CE EN 341
Soil Mechanics Laboratory
Fall 1994
Section 6

Atterburg Limits

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by
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I. Introduction

Objective of the Hydrometer Test

The objective of the hydrometer test is to determine the grain-size distribution in a soil sample for the fraction that is finer than the No. 200 sieve size. The hydrometer test can measure the particle-size distribution in soils down to 0.001 mm. Therefore, the hydrometer test is very effective in determining the amount of silt- and clay-sized particles in a soil sample.

Purpose for Running the Test

When soil particles settle in water, the particles settle at different velocities. Each particle's velocity depends on its shape, size, weight, and the viscosity of water. The hydrometer test is formulated to measure the size of soil particles when all the other variables are known.

By running the hydrometer analysis test in conjunction with the sieve analysis test, the grain-size distribution curve can be plotted and the soil can be classified. After classifying a soil according to the Unified or the AASHTO classification system, the soil can be used for engineering purposes.

II. Test Procedure

1. A soil sample had already been prepared for us. The soil sample was made by combining 62.27 grams of soil with 125 cc of a deflocculating agent in water. The soil sample was allowed to soak for 8 to 12 hours.

2. We then filled a 1000 cc graduated cylinder with a deflocculating agent solution.

3. Next, we placed the hydrometer in the graduated cylinder containing the deflocculating solution. By taking the reading off the hydrometer, we obtained the zero correction factor (F_z) and we observed the meniscus correction (F_m).

4. Fourth, we poured the soil sample into a 1000 cc graduated cylinder. We used a spray bottle to insure that all of the soil was washed out of the cup.

5. Fifth, we filled the second 1000 cc graduated cylinder with distilled water. After filling the cylinder with distilled water, we made sure the soil mix in the graduated cylinder was mixed well by turning the cylinder upside-down and shaking it several times.

6. Sixth, we set the cylinder down and immediately recorded the time. We then proceeded to take hydrometer readings at 1, 4, 8, 15, and 30 minutes. We then took hydrometer readings at 1, 6, 15, and 26 hours.

7. Finally, we compiled all our data and made calculations to create the grain size distribution curve. The raw data and calculations are located in the appendix.

III. Results

Graphs and Tables

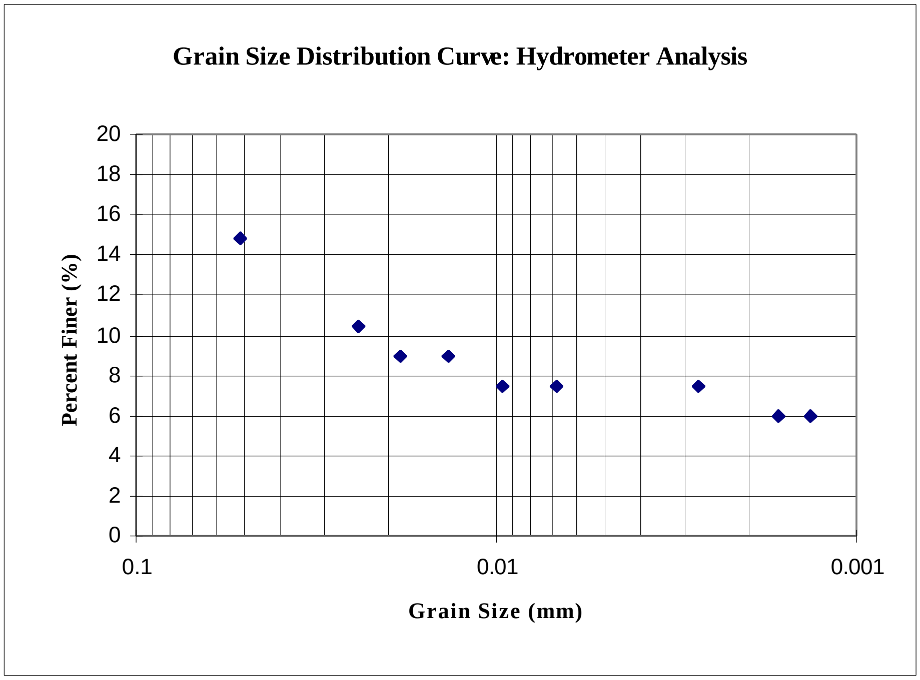

Figure 1: Grain Size Distribution Curve from the Hydrometer Analysis Only.

Table 1: Results from the Hydrometer Analysis.

Diameter	Percent Finer
0.05131	14.87
0.02419	10.41
0.01857	8.92
0.01356	8.92
0.00964	7.43
0.00682	7.43
0.00273	7.43
0.00165	5.95
0.00135	5.95

Table 2: Sieve Test Values Showing the Mass Retained in Each Sieve, the Percent Retained in Each Sieve, and the Percent Finer than Each Sieve Size.

