T 89

DETERMINING THE LIQUID LIMIT OF SOILS

FOP FOR AASHTO

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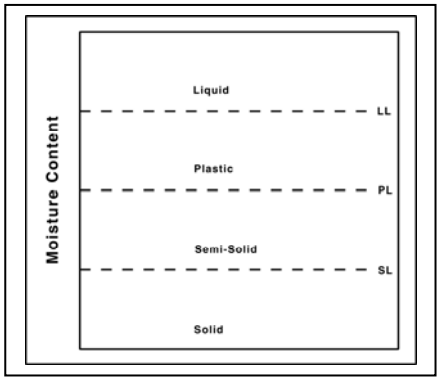


Material phase and moisture content

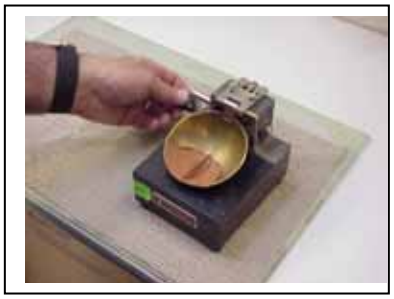
Significance

Fine-grained soils, particularly clays, exhibit different properties at different moisture contents. At very low moisture contents, the material acts like a solid. As the moisture content rises, the material moves from solid to semi-solid to plastic to liquid form.

The moisture content at the boundary between semi-solid and plastic states is known as the plastic limit (PL). The moisture content at the boundary between the plastic and liquid states is known as the liquid limit (LL). The difference between the plastic and liquid limits is called the plasticity index (PI), and indicates the size of the range over which the material acts as a plastic – capable of being deformed under stress, but maintaining its form when unstressed.

Fine-grained soils also exhibit shrinking and swelling as the moisture content changes. As water content increases from dry to wet, no change in volume occurs below a certain moisture content, known as the shrinkage limit (SL). Above the SL, volume increases as moisture content increases.

For these reasons, knowledge of the LL, PL, and PI, and sometimes the SL, are important to quality assurance in roadway construction.



Liquid limit apparatus

Scope

This procedure covers the determination of the liquid limit of a soil in accordance with AASHTO T 89. It is used in conjunction with the FOP for AASHTO T 90, Determining the Plastic Limit and Plasticity Index of Soils. The three values are used for soil classification and other purposes.

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Apparatus

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- Dish: preferably unglazed porcelain or similar mixing dish, of approximately 4.5 inch diameter.
- Spatula: having a blade 3 to 4 in. long and about 3/4 in. wide.
- Liquid Limit Device: manually or mechanically operated, consisting of a brass cup, carriage, and base plate.
- Grooving Tool: used to cut the soil in the liquid limit device cup.
- Gauge: part of the grooving tool or a separate metal bar, 10.0 ±0.2 mm (0.394 ±0.008 in). thick and approximately 50 mm (2 in.) long.
- Containers: corrosion resistant, suitable for repeated heating and cooling, having close fitting lids to prevent the loss of moisture. One container is needed for each moisture content determination.
- Balance: conforming to AASHTO M 231, class G1, sensitive to 0.01 g with a 1200 g capacity.
- Oven: thermostatically controlled, capable of maintaining temperatures of 230 ±9°F.
- Graduated cylinders for measuring distilled or demineralized water.

- Pulverizing Apparatus**:** Either mortar and rubber-covered pestle or any device suitable for breaking up the aggregations of soil particles without reducing the size of the individual grains of soil.
- Sieves: A series of the following sizes: ¼ in., #4, #10, #40 and a pan.

Adjustment of Liquid Limit Device

07 The liquid limit device shall be inspected to determine that the device is in good working order; that the pin connecting the cup is not worn to permit side play; that the screws connecting the cup to the hanger are tight; that the points of contact on the cup and base are not excessively worn; that the lip of the cup is not excessively worn; and that a groove has not been worn in the cup. The grooving tool shall be inspected to determine that the critical dimensions are correct.

Note 1: Wear is considered excessive when the point of contact on the cup or base exceeds approximately 0.5 in. in diameter, or when any point on the rim of the cup is worn to approximately 1/2 the original thickness. A slight groove in the center of the cup is not objectionable. If the groove becomes pronounced, the cup shall be replaced. A base that is excessively worn may be refinished as long as it is maintained within the tolerances specified.

Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10.0 ±0.2 mm (0.394 ±0.008 in).

Note 2: Check the height of the drop, before each new sample, by turning the crank at two revolutions per second while holding the gauge in position against the cup. If a ringing or clicking sound is heard without the cup rising from the gauge, the adjustment is correct. If no ringing is heard or if the cup rises from gauge, readjust the height of the drop. If the cup rocks on the gauge during this checking operation, the cam follower pivot is excessively worn and should be replaced.

Sample Preparation

Spreading soil

Liquid limit procedure

Sample

08 Samples must be prepared per AASHTO T 87 or T 146. Obtain a sample with a mass of about 100 g taken from the portion of the material passing the No. 40 sieve.

09 The mass required depends upon the method chosen. Method A (multi-point method) requires approximately 100 g. Method B (single point method) requires approximately 50 g.

Procedure – Method A (Multi-Point)

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1. Place the sample in the dish and thoroughly mix with 15 to 20 mL of distilled or demineralized water by alternately and repeatedly stirring, kneading, and chopping with a spatula. Further additions of water shall be in increments of 1 to 3 mL. Each increment shall be thoroughly mixed with the soil before another increment is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit device shall not be used for mixing soil and water. If too much water is added, the sample shall either be discarded or mixed and kneaded until natural evaporation lowers the moisture content.

Note 3: Some soils are slow to absorb water. It is possible to add water so fast that a false LL value is obtained. This can be avoided by allowing more mixing and/or time. Also, tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water.

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2. Add sufficient water to form a uniform mass of a stiff consistency.

3. Place enough material in the cup so that, when squeezed and spread with the spatula, the soil will rest in the cup above the spot where the cup rests on the base and will be 10 mm thick at the point of maximum thickness. Use as few strokes of the spatula as possible, taking care to prevent the entrapment of air bubbles in the sample.

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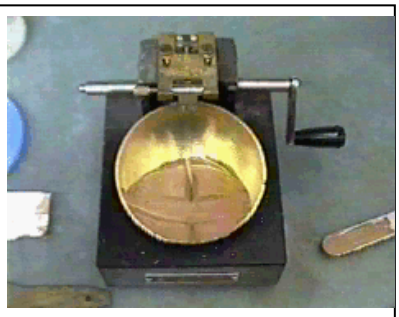
4. Divide the soil in the cup with a firm stroke of the grooving tool. Avoid tearing of the sides of the groove or slipping of the soil cake on the cup. Up to six strokes are permitted. The depth

of the groove should be increased with each stroke, and only the last stroke should scrape the bottom of the cup.

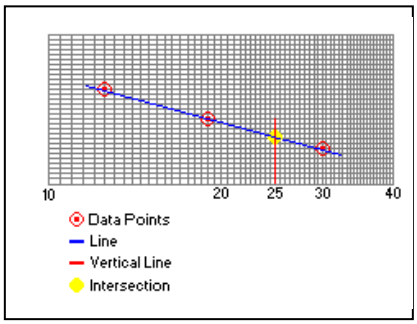
5. Lift and drop the cup by turning the crank at a rate of approximately two revolutions per second until the two halves of the soil pat come together along a distance of about 0.5 in. Do not hold the base while the crank is turned. Record the number of shocks required to close the groove.

Note 4: Some soils tend to slide on the cup instead of flowing. If this occurs, water should be added, the sample remixed, and the procedure repeated. If the soil continues to slide on the cup, the test is not applicable and a note should be made that the liquid limit could not be determined.



Sampling for moisture

6. Obtain a moisture content sample by slicing through the soil pat perpendicularly with the spatula and through the center of the groove. Place it into a suitable container for subsequent moisture determination.
7. Determine the moisture content of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil).
8. Place the soil remaining in the cup back in the mixing dish and add 1 to 3 mL of water, or use previously prepared portions to which sufficient water has been added to result in a more fluid condition.
9. Repeat Steps 3 through 8, a minimum of two times. The object is to have a determination in all three shock ranges 25-35, 20-30, & 15-25.



Liquid limit flow curve

Flow Curve – Method A

18 Prepare a flow curve on a semi-logarithmic graph with moisture content on the arithmetic vertical axis and the number of shocks on the logarithmic horizontal axis. The flow curve is a straight line drawn as closely as possible through three or more plotted points.

