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METHODS OF TEST FOR SOILS

PART VI DETERMINATION OF SHRINKAGE FACTORS

(First Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

METHODS OF TEST FOR SOILS

PART VI DETERMINATION OF SHRINKAGE FACTORS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part VI) (First Revision) was adopted by the Indian Standards Institution on 25 February 1972, 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 also for facilitating a comparative study of the results, the Indian Standards Institution is bringing out this ' Indian Standard methods of test for soils ' (IS : 2720) which is being published in parts. Thirty-three parts of this series have been published so far.

0.3 This part, first published in 1964, deals with the methods of test for the determination of shrinkage factors for soils. Factors, such as the shrinkage limit, shrinkage ratio, shrinkage index and volumetric shrinkage may be determined from the results of the test described. The method for determining the value of linear shrinkage on the basis of results of test conducted for obtaining the shrinkage limit has been found unsatisfactory and a direct method for determining this property has been covered in IS : 2720 (Part XX)-1966*. Hence reference to linear shrinkage has been deleted from this revision. As weight measurements can be made more accurately than volume measurements, the former method has been specified in this revision for the determination of the volume of the soil pat. The inside edge of the shrinkage dish has been rounded so that air entrapped during the measurement of the volume of the pat is minimized. Recently it has been recognized that shrinkage upon drying is also indicative of the structure of the soil. The greater the shrinkage the more dispersed the strcture. It is possible, therefore, to study the shrinkage behaviour of undisturbed soil of natural or man-made deposits and get an idea of its structure. In this revision the term shrinkage limit (undisturbed soil) has been introduced to define this property and a method included for its determination. Consequently, the term originally known as shrinkage limit has been re-designated as shrinkage limit (remoulded soil).

*Methods of test for soils: Part XX Determination of linear shrinkage.

0.4 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.5 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 VI) lays down the method of test for obtaining data from which the shrinkage factors, namely shrinkage limit (remoulded soil), shrinkage limit (undisturbed soil), shrinkage ratio, shrinkage index and volumetric shrinkage of soils may be calculated.

2. TERMINOLOGY

2.1 For the purpose of this standard, the following definitions shall apply. For definitions of terms not given below, reference may be made to IS : 2809-1972†.

2.1.1 *Shrinkage Index* (I_s) — The numerical difference between the plastic limit and shrinkage limit (remoulded soil).

2.1.2 *Shrinkage Limit (Undisturbed Soil)* (w_{su}) — The maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass, the soil mass being initially of soil in its undisturbed state.

2.1.3 *Shrinkage Limit (Remoulded Soil)* (w_s) — The maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass, the soil mass being prepared initially from remoulded soil.

2.1.4 *Shrinkage Ratio* (R) — The ratio of a given volume change, expressed as a percentage of the dry volume, to the corresponding change in water content above the appropriate shrinkage limit, expressed as a percentage of the weight of the oven-dried soil.

2.1.5 *Volumetric Shrinkage (Volumetric Change)* (V_s) — The decrease in volume, expressed as a percentage of the soil mass when dried, of a soil mass when the water content is reduced from a given percentage to the appropriate shrinkage limit.

*Rules for rounding off numerical values (*revised*).
†Glossary of terms and symbols relating to soil engineering (*first revision*).

3. APPARATUS

3.1 Evaporating Dish — two, porcelain, about 12 cm in diameter with a pour out and flat bottom, the diameter of flat bottom, being not less than 55 mm or an enamel iron tray with pour out.

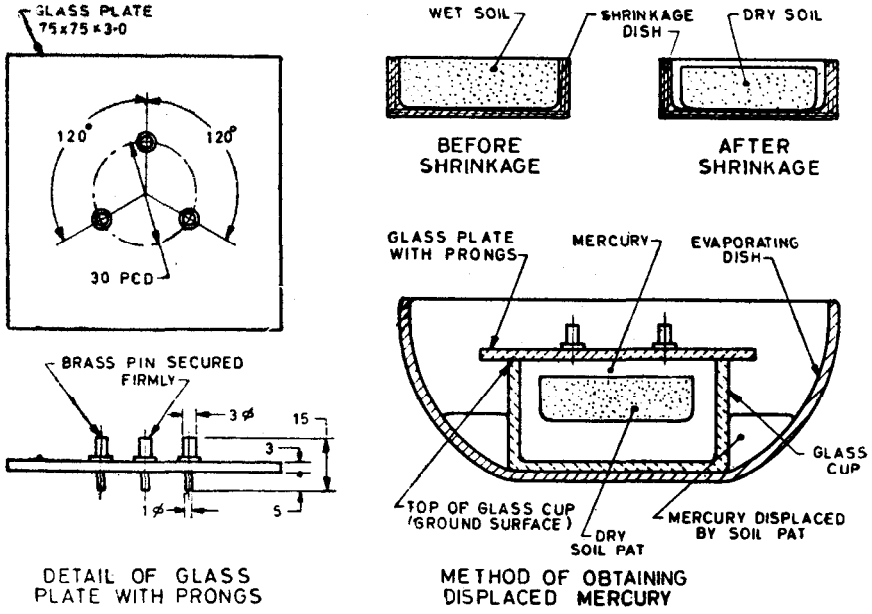
3.2 Spatula — flexible, with the blade about 8 cm long and 2 cm wide.

