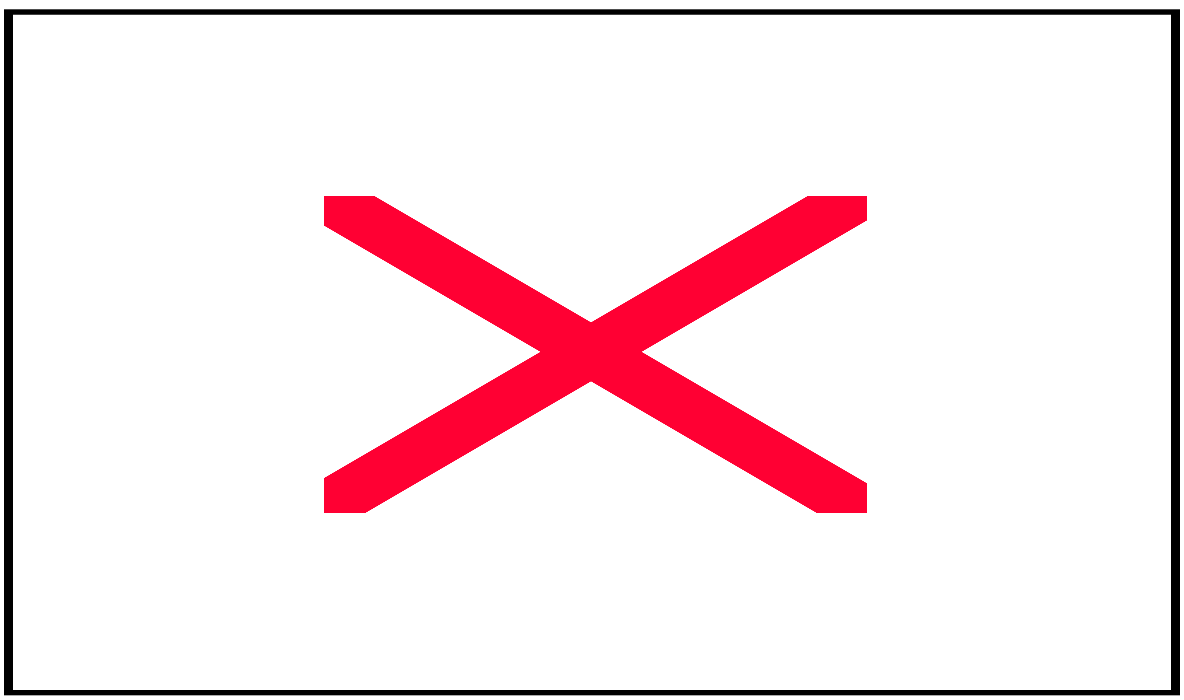
1. Determine the mass of each of the three moisture cans (W_1).
2. Make sure to calibrate the drop of the cup using the other edge of the grooving tool so that there is a consistency in height of drop.
3. Put about 250 g of air dried soil passing # 40 into an evaporating dish and add a little water with a plastic squeeze bottle to barely form a paste like consistency.
4. Place the soil in the Casagrande's cup and using a spatula, smoothen the surface so that the maximum depth is about 8mm.
5. Using the grooving tool, cut a grove at the center line of the soil pat.
6. Crank the device at a rate of 2 revolutions per second until there is a clear visible closure of ½" or 12.7 mm in the soil pat placed in the cup. Count the number of

blows (*N*) that caused the closure (make the paste so that *N* begins with a value higher than 35).

7. If *N* ~ 20 to 40, collect the sample from the closed part of the pat using a spatula and *determine the water content* weighing the weight of the can + moist soil (W_2). If the soil is too dry, *N* will be higher and reduces as water is being added.
8. Additional soil shouldn't be added to make the soil dry, expose the mix to a fan or dry it by continuously mixing it with the spatula.
9. *CLEAN THE CUP AFTER EACH TRIAL*, obtain a minimum of three trials with values of *N* ~ 20 to 40.
10. Determine the corresponding w% after 24 hrs and plot the *N* vs w%, called the "*flow curve*".

TEST RESULTS:

Liquid Limit Test No.	1	2	3
Can No.	1	2	3
Mass of can, W_1 (g)	89.15	80.18	105.66
Mass of can + moist soil, W_2 (g)	97.77	90.72	115.42
Mass of can + dry soil, W_3 (g)	96.31	88.90	113.68
Moisture content, w(%) = $\frac{W_2 - W_3}{W_3 - W_1} \times 100$.	20.39%	20.87%	21.70%
Number of blows, *N*	43	35	22



Calculations:

7. Liquid Limit (*LL*) = **21.5**

8. Flow Index (F_1) = $\frac{w_1(\%) - w_2(\%)}{\log N_2 - \log N_1} = \frac{21.70 - 20.39}{\log 43 - \log 22} = \mathbf{4.50}$

B) PLASTIC LIMIT TEST

APPARATUS REQUIRED:

1. Mixing dishes
2. Spatula
3. Balance Sensitive up to 0.01 g
4. TxDOT recommended Plastic limit device (for this session).