Liquid Limit – Method A

19 Determine the liquid limit. The moisture content at the intersection of the flow curve and the 25 shock line is the liquid limit.

Procedure – Method B (Single-Point)

20 1. Place the sample in the dish and thoroughly mix with 8 to 10 mL of distilled or demineralized water, and following the mixing procedure in Method A, Step 1.

2. Follow the procedure in Method A except that the soil pat should be prepared with water to produce a consistency that will close the two halves of the soil pat at least 0.5 in. within 22 to 28 shocks of the cup.

Note 5: Groove closures occurring between 15 and 40 blows may be accepted if variations of ±5 percent of the true liquid limit are tolerable.

21 3. Return the soil remaining in the cup to the mixing dish and, without adding any additional water, repeat Step 2. If the closure again occurs within the acceptable range, obtain a moisture content specimen.

4. Determine the moisture content of the moisture content sample in accordance with the FOP for AASHTO T 255/T 265 (Soil).

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Liquid Limit – Method B

Calculate the liquid limit as follows:

$$LL = (w_N)(N/25)^{0.121}$$

N	$(N/25)^{0.121}$	N	$(N/25)^{0.121}$
22	0.985	26	1.005
23	0.990	27	1.009
24	0.995	28	1.014
25	1.000		

$$LL = (w_N)(N/25)^{0.121}$$

Where:

LL = liquid limit

w_N = moisture content of sample at N blows

N = number of blows

Example:

w_N = 16.0 % and N = 23

$LL = (16.0)(23/25)^{0.121} = 15.8$, say 16%

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Report

Results shall be reported on standard forms approved by the agency. Report LL to the nearest whole percent.

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Tips!

- Do <u>not</u> mix dry soil with moist soil in order to reduce moisture content.
- Be careful with grooving tool. Use up to six strokes to carefully separate the sample, rather than forcing the sample apart with just one or two strokes.

REVIEW QUESTIONS

1. Describe how to mix the soil with water.

2. Describe how to obtain the moisture content sample.

3. What does the liquid limit represent?

4. How is the liquid limit used with the plastic limit?

5. Describe how to adjust the liquid limit apparatus.

PERFORMANCE EXAM CHECKLIST

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FOP FOR AASHTO T 89

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Describe the inspection for wear of the liquid limit device:	_____	_____
a. Wear at contact between cup and base ½" or less?	_____	_____
b. Edge of cup no less than ½ original thickness?	_____	_____
2. Describe how the height of the cup drop is adjusted:	_____	_____
a. Checked before each use?	_____	_____
b. Turn crank while holding gauge in position under cup?	_____	_____
c. Check for ringing or clicking without rising of cup?	_____	_____
d. Cup does not rock?	_____	_____
3. Describe initial sample preparation:	_____	_____
a. Material separated on appropriate sieves?	_____	_____
b. Soil sufficiently pulverized for separation of grains?	_____	_____
c. Material passing the # 40 recombined and mixed?	_____	_____
4. Describe the preparation of the liquid limit sample for Method A:	_____	_____
a. Sample mass approximately 100 g. of minus #40?	_____	_____
b. Mixed in dish with 15 to 20ml of distilled or demineralized water?	_____	_____
c. Mix by stirring, chopping, kneading with spatula until stiff consistency?	_____	_____
d. No dry soil added to lower moisture content?	_____	_____
5. Material placed in cup, centered, 10 mm thick?	_____	_____
6. Soil divided by using up to 6 strokes, preventing tearing or slipping of soil pat?	_____	_____
7. Cup lifted and dropped at a rate of 2 per second?	_____	_____
8. Pat halves come together over length of ½"?	_____	_____
9. Moisture container tare mass determined?	_____	_____
10. Moisture sample properly taken and wet mass determined?	_____	_____
11. Moisture content determined by AASHTO T 265?	_____	_____

12. Multiple tries conducted to achieve sample in shock ranges of 25-35, 20-30, and 15-25? _____ _____
13. Flow curve plotted with shocks on logarithmic scale and the moisture on arithmetic scale? _____ _____
14. Liquid Limit correctly calculated and rounded to nearest whole number? _____ _____
15. Reported on standard agency form? _____ _____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

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_____
_____
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_____
_____
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Signature of Examiner _____