EXPERIMENT 2
ATTERBERG LIMITS

Purpose:

This lab is performed to determine the plastic and liquid limits of a fine-grained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a pat of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

The Theoretical Part:

When clay minerals are present in fine-grained soil, the soil can be remolded in the presence of some moisture without crumbling. This cohesive nature is caused by the adsorbed water surrounding the clay particles. In the early 1900s, a Swedish scientist named Atterberg developed a method to describe the consistency of fine-grained soils with varying moisture contents. At a very low moisture content, soil behaves more like a solid.

When the moisture content is very high, the soil and water may flow like a liquid. Hence, on an arbitrary basis, depending on the moisture content, the behavior of soil can be divided into four basic states—solid, semisolid, plastic, and liquid—as shown in **Figure 2-1**.

The moisture content, in percent, at which the transition from solid to semisolid state takes place is defined as the shrinkage limit. The moisture content at the point of transition from semisolid to plastic state is the plastic limit, and from plastic to liquid state is the liquid limit. These parameters are also known as Atterberg limits. This chapter describes the procedures to determine the Atterberg limits. Also discussed in this chapter are soil structure and geotechnical parameters, such as activity and liquidity index, which are related to Atterberg limits

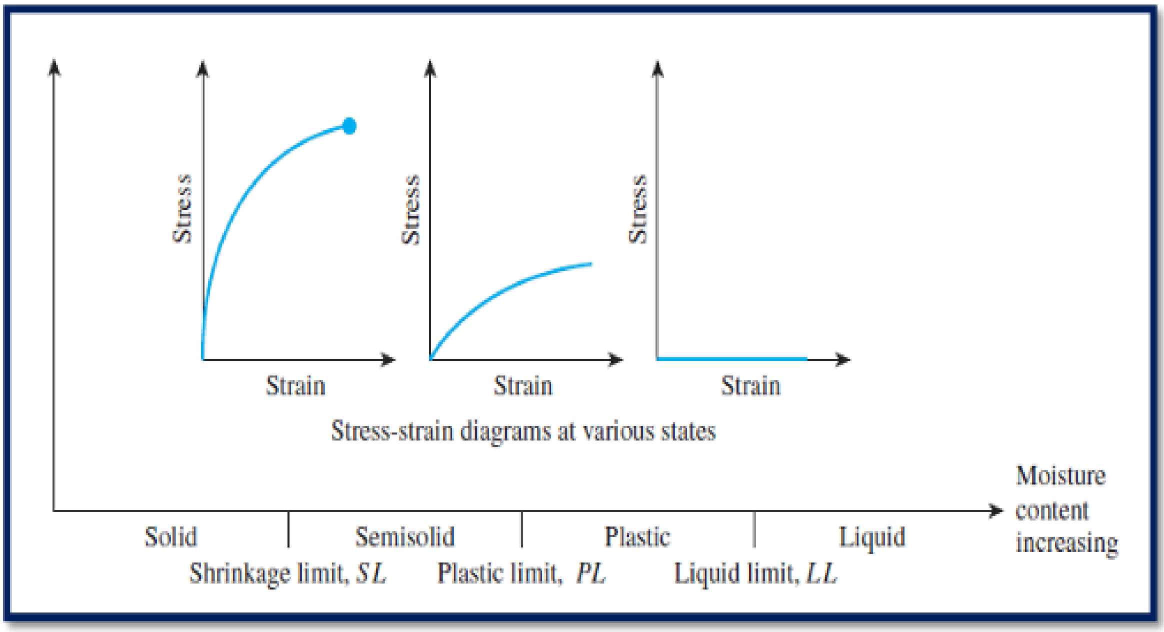

Figure 2-1 Atterberg limits.

