IS 2720-5 (1985): Methods of test for soils, Part 5: Determination of liquid and plastic limit [CED 43: Soil and Foundation Engineering]

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Indian Standard

METHOD OF TEST FOR SOILS

PART 5 DETERMINATION OF LIQUID AND PLASTIC LIMIT

(Second Revision)

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

METHOD OF TEST FOR SOILS

PART 5 DETERMINATION OF LIQUID AND PLASTIC LIMIT

(Second Revision)

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Indian Standard

METHOD OF TEST FOR SOILS

PART 5 DETERMINATION OF LIQUID AND PLASTIC LIMIT

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 5) (Second Revision) was adopted by the Indian Standards Institution on 25 January 1985, after the draft finalized by the Soil Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 With a view to establish uniform procedures for the determination of different characteristics of soils and to facilitate comparative study of the results, the Indian Standards Institution is bringing out the 'Indian Standard methods of test for soils' (IS : 2720) which is being published in parts covering various properties of soils. This Part 5, which deals with the methods of test for the determination of liquid and plastic limits and other related indices of soils, was first published in 1965 and revised in 1970.

0.2.1 In this second revision, cone penetration method has been revised based on the 'revised cone' which is now universally used in other countries. The conventional Casagrande apparatus has certain shortcomings, such as the difficulty of cutting groove in soils of low plasticity and the tendency of soils to slip rather than flow. Cone penetrometer forms an alternative method to overcome the inherent shortcomings.

0.3 The liquid and plastic limits of soils are both dependent on the amount and type of clay in a soil and form the basis for the soil classification system for cohesive soils based on the plasticity tests. Besides their use for identification, the plasticity tests give information concerning the cohesion properties of soil and the amount of capillary water which it can hold. They are also used directly in specifications for controlling soil for use in fill. These index properties of soil have also been related to various other properties of the soil.

0.4 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part 5) lays down methods of test for the determination of the liquid limit and plastic limit of soils. Three methods, namely, mechanical method, one point method and the cone method are given for the determination of liquid limit.

1.1.1 Liquid limits over about 120 percent shall be obtained by the procedure specified in **3** or **4**. The one point method shall not be used for highly organic soils (*see* Note).

NOTE — The one point method may be applicable to the region for which the constants are obtained based upon results of tests on soils from that region. For all national and international reports the results obtained by the method in **3** or **4** may be reported.

1.2 The methods for calculating the following indices which are related to the liquid and plastic limits are also given:

a) Flow index (*see* **3.5.2**),
b) Plasticity index (*see* **8**),
c) Toughness index (*see* **9**),
d) Liquidity index (or water plasticity ratio) (*see* **10**), and
e) Consistency index (*see* **11**).

2. TERMINOLOGY

2.1 For the purpose of this standard, definitions of terms given in IS : 2809-1972† shall apply.

3. TEST FOR THE DETERMINATION OF LIQUID LIMIT (MECHANICAL METHOD)

3.1 Apparatus

3.1.1 *Mechanical Liquid Limit Device* — It shall conform to IS : 9259-1979‡.

3.1.2 *Grooving Tool* — It shall conform to IS : 9259-1979‡.

*Rules for rounding off numerical values (*revised*).
†Glossary of terms and symbols relating to soil engineering (*first revision*).
‡Specification for liquid limit apparatus for soils.

3.1.3 *Porcelain Evaporating Dish* — about 12 to 15 cm in diameter.

3.1.4 *Flat Glass Plate* — 10 mm thick and about 45 cm square or larger (alternative to porcelain evaporating dish for mixing soil with water).

3.1.5 *Spatula* — flexible, with the blade about 8 cm long and 2 cm wide (for mixing soil and water in the porcelain evaporating dish).

3.1.6 *Palette Knives* — two, with the blade about 20 cm long and 3 cm wide (for mixing soil and water on the flat glass plate).

3.1.7 *Balance* — sensitive to 0·01 g.

