CE EN 341
Soil Mechanics Laboratory
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Section 6

Atterberg Limit Tests: Liquid and Plastic Limits

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I. Introduction

Objective of the Liquid Limit and Plastic Limit Tests

The objective in running the liquid and plastic limit tests was to determine two important soil classification properties in a soil specimen--the liquid limit and the plastic limit. In the early 1900's, a Swedish soil scientist named Atterberg created a test that would determine the consistency of fine-grained soils. He divided fine grain soils into four states: the solid, semi-solid, plastic, and liquid states.

Atterberg also defined three properties of soils which depended on the moisture content: the liquid limit, the plastic limit, and the shrinkage limit. The four soil states and three properties of the soil can be explained by the following diagram, which is a plot of the volume of soil with increasing moisture content:

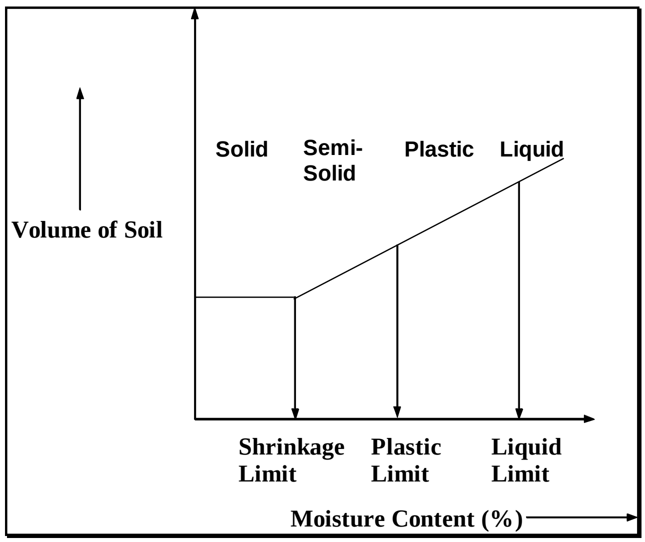

Figure 1: As the Moisture Content of a Soil Increases, the Volume Remains the Same Until the Shrinkage Limit is Reached. Then, the Volume Continually Increases Since Most of the Void Spaces are Filled.

The objective of this lab was to determine the Atterberg liquid limit and plastic limit. This lab also helped me gain familiarity with the liquid and plastic limit tests. If I am familiar with the Atterberg tests, I will be able to tell when they are performed properly and if the results seem reasonable.

Purpose for Running the Tests

There are two purposes for running the liquid limit and plastic limit tests:

1. After determining the liquid and plastic limits of a soil, you can calculate the plasticity index (PI) of a soil. The plasticity index is simply the difference between the liquid and plastic limits. You can then use the plasticity index and liquid limit to classify the soil according to the AASHTO or the USCS classification systems.
2. After you classify the soil according to the AASHTO or the USCS classification system, the physical properties of the soil can be determined. The activity, or swelling potential of the soil, is one physical property that you can identify.

When the Atterberg tests are run in conjunction with a sieve and hydrometer analysis, the soil classification can be completely determined. The Atterberg tests are especially important for fine-grained soils with a high percentage of clay.

II. Test Procedure

First, I determined the liquid limit of the soil by the following procedure:

1. First, I passed some soil through a No. 40 sieve. I then added water from a bottle to form a soil paste.
2. Second, I collected three moisture cans and weighed them.
3. Third, after mixing the soil thoroughly, I added the soil to the liquid limit testing device, leveling it off at a depth of about 8 mm.
4. Fourth, I cut a groove along the center line of the soil, then began to turn the crank on the testing device.

5. Fifth, I determined the number of turns of the crank which it took to create a 1/2 in. closure at the bottom of the groove. I had to go through a process of adding more water to the soil and testing to obtain a moisture content where less than 40 turns (N=40) were needed.
6. I collected three samples of the soil. One with N = 26, one with N = 15, and one with N = 27. I weighed each of these soil samples immediately after testing. Then I dried each of the samples and obtained the dry weight to determine the moisture content.
7. Finally, I plotted the flow curve and determined the liquid limit.