1-Liquid Limit Test:

When a *cohesive soil* is mixed with an excessive amount of water, it will be in a somewhat *liquid state* and flow like a viscous liquid. However, when this viscous liquid is gradually dried, with the loss of moisture it will pass into a *plastic state*. With further reduction of moisture, the soil will pass into a semisolid and then into a solid state. This is shown in Fig. 2-1 The moisture content (in percent) at which the cohesive soil will pass from a liquid state to a plastic state is called the *liquid limit* of the soil

Equipment And Tools:

1. Casagrande liquid limit device
2. Grooving tool
3. Moisture cans
4. Porcelain evaporating dish
5. Spatula
6. Oven
7. Balance sensitive up to 0.01 g
8. Plastic squeeze bottle
9. Paper towels

Figure. 2-2 Equipment and tools for liquid limits test

The Casagrande liquid limit device essentially consists of a brass cup that can be raised and dropped through a distance of 10 mth on a hard rubber base by a cam operated by a crank (see Figure. 2-3a). Figure. (2-3b) shows a schematic diagram of a grooving tool.

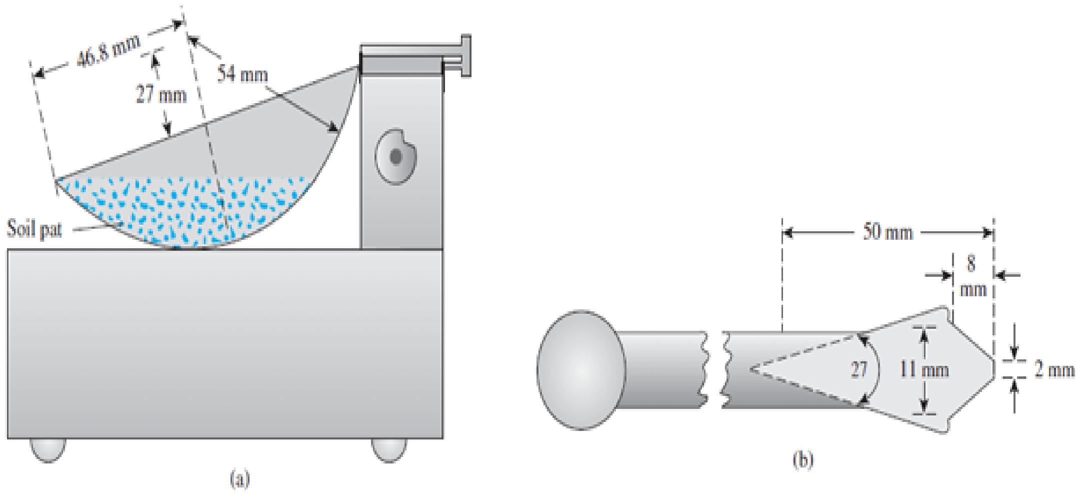

Figure. 2-3

Procedure:

1. Determine the mass of three moisture cans (WI).

2. Put about 250 g of air" dry soil, passed through No. 40 sieve, into an evaporating dish. Add water from the plastic squeeze bottle and mix the soil to the form of a uniform paste.

3. Place a portion of the paste in the brass cup of the liquid limit device. Using the spatula, smooth the surface of the soil in the cup such that the maximum depth of the soil is about 8 mm.

4. Using the grooving tool, cut a groove along the center line of the soil pat in the cup **(Figure. 2-4a).**

5. Turn the crank of the liquid limit device at the rate of about 2 revolutions per second. By this, the liquid limit cup will rise and drop through a vertical distance of 10 mm once for each revolution. The soil from two sides of the cup will begin to flow toward the center. Count the number of blows, N, for the groove in the soil to close through a distance of Yz in. (12.7 mm) as shown in Fig. 2-4b

