3.2 Determination of Atterberg Limits

3.2.1 Scope. As the moisture content of a soil decreases the soil passes from the liquid state to the plastic state to the solid state. The range of moisture contents over which the soil is plastic is used as a measure of the plasticity index. The points at which a soil changes from one state to another are arbitrarily defined by simple tests called the liquid limit test and plastic limit test. These tests are known as the Atterberg limits. The Atterberg limits are empirical tests which are used to indicate the plasticity of fine grained soil by the differentiation between highly plastic, moderately plastic and non-plastic soils. The tests enable classification and identification of the soil to be carried out and give a rough guide to the engineering properties.

3.2.2 Sample preparation. It is preferable not to dry the soil before preparation for the test. Two preferred methods of preparation are described, depending on whether the soil contains a significant proportion of particles larger than the 425 µm sieve.

3.2.2.1 Method for fine soils. If the soils contains few or no particles retained on a 425 µm sieve, take a representative sample weighing about 500 g, chop it up and mix thoroughly for at least 10 minutes with distilled water to form a thick homogeneous paste. Seal in an airtight container (e.g. a corrosion-resistant tin or a polythene bag) for 24 hours before testing. Mixing should be carried out on a glass plate with two palette knives. The required 24 hour maturing period may be shortened for soils with low clay contents.

If only a few particles larger than 425 µm are present, these can be removed by fingers or with tweezers during mixing. If coarse particles are present determine their mass and the mass of the sample used. These weighings enable the approximate proportion of coarse material to be reported if required.

3.2.2.2 Wet preparation method. This is the preferred method for soil containing coarse particles, and should be used for all such soils that are sensitive to the effects of drying.

Procedure

1. Take a representative specimen that will give at least 350 g passing a 425 µm sieve, and weigh it (m grams). This quantity should be sufficient for a liquid limit and a plastic limit test. Weighings should be carried out to an accuracy of within 0.01 g.
2. Take another representative sample for determination of moisture content (w %). Calculate and record the mass of dry soil in the test sample (m_D) from the equation:

   \[ m_D = \frac{100m}{100 + w} \]

3. Cut up the weighed sample in a beaker and just cover with distilled water. Stir to form a slurry. Do not use a dispersant.
4. Pour the slurry through a 2 mm sieve nested on a 425 µm sieve. Use the minimum amount of distilled water to wash clean the particles retained on both sieves. Continue until the water passing the 425 µm sieve is virtually clear. Collect all the washings.
5. Dry (at 105°C to 110°C) and weigh the retained material (m_R grams) to an accuracy of within 0.01 g.
6. Allow the collected wash water to stand undisturbed, and pour or siphon off any clear water. A settling time of several hours may be required. It is important no to lose any soil particles during the siphoning procedure (see Note).
7. Allow the suspension to partially dry in warm air, or in an oven at not more than 50°C, or by filtration under vacuum or pressure, until it forms a stiff paste. But prevent local drying at the surface or edges, by repeated stirring.

Note 1. A suitable consistency for the paste corresponds to not less than 50 blows of the Casagrande apparatus.

Note 2. When using this method, care should be taken with samples containing soluble salts. These samples should be allowed to dry by evaporation only, and not by siphoning or pouring off excess water.

3.2.2.3 Dry preparation method. If the use of a dry preparation method is unavoidable then the procedure should be followed as shown schematically in Figure 3.2.1.

3.2.3 Liquid limit test (Casagrande method)

1. Apparatus

   a) Equipment for the determination of moisture content (weighing to 0.01 g).
   b) Soil mixing equipment (glass plate, spatulas, distilled water).
   c) Timer clock.
   d) Casagrande liquid limit device (Figure 3.2.2).
   e) Grooving tool and height gauge (Figure 3.2.3).

2. Calibration of apparatus

   The height of the underneath of the cup when fully lifted should be such that the 10 mm gauge will just pass between it and the base. Some grooving tools incorporate a block of the correct thickness. The locking nuts must be adjusted to maintain the correct height of drop.

   The device should be checked to make sure that the cup falls freely, that there is no side play in the cup, that the screws are tight, that the cup and base are not worn and that the blow counter works correctly and is set to zero. Details of the liquid limit device and how the cup fall is set are shown in Figure 3.2.4.

   The dimensions of the grooving tool are important and a reference (unused) tool should be available to check the tool being used against. When the tip of the tool being used becomes worn to a width of 3 mm it should be re-ground to the correct dimensions.