Then, I determined the plastic limit of the soil by the following procedure:

First, I took the sample of soil used in the liquid limit test and rolled it into a circular shape.
Then, I began rolling the soil sample in my hands until the sample got down to the size of 1/8-in.
I made sure all the bits of soil were rolled to a size of 1/8 in. before I reformed the soil mass.
After reforming the soil mass, I rolled the soil to a diameter of 1/8-in. again.
I continually rolled the soil down to 1/8 of an inch until the soil crumbled when it reached a diameter of 1/8-in.
After the soil crumbled, I put the soil in a moisture cup, weighed the soil and the cup together, and placed the soil sample in the oven. After 24 hours, I determined the dry weight of the soil and the moisture content.

III. Results

Graphs and Tables

Table 1: Results from the Liquid Limit Test.

Can Number	Weight of can (g)	Weight of can + wet soil (g)	Weight of can + dry soil (g)	Moisture content, w (%)	Number of blows
1	27.20	35.60	33.93	24.81%	26
3	33.50	46.30	43.63	26.36%	15
4	20.40	35.20	32.27	24.68%	27

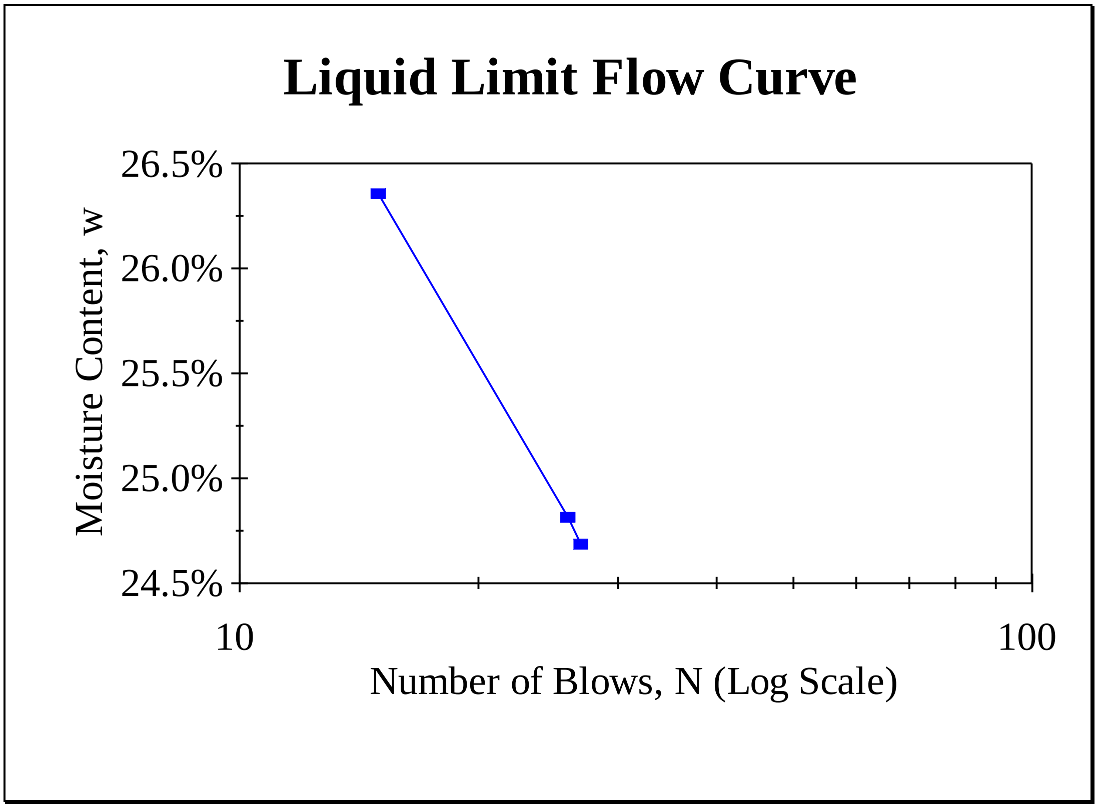

Figure 2: Flow Curve from the Liquid Limit Test: LL = 24.9%.