3.3 Shrinkage Dish — circular, porcelain or non-corroding metal dish inert to mercury having a flat bottom and 45 mm in diameter and 15 mm height internally. The internal corner between the bottom and the vertical sides shall be rounded into a smooth concave curve.

3.4 Straight Edge — steel, about 15 cm in length.

3.5 Glass Cup — 50 to 55 mm in diameter and 25 mm in height, the top rim of which is ground smooth and level.

3.6 Glass Plates — two, each 75 × 75 mm, 3 mm thick. One plate shall be of plain glass and the other shall have three metal prongs inert to mercury (*see* Fig. 1).



All dimensions in millimetres.

FIG. 1 APPARATUS FOR DETERMINING VOLUMETRIC CHANGE

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

3.8 Sieve — 425-micron IS Sieves.

3.9 Balances — sensitive to 0·1 g and 0·01 g (*see* IS : 1433-1965*).

3.10 Mercury — clean, sufficient to fill the glass cup to overflowing.

3.11 Desiccator — with any desiccating agent other than sulphuric acid.

4. SOIL SAMPLE FOR TEST

4.1 For Shrinkage Limit (Remoulded Soil) Test (and Determination of Other Allied Properties) — Take a sample weighing about 100 g from the thoroughly mixed portion of the material passing the 425-micron IS Sieve which has been obtained in accordance with IS : 2720 (Part I)-1972†.

4.2 Shrinkage Index (Undisturbed Soil) Test

4.2.1 Preserve the undisturbed soil sample received from the field in its undisturbed state.

4.2.2 Trim from the undisturbed soil sample soil pats approximately 45 mm in diameter and 15 mm in height. Round off their edges to prevent the entrapment of air during mercury displacement.

5. PROCEDURE FOR DETERMINATION OF SHRINKAGE LIMIT (REMOULDED SOIL) AND OTHER ALLIED PROPERTIES

5.1 Preparation of Soil Paste — Place about 30 g of the soil sample obtained in **4.1** in the evaporating dish and thoroughly mix with distilled water in an amount sufficient to fill the soil voids 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 is 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.

5.2 Weight and Volume of the Shrinkage Dish — Determine the weight of the clean empty shrinkage dish and record. Determine the capacity of the shrinkage dish in cubic centimetres, which is also the volume of the wet soil pat, by filling the shrinkage dish to overflowing with mercury, removing the excess by pressing the plain glass plate firmly over the top of the shrinkage dish in such a way that the plate is flush with the top of the dish and no air is entrapped, weighing the mercury held in the shrinkage dish to an accuracy of 0·1 g and dividing this weight by the unit weight of mercury to obtain the volume. Record this volume as the volume of the wet soil pat, V.

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*Specification for beam scales (*revised*).

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

5.3 Filling the Shrinkage Dish — Coat the inside of the shrinkage dish with a thin layer of silicone grease or vaseline or some other heavy grease to prevent the adhesion of soil to the dish. Place in the centre of the shrinkage dish an amount of the soil paste equal to about one-third the volume of the shrinkage dish, and allow the paste to flow to the edges by tapping the shrinkage dish on a firm surface cushioned by several layers of blotting paper, rubber sheet or similar material. Add an amount of the soil paste approximately equal to the first portion, and tap the shrinkage dish as before until the paste is thoroughly compacted and all included air has been brought to the surface. Add more soil paste and continue the tapping until the shrinkage dish is completely filled and excess soil paste stands out about its edge. Then strike off the excess soil paste with a straight edge, and wipe off all soil adhering to the outside of the shrinkage dish.

5.4 Weigh immediately the shrinkage dish as filled in **5.3** and record the weight as the weight of the shrinkage dish and wet soil pat. Allow the soil pat to dry in air until the colour of the pat turns from dark to light. Then oven-dry the pat in the shrinkage dish to constant weight at 105 to 110°C, cool in a desiccator and weigh immediately after removal from the desiccator. Record the weight as the weight of shrinkage dish and dry soil.