3. Test Procedure

   a) Mix about 300 g of the prepared soil (after 24 hours maturing) with a little distilled water if necessary, using two spatulas, for at least 10 minutes. At this point the first blow count should be about 50 blows. If a plastic limit test is required it is convenient to set aside a portion of soil for this purpose.

   b) With the cup resting on the base, press soil into the cup being careful to avoid trapping air. Form a smooth level surface parallel to the base giving a maximum thickness of 10 mm (see Figure 3.2.5).

   c) Beginning at the hinge, and with the chamfered edge of the tool facing the direction of movement, make a smooth groove with a firm stroke of the grooving tool, dividing the sample into two equal parts. The tip of the grooving tool should lightly scrape the inside of the bowl, but do not press hard.

When using the tool, apply a circular motion so that it is always normal to the surface of the cup (see Figure 3.2.5).
1. Air-dry soil or oven-dry at not more than 50°C. Bring the soil to a condition at which it can be crumbled.

2. Weigh air or oven-dried material. Determine moisture content if required.

3. Break down aggregations of particles (rubber pestle) - Do NOT break individual particles.

4. Sieve on 2 mm sieve. Material retained to be individual particles only.

5. Riffle to obtain representative sample. Determine riffle factor by weighing.

6. Sieve on 425 mm.

7. Weigh retained soil Calculate % retained if required.

8. Mix with distilled water.

9. Seal and store for 24 hours.

10. Mix 10 minutes.

LL & PL test Cone Penetrometer method Casagrande method

Figure 3.2.1 Dry preparation method for Atterberg limits
Chapter 3
Classification Tests

Chapter 3
Standard Test Procedures

Chapter 3
Standard Test Procedures

Classification Tests

Figure 3.2.2 Casagrande liquid limit apparatus.

Figure 3.2.3 Grooving tool and height gauge.
d) Rotate the handle at a speed of two turns per second – check with a seconds timer. Stop turning when the bottom of the groove closes along a continuous length of 13 mm (use the back of the grooving tool as a gauge). Record the number of blows.

e) Add a little more soil from the mixture on the glass plate to the cup and mix in the cup. Repeat stages (b) to (d) stated above until two consecutive runs give the same number of blows for closer. Record the number of blows.

f) Remove a portion of about 10 g of the soil adjacent to the closed gap with a clean spatula, transfer to a weighed container and fit the lid immediately. Record the container number and determine the moisture content.

g) Repeat steps (b) to (f) stated above after adding increments of distilled water, mixing the water well in. At least two determinations should give more than 25 blows, and two less than 25, in the range of about 10 to 50 blows. **Do not add dry soil to the soil paste.** Protect the soil on the glass plate from drying out at all times. Each time the soil is removed from the cup for the addition of water, wash and dry the cup and grooving tool.
4. **Calculation and Expression of Results**

After determining the moisture contents plot each moisture content against the number of blows on the printed test sheet. A line of best fit is drawn through the plotted points. This is called the ‘flow curve’. The liquid limit is defined as the percentage moisture content that corresponds to 25 blows as determined from where the ordinate at 25 blows intersects the flow curve. Record this value of moisture content to the nearest 0.1%. An example is given on the attached test sheet (see Form 3.2.1)

5. **Report**

The full report will include the sample details, method of preparation of the sample and the percentage passing the 425 μm sieve. The operator should sign and date the test form.

**3.2.4 Plastic limit test**

1. **Apparatus**

a) Equipment for the determination of moisture content (weighing to 0.01 g).
b) Soil mixing equipment (glass plate, spatulas, distilled water).
c) Smooth glass plate free from scratches, for rolling threads on.
d) A length of rod, 3 mm in diameter and about 100 mm long.