Table 2: Data from the Plastic Limit Test.

Can Number	Weight of can (g)	Weight of can + wet soil (g)	Weight of can + dry soil (g)	Plastic Limit, PL (%)
2	27.50	36.72	35.39	16.86%

Results From the Liquid and Plastic Limit Tests

The results from the liquid limit test and the plastic limit test are located in figure two and tables one and two. The flow curve indicates that the soil tested had a liquid limit of 24.9% and a plastic limit of 16.86%. The plasticity index is the difference between these values and is 8.04%.

Flow Index (FI)

The flow index was calculated according to the equation:

$$F_I = \frac{w_1(\%) - w_2(\%)}{\log N_2 - \log N_1}$$

The values of w1 , w2 , N1 , and N2 were taken from table 1. From these values, the flow index was calculated to be 6.58.

Determination of the Liquid Limit (LL)

Three-point graphical liquid limit determination (from the flow curve). Using the flow curve, I was able to graphically determine the liquid limit. From the straight line, I determined the moisture content corresponding to 25 blows. This was the liquid limit. Graphically, I found the liquid limit to be 24.9%.

One-point liquid limit determination (from an empirical equation). I also determined the liquid limit from an equation formulated by the U.S. Army Waterways Experiment Station in 1949. This equation gives the liquid limit for any value of N (number of blows) between 20 and 30. The equation goes like this:

$$LL = w_N(\%)\left(\frac{N}{25}\right)^{0.121}$$

Using a water content of 24.68% and an N of 27 in this equation (see table 1), I calculated the liquid limit to be 24.91%. Thus, the graphical determination and the calculation of the liquid limit gave similar values.

Determination of the Plastic Limit (PL)

The plastic limit was simply the moisture content at which a ball of clay crumbled when rolled to a diameter of 1/8-in. Looking at table 2, you can see that I determined the plastic limit to be 16.86%

The Plasticity Index (PI)

The plasticity index is the difference between the liquid limit and the plastic limit:

PI = LL - PL

The plasticity index was found to be 8.0%.

Activity

The activity of the soil can be calculated according to the equation:

$$A = \frac{PI}{(\%clay)}$$

The activity of the soil tested could have been found if a hydrometer analysis had been run and the percent of clay-size particles was known from that test.

Summary

Table 3: Summary of Results.

Flow Index	Liquid Limit	Plastic Limit	Plasticity Index
6.58	24.9%	16.86%	8.0%

IV. Discussion

What do the Results Mean?

Liquid Limit. The liquid limit gives us the moisture content at which the soil changes from the plastic to the liquid state. When the soil passes to the liquid state, a slight increase in stress on the soil will result in a large amount of strain, and the soil will flow like a liquid. At 24.9% moisture content, this soil will display liquid properties.

Plastic Limit. The plastic limit gives us the moisture content at which the soil changes from the semisolid to the plastic state. After a soil passes the plastic limit, it behaves like a plastic. The strength of the soil significantly decreases past the plastic limit. This soil began to display plastic properties at 16.86% moisture content.

Plasticity Index. The plasticity index of a soil gives the range over which a soil will display plastic properties. The plasticity index is useful in determining the type of soil. It is used to classify a soil according to the AASHTO and USCS classification systems. The range over which the soil was found to be plastic was 8.0%.

Comparison to Typical Values

Typical values for the liquid limit and plasticity index, along with the actual test values, are located in table 4:

Table 4: Comparison of the Soil Tested with Actual LL and PI values for High-Plasticity Clays.