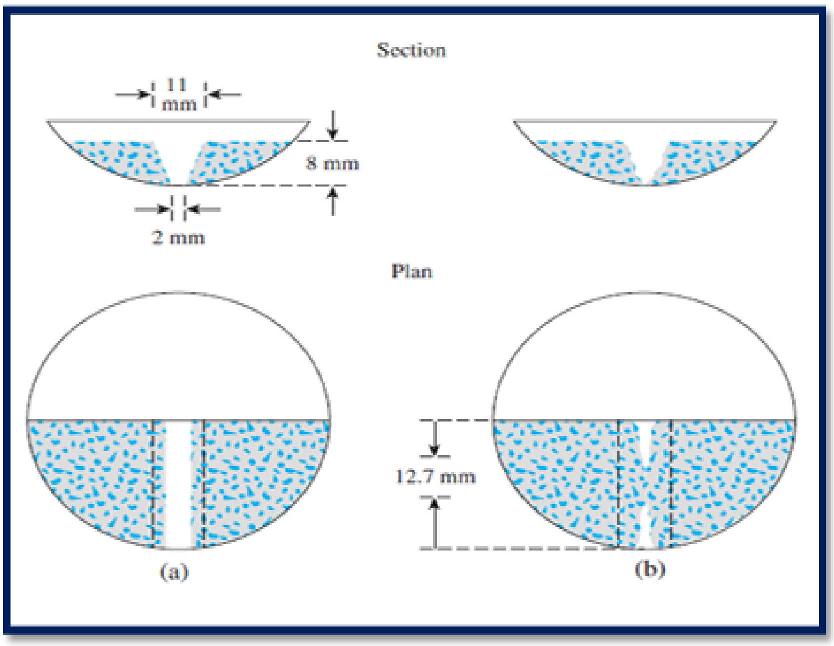

Figure. 2-4

If N = about 25 to 35,

collect a moisture sample from the soil in the cup in a moisture can. Close the cover of the can , and determine the mass of the can plus the moist soil (W2).

Remove the rest of the soil paste from the cup to the evaporating dish. Use paper towels to thoroughly dean the cup.

If the soil is too dry, Nwill be more than about 35. In that case, remove the soil with the spatula to the evaporating dish. Clean the liquid limit cup thorollghly with paper towels. Mix the soil in the evaporating dish with more water, and try again.

If the soil is too wet, N will be It;ss than about 25. In that case, remove the soil in the cup to the evaporating dish. ,Clean the liquid limit cup carefully with paper towels. Stir the soil paste with the spatula for some time to dry it up. The evaporating dish may be placed in the oven for a few minutes for drying also. Do not add dry soil to the wet-soil paste to reduce the moisture content for bringing it to the proper consistency. Now try again in the liquid limit device to get the groove closure of Yz in. (12.7 mm) between 25 and 35 blows.

6. Add more water to the soil paste in the evaporating dish and mix thoroughly. Repeat Steps 3, 4 and 5 to get a groove closure of Yz in. (12.7 mm) in the liquid limit device at a blow count N = 20 to 25. Take a moisture sample from the cup. Remove the rest of the soil paste to the. evaporating dish. Clean the cup with paper towels.

7. Add more water to the soil paste in the evaporating dish and mix well. Repeat Steps . 3, 4 and 5 to get a blow count N between 15 and 20 for a groove closure of Yz in. (12.7 mm) in the liquid limit device. Take a moisture sample from the cup.

8. Put the three moisture cans in the oven to dry to constant masses (W3). (The caps of the moisture cans should be removed from the top and placed at the bottom of the respective cans in the oven.).

Calculation:

Detennine the moisture content for each of the three trials (Steps 5, 6 and 7) as

$$W(\%) = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Graph

Plot a semi-log graph between moisture content (arithmetic scale) versus number of blows, N (log scale). This wiIl approximate a straight line, which is called the flow curve. From the straight line, determine the moisture content w (%) corresponding to 25 blows. This is the liquid limit of the soil.