U.S. sieve no.	Opening (mm)	Mass Retained on each sieve (g)	Percent retained on each sieve	Percent finer
3/8"	9.51	84.80	13.40	86.60
4	4.75	15.90	2.51	84.09
8	2.36	18.90	2.99	81.10
16	1.18	22.90	3.62	77.48
30	0.60	50.10	7.92	69.57
50	0.30	157.50	24.89	44.68
100	0.15	99.90	15.78	28.90
200	0.08	110.00	17.38	11.52
Pan	XX	72.90	11.52	0.00
Total	XX	632.90	100.00	XX

D10 = 0.07
D30 = 0.15
D60 = 0.42

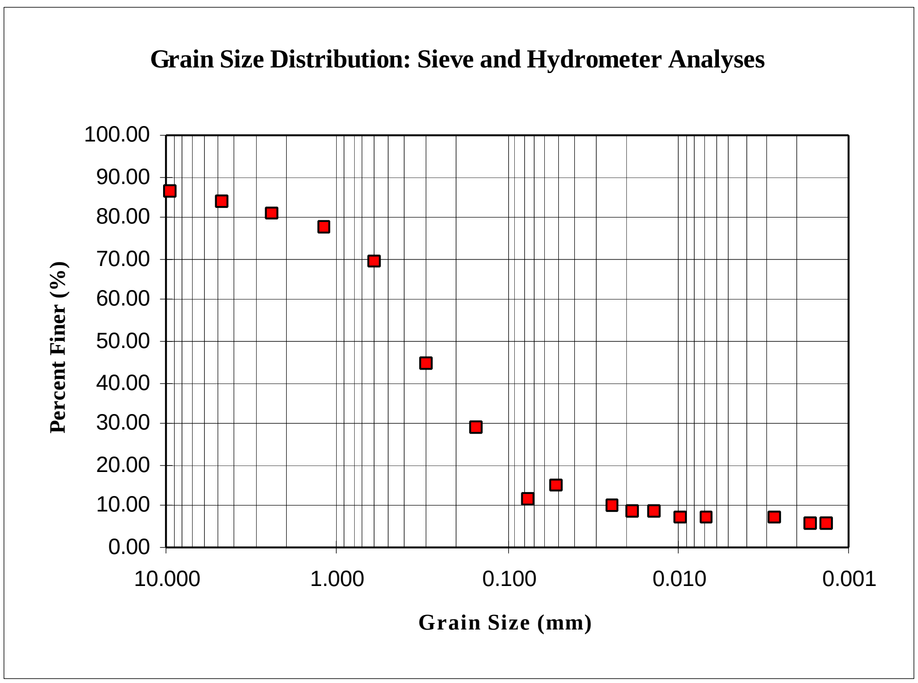

Figure 2: Grain Size Distribution Curve From the Sieve and Hydrometer Analyses

Results From the Hydrometer and Sieve Analyses

The results from the hydrometer analysis of the soil are represented graphically in figure 1. The data used to create the graph is located in table 1. Table 2 contains the results from the sieve analysis on the same soil. The combined results from the hydrometer and sieve analyses are plotted in figure 2. Because the hydrometer analysis gave us new points on the graph, the value of D_{10} was adjusted to take the hydrometer readings into account.

Diameters Corresponding to Percents Finer

In figures 2, 3, and in table 2, you can see that the diameters corresponding to percents finer of 10%, 30%, and 60% (D_{10}, D_{30}, and D_{60}) are 0.025 mm, 0.15 mm, and 0.42 mm, respectively.

Uniformity Coefficient, C_u

The uniformity coefficient was calculated according to the equation:

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

The soil tested had a uniformity coefficient of 16.8.

Coefficient of Gradation, C_c

The coefficient of gradation was calculated according to the equation:

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

The soil tested had a coefficient of gradation of 2.14.

Classification Criteria

For classification by the Unified Soil Classification System, we determined the percent passing through sieve numbers 4 and 200. The results were the following:

Table 2: Percent passing through sieve numbers 4 and 200.

Percent passing through number 4 sieve	Percent passing through number 200 sieve
84.09	11.52

IV. Discussion

What do the Results Mean?

The purpose of the hydrometer test was to determine the grain size distribution of the fine particles of a soil sample. Last week, we determined the grain size distribution of the larger particles from a sieve analysis. This week, I combined the results from the sieve analysis with the results from the hydrometer analysis. By combining these results, you can determine the type of soil and a few of its engineering properties.

As you can see in table 2, there was a large percentage of particles passing through the number 4 sieve, but a small percentage of particles passing through the number 200 sieve. Overall, 72.57% of the particles were the size of sand. From the hydrometer analysis (table 1 and figure 1), you can see that 4-8% of the particles were the size of silt (between 0.075 and 0.002 mm diameter). You can also see that 4-7% of the particles were clay-sized particles.