2. **Test Procedure**

a) Prepare and mature the test sample using wet or dry preparation method or take the sample previously set aside from the liquid limit test.
b) Take about 20 g of the soil and allow it to lose moisture until it is plastic enough to be shaped into a ball without sticking to the fingers. Mould into a ball between the fingers and roll between the palms of the hands until slight cracks appear on the surface. Moulding and kneading is necessary throughout the test to preserve a uniform distribution of moisture and to prevent excessive drying of the surface only.
c) Divide the sample into two roughly equal portions and carry out a separate test on each portion.
d) Divide the first portion into four pieces. Mould one piece into a cylinder about 6 mm diameter between the first finger and thumb.
e) Roll the cylinder under the fingers of one hand on a smooth glass surface, applying enough pressure to reduce the diameter to about 3 mm in about 5 to 10 complete forward and backward movements. Maintain a uniform pressure. Do not reduce pressure as the 3 mm diameter is approached. Use a metal rod of 3 mm diameter to judge the thread diameter.
f) Pick up the soil thread, mould further and repeat the above. Repeat until the thread shears both longitudinally and transversely at a diameter of 3mm. Crumbling may consist of one of the forms shown in Figure 3.2.6 depending on the nature of the soil.
g) Crumbling can usually be felt by the fingers. The crumbling condition must be achieved, even if greater than 3 mm diameter. If smooth threads of 3 mm diameter (like noodles) are formed, the soil is not dry enough, as illustrated in Figure 3.2.5. The first crumbling point is the plastic limit, do not attempt to continue reforming and rolling beyond this point.
Classification Tests

3. Calculation and Expression of Results

Dry the specimens at 105°C – 110°C, weigh and calculate the moisture contents to the nearest 0.1%. If the two values differ by more than 0.5% moisture content repeat the whole test on another portion of soil. Otherwise, the average of the two values is the plastic limit. If it is not possible to determine the plastic limit this fact should be reported.

4. Report

The plastic limit is reported to the nearest whole number. The test sheet must be completed in full to give sample details, method of preparation and the percentage of material passing the 425 µm sieve. The test sheet should be signed and dated by the test operator. An example of a completed test sheet is attached (Form 3.2.1).
### ATTERBERG LIMITS TEST (Casagrande Method)

**BANGLADESH ROAD RESEARCH LABORATORY**

**Contract:** Dhaka-Aricha Road  
**Origin of sample:** TP#16 Km 16+250 o/s 13m LHS  
**Depth:** 1.15 - 1.80 m  
**Description of soil:** Moist very soft to soft grey mottled brown, silty CLAY

<table>
<thead>
<tr>
<th>Test</th>
<th>Plastic Limit</th>
<th>Liquid Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Container No.</td>
<td>No. of Blows</td>
<td>16</td>
</tr>
<tr>
<td>Wt. of cont. + wet soil</td>
<td>g</td>
<td>7.70</td>
</tr>
<tr>
<td>Wt. of cont. + dry soil</td>
<td>g</td>
<td>6.35</td>
</tr>
<tr>
<td>Wt. of moisture</td>
<td>g</td>
<td>1.35</td>
</tr>
<tr>
<td>Wt. of container</td>
<td>g</td>
<td>1.72</td>
</tr>
<tr>
<td>Wt. of dry soil</td>
<td>g</td>
<td>4.63</td>
</tr>
<tr>
<td>Moisture content</td>
<td>%</td>
<td>29.2</td>
</tr>
<tr>
<td>Average</td>
<td>%</td>
<td>29.4</td>
</tr>
</tbody>
</table>

**Sample preparation:**
- as received
- washed on 425 mm sieve
- air dried at __________ °C
- oven dried at __________ °C  
- unknown

**Summary:**
- % of total sample passing  
  425mm Sieve: 98 %  
  Liquid Limit (LL): 48 %  
  Plastic Limit (PL): 29 %  
  Plasticity Index (PI): 19 %  
  Linear Shrinkage (LS): %  
  If LL or PL cannot be determined
  Use PI = 2.13 x LS = ______ %

**Remarks:**

**Name and Designation:**
- Operator
- Checked
- Approved

**Date of Test:** 26/2/07  
**Sample No:** 4  
**Date of Sample:** 21/2/07
3.2.5 Determination of the plasticity index

1. Procedure

The Procedure is a simple calculation and requires the determination of the liquid and plastic limits for the soil. The Casagrande method is to be used to determine the liquid limit.

The plasticity index of a soil is the numerical difference between the liquid limit and the plastic limit: \( PI = LL – PL \)

2. Report

The plasticity index is reported to the nearest whole number. If both the liquid and plastic limits cannot be determined the soil is described as non-plastic (NP). Two special cases may be found. If it is possible to determine the liquid limit but not the plastic limit, the soil is reported as non-plastic. If the plastic limit is found to be equal to or greater than the liquid limit (as with some highly micaceous soils), the sample is also reported as non-plastic.