Clay Mineral	Liquid Limit	Plasticity Index
Kaolinite	35-100	20-40
Illite	55-120	35-55
Montmorillonite	100-800	50-100
Soil tested	24.9	8.0

As you can see, the liquid limit of 24.9 and the plasticity index of 8.0 are much less than those for inorganic clays of high plasticity, such as kaolinite, illite, and montmorillonite. Using Casagrande's plasticity chart, we can see that the PI and the LL of this soil plots above the "A" line that separates the inorganic clays from the inorganic silts. If more than half of the soil tested were less than the No. 200 sieve size, it would be an inorganic clay of low plasticity.

How Can the Soil be Classified?

The soil I tested demonstrated the following properties:

- A liquid limit of 24.9%.
- A plasticity index of 8.0%.
- Plots above the A-line of the plasticity chart.

Using these three characteristics of the soil, the soil can be classified as a CL, or an inorganic clay with low plasticity (according to the USCS classification system). The soil may have been mixed with some sand, however, and more than half of the soil may not have passed the No. 200 sieve. If this is the case, the soil could have been classified as a coarse-grained soil.

What Were the Sources of Error?

The following were possible sources of error:

1. In both the liquid limit and the plastic limit tests, there was a high potential for error. Once a person becomes experienced in performing the Atterberg tests, that person can get reasonably accurate results. But with an amateur like myself, it is impossible to get an accurate result according to ASTM standards the first time.
2. The measured weights of the soil and the cans may have been slightly different than what was read because of inaccuracy in the scale.
3. When I performed the liquid limit test, I may have applied more soil than the required 8 mm to the testing cup. This would have put greater weight and greater stress on the soil which would result in early closure.
4. Also, when I performed the liquid limit test, I may have incorrectly estimated the number of blows causing a 1/2 inch closure. Perhaps the closure was almost 3/4 of an inch before I recorded the reading.
5. When I performed the plastic limit test, the soil may not have had a uniform moisture content at the time of crumbling. This may have caused an inaccurate plastic limit.
6. Also, when I performed the plastic limit test, the soil crumbled before it reached 1/8 inch. This may have caused a low plastic limit measurement.

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. Being more experienced and more careful in performing the test.
2. Insuring that an accurate scale is used to measure the mass of the soil specimen.
3. Insuring that only a small layer of soil (less than 8 mm) is deposited on top of the liquid limit testing cup. This will keep extra stress caused by the weight of the soil specimen from destroying the meniscus reading.
4. Insuring that the soil closes exactly 1/2 inch by carefully observing the liquid test as it proceeds.
5. Keeping the moisture content uniform throughout the soil specimen when performing the liquid limit test.

6. Insuring that the soil crumbles at 1/8 inch when performing the liquid limit test. If the soil crumbles at a diameter greater than 1/8 inch, it may be necessary to perform the test again on another soil specimen.

V. Conclusion

From the liquid limit and plastic limit laboratories, I have learned the proper method for determination of the Atterberg limits of soils by testing the particles of a soil passing through a No. 40 sieve. Also, I have learned how to calculate the Liquid limit, plastic limit, and plasticity index with data from liquid and plastic limit tests.

If the soil was a fine-grained soil (more than 50% passing the No. 200 sieve), the soil would be classified as an inorganic clay with low plasticity (from Casagrande's plasticity chart). But if the soil was mostly coarse-grained, it could be classified as a number of things. The soil's liquid limit was found to be 24.9%, the plastic limit was found to be 16.86%, and the plasticity index was found to be 8.0%. By comparison with the Atterberg limits for Kaolinite, Illite, and Montmorillonite, this soil does not come close to the values of the liquid limit and plasticity index for these clays. (See Table 4).

Thus this soil may exhibit some swelling, but not a significant amount as in Montmorillonite. The soil would also have low plasticity, as opposed to the high plasticity of some fatty clays.

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.