We found the soil's uniformity coefficient (C_u) to be 16.8 and the coefficient of gradation (C_c) to be 2.14. These values for C_u and C_c indicate that the soil falls into the *well graded* category.

Comparison to Typical Values

For sandy soils such as this one, a well-graded soil has a uniformity coefficient greater than 6 and a coefficient of gradation between 1 and 3. Comparing these values with the uniformity coefficient of 16.8 and the coefficient of gradation of 2.14 for the soil tested, we can see that this soil meets the requirements for a well-graded soil.

In the Unified Soil Classification System, the cutoff size for gravel is 4.75 mm diameter, the cutoff point for sand is 0.075 mm diameter, and the cutoff point for silt is 0.002 mm diameter. All particles below 0.002 mm diameter are classified as clay. For the soil we tested, 15.91% of the soil would be classified as gravel, 72.57% of the soil would be classified as sand, and the remaining 11.52% would be classified as silt and clay in the Unified Classification System.

How Can the Soil be Classified?

The soil we tested demonstrated the following properties:

- More than half (88.48%) of the soil material was larger than the No. 200 sieve. Therefore, the soil is coarse-grained.
- More than half of the coarse fraction was smaller than the No. 4 sieve size. This indicates that the soil is a sand.
- The soil met the requirements for a well-graded soil since the coefficient of gradation was 2.14 and the coefficient of uniformity was 16.8.
- Between 5 and 12% of the soil was composed of fine particles passing through the No. 200 sieve. This indicates that the soil is either an SW-SM or a SW-SC.

From this information, we can see that the soil can either be classified as an SW-SM or an SW-SC. A liquid limit and plastic limit analysis would show whether the soil is an SW-SM or an SW-SC. But there seemed to have been more silt than clay. Therefore, the soil is most probably an SW-SM. Making the assumption that the soil is an SW-SM (and using figure 3.4 in Principles of Geotechnical Engineering, by Das), the group name of the soil is a *well graded sand with silt and gravel*.

What Were the Sources of Error?

The following were possible sources of error:

1. The temperature of the test was variable since we did not use a constant temperature bath. This change in temperature may have caused an error in the hydrometer analysis.
2. The measured dry weight of the soil may have been slightly different than what was read because of inaccuracy of the scale.
3. It was very possible that some of the hydrometer readings may have been inaccurate. It was difficult for us to see where the top of the meniscus was. Also, we had accidentally left the hydrometer in the 1000 cc graduated cylinder overnight. Because we left the hydrometer in the cylinder overnight, the soil particles fell in a curved direction instead of a straight line. Stoke's law assumes that the soil particles fall in a straight line. However, the hydrometer readings were within +/- 1 of the actual value.
4. Although a deflocculating agent was added to the soil, chunks of small particles may have still formed, causing the particles to settle faster. These faster-settling particles may have caused an error in the specific gravity reading.

What Could be done to Reduce the Error?

To reduce the error, we could simply change the effects of the errors listed above. We could have reduced experimental error by:

1. Keeping the tested soil sample in a constant temperature bath, insuring that the unit weight and viscosity of water remain constant. Then, we could have used the temperature correction to determine the actual hydrometer reading.
2. Insuring that an accurate scale is used to measure the mass of the soil specimen.
3. Obtaining a more accurate hydrometer. This hydrometer could possibly be divided into tenths. After determining the meniscus correction and the zero correction, we could have read the hydrometer exactly at the top of the meniscus.
4. Insuring that the hydrometer is taken out of the soil test cylinder immediately after the hydrometer reading was taken. Leaving the hydrometer inside the graduated cylinder can cause the soil particles to fall in a curved instead of a straight line.
5. Making sure that the deflocculating agent is thoroughly mixed with the soil solution by allowing the deflocculating agent to soak with the soil for 8 to 12 hours.

V. Conclusion

From the hydrometer analysis laboratory, I have learned the proper method for hydrometer analysis of soils by testing a soil with some fine particles. Also, I have learned how to calculate the particle size distribution from a hydrometer analysis of a fine soil.

From both the sieve and the hydrometer analyses, we found the soil to be coarse-grained and mostly composed of sand. According to the Unified Classification System, the soil contains 15.91% gravel, 72.57% sand, about 6% silt, and about 5% clay. Tests for Atterberg limits would reveal further information, but the soil may be classified as either an SW-SM or an SW-SC. If the soil is classified as an SW-SM, then its group name is a well graded sand with silt and gravel.

This well-graded soil with silt and gravel would exhibit fairly good strength properties. Although some expansion is possible, a large amount of soil expansion is not very likely because of the small amount of clay particles.

VI. Appendix

References

Das, B. M. (1993). Principles of geotechnical engineering, PWS Publishing Company, Boston.

Das, B. M. (1992). Soil Mechanics Laboratory Manual, Engineering Press, Inc., San Jose, California.

Data and Calculations

**Raw data and calculations are located on the following pages.