3.1.8 *Oven* — thermostatically controlled with interior of non-corroding material to maintain the temperature between 105 and 110°C.

3.1.9 *Wash Bottle or Beaker* — containing distilled water.

3.1.10 *Containers* — air-tight and non-corrodible for determination of moisture content.

3.2 Soil Sample — A sample weighing about 120 g shall be taken from the thoroughly mixed portion of material passing 425-micron IS Sieve [*see* IS : 460 (Part 1)-1978*] obtained in accordance with IS : 2720 (Part 1)-1983† (*see* Note and **6.2**).

NOTE — When no stones are present in the soil and practically all of the soil passes 425-micron IS Sieve, there is sometimes a practice of testing samples without previously preparing them. When soils are tested in the natural condition, the results will usually differ from those obtained with air-dried samples. The test record shall state that soil in the natural condition was used.

If this is done and stones are present, only the material passing 425-micron IS Sieve shall be used for the test; this can be obtained by rubbing the wet soil through the sieve until a sufficient quantity of the size passing 425-micron IS Sieve is obtained.

3.3 Adjustment of the Mechanical Device

3.3.1 The liquid limit device shall be inspected to determine that it is clean, dry and in good working order, that the cup falls freely and it does not have too much side play at its hinge. The grooving tool shall also be inspected to determine that it is clean and dry.

3.3.2 Using the gauge on the handle of the grooving tool or a separate gauge and by means of the adjustment plate of the mechanical liquid limit device, the height through which the cup is lifted and dropped shall be adjusted so that the point on the cup which comes in contact

*Specification for test sieves: Part 1 Wire cloth test sieves (*second revision*).

†Methods of test for soils: Part 1 Preparation of dry soil samples for various tests (*second revision*).

with the base falls through exactly one centimetre for one revolution of the handle. The adjustment plate shall then be secured by tightening the screw.

NOTE — If evenness of the base is not maintained in course of time, the base of the liquid limit device should be changed.

3.4 Procedure

3.4.1 About 120 g of the soil sample passing 425-micron IS Sieve shall be mixed thoroughly with distilled water in the evaporating dish or on the flat glass plate to form a uniform paste. The paste shall have a consistency that will require 30 to 35 drops of the cup to cause the required closure of the standard groove. In the case of clayey soils, the soil paste shall be left to stand for a sufficient time (24 hours) so as to ensure uniform distribution of moisture throughout the soil mass (*see* Note 1 under **3.4.3**).

3.4.2 The soil should then be re-mixed thoroughly before the test. A portion of the paste shall be placed in the cup above the spot where the cup rests on the base, squeezed down and spread into position shown in Fig. 1, with as few strokes of the spatula as possible and at the same time trimmed to a depth of one centimetre at the point of maximum thickness, returning the excess soil to the dish. The soil in the cup shall be decided by firm strokes of the grooving tool along the diameter through the centre line of the cam follower so that a clean, sharp groove of the proper dimensions is formed (*see* Note 2 under **3.4.3**). In case where grooving tool, Type A does not give a clear groove as in sandy soils, grooving tool Type B or Type C (*see* Note 3 under **3.4.3**) should be used.

DIVIDED SOIL CAKE
BEFORE TEST

SOIL CAKE AFTER
TEST

FIG. 1 DIAGRAM ILLUSTRATING LIQUID LIMIT TEST

The cup shall be fitted and dropped by turning the crank at the rate of two 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 (*see* Note 4). This length shall be measured with the end of the grooving tool or a ruler. The number of drops required to cause the groove close for the length of 12 mm shall be recorded.

3.4.3 A little extra of the soil mixture shall be added to the cup and mixed with the soil in the cup. The pat shall be made in the cup and the test repeated as in **3.4.2**. In no case shall dried soil be added to the thoroughly mixed soil that is being tested. The procedure given in **3.4.2** and in this clause shall be repeated until two consecutive runs give the same under of drops for closure of the groove (*see* Notes 4 and 5).

