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METHODS OF TEST FOR SOILS

PART XXXIII DETERMINATION OF THE DENSITY IN-PLACE BY THE RING AND WATER REPLACEMENT METHOD

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BUREAU OF INDIAN STANDARDS
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Indian Standard

METHODS OF TEST FOR SOILS

PART XXXIII DETERMINATION OF THE DENSITY IN-PLACE BY THE RING AND WATER REPLACEMENT METHOD

0. FOREWORD

0.1 This Indian Standard (Part XXXIII) was adopted by the Indian Standards Institution on 24 September 1971, 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 to facilitate comparative studies of results, the Indian Standards Institution is bringing out this Indian Standard methods of test for soils (IS : 2720) which will be published in parts. Thirty-one parts of this standard have been published so far.

0.3 This part (Part XXXIII) deals with the determination of dry density of soil in-place by the water replacement method using a ring. The in-place density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of natural slopes, for the determination of pressures on underlying strata for calculation of settlement, etc. In compacted soils the in-place density is needed to check the amount of compaction that the soil has undergone for comparison with design data. The correct estimation of the in-place density of both natural and compacted soils is therefore of importance.

0.4 In reporting the results 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 XXXIII) covers the method for determining the in-place density of a coarse grained soil including gravels, cobbles, boulders and rock by the water replacement method using a circular ring on the surface and a plastics film to retain the water (*see* Notes 1 and 2).

NOTE 1 — If desired, successive density tests may be performed as the hole is progressively deepened to determine the variation of density with depth, for example, when placing and compacting material in relatively thick layers.

*Rules for rounding off numerical values (*revised*).

NOTE 2 — A field grading of the excavated soil, may, if desired, be done while the test hole is being excavated.

1.1.1 The field dry density is determined either for the total material or for the material smaller than a specified or given size.

2. APPARATUS

2.1 Density Ring and Steel Spikes (*if required*) — The ring diameter shall be at least 3 to 4 times the size of the largest particle. The diameter usually ranges between 0·5 and 2·5 m in multiples of 0·5 m. The rings may be made of 4 to 8 mm mild steel sheet, either in one unit (when smaller) or in segments (when bigger) with suitable provisions for assembling in the field. The rings may be of any construction provided the inner surface is that of a right cylinder approximately 10 to 20 cm high and horizontal flanges of 10 to 25 cm suitably varying with the diameter of the ring. Stiffening flanges shall be provided to resist distortion.

2.2 Straightedge

2.3 Plastics Film

a) 0·1 mm thick, 2 to 4 m square (for small diameter rings); and

b) 0·2 mm thick, 4 to 8 m square (for large diameter rings).

2.4 Pointer Gauge Assembly and Supports — Horizontal bar with supports resting on or outside the ring, fitted with an adjustable vertical pointer and lock nut.

2.5 Quick-Setting Plaster or Sand Filled Gunny Bags

2.6 Apparatus for Delivering into the Hole, Measuring and Removing the Volume of Water Required

2.6.1 For small test holes, and for test holes located in sites which are not readily accessible, the most convenient and economical method of delivering and measuring water may be by hand or by syphon hose from a small calibrated container (water can).

2.6.2 For larger test holes in readily accessible sites, it is usually advantageous to use one or more calibrated water tanks for measuring the water when filling the hole covered with plastics film, and to provide a portable, power driven, self priming pump for removing the water after each filling. Each calibrated tank should be provided with an outlet valve and an attached volume measuring gauge. Delivery holes from such tanks shall be fitted with a valve at the delivery end so that the flow of water into the hole covered with the plastics film can be suitably controlled when the water level approaches the level of the pointer gauge.

2.6.2.1 The area of each calibrated tank should be such that the graduations on its volume measuring gauge can be easily read. Tanks used for filling holes of large capacity should have volume gauges graduated at 10 and 1 litre intervals; gauges on tanks used for filling holes of smaller capacity should be graduated at 2 and 0·2 litre intervals.

2.6.2.2 The graduations on the volume measuring gauges of calibrated tanks shall be verified. To verify the graduations proceed as follows:

a) Fill each tank with water to the top graduation on the gauge and draw off successive volumes so that the water level drops to each graduation in turn.

b) Calculate the volumes drawn off from the weight of each withdrawal and compare with the volumes read on the gauge.

2.7 A Balance — capable of weighing up to 20 kg (class C type) of IS : 1433-1965*, sensitiveness at no load and at full load 10 g, greatest error allowed when fully loaded 20 g (*see* Note under **2.9**).

2.8 Apparatus for Moisture Content Determination — shall be in accordance with IS : 2720 (Part II)-1969†.

2.9 Platform Weighing Machine — capable of weighing up to 100 kg (dial type) in accordance with IS : 1435-1960‡, sensitiveness when fully loaded 20 g, greatest error when fully loaded 40 g (*see* Note).

NOTE — Other types of weighing scales of similar accuracy may be used.

2.10 Containers

2.11 Suitable Hand Tools — for excavating and cleaning holes in coarse soils and rocky materials, such as pick, shovel, crowbar, broom and scoop.