The magnitude of the slope of the flow line is called theflow index, F], or

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

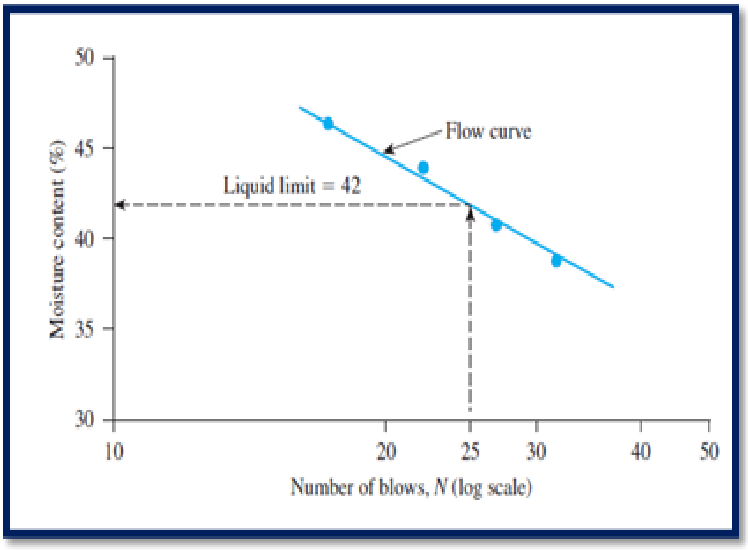

Figure 2-5. Plot of moisture content (%) vs. number of blows for the liquid limit test result

2-<u>Plastic Limit Test:</u>

The fundamental concept of *plastic limit* was introduced in the introductory section of the

preceding chapter (see Figure. 2-1). Plastic limit is defined as the moisture content, in percent, at which a cohesive soil will change from a *plastic state* to a *semisolid state*. In the laboratory, the *plastic limit* is defined as the moisture content (%) at which athread of soil will just crumble when rolled to a diameter of%-in. (3.18 mm). This test might be seen as somewhat arbitrary and, to some extent, the result may depend on the person performing the test. With practice, however, fairly consistent results may be obtained.

Equipment And Tools:

1. Porcelain evaporating dish
2. Spatula
3. Plastic squeeze bottle with water
4. Moisture can
5. Ground glass plate
6. Balance sensitive up to 0.01 g

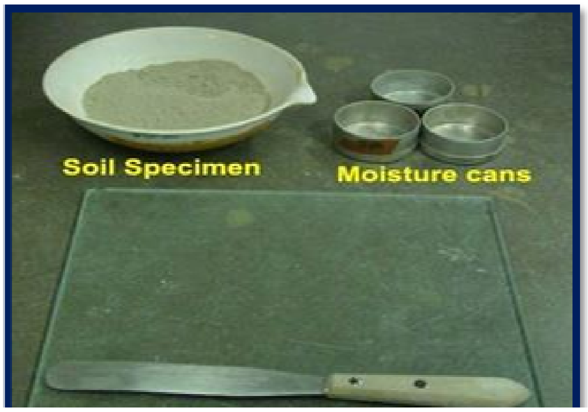

Figure. 2-6 Equipment and tools for plastic limits test

Procedure:

1. Put approximately 20 grams of a representative, air-dry soil sample, passed through No. 40 sieve, into a porcelain evaporating dish.

2. Add water from the plastic squeeze bottle to the soil and mix thoroughly.

3. Determine the mass ofa moisture can in grams and record it on the data sheet *(WI)'*

4. From the moist soil prepared in Step 2, prepare several ellipsoidal-shaped soil masses by squeezing the soil with your fingers.

5. Take one of the ellipsoidal-shaped soil masses (Step 4) and roll it on a ground glass plate using the palm of your hand (Figure. 2-7). The rolling should be done at the rate of about 80 strokes per minute. Note that one complete backward and one complete forward motion of the palm constitute a stroke.