NOTE 1 — Light textured soils (of low clay content) may be tested immediately after thorough mixing of water.

NOTE 2 — To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes, from front to back or from back to front counting as one stroke, shall be permitted. Each stroke penetrate a little deeper until the last stroke from back to front scrapes the bottom of the cup clean. The groove shall be made with as few strokes as possible.

NOTE 3 — With soils having low plasticity indices it is sometimes difficult to cut a smooth groove in the soil with grooving tool, Type A. Grooving tool, Type B or Type C may be used in such cases. Grooving tool, Type B inserts a wedge into the pat of soil causing the two halves of the pat to slide at the cup-soil interface. During the test the tendency is then for the soil to slide back again on this same face instead of flowing as it should do. It should, therefore, be used with caution.

NOTE 4 — Some soils tend to slide on the surface of the cup instead of the soil flowing. If this occurs, the results should be discarded and the test repeated until flowing does occur. If sliding still occurs, the test is not applicable and a note should be made that the liquid limit could not be obtained.

NOTE 5 — Care shall be taken to see that the soil paste does not dry out too rapidly between repeat tests as the number of blows for closure will increase gradually as the sample dries out.

3.4.4 A representative slice of soil approximately the width of the spatula, extending from about edge to edge of the soil cake at right angle to the groove and including that portion of the groove in which the soil flowed together, shall be taken in a suitable container and its moisture content expressed as a percentage of the oven dry weight otherwise determined as described in IS : 2720 (Part 2)-1973*. The remaining soil in the cup shall be transferred to the evaporating dish and the cup and the grooving tool cleaned thoroughly.

3.4.5 The operations specified in **3.4.2** to **3.4.4** shall be repeated for at least three more additional trails (minimum of four in all), which the soil collected in the evaporating dish or flat glass plate, to with sufficient water has been added to bring the soil to a more fluid

*Methods of test for soils: Part 2 Determination of moisture content (*second revision*).

condition. In each case the number of blows shall be recorded and the moisture content determined as before. The specimens shall be of such consistency that the number of drops required to close the groove shall be not less than 15 or more than 35 and the points on the flow curve are evenly distributed in this range. The test should proceed from the drier (more drops) to the wetter (less drops) condition of the soil. The test may also be conducted from the wetter to the drier condition provided drying is achieved by kneading the wet soil and not by adding dry soil.

3.5 Determination of Liquid Limit and Flow Index

3.5.1 *Liquid Limit* (w_L) — 'A flow curve' shall be plotted on a semi-logarithmic graph representing water content on the arithmetical scale and the number of drops on the logarithmic scale. The flow curve is a straight line drawn as nearly as possible through the four or more plotted points. The moisture content corresponding to 25 drops as read from the curve shall be rounded off to the nearest whole number and reported as the liquid limit of the soil.

3.5.2 *Flow Index* (I_f) — The flow curve (straight line) plotted on semi-logarithmic graph as in **3.5.1** shall be extended at either end so as to intersect the ordinates corresponding to 10 and 100 drops. The slope of this line expressed as the difference in water contents as 10 drops and at 100 drops shall be reported as the flow index.

NOTE — The flow index may be calculated from the following equation also:

$$I_f = \frac{w_1 - w_2}{\log 10 \frac{N_2}{N_1}}$$

where

I_f = flow index,

w_1 = moisture content in percent corresponding to N_1 drops, and

w_2 = moisture content in percent corresponding to N_2 drops.

3.6 Report

3.6.1 The results of the observations of the test shall be recorded suitably. A recommended proforma for the record of results is given in Appendix A.

3.6.2 The liquid limit should be reported to the nearest whole number. The history of the soil sample, that is, natural state, air-dried, oven dried or unknown, the method used for the test reported and the period of soaking allowed after mixing of water to the soil shall also be reported.

