EXPERIMENT NO.

DETERMINATION OF ATTERBERG LIMITS (LIQUID LIMIT, PLASTIC LIMIT AND SHRIKAGE LIMIT)

(IS: 2720 (Part 5) – 1985 – Determination of liquid limit and plastic limit,
IS: 2720 (Part 6) – 1972 – determination of shrinkage limit)

PART A: DETERMINATION OF LIQUID LIMIT

Objective: The objective of the experiment is to determine the liquid limit of the given soil sample by using Casagrande liquid limit device.

For fine grained soil, addition of water into it may cause the change of its firmness. The consistency limits are the water contents at which soil undergoes from one state to the other. Therefore liquid limit is the water content corresponding to arbitrary limit between liquid and plastic states of consistency.

Apparatus: **Mechanical liquid limit device:** It conforms to IS: 9259 - 1979.

Grooving tool: Grooving tool 'a' (Casagrande tool or BS tool), grooving tool 'b' (ASTM tool) shall conform IS: 9259 - 1979**.**

Porcelain evaporating dish: Porcelain dish with 12 to 15 cm in diameter.

Flat glass plate: Glass plate of 450 mm square and 10 mm thick or longer.

Spatula: Flexible spatula with the blade about 8 cm long and 2 cm wide. It is used for mixing the soil and water in the porcelain evaporating dish.

Palette knives: Two palette knives with the blade about 20 cm long and 3 cm wide. It is used for mixing the soil and water on the flat glass plate.

Balance: A balance sensitive up to 0.01 g.

Oven: thermostatically controlled oven with interior of non-corroding material to maintain the temperature between 105 and 110^{o} C temperature.

Wash bottle: Wash bottle with containing distilled water.

Containers: Air tight and non-corrodible containers for determination of moisture content.

Sieve: 425 micron sieve.

Desiccator: Desiccator to cool the soil.

Material: A sample weighing 120 g, shall be taken from thoroughly mixed portion of material passing 425 micron IS sieve (IS: 460 (Part 1) 1960) in accordance with IS: 2720 (Part 1) 1983. Difference is observed for soils with tested in natural condition and obtained with air dried sample.

Procedure:

1. Adjust the liquid limit device. The liquid limit device should be inspected to determine that it is clean, dry and in good working condition or not. The good working condition is ensured if the cup falls freely and its does not have too much side play at its hinge. The grooving tool should also be inspected to determine that it is clean and dry.

2. After the initial adjustment, take 120 g. of soil sample passing through IS sieve 425 micron and mix it thoroughly with distilled water in a porcelain dish to form a uniform paste. Allow sufficient time to the mixture for uniform distribution of moisture throughout the soil mass. For clayey soil the soil paste shall be left to stand for 24 hours. For an average soil, 15 to 30 minutes time is sufficient.

3. Take a portion of the soil paste with spatula and place it in the centre of the cup so that it is almost half filled. Level off the top surface of the wet soil symmetrically with the help of spatula so that it is parallel to the rubber base and the maximum depth of the soil sample is 1 cm.

4. With the help of grooving tool 'a', the paste in the cup is cut along the cup diameter (through the centre line of the cam follower) by holding the tool normal to the surface of the cup and drawing it firmly across. A V-shaped gap of 2 mm wide at the bottom and 11 mm wide at top and 8 mm deep will be appeared. In case of sandy soil 'a' type tool does not form a neat groove and hence tool 'b' can be used.

5. Turn the crank of the apparatus at the rate of the 2 revolutions per second until the two halves of the soil cake come in contact with bottom of the groove along a distance of about 12 mm. Record the number of blows required to cause the groove close for the length of 12 mm.

6. Collect a representative slice of soil by moving the spatula width wise from one edge to the other edge of the soil cake at right angles to the groove including the portion of the groove in which the soil flowed through and collect it in an air tight c container for determination of water content.