5.5 Volume of the Dry Soil Pat — Determine the volume of the dry soil pat by removing the pat from the shrinkage dish and immersing it in the glass cup full of mercury in the manner given in **5.5.1**.

5.5.1 Fill the glass cup to overflowing with mercury and remove the excess mercury by pressing the glass plate with the three prongs (*see* Fig. 1) firmly over the top of the cup, collecting the excess mercury in a suitable container. Carefully wipe off any mercury which may be adhering to the outside of the cup. Place the cup, filled thus with mercury, in the evaporating dish taking care not to spill any mercury from the glass cup, and place the oven-dried soil pat on the surface of the mercury in the cup. Then carefully force the pat under the mercury by means of the glass plate with the same prongs (*see* Fig. 1) and press the plate firmly over the top of the cup, the displaced mercury being collected in the evaporating dish without spilling out of it. Care shall be taken to ensure that no air is trapped under the soil pat. Weigh the mercury so displaced by the dry soil pat to an accuracy of 0·1 g and determine its volume by dividing this weight by the unit weight of mercury. Record this volume as the volume of the oven-dry soil pat, V_0.

6. PROCEDURE FOR DETERMINING SHRINKAGE LIMIT (UNDISTURBED SOIL)

6.1 Keep the specimen as prepared in **4.2** in a suitable small dish and

air-dry it. Then dry the specimen in the dish to constant weight in an oven at 105 to 110°C. Remove the specimen from the oven and smoothen the edges by sand papering. Brush off the soil dust from the specimen by a soft paint brush. Place the specimen again in the cleaned dish and dry it in an oven to constant weight. Cool the oven-dry specimen in a desiccator and weigh it with the dish. Determine the oven-dry weight of the specimen, W_{os}.

6.2 Determine the volume V_{os} of the oven-dry specimen of **6.1** as described in **5.5.1.**

6.3 Determine the specific gravity of the soil in accordance with IS : 2720 (Part III)-1964*.

7. CALCULATIONS

7.1 Moisture Content (w) — Calculate the moisture content of wet soil pat (*see* **5**) as a percentage of the dry weight of the soil as follows:

$$w = \frac{W - W_o}{W_o} \times 100$$

where

w = moisture content of the pat (*see* **5**),

W = weight of wet soil pat obtained by subtracting the weight of the shrinkage dish from the weight of the dish and wet pat, and

W_o = weight of dry soil pat obtained by subtracting the weight of the shrinkage dish from the weight of the dish and dry pat.

7.2 Shrinkage Limit (Remoulded Soil) (w_s) — Calculate the shrinkage limit using the following formula:

$$w_s = w - \left(\frac{V - V_o}{W_o} \right) 100$$

where

w_s = shrinkage limit in percent,

w = moisture content of wet soil pat (*see* **7.1**) in percent,

V = volume of wet soil pat in ml,

V_o = volume of dry soil pat in ml, and

W_o = weight of oven-dry soil pat in g.

NOTE — When the specific gravity of the soil is known the shrinkage limit may also

*Methods of test for soils : Part III Determination of specific gravity.

be calculated by the following formula (in this case, step indicated in **5.4** is not required):

$$w_s = \left(\frac{1}{R} - \frac{1}{G} \right) 100$$

where

w_s = shrinkage limit in percent,

R = shrinkage ratio (*see* **7.4**), and

G = specific gravity for the fraction used in the test determined in accordance with IS : 2720 (Part III)-1964*.

7.3 Shrinkage Index (I_s) — Calculate the shrinkage index using the following formula:

$$I_s = I_p - w_s$$

where

I_p = plasticity index [determined in accordance with IS : 2720 (Part V)-1970†].

7.4 Shrinkage Ratio (R) — Calculate the shrinkage ratio using the following formula:

$$R = \frac{W_o}{V_o}$$

where

W_o = weight of oven-dry pat in g, and

V_o = volume of oven-dry soil pat in ml.

7.5 Volumetric Shrinkage (Volumetric Change) (V_s) — Calculate the volumetric shrinkage using the following formula:

$$V_s = (w_1 - w_s) R$$

where

w_1 = given moisture content in percent,

w_s = shrinkage limit (*see* **7.2**), and

R = shrinkage ratio (*see* **7.4**).

7.6 Shrinkage Limit (Undisturbed Soil) (w_{su}) — Calculate the shrinkage limit (undisturbed soil) using the following formula (of sample referred in **6**):

$$w_{su} = \left(\frac{V_{os}}{W_{os}} - \frac{1}{G} \right) 100$$

where

w_{su} = shrinkage limit (undisturbed soil) in percent,

*Methods of test for soils: Part III Determination of specific gravity.