4. TEST FOR THE DETERMINATION OF LIQUID LIMIT BY CONE PENETRATION METHOD

4.1 The basic principle is to observe depths of penetrations of soils at various initial moisture contents of a metal cone of a certain weight and apex angle with the point barely touching the surface is allowed to drop into the surface. The standardization has been to identify liquid limit water content for a specified depth of penetration.

4.2 Apparatus

4.2.1 It shall conform to IS : 11196-1985*

4.2.2 *Balance* — Sensitive to 0·01 g.

4.2.3 *Containers* — non-corrodible and air-tight for moisture determination.

4.2.4 *Oven* — thermostatically controlled with interior non-corroding material to maintain the temperature between 105 and 110°C.

4.3 Soil Sample — A soil sample weighing about 150 g from thoroughly mixed portion of the soil passing 425 micron IS Sieve obtained in accordance to IS : 2720 (Part 1)-1983†.

4.4 Procedure — About 150 g of soil sample obtained as in **4.3** shall be worked well into a paste with addition of distilled water. In the case of highly clayey soils, to ensure uniform moisture distribution, it is recommended that the soil in the mixed state is left for sufficient time (24 hours) in an air-tight container. The wet soil paste shall then be transferred to the cylindrical cup of cone penetrometer apparatus, ensuring that no air is trapped in this process. Finally the wet soil is levelled up to the top of the cup and placed on the base of the cone penetrometer apparatus. The penetrometer shall be so adjusted that the cone point just touches the surface of the soil paste in the cup clamped in this position. The initial reading is either adjusted to zero or noted down as is shown on the graduated scale. The vertical clamp is then released allowing the cone to penetrate into the soil paste under its own weight. The penetration of the cone after 5 seconds shall be noted to the nearest millimetre. If the difference in penetration lies between 14 and 28 mm the test is repeated with suitable adjustments to moisture either by addition of more water or exposure of the spread paste on a glass plate for reduction in moisture content. The test shall then be repeated at least to have four sets of values of penetration in the range of 14 to 28 mm. The exact moisture content of each trial shall be determined in accordance with IS : 2720 (Part 2)-1973‡.

*Specification for equipment for determination of liquid limit of soils by cone penetration method.

†Methods for test for soils: Part 1 Preparation of dry soil samples for various tests (*second revision*).

‡Methods of test for soils: Part 2 Determination of moisture content (*second revision*).

4.5 Determination of Liquid Limit — A graph representing water content on the y-axis and the cone penetration on the x-axis shall be prepared. The best fitting straight line is then drawn. The moisture content corresponding to cone penetration of 20 mm shall be taken as the liquid limit of the soil and shall be expressed to the nearest first decimal place.

4.6 Report

4.6.1 The results of observations of the test shall be recorded suitably.

4.6.2 The liquid limit should be reported to the nearest first decimal place. The history of the sample, that is, natural state, air-dried, or unknown, the pretreatment, if any to the soil shall be reported.

5. TEST FOR DETERMINATION OF LIQUID LIMIT BY ONE POINT METHOD USING (CASAGRANDE APPARATUS)

5.1 Principle — It has been established by basic characteristics of soils and associated physico-chemical factors that critical shear strengths at liquid limit water contents arise out of force field equilibrium and are independent of soil type. This has lead to the formation of a scientific base for liquid limit determination by one point method.