7. Collect the remaining soil sample from the cup and mix it with the earlier soil sample left in porcelain dish. Change the consistency of the mix by

either adding water or leaving the soil paste to dry as the case may be and repeat the above mentioned steps 2 to 6. These operations (steps 2 to 7) are repeated for 3 to 4 times. The soil paste in these operations should be of such consistency that number of revolutions or drops to close the groove is 25 $\pm$ 10. The test should always proceed from the

Observations:

Table A: Determination of Liquid Limit

Mass of soil sample taken:

Soil type: Passing through IS sieve 425 micron

Serial No.	**Parameters**	**Quantity**				
		Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**
1.	Number of blows					
2.	Container number					
3.	Mass of container with lid (M_1 g.)					
4.	Mass of container + wet soil + lid (M_2 g.)					
5.	Mass of container + dry soil + lid (M_3 g.)					
6.	Mass of water, M_w (g.) = M_3- M_2					
7.	Mass of dry soil, M_d (g.) = M_3- M_1					
8.	Water content, $w = \frac{M_w}{M_d} \times 100\%$					

From the above mentioned test results plot the flow curve with water content as ordinate and number of blows as abscissa (on logarithmic scale). The water content corresponding to 25 numbers of blows is considered as liquid limit of the soil.

Results: Liquid limit of the given soil is _____ %

Fig 1. Liquid limit device and grooving tools

PART B: DETERMINATION OF PLASTIC LIMIT

Objective: The objective of the experiment is to determine the plastic limit of the given soil sample and then the plasticity index. Plastic limit is the boundary water content at which soil changes from plastic state to semi-solid state.

Apparatus: **Porcelain evaporating dish:** Porcelain dish with 12 to 15 cm in diameter.

Flat glass plate: Glass plate of 450 mm square and 10 mm thick or longer.

Spatula: Flexible spatula with the blade about 8 cm long and 2 cm wide. It is used for mixing the soil and water in the porcelain evaporating dish.

Surface for rolling: Ground-glass plate about 20 cm $\times$ 15 cm.

Palette knives: Two palette knives with the blade about 20 cm long and 3 cm wide. It is used for mixing the soil and water on the flat glass plate.

Balance: A balance sensitive up to 0.01 g.

Oven: thermostatically controlled oven with interior of non-corroding material to maintain the temperature between 105 and 110^{o} C temperature.

Wash bottle: Wash bottle with containing distilled water.

Containers: Air tight and non-corrodible containers for determination of moisture content.

Sieve: 425 micron sieve.

Rod: A rod of 3 mm in diameter and about 10 mm long.

Material: A soil sample weighing about 20 g, shall be taken from thoroughly mixed portion of material passing through 425 micron IS sieve (IS: 460 (Part 1) – 1960) in accordance with IS: 2720 (Part 1) – 1983.

When both liquid and plastic limits are to be determined a quantity of soil sufficient for both the tests shall be taken for preparation of the soil. At a stage in the process of mixing of soil and water at which the mass becomes plastic enough to be easily shaped into a ball and, a portion of the soil sample in the plastic state should be taken for the plastic limit test.

Procedure:

1. Take around 20 g. of soil sample in the porcelain dish and mix it thoroughly with distilled water to make it plastic enough so that it can be shaped by a finger. Leave the plastic soil mass for some time to stand around 24 hours to allow water to permeate throughout the soil mass.
2. Take around 8 g. of the plastic soil, make a ball of it, and roll it on the glass plate with hand with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. When the

diameter of the thread will decrease to 3 mm, the specimen shall be kneaded together and rolled out again. This process will continue till the thread just crumbles at 3 mm diameter.

3. Collect the crumbled soil thread and place it in an air tight container for determination of water content. Repeat the process for three more times.
4. Also determine the natural water content of the soil sample obtained from the field.

Observations:

Table B: Determination of plastic limit

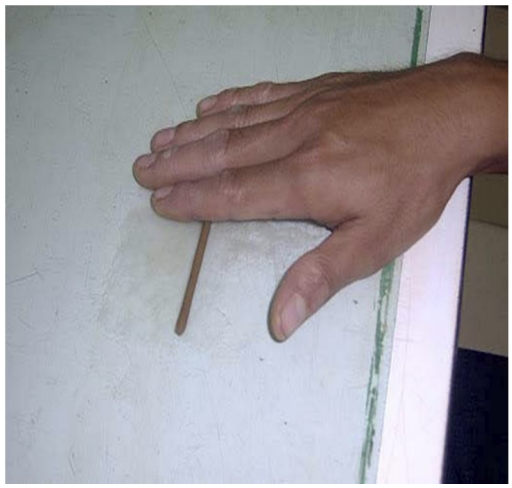
Mass of soil sample taken: 20 g.