†Methods of test for soils: Part V Determination of liquid and plastic limits (*first revision*).

V_{os} = volume of oven-dry specimen in ml (*see* **6.2**),

W_{os} = weight of oven-dry specimen in g (*see* **6.1**), and

G = specific gravity of soil determined in accordance with IS : 2720 (Part III)-1964*.

8. REPORT

8.1 The observations and results of the test shall be reported suitably. A recommended *pro forma* for the record of results is given in Appendix A.

8.2 The tests shall be repeated at least three times for each soil sample and the average of the results thus obtained reported. If any individual value varies from the average by more than ± 2 percent, it shall be discarded and the test repeated.

APPENDIX A

(*Clause* 8.1)

PRO FORMA FOR RECORD OF TEST RESULTS

a) *Shrinkage Limit (Remoulded Soil)*

Project: Laboratory number of sample:

Name of work: Description of soil sample:

Soil fraction taken for the test:

Location	Bore/Trial Pit No.	Depth	Test No.
1. Determination No.			
2. Shrinkage dish No.			
3. Weight of shrinkage dish in g			
4. Weight of shrinkage dish + wet soil pat in g			
5. Weight of shrinkage dish + dry soil pat in g			
6. Weight of oven-dry soil pat (W_o) in g			
7. Weight of water in g			
8. Moisture content (w) of soil pat, percent			
9. Evaporating dish No. (dish into which mercury filling shrinkage dish is transferred for weighing) in g			
10. Weight of mercury filling shrinkage dish + weight of evaporating dish			
11. Weight of evaporating dish			

*Methods of test for soils: Part III Determination of specific gravity.

12. Weight of mercury filling shrinkage dish in g			
13. Volume of wet soil pat (V) in ml			
14. Evaporating dish No.			
15. Weight of mercury displaced by the dry soil pat + weight of evaporating dish in g			
16. Weight of evaporating dish in g			
17. Weight of mercury displaced by the dry soil pat in g			
18. Volume of dry soil pat (V_o) in ml			
19. $\left(\frac{V-V_o}{W_o}\right) 100$			
20. Shrinkage limit (remoulded soil) $w_s = \left(w - \frac{V-V_o}{W_o}\right) 100$			
21. Shrinkage ratio $R = \frac{W_o}{V_o}$			
22. Given moisture content w, percent			
23. $(W_1 - w_s)$			
24. Volumetric shrinkage $V_s = (W_1 - w_s) R$			

b) *Shrinkage Limit (Undisturbed Soil)*

Project: Laboratory number of sample:

Name of work: Description of soil sample (including method of compaction used in the field, sampling method used, etc):

Location	Bore/Trial Pit No.	Depth	Test No.
1. Determination No.			
2. Dish No.			
3. Weight of dish + oven-dry soil specimen in g			
4. Weight of dish in g			
5. Weight of oven-dry soil specimen W_{os} in g			
6. Evaporating dish No.			
7. Weight of mercury displaced by the oven-dry specimen + weight of evaporating dish in g			
8. Weight of evaporating dish in g			
9. Weight of mercury displaced by the oven-dry soil specimen in g			
10. Volume of the oven-dry soil specimen V_{os} in ml			
11. $\frac{V_{os}}{W_{os}}$			
12. Specific gravity of the soil of the specimen G			
13. $1/G$			
14. Shrinkage limit (undisturbed soil) $w_{su} = \left(\frac{V_{os}}{W_{os}} - \frac{1}{G}\right) 100$			

(*Continued from page* 2)

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PART VI DETERMINATION OF SHRINKAGE FACTORS

(First Revision)

Alterations

(*Page* 5, *clauses* **3.1** *to* **3.6**) — Substitute the following for the existing clauses and re-number the subsequent clauses:

'**3.1** The evaporating dish, spatula, shrinkage dish, straight edge, glass cup, prong plate, plain plate and measuring cylinder shall conform to IS : 10077-1982*.'

(*Page* 5, *Fig.* 1) — Delete.

(*Page* 8, *clause* **6.3**; *page* 9, *clause* **7.2**; and *page* 10, *clause* **7.6**) — Substitute ' IS : 2720(Part III/Sec 2)-1980* ' *for* ' IS : 2720(Part III)-1964* ' wherever appearing.

(*Pages* 8, 9 *and* 10, *foot-note with* ' * ' *mark*) — Substitute the following for the existing foot-note:

'*Method of test for soils : Part III Determination of specific gravity, Section 2 Fine, medium and coarse grained soils (*first revision*).'

Addenda

(*Page* 5) — Add the following foot-note at the bottom:

'†Specification for equipment for determination of shrinkage factors.'

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