5.2 Apparatus — The requirements for apparatus are the same as specified in **3.1**.

5.3 Soil Sample — The requirements for the soil sample are the same as specified in **3.2**.

5.4 Adjustment of the Mechanical Device — The requirements for mechanical device are the same as specified in **3.3**.

5.5 Procedure — A sample of soil weighing at least 50 g from the soil sample passing 425 micron IS Sieve shall be mixed thoroughly with distilled water in the evaporating dish or on the flat glass plate to form a uniform paste with a moisture content as near as possible to that corresponding to the 25 drops value. The trial addition of water to give about 25 drops may be checked with the mechanical device until experience with the soil under test renders this stop unnecessary. The procedure given in **3.4.1** to **3.4.4** should otherwise be followed, except that a moisture content sample shall be taken only for the accepted trial. For soils with liquid limits above 50 to 120 percent the accepted range shall require between 20 and 30 drops to close the groove (*see* **1.1.1**); for soils with liquid limit less than 50 percent a range of 15 to 35 drops is acceptable. At least two consistent consecutive closures shall be observed before taking the moisture content sample for calculation of the liquid limit. The test shall always proceed from the wetter to the drier condition of the soil.

5.6 Computations — The water content w_N of the soil of the accepted trial shall be calculated. For the range of blows between 15 and 35 the liquid limit water content shall be calculated employing the formula.

$$w_L = \frac{w_N}{1{\cdot}321\ 5 - 0{\cdot}23 \log N}$$

5.7 Report — *See* **4.6.**

6. TEST FOR DETERMINATION OF LIQUID LIMIT BY ONE POINT METHOD USING CONE PENETROMETER APPARATUS

6.1 Principle — Since the depth of penetration is in an indirect reflection of shear strength at different water contents, it has been found, within the framework of a scientific base that w/w_L against log D or D is unique and is independent of soil type. The resulting linear relation enables to determine liquid limit water content corresponding to 20 mm penetration of the cone.

6.2 Apparatus — The requirements for apparatus are the same as in **4.3.**

6.3 Soil Sample — The requirements for the soil sample are the same as in **4.4.**

6.4 Procedure — Same as in **4.5.** The accepted trial is such that the depth of cone penetration is between 16 and 26 mm.

6.5 Computations — The water content is determined for the accepted trial. The liquid limit water content is computed from any one of the following relationships:

$$w_L = w_N/0{\cdot}77 \log D$$

$$w_L = w_N/(0{\cdot}65 + 0{\cdot}017\ 5\ D)$$

6.6 Report — *See* **4.6.**

7. TEST FOR THE DETERMINATION OF PLASTIC LIMIT

7.1 Apparatus

7.1.1 *Porcelain Evaporating Dish* — about 12 cm in diameter.

or

Flat Glass Plate — 10 mm thick and about 45 cm square or larger.

7.1.2 *Spatula* -- flexible, with the blade about 8 cm long and 2 cm wide.

or

Palette Knives -- two, with the blade about 20 cm long and 3 cm wide (for use with flat glass plate for mixing soil and water).

7.1.3 *Surface for Rolling* — ground-glass plate about 20 × 15 cm.

7.1.4 *Containers* — air-tight to determine moisture content.

7.1.5 *Balance* — sensitive to 0·01 g.

7.1.6 *Oven* — thermostatically controlled with interior of non-corroding material to maintain the temperature between 105°C and 110°C.

7.1.7 *Rod* — 3 mm in diameter and about 10 cm long.

7.2 Soil Sample — A sample weighing about 20 g from the thoroughly mixed portion of the material passing 425-micron IS Sieve, obtained in accordance with IS : 2720 (Part 1)-1983* shall be taken.

7.2.1 When both the liquid limit and the plastic limit of a soil 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, a portion of the soil sample in the plastic state should be taken for the plastic limit test.

7.3 Procedure — The soil sample shall be mixed thoroughly with distilled water in an evaporating dish or on the flat glass plate till the soil mass becomes plastic enough to be easily moulded with fingers. In the case of clayey soils the plastic soil mass shall be left to stand for a sufficient time (24 hours) to ensure uniform distribution of moisture throughout the soil (*see* **7.2.1**). A ball shall be formed with about 8 g of this plastic soil mass and rolled between the fingers and the glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes/min counting a stroke as one complete motion of the hand forward and back to the starting position again. The rolling shall be done till the threads are of 3 mm diameter. The soil shall then be kneaded together to a uniform mass and rolled again. This process of alternate rolling and kneading shall be continued until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the thread has a diameter greater than 3 mm. This shall be considered a

