The University of Iowa
Department of Civil & Environmental Engineering
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53:030 Soil Mechanics
Lab Experiment No. 3:
Liquid and Plastic Limits of Fine-Grained Soils

Equipment: liquid limit device, grooving tool, porcelain evaporating dish, spatula, 5 water content tins, mass balance, oven, plastic squeeze bottle, glass rolling plate and paper towels.

A. Background

The *liquid limit* (LL) of a soil is defined as the water content at which a trapezoidal groove of a specified shape, cut in a moist soil in a special cup, is closed after 25 taps on a hard rubber plate. The *plastic limit* (PL) is the water content at which the soil begins to break apart and crumble when rolled into threads 3mm ($\frac{1}{8}$in) in diameter. The *shrinkage limit* (SL) is the water content at which soil reaches its minimum volume as it dries out from a saturated condition. These limits, customarily expressed as whole numbers of water content percentage, are the so-called **Atterberg Limits** of a soil. In this laboratory assignment, we will measure the *liquid and plastic limits* of a given soil.

In and of themselves, the Atterberg limits mean little. But as indices to the significant properties of a fine-grained soil, they are quite useful. The liquid limit has, for example, been found to be directly proportional to the compressibility of a soil whereas the *plasticity index* or (LL - PL) represents the range in water content through which the soil is plastic. The liquid and plastic limits are further used in both the AASHTO and UCS classification schemes.

B. Experimental Procedure for the Liquid Limit Test

1. Calibrate the liquid limit device such that the bottom of the brass cup falls from a height of 10mm when dropped in each crank cycle. The base of the grooving tool is 10mm square and can be used in this process. If necessary, ask the lab instructor for assistance.
2. Take the mass of three empty, dry moisture content tins. So that you do not confuse your tins with those of other students, identify and record the number on each tin you use.
3. Obtain approximately 125 grams air-dry soil passing a No. 40 sieve.
4. Add water to the soil in increments of about 2-5 cm^3 until a smooth paste is formed.
5. Spread the paste in the front half of the liquid limit device's brass cup. Using the spatula, smooth the surface of the soil in the cup such that the maximum depth of the soil is about 8mm.
6. Using the grooving tool, cut a groove in the soil paste along the centerline of the cup.
7. Turn the crank on the liquid limit device at a rate of about 2 revolutions per second. The soil from the two sides of the cup will begin to flow toward the centerline and to close the groove. Count the number of blows N required for the groove in the soil to close through a distance of 12.7mm or $\frac{1}{2}$in when viewed from above.
8. The measurement objective is to obtain three values for N and the corresponding value of the water content for each: One value of N in the range of 25-35 blows, one value in the range of 20-25 blows, and one value in the range of 15-20 blows.
   a. After each attempt, remove the soil from the cup. Use water and paper towels to completely clean the cup. Thoroughly dry the clean cup before each successive attempt.
   b. If the soil is too dry, remove the soil to the evaporating dish. Mix the soil with additional water and try again.
   c. If the soil is too moist, remove the soil to the evaporating dish. **Do not** add dry soil to the mixture, but rather air-dry or oven dry the soil for a few minutes to reduce the moisture content.
9. After each successful test in which N falls into one of the three appropriate ranges, immediately commence taking the water content of the soil. When taking the moisture content of the soil, a small sample such as a heaping teaspoonful is a sufficient quantity. After obtaining the moist mass of the soil, allow the soil to oven dry for approximately 24 hours to determine its dry mass and water content w.

C. Liquid Limit Computations

1. On a log-linear scale, plot the moisture content (vertical linear scale) versus the number of blows (logarithmic horizontal scale). The three values obtained should plot roughly as a straight line which is called the *flow curve.* The slope of this line is called the *flow index* F_I:

$$F_I = \frac{w_1(\%) - w_2(\%)}{log_{10}(N_2) - log_{10}(N_1)},$$

where (N_1, w_1) and (N_2, w_2) are two arbitrary points on the curve. Based on the curve, determine the moisture content corresponding to 25 blows. This is the measured *liquid limit* for the soil.

2. The suggested format for both *liquid limit* and *plastic limit* water content computations is shown in Table 1.

Tin No.	M_1(g)♣	M_2(g)♠	M_3(g)♡	$w(\%)$	N

♣ Mass of empty, dry tin.

♠ Mass of tin + moist soil

♡ Mass of tin + dry soil

Table 1. Table for liquid limit and plastic limit water contents.

D. Procedure for Plastic Limit Test

1. Take approximately 20 grams of the provided air-dry soil which passes a No. 40 sieve.
2. Add water from the plastic squeeze bottle to the soil and mix thoroughly. Form two separate balls.
3. With the first ball, form a thread of uniform diameter by rolling the moist soil with the palm of your hand on a ground glass surface. Roll the soil at a rate of approximately 80 strokes/minute, where a stroke constitutes a forward and backward motion of the palm.
4. Roll the thread until it is 3mm or $\frac{1}{8}$in in diameter. Continue remolding and re-rolling the soil until it crumbles when it reaches this diameter.
5. When the soil thread crumbles at the appropriate diameter, immediately commence obtaining the water content. The measured water content will be the estimated *plastic limit* of the soil.
6. Repeat steps 3, 4, and 5 with the second lump of soil to obtain a second estimate of the soil's plastic limit.

E. Plastic Limit Computations

1. Compute the water content for the two samples.
2. Take the *plastic limit* for the soil as the mean of the two measured water content values.
3. Compute the activity index

$$A = \frac{PI}{\%(\text{finer than 0.002 mm})}$$

and attempt to identify what clay minerals characterize the soil. (*c.f.* Sec. 2.7 of the text.)