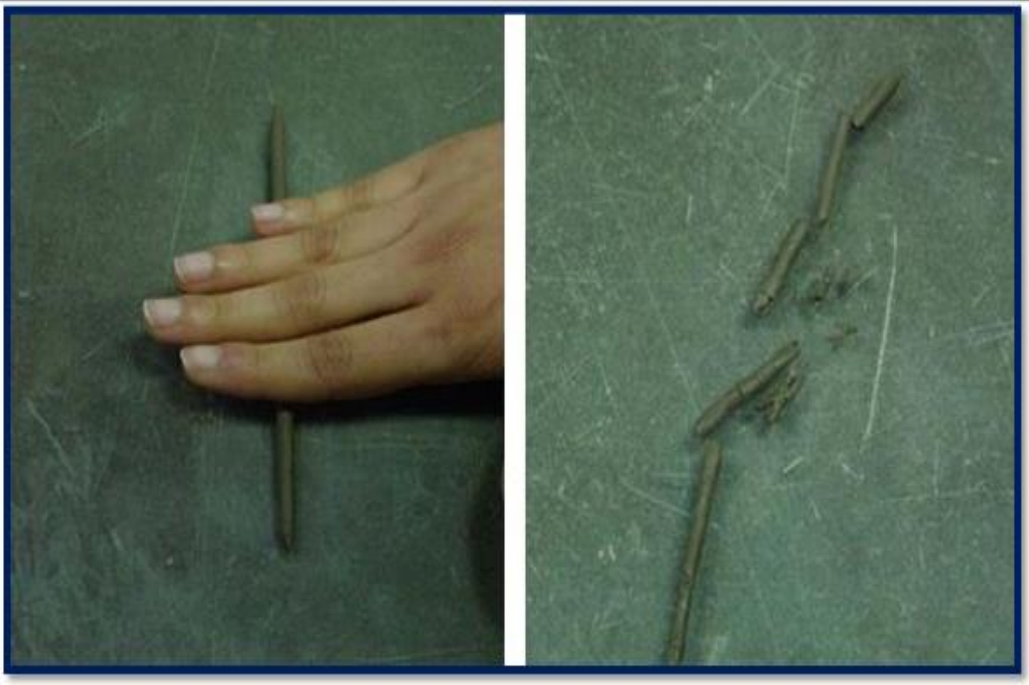

Figure 2-7. An ellipsoidal soil mass is being rolled into a thread on a glass plate.

6. When the thread is being rolled in Step 5 reaches *Va-in.* (3.18 mm) in diameter, break it up into several small pieces and squeeze it with your fingers to form an ellipsoidal mass agam.

7. Repeat Steps 5 and 6 until the thread crumbles into several pieces when it reaches a diameter of *'la-in.* (3.18 JIl1ll).It is possible that a thread may crumble at a diameter larger than *'la-in.* (3.18 mm) during a given rolling process, whereas it did notcrumble at the same diameter during the immediately previous rolling.

8. Collect the small crumbled pieces in the moisture can put the cover on the can.

9. Take the other ellipsoidal soil masses formed in Step 4 and repeat Steps 5 through 8.

10. Determine the mass of the moisture can plus the wet soil *(W2)* in grams. Remove the

cap from the top of the can and place the can in the oven (with the cap at the bottom qf the can).

11. After about 24 hours, remove the can from the oven and determine the mass of the can plus the dry soil *(W3)* in grams.

Calculations:

$$\text{Plastic limit} = \frac{\text{mass of moisture}}{\text{mass of dry soil}} = \frac{W_2 - W_3}{W_3 - W_1}(100)$$

The results may be presented in a tabular form as shown in Table 7-1. If the liquid limit of the soil is known, calculate the *plasticity index, PI,* as

$$PI = LL - PL$$

Standard Results:

Typical Values of Liquid Limit, Plastic Limit, and Activity of Some Clay Minerals are shown in **Table 2-1and Table 2-2**.

Standard Reference:

ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

Discussion and Conclusions:

- The liquid limit and the plasticity index of cohesive soils are importar parameters for classification purposes.
- The plasticity index is important in classifying fine-grained soils which i currently the basis for the Unified Soil Classification System.
- The plasticity index is also used to determine the activity, A, of a clayey so which is defined as:

$$A = \frac{PI}{(\%\text{ of clay - size fraction, by weight})}$$

Mineral	Liquid limit, *LL*	Plastic limit, *PL*	Activity, *A*
Kaolinite	35–100	20–40	0.3–0.5
Illite	60–120	35–60	0.5–1.2
Montmorillonite	100–900	50–100	1.5–7.0
Halloysite (hydrated)	50–70	40–60	0.1–0.2
Halloysite (dehydrated)	40–55	30–45	0.4–0.6
Attapulgite	150–250	100–125	0.4–1.3
Allophane	200–250	120–150	0.4–1.3

Table 2-1 Typical Values of Liquid Limit, Plastic Limit, and Activity of Some Clay Minerals

PI	Description
0	Nonplastic
1–5	Slightly plastic
5–10	Low plasticity
10–20	Medium plasticity
20–40	High plasticity
>40	Very high plasticity

Table 2-2