*Methods of test for soils : Part 1 Preparation of dry soils samples for various tests (*second revision*).

satisfactory end point, provided the soil has been rolled into a thread 3 mm in diameter immediately before. At no time shall an attempt be made to produce failure at exactly 3 mm diameter by allowing the thread to reach 3 mm, then reducing the rate of rolling or pressure or both, and continuing the rolling without further deformation until the thread falls apart. The pieces of crumbled soil thread shall be collected in an air-tight container and the moisture content determined as described in IS : 2720 (Part 2)-1973*.

7.4 Report

7.4.1 The observations of the test should be recorded suitably. A recommended proforma for the record of results is given in Appendix A.

7.4.2 The moisture content determined as in **7.3** is the plastic limit of the soil. The plastic limit shall be determined for at least three portions of the soil passing 425-micron IS Sieve. The average of the results calculated to the nearest whole number shall be reported as the plastic limit of the soil.

7.4.3 The history of the soil sample (that is, natural state, air-dried, oven-dried or unknown) and the period of soaking allowed after mixing of water to the soil shall also be reported.

8. PLASTICITY INDEX

8.1 Calculation — The plasticity index is calculated as the difference between its liquid limit and plastic limit:

Plasticity index (I_p) = liquid limit (w_L) — plastic limit (w_p).

8.2 Report — The difference calculated as indicated in **8.1** shall be reported as the plasticity index, except under the following conditions:

a) In the case of sandy soils plastic limit should be determined first. When plastic limit cannot be determined, the plasticity index should be reported as N_p (non-plastic).

b) When the plastic limit is equal to or greater than the liquid limit, the plasticity index shall be reported as zero.

*Methods of test for soils: Part 2 Determination of moisture content (*second revision*).

9. TOUGHNESS INDEX

9.1 Calculation — The toughness index shall be calculated as follows:

$$\text{Toughness index } (I_T) = \frac{I_p}{I_f}$$

where

I_p = plasticity index (*see* **8.1**), and
I_f = flow index (*see* **3.5.2**).

10. LIQUIDITY INDEX

10.1 Calculation — The liquidity index shall be calculated as follows:

$$\text{Liquidity index } (I_L) = \frac{w_o - w_p}{I_p}$$

where

w_o = natural moisture content of the soil,
w_p = plastic limit of the soil, and
I_p = plasticity index of the soil.

11. CONSISTENCY INDEX

11.1 Calculation — The consistency index shall be calculated as follows:

$$\text{Consistency index } (I_c) = \frac{w_L - w_o}{I_p}$$

where

w_L = liquid limit of the soil,
w_o = natural moisture content of the soil, and
I_p = plasticity index of the soil.

12. GENERAL REPORT

12.1 The result of all the tests and calculations may be reported in the proforma given in Appendix A.

APPENDIX A

(*Clauses* 3.6.1, 7.4.1 *and* 12.1)

PROFORMA FOR TESTS AND CALCULATIONS

IS No. with year ..... Date .....
Details of soil sample ..... Room Temperature ....
Natural water content .....
History of soil sample .....
Period of soaking of soil sample before test .....

	LIQUID LIMIT					PLASTIC LIMIT				
Determination number	1	2	3	4	5	1	2	3	4	5
Number of drops										
Container number										
Weight of container + wet soil, g										
Weight of container + oven dry soil, g										
Weight of water, g										
Weight of container, g										
Weight of oven dry soil, g										
Moisture percent										

RESULT SUMMARY

Liquid Limit w_L	Flow Index I_f	Plastic Limit w_p	Plasticity Index I_p	Toughness Index I_T	Liquidity Index I_L	Consistency Index I_c
(1)	(2)	(3)	(4)	(5)	(6)	(7)

REMARKS

(*Continued from page* 2)

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