TEST PROCEDURE:

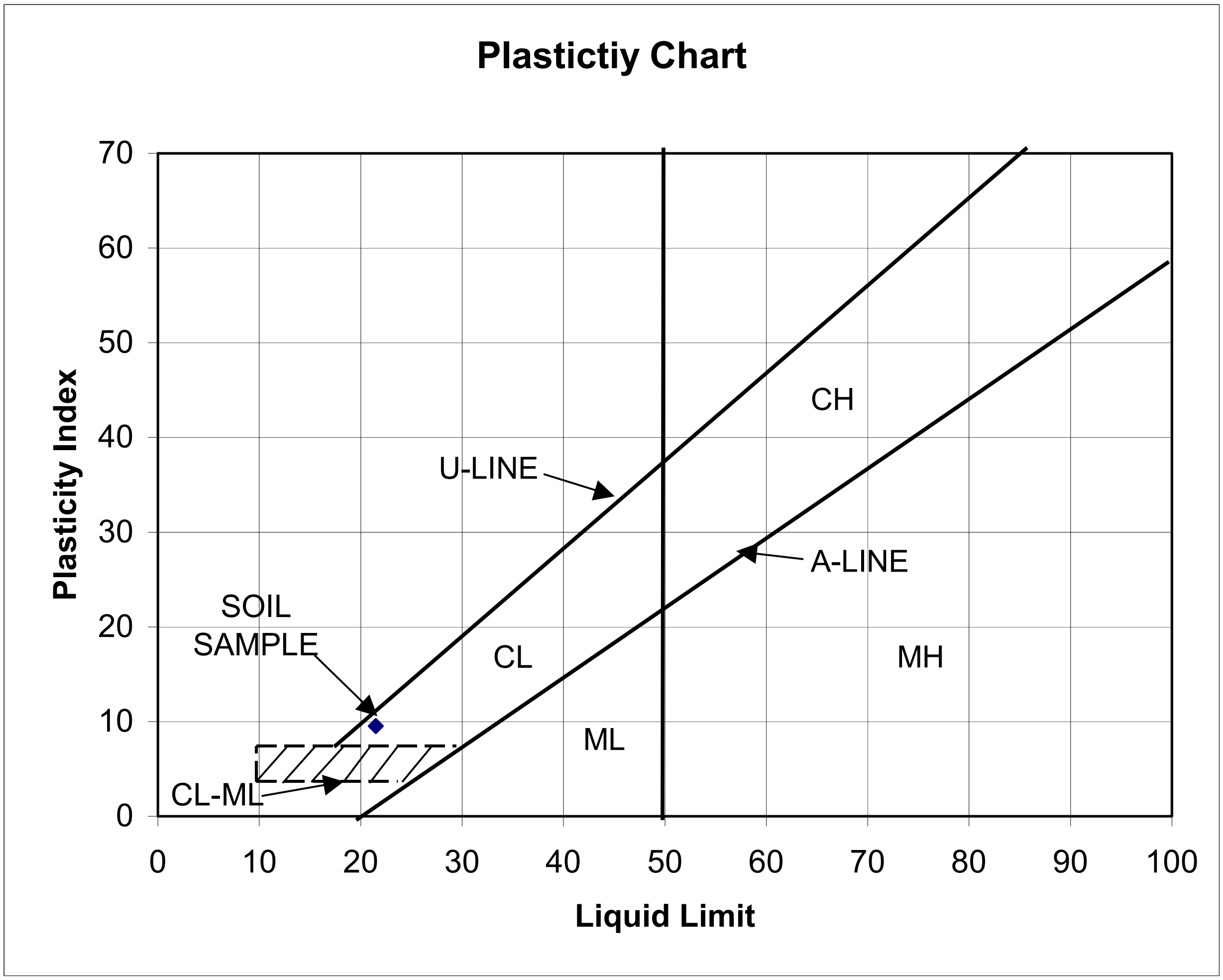
1. Take approximately 20 g of dry soil and mix some amount of water from the plastic squeeze bottle.
2. Determine the weight of empty moisture can, (W_1).
3. Prepare several small, ellipsoidal rolls of soil and place them in the plastic limit device. Place two fresh sheets of filter papers on either faces of the plates.
4. Roll the upper half of the device which has a calibrated opening of 3.18 mm with the lower half plate.
5. If the soil gets crumbled forming a thread of about the size of the opening between the plates, collect the crumbled sample, weigh it in the moisture can (W_2) for water content determination. Otherwise repeat the test with the same soil but drying it by squeezing between your palms.
6. Determine the weight of the dry soil + moisture can, (W_3).
7. The water content obtained is the plastic limit.

TEST RESULTS:

Plastic Limit Test No.	1
Can No.	A
Mass of can, W_1 (g)	86.84
Mass of can + moist soil, W_2 (g)	91.24
Mass of can + dry soil, W_3 (g)	90.77
Plastic Limit (*PL*)= $\frac{W_2 - W_3}{W_3 - W_1} \times 100$	11.96%

Calculations:

1. Plastic Limit (*PL*) = **11.96**
2. Liquid Limit (*LL*) = **21.50** (from part A)
3. Plasticity Index (*PI) = LL - PL* = 21.50 - 11.96 = **9.54**



CLASS DATA COMPARISONS:

	Group A	Group B	Group C	Group D
Liquid Limit	21.50	20.80	19.98	21.28
Plastic Limit	11.96	10.50	9.60	5.93
Plasticity Index	9.54	10.30	10.38	15.35

Mean: $\bar{x} = \frac{\sum w_i}{n} =$

Liquid Limit = 20.89
Plastic Limit = 9.50
Plasticity Index = 11.39

Standard Deviation: $\sigma = \sqrt{(1/n * \sum(x - w_i)^2}$
Liquid Limit = 0.583
Plastic Limit = 2.225
Plasticity Index = 2.308

SUMMARY AND CONCLUSIONS:

- From the experimental values of the *Liquid Limit (LL)* and the *Plastic Limit (PL)* the *Plasticity Index (PI)* was calculated to be **9.54**.
- From the Plasticity Chart, the soil sample was determined to be a fine-grained Clay soil of Low Plasticity (CL).
- The results found by Groups A, B, and C were fairly consistent. However the results found by group D were quite inconsistent with the other 3 groups. The Group C calculation for plastic limit was much lower than the average value for the other groups, which in turn caused the calculation for PI to be much higher than the average.