2.12 IS Sieves — 100-mm, 80-mm, 40-mm, 25-mm, 20-mm, 10-mm and 4·75-mm, 30 cm in diameter, as required.

2.13 Syphon Can and Measuring Cylinders

3. PROCEDURE

3.1 Approximately level the ground at the site of the test. Place the ring on the levelled ground and secure it to the surface to prevent any movement during the performance of the test.

3.2 Fill the voids between the underside of the ring and the surface with quick-setting plaster. As the plaster is setting, clean the surplus from the

*Specification for beam scales (*revised*).

†Methods of test for soils: Part II Determination of moisture content (*first revision*).

‡Specification for platform weighing machines.

inside of the ring. Remove all loose material and sharp projections from the test surface.

3.2.1 If required, sand-filled gunny bags may also be placed on the flange of the ring to prevent the movement of the ring.

3.3 Set up the pointer gauge assembly so that the pointer can be removed and returned to a fixed position below the top of the ring (*see* Note). Remove the pointer gauge bar to a safe position.

NOTE — For small rings the pointer is often mounted on a datum bar supported on legs driven into the ground outside the ring. The datum should be made so that it can be removed between readings, and replaced with the pointer in precisely the same position. For large rings, which are usually more stable, it is usual to lay a small datum bar on the rim of the ring if it is a flat flange, marking the position so that the bar can be returned accurately to the same position, or the bar may be suitably clamped to the ring.

3.4 After checking for punctures, spread the plastics film over the test surface and the ring taking care to remove all the wrinkles. Replace the pointer gauge bar.

3.5 Fill the plastics film-ring assembly with water to the precise level of the pointer (*see* Note 1). While filling, ensure the film makes full contact with the test surface and the inside surface of the ring. Check for leaks (*see* Note 2). The measured volume of water used is the initial reading V_i for the test.

NOTE 1 — The required accuracy of volume measurement depends on the volume of the test hole and the diameter of the ring used. For smaller test holes and rings, record the volume to the nearest 0·2 litre. For larger test holes and rings, a lesser accuracy may suffice. Since the test cannot be easily repeated, all observations and recordings should be independently checked.

NOTE 2— Observe the water level at the pointer gauge tip for several minutes to determine whether water is leaking through the plastic film. If leakage is occurring, repeat the volume measurement with a sound film. Do not walk upon the plastics film or drag it across the ground or sharp projections.

3.6 Remove the pointer gauge bar to a safe position. Remove the water and the plastics film, checking the ground surface for indications of leakage.

3.7 Excavate, as nearly as practicable, a cylindrical cavity within the ring using the digging tools. When excavating very coarse materials, it may be necessary to employ a mechanical device, such as a tripod with either a block and tackle or a chain hoist, for lifting large rocks from the cavity. Make the wall of the cavity as near vertical as possible; but avoid undercutting the ring and deformation of the cavity. The movement of heavy equipment in the immediate test area should not be permitted. Leave in place any large rocks near the cavity boundary. Keep the floor and wall of the cavity as even as possible and free from sharp protrusions which

may puncture the plastics film. When the desired depth (*see* Note 1 under **1.1**) has been reached, clean all loose material from the cavity. Carefully collect all the excavated material in containers (*see* Note 1) and weigh each to the nearest 0·1 kg. Sum the individual weights of the material in the containers to obtain the total weight (W_w) of the excavated material (*see* Note 2).

NOTE 1 — Use containers with close fitting lids when testing soils and absorbent rocks holding significant amounts of water. To avoid undue loss of moisture, the cover shall be kept on the container at all times when the soil is not being placed in it. In hot and dry climate, shade for the test area and a damp cloth over the container shall be provided. When the material consists predominantly of hard, non absorbent rock of negligible moisture content, open containers are satisfactory.

NOTE 2 — If practicable, large rocks in excess of scale capacity may be broken into smaller pieces. Alternatively, their volume may be determined by water displacement and their weight computed using the specific gravity of the stone. If larger rocks are broken, it shall be ensured that all fragments from each rock are weighed.

3.7.1 The gradation of particles in the excavated material may be determined, if desired by sieving it through sieves specified in **2.12.**

3.8 When the moisture content of all or part of the material will have a significant effect on the field dry density, determine the moisture content of the soil in accordance with IS : 2720 (Part II)-1969*.

3.8.1 The sample for moisture content shall be representative of the whole of the soil excavated except that, if only the density of the material smaller than a given size is required, any stone coarser than this size shall first be removed. The moisture sample should be as large as is practicable and convenient. It should be collected in an airtight moisture content container by incrementally sampling the excavated soil during the course of the digging operations and after the increments of W_w (*see* **3.7**) have been weighed. In taking moisture content sub-samples of soil containing coarse rock fragments, neglect rocks larger than 80 mm if these are predominantly non-absorbent and in surface dry condition.

3.9 After checking for punctures, and taking care to remove all wrinkles, spread the plastics film properly into the cavity thus formed. Replace the pointer gauge bar.