Soil type: Passing through IS sieve 425 micron

Serial No.	**Parameters**	**Quantity**				
		Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**
1.	Container number					
2.	Mass of container with lid (M_1 g.)					
3.	Mass of container + wet soil + lid (M_2 g.)					
4.	Mass of container + dry soil + lid (M_3 g.)					
5.	Mass of water, M_w (g.) = M_3- M_2					
6.	Mass of dry soil, M_d (g.) = M_3- M_1					
7.	Water content, $w = \frac{M_w}{M_d} \times 100\%$					
8.	Average plastic limit (water content, %)					

Results: Plastic limit of the given soil is _____ %

(a)



(b)

Fig 2. (a) Experimental setup and (b) experimental procedure for plastic limit test

PART C: DETERMINATION OF SHRINKAGE LIMIT

Objective: The objective of the experiment is to determine the shrinkage limit of the given soil sample and then the plasticity index. Shrinkage limit is defined as the maximum water content at which any further reduction in water content will not cause a decrease in volume of the soil mass.

Apparatus: **Porcelain evaporating dish:** Porcelain dish with 12 to 15 cm in diameter.

Flat glass plate: Glass plate of 450 mm square and 10 mm thick or longer.

Spatula: Flexible spatula with the blade about 8 cm long and 2 cm wide. It is used for mixing the soil and water in the porcelain evaporating dish.

Shrinkage dish: Stainless steel shrinkage dish confirming to IS: 6911 – 1972. It should be inert to mercury and have a have a flat bottom with 45 mm in diameter and 15 mm height internally.

Prong plate: Two glass plates of each 75 mm × 75 mm and 3 mm thick. One glass plate shall be of plain glass and the other shall have three metal prongs inert to mercury.

Palette knives: Two palette knives with the blade about 20 cm long and 3 cm wide. It is used for mixing the soil and water on the flat glass plate.

Balance: A balance sensitive up to 0.01 g.

Oven: thermostatically controlled oven with interior of non-corroding material to maintain the temperature between 105 and 110^{o} C temperature.

Containers: Air tight and non-corrodible containers for determination of moisture content.

Sieve: 425 micron sieve.

Desiccator: Desiccator with suitable desiccating agent other than sulphuric acid to cool the soil.

Material: A soil sample weighing about 100 g, shall be taken from thoroughly mixed portion of material passing through 425 micron IS sieve (IS: 460 (Part 1) – 1960) in accordance with IS: 2720 (Part 1) – 1972.

Clean, sufficient amount of mercury is also required to fill the glass cup to over flowing condition.

Procedure:

Part i: Preparation of soil paste

1. Take around 30 g. of soil sample out of 100 g. soil material passing through 425 micron IS sieve in the evaporating dish and thoroughly mix

with distilled water. Sufficient amount of water should be added to fill the voids in the soil completely and to make the soil pasty enough to be readily worked into the shrinkage dish without entrapping air bubbles. In the case of friable soils the amount of water required to obtain the desired consistency equal to or slightly greater than the liquid limit. In the case of plastic soils it may exceed the liquid limit by as much as 10 percent.

Part ii: Preparation of soil paste

2. Clean the shrinkage dish and determine its mass accurate up to 0.1 g.
3. For determining its volume, place the shrinkage dish in the evaporating dish and fill it to overflowing the mercury.
4. Remove the excess mercury by pressing the plain glass plate firmly on its top ensuring that no air is entrapped.
5. Wipe off carefully any mercury which may be adhering to the external walls of the shrinkage dish.
6. Determine the mass of shrinkage dish full with mercury accurate up to 0.1 g.
7. The mass of mercury divided by its density would give the volume of the shrinkage dish, which is also the volume of the wet soil pat.