3.2.6 Determination of linear shrinkage

1. Apparatus

a) A drying oven capable of operating at 60\(^{\circ}\)C – 65\(^{\circ}\)C and 105\(^{\circ}\)C – 110\(^{\circ}\)C.
b) Soil mixing equipment (glass plate, spatulas, distilled water).
c) Vernier calipers measuring up to 150 mm and reading to 0.1 mm. Alternatively, a steel rule graduated to 0.5 mm.
d) Silicone grease or petroleum jelly.
e) Evaporating dish (approx. 150 mm \( \Phi \)).
f) Moulds made of brass or other non-corrodible material. They shall be semi-circular in cross section with an internal radius of 12.5 ± 0.5 mm and 140 mm long, with square end pieces attached as supports which also serve to confine the soil (see Figure 3.2.7).

![Mould for linear shrinkage test](image)

All dimensions are in millimetres.

2. Test Procedure

a) Preparation of apparatus. Clean the mould thoroughly and apply a thin film of silicone grease or petroleum jelly to its inner faces to prevent the soil adhering to the mould.
b) Prepare and mature the test sample using wet or dry preparation method. Place a sample of about 150 g on the flat glass plate or in the evaporating dish.

c) Add distilled water if necessary and mix thoroughly using the palette knives until the mass becomes a smooth homogeneous paste with a moisture content at about the liquid limit of the soil.

Note. The required consistency will require about 25 bumps of the Casagrande apparatus. This moisture content is not critical to within a few percent.

d) Place the soil / water mixture in the mould such that it is slightly proud of sides of the mould. Gently jar the mould to any air pockets in the mixture.

e) Level the soil along the top of the mould with the palette knife and remove all soil adhering to the rim of the mould by wiping with a damp cloth.

f) Place the mould where the soil / water can air-dry slowly in a position free from draughts until the soil has shrunk away from the walls of the mould. Then complete the drying, first at a temperature not exceeding 65° C until shrinkage has largely ceased, and then at 105° C to 110° C to complete the drying.

g) Cool the mould and soil and measure the mean length of the soil bar. If the specimen has become curved during drying, remove it carefully from the mould and measure the lengths of the top and bottom surfaces. The mean of these two lengths shall be taken as the length of the oven dry specimen.

Note. Should a specimen crack badly, or break, such that measurement is difficult, the test should be repeated at a slower drying rate.

3. Calculation and expression of results

Calculate the linear shrinkage of the soil as a percentage of the original length of the specimen, \(L_0\) (in mm), from the equation:

\[
\text{Percentage of linear shrinkage} = \left(1 - \frac{L_D}{L_0}\right) \times 100
\]

Where, \(L_D\) is the length of the oven-dry specimen (in mm).

4. Report

The linear shrinkage is reported to the nearest whole percentage. The test sheet (see Form 3.2.2) must be completed in full to give sample details, method of preparation and the percentage of material passing the 425 µm sieve. The test sheet should be signed and dated by the test operator. An example of the calculation is shown in Form 3.2.2.
### BANGLADESH ROAD RESEARCH LABORATORY

#### LINEAR SHRINKAGE TEST

<table>
<thead>
<tr>
<th>Contract</th>
<th>Dhaka-Aricha Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin of sample</td>
<td>TP#18, Km 18+250 o/s 10m LHS</td>
</tr>
<tr>
<td>Depth</td>
<td>0.85 - 1.15m</td>
</tr>
<tr>
<td>Description of soil</td>
<td>Moist loose yellowish brown slightly clayey very silty fine SAND</td>
</tr>
</tbody>
</table>

#### Sample No. 3

**Date of sample:** 21/2/97  
**Date of Test:** 25/2/97

#### TEST DATA

<table>
<thead>
<tr>
<th>Specimen reference</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage passing 425 mm sieve</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Initial length $L_0$ mm</td>
<td>140.0</td>
<td>140.0</td>
</tr>
<tr>
<td>Oven-dried length $L_0$ mm</td>
<td>137.9</td>
<td>137.8</td>
</tr>
<tr>
<td>Linear shrinkage $100 \left(1 - \frac{L_0}{L_0}\right)$ %</td>
<td>1.5</td>
<td>1.6</td>
</tr>
</tbody>
</table>

#### Sample preparation *

<table>
<thead>
<tr>
<th>as received</th>
<th>washed on 425 mm sieve</th>
<th>air-dried at $^\circ$C</th>
<th>oven-dried at $^\circ$C</th>
<th>not known</th>
</tr>
</thead>
</table>

**Remarks**  
Specimens curved during drying  
Result reported as 2%

**Recorded by**

---

#### Name and Designation

<table>
<thead>
<tr>
<th>Operator</th>
<th>Checked</th>
<th>Approved</th>
</tr>
</thead>
</table>