3.10 Fill the cavity covered with plastics film with water to the precise level of the pointer as set for the initial volume measurement (*see* Note 1 under **3.5**). When delivering water to larger test cavities from calibrated tanks, run an exact number of litres of water rapidly into the film-covered cavities, from a larger tank equipped with a delivery hose capable of supplying the bulk of the water in a relatively few minutes. A smaller tank may then be used for slowly bringing the water level to the tip of the pointer gauge and for obtaining the required accuracy of the volume

*Methods of test for soils: Part II Determination of moisture content (*first revision*).

measurement. While filling, loosely support the sheet away from the wall of the cavity and allow the rising water to form the film to the shape of the cavity and the ring. Check for leaks (*see* Note 2 under **3.5**). The measured volume of water used is the final reading (V_f) for the test.

3.11 The steps given in **3.1** to **3.10** complete the work specifically required at the test site to determine the in-place density.

3.12 If a soil contains particles larger than a given size and only the density of the material smaller than this size is required, proceed as in **3.12.1** to **3.12.3**.

3.12.1 Sieve the material excavated from the cavity. Determine the weight W_r and volume V_r of stones retained on the sieve.

3.12.2 The volume V_r of the stones in the sample may be determined directly by displacement of water from a graduated flask or syphon can from which the overflow can be accurately measured or by weighing the stones, or by weighing the stones in air and water, calculating their specific gravity (*see* Note) and determining their volume by dividing their weight by their specific gravity.

NOTE — For construction control, the volume of stones need not be measured every time a test is made. From the experience gained after a number of successive tests, if it is found that the specific gravity of stones from particular source is constant, a suitable value for the specific gravity may be assumed and the volume computed by obtaining the weight of stones in a wet surface-dry condition and dividing the weight by the assumed specific gravity of the stone.

3.12.3 Calculate the dry density γ_d of the soil from the formula:

$$\gamma_d = \frac{W_w - W_r}{(V - V_r)\left(1 + \frac{w}{100}\right)}$$

where

W_w = total weight of the material excavated to form the cavity,

W_r = total weight of the portion (stones) of the excavated material retained on a given sieve,

V = volume of the cavity,

V_r = volume of the stones in the excavated material retained on the given sieve, and

w = moisture content of material finer than the given sieve determined in accordance with IS : 2720 (Part II)-1969*.

*Methods of test for soils : Part II Determination of moisture content (*first revision*).

If there is a large proportion of stone in the sample, the calculated density value for the fraction passing the given sieve may lack physical significance.

4. CALCULATIONS

4.1 Calculate the volume of the cavity V from the formula:

$$V = V_f - V_i$$

where

V_f = final volume reading (*see* **3.10**), and

V_i = initial volume reading (*see* **3.5**).

4.2 Calculate the wet density of the soil γ from the formula:

$$\gamma = \frac{W_w}{V}$$

where

W_w = weight of the wet material from the cavity (*see* **3.7**), and

V = volume of the cavity (*see* **4.1**).

4.3 Calculate the dry density of the soil γ_d from the formula:

$$\gamma_d = \frac{\gamma \times 100}{(100+w)}$$

where

γ = wet density of the soil (*see* **4.2**), and

w = the moisture content in percent of the soil determined in accordance with IS : 2720 (Part II)-1969* (*see also* **3.8.1** and **3.12**).

5. REPORTING OF RESULTS

5.1 The results of the test shall be suitably reported and the report shall specifically mention about the following. A recommended proforma for the record of test results is given in Appendix A:

a) The date of the test,

b) The test location,

c) The elevation of the test,

d) The soil description,

e) The method used,

*Methods of test for soils : Part II Determination of moisture content (*first revision*).

f) The fraction of the soil for which the density has been determined, and

g) The dry density in kg/m^3 to the nearest 10 kg/m^3 or in g/cm^3 to the second place of decimals.

APPENDIX A

(*Clause* 5.1)

DETERMINATION OF DENSITY OF SOIL IN-PLACE BY RING AND WATER REPLACEMENT METHOD

Project: Test No.:

Date: Elevation of test location:

Test location:

Soil description:

Fraction of soil for which density is determined:

DETERMINATION OF VOLUME OF CAVITY

Initial volume reading (with ring only) V_i			Final volume reading (with ring and cavity) V_f		
Initial reading	Final reading	Difference V_i	Initial reading	Final reading	Difference V_f

Volume of cavity $V = V_f - V_i$

DENSITY OF OVERALL MATERIAL

No. of container						
Weight of container + wet material						
Weight of container						
Weight of wet material						

Total weight of wet material = W_w

Moisture content of portion for which density is determined, w percent

Volume of cavity = V

Wet density $\gamma = \frac{W_w}{V}$

Dry density $\gamma_d = \frac{100\,\gamma}{(100+w)}$

GRADATION OF EXCAVATED MATERIAL

IS Sieve Size (mm)	100	80	40	20	10	4·75
Percent retained						
Gradation of stones larger than 100 mm — Size						
Gradation of stones larger than 100 mm — Percent of total material						

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