Part iii: Filling the shrinkage dish with soil pat

8. Coat the inside of shrinkage dish with a thin layer of grease or vaseline. In the centre of the dish, place the soil pat, about 1/3rd of the volume of the dish, with the help of the spatula.
9. Tap the dish gently on a firm surface, cushioned with the layers of blotting paper or rubber sheet and allow the paste to flow towards the edges.
10. Place another equal instalment of the paste in the dish and make it flow towards the edges by tapping.
11. Tapping is continued till the paste is compacted and all the entrapped air is brought to the surface. Repeat the process till the plate dish is completely full and excess soil overflows.
12. Strike off the excess soil paste with the help of straight edge. Also wipe off the excess soil adhering to the external walls of the dish.

Part iv: Determination of mass of wet and dry soil pat

13. Weigh immediately the shrinkage dish with wet soil pat, accurate up to 0.1 g.
14. Keep the shrinkage dish open in air until the colour of the pat turns from dark to light.

15. Keep the shrinkage dish in the oven and dry the pat to constant mass at a temperature of 105^{o} C to 110^{o} C.
16. Cool the dish in the desiccator and weigh immediately.

Part v: Determination of volume of dry soil pat

17. Put a glass cup in an evaporating dish.
18. Fill the cup overflowing with mercury.
19. Remove the excess mercury by pressing the glass plate with the three prongs firmly over the top of the cup.
20. Put the glass cup full of mercury in another evaporating dish carefully without losing a single drop of mercury. Clean any mercury attached to the exterior walls of the glass cup.
21. Place the oven dried soil pat on the surface of mercury.
22. Carefully force down the dry soil pat inside the mercury by pressing it with the glass plate with three prongs.
23. Press the plate firmly on top of the cup.
24. Collect all the mercury displaced by the dry soil pat from the evaporating dish carefully.
25. Weigh this displaced mercury accurate up to 0.1 g.
26. The volume of dry soil pat is determined by dividing the mass of collected mercury with the density of the mercury.

Observations:

Mass of soil sample taken: 100 g.

Soil type: Passing through IS sieve 425 micron

Shrinkage limit of the given soil sample: _____ %

(The shrinkage limit can be determined by using following Table C)

Fig 3. Experimental setup for shrinkage limit test

Table C: Determination of shrinkage limit

Serial No.	Parameters	Quantity		
		Test 1	**Test 2**	**Test 3**
Part i: Determination of water content of wet soil pat				
1.	Shrinkage dish number			
2.	Mass of shrinkage dish (M_1 g.)			
3.	Mass of shrinkage dish + wet soil pat M_2 (g.)			
4.	Mass of shrinkage dish + dry soil pat M_3 (g.)			
5.	Mass of water, M_w (g.) = M_2- M_3			
6.	Mass of dry soil, M_d (g.) = M_3- M_1			
7.	Water content, w = $\frac{M_w}{M_d} \times 100\%$			
Part ii: Determination of volume of wet soil pat				
8.	Evaporating dish no.			
9.	Mass of evaporating dish M_4 (g.)			
10.	Mass of evaporating dish + shrinkage dish with mercury M_5 (g.)			
11.	Mass of mercury filling the shrinkage dish M_{Hg} (g.) = $M_5 - M_4$			
12.	Volume of wet soil pat $V_{wet} = \frac{M_{Hg}}{13.6}$ (cc) **Density of mercury = 13.6 g./cc			
Part iii: Determination of volume of dry soil pat				
13.	Evaporating dish no.			
14.	Mass of evaporating dish M_4 (g.)			
15.	Mass of evaporating dish + mercury displaced by the dry soil pat M_6 (g.)			
16.	Mass of mercury displaced by dry soil pat $M_{Hg\ dry}$ (g.) = $M_6 - M_4$			
17.	Volume of dry soil pat $V_{dry} = \frac{M_{Hg\ dry}}{13.6}$ (cc)			
18.	Shrinkage limit, $w_s = w - \frac{(V_{wet} - V_{dry}) \times \gamma_w}{M_{Dry}}$ (%) ** M_{Dry} = Mass of oven dry soil pat in g.			
19.	Average shrinkage limit (%)			

Discussions: