Plasticity of Fine-Grained Soils

Consistency and Atterberg's limits of fine-grained soils

Consistency of soil

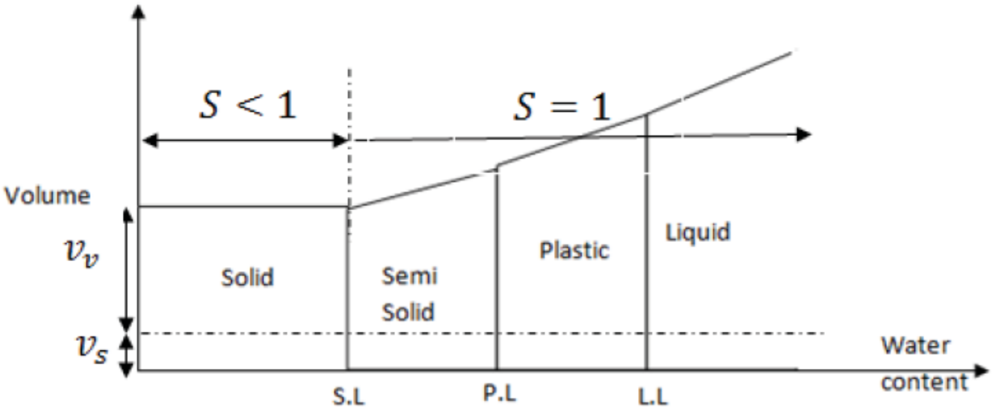
Soil consistency describes the degree and kind of cohesion and adhesion between the soil particles as related to the resistance of the soil to deform or rupture.

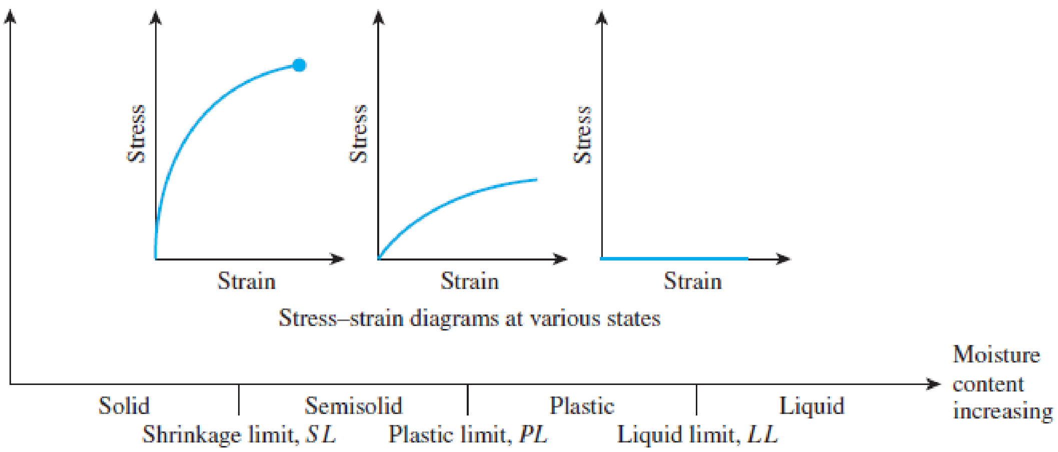
Atterberg's Limits

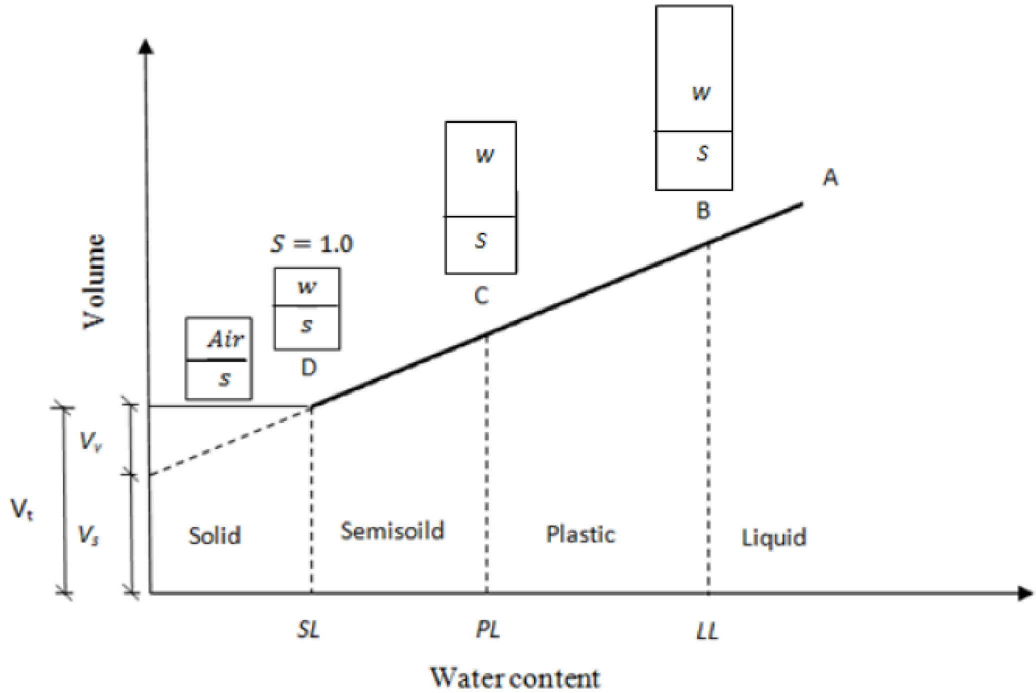
Atterberg's limits are the limits of water content and important to describe the consistency of fine-grained soils.

- 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.

Effect of moisture content







1- shrinkage limit

The moisture content, in percent, at which the transition from solid to semisolid state takes place

2- plastic limit

The moisture content at the point of transition from semisolid to plastic state

3- liquid limit

The moisture content at the point of transition from plastic to liquid state.

These parameters are also known as Atterberg limits.

- **Plasticity Index (P.I.):** it is the range in moisture content when the soil exhibited its plastic behavior.

$$P.I. = L.L - P.L.$$

- **Liquidity Index (L.I.) :** a relation between the natural moisture contents $(\omega_n$ and (L.L.) and (P.L.) in form:

$$L.I. = \frac{\omega_n - P.L}{L.L. - P.L.}$$

If LI > 1 Then the soil at Liquid state

If LI = 1 then the soil at L.L.

If $LI < 1$ then the soil below L.L.

Activity:

The degree of plasticity of the clay-size fraction of a soil is expressed by the ratio of the plasticity index to the percentage of clay-size particles in the soil.

$$Activity = \frac{P.I}{\%\ of\ clay\ size\ particles}$$

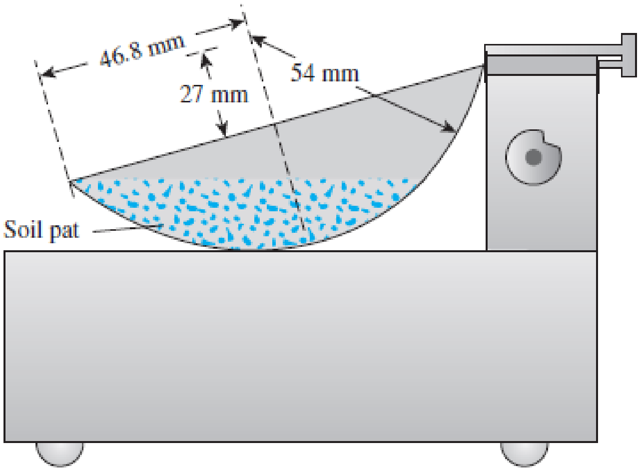
- Soils have an activity between 0.75 and 1.25. Activity below 0.75 is considered inactive, while soils with activity above 1.25 are considerd active.
- Soils of high activity have a greater change in volume when the water content is changed (greater swelling, when wetted and greater shrinkage when drying. Soils of high activity can be particularly damaged to geotechnical works.

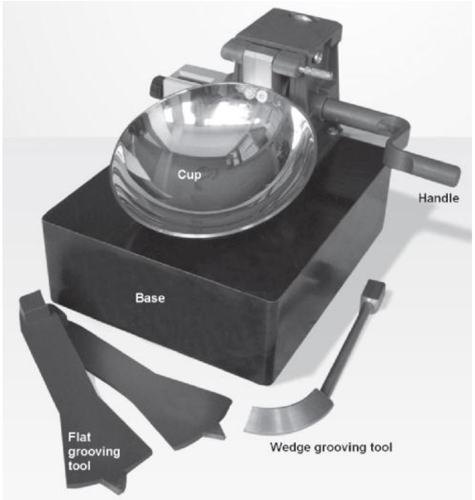
Procedures to determine the Atterberg limits

- **Liquid Limit (*LL*)**

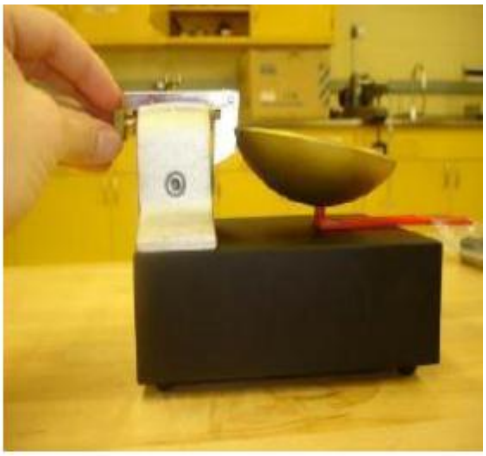
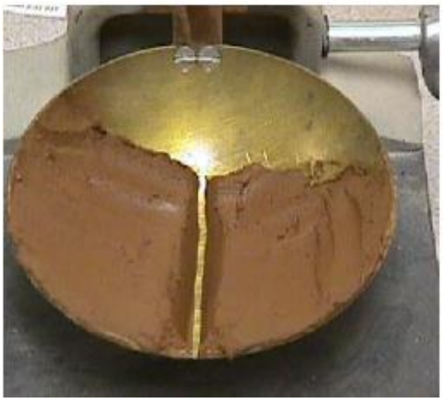
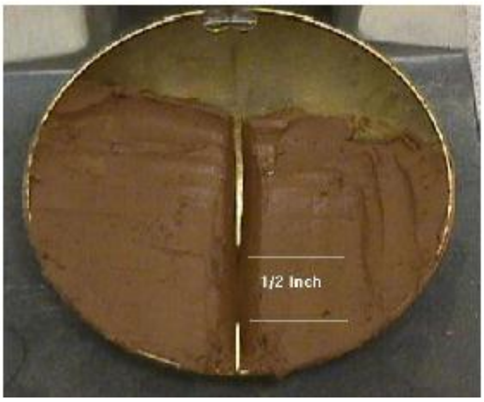
1- **Casagrande apparatus**

A schematic diagram (side view) of a liquid limit device is shown in Figure.





This device consists of a brass cup and a hard rubber base. The brass cup can be dropped onto the base by a cam operated by a crank. To perform the liquid limit test, one must place a soil paste in the cup. A groove is then cut at the center of the soil pat with the standard grooving tool. Note that there are two types of grooving tools in use. They are flat grooving tools and wedge grooving tools.

By the use of the crank-operated cam, the cup is lifted and dropped from a height of 10 mm. The moisture content, in percent, required to close a distance of 12.5 mm along the bottom of the groove after 25 blows is defined as the liquid limit.

multi-point method

It is difficult to adjust the moisture content in the soil to meet the required 12.5 mm closure of the groove in the soil pat at 25 blows. Hence, at least three tests for the same soil are conducted at varying moisture contents, with the number of blows, *N*, required to achieve closure varying between 15 and 35.

The moisture content of the soil, in percent, and the corresponding number of blows are plotted on semi logarithmic graph paper. The relationship between moisture content and log *N* is approximated as a straight line. This line is referred to as the *flow curve.* The moisture content corresponding to *N*= 25, determined from the flow curve, gives the liquid limit of the soil.

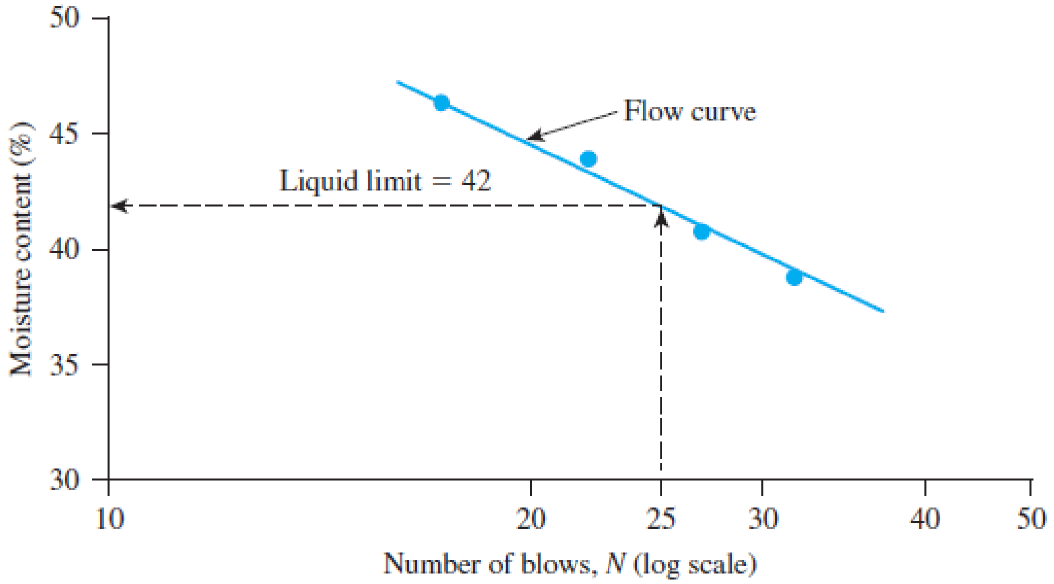


Figure 4.5 Flow curve for liquid limit determination of a clayey silt

one-point method

For routine laboratory tests, it may be used to determine the liquid limit when only one test is run for a soil. This procedure is generally referred to as the *one-point method*

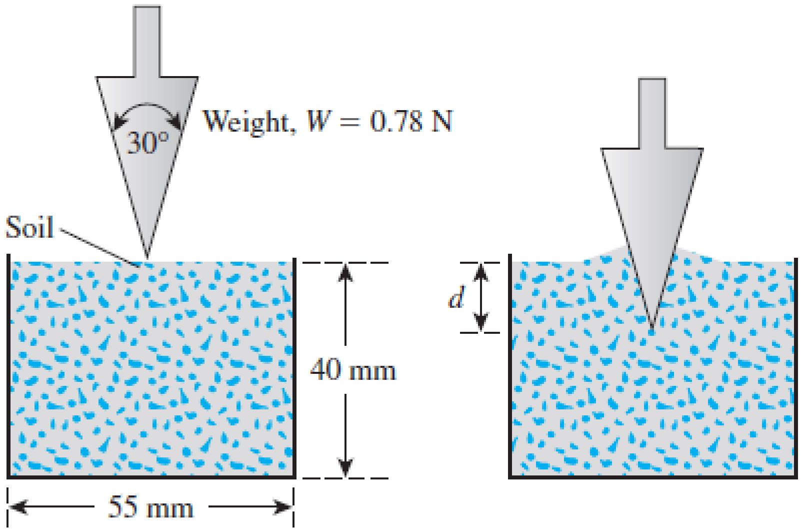
$$LL = w_N \left(\frac{N}{25}\right)^{\tan \beta}$$

where N = number of blows in the liquid limit device for a 12.5 mm groove closure
w_N = corresponding moisture content
$\tan \beta$ = 0.121 (but note that $\tan \beta$ is not equal to 0.121 for all soils)

the following Equation generally yields good results for the number of blows between 20 and 30. The reason that the one-point method yields fairly good results is that a small range of moisture content is involved when N = 20 to N =30.

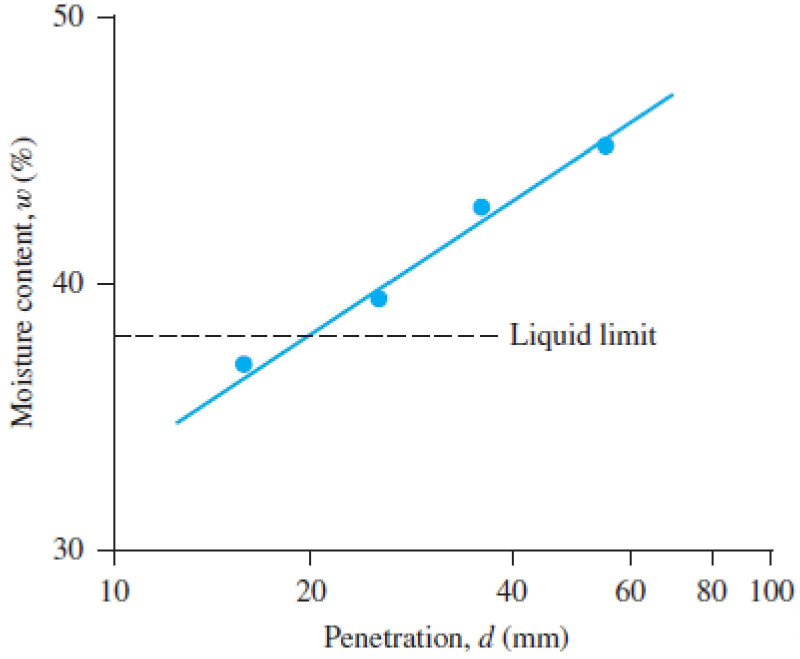
2- Penetrometer apparatus.

Another method of determining liquid limit is the fall cone method.



In this test the liquid limit is defined as the moisture content at which a standard cone of apex angle 30° and weight of 0.78 N will penetrate a distance *d* = 20 mm in 5 seconds when allowed to drop from a position of point contact with the soil surface. Figure 4.7 shows the photograph of a fall cone apparatus.

Due to the difficulty in achieving the liquid limit from a single test, four or more tests can be conducted at various moisture contents to determine the fall cone penetration, *d*. A semi logarithmic graph can then be plotted with moisture content (w) versus cone penetration *d*. The plot results in a straight line. The moisture content corresponding to *d* = 20 mm is the liquid limit.



(b)

4.3 Plastic Limit (*PL*)

The *plastic limit* is defined as the moisture content in percent, at which the soil crumbles, when rolled into threads of 3.2 mm in diameter.

The plastic limit test is simple and is performed by repeated rollings of an ellipsoidal-sized soil mass by hand on a ground glass plate. The procedure for the plastic limit test is given by ASTM in Test Designation D-4318.

- The procedure of test is:

1) Take 20g of soil passing No.40 sieve into a dish;

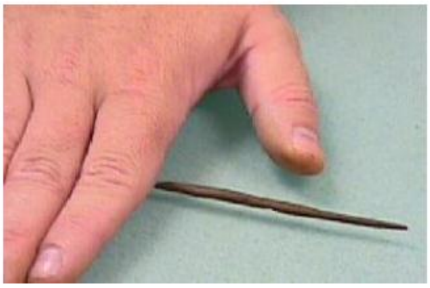
2) Add water and mix thoroughly;

3) Prepare several ellipsoidal-shaped soil masses by quizzing the soil with your hand;

4) Roll the soil until the thread reaches 1/8 in;

5) Continue rolling until the thread crumbles into several pieces;

6) Determine the water content of about 6g of the crumbled soil.


As in the case of liquid limit determination, the fall cone method can be used to obtain the plastic limit. This can be achieved by using a cone of similar geometry but with a mass of 2.35 N . Three to four tests at varying moisture contents of soil are conducted, and the corresponding cone penetrations (d) are determined. The moisture content corresponding to a cone penetration of d = 20 mm is the plastic limit.

- The *plasticity index* (*PI*) is the difference between the liquid limit and the plastic limit of a soil, or

$$PI = LL - PL$$

Plasticity Class

Burmister (1949) classified the plasticity index in a qualitative manner as follows:

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