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METHODS OF TEST FOR SOILS

PART 8 DETERMINATION OF WATER CONTENT—DRY DENSITY RELATION USING HEAVY COMPACTION

(Second Revision)

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Indian Standard

METHODS OF TEST FOR SOILS

PART 8 DETERMINATION OF WATER CONTENT — DRY DENSITY RELATION USING HEAVY COMPACTION

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Second Revision) was adopted by the Indian Standards Institution on 28 November 1983, after the draft finalized by the Soil Engineering and Rocks Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Purpose of a laboratory compaction test is to determine the proper amount of mixing water to be used, when compacting the soil in the field and the resulting degree of denseness which can be expected from compaction at optimum moisture content. To accomplish this, a laboratory test which will give a degree of compaction comparable to that obtained by the field method used is necessary. This procedure is satisfactory for cohesive soils but does not lend itself well to the study of the compaction characteristics of clean sands or gravels which displace easily when struck with rammer. Some nearly cohesionless soils compact satisfactorily in the standard test although in many cases the water density curve is not well defined. Frequently, too in these cases indicated, maximum density is not as great as can be achieved readily in the field under available compaction methods. With a knowledge of the water density relation as determined by this test, better control of the field compaction of soil fill is possible because the optimum moisture content and the density which should be obtained are known by using this test procedure and these can be checked by field control tests. This part which was first published in 1965 and revised in 1974 covers the method of test based on heavy compaction. The method of test based on light compaction is covered in IS : 2720 (Part 7)-1980*. This revision is prepared so as to cover such cases when soil could be susceptible to crushing during compaction.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated,

*Methods of test for soils : Part 7 Determination of water content — dry density relation using light compaction (*second revision*).

expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part 8) lays down the method for the determination of the relation between the water content and the dry density of soils using heavy compaction.

2. TERMINOLOGY

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

3. APPARATUS

3.1 Cylindrical Metal Mould — It shall be either of 100 mm diameter and 1 000 cm^3 volume or 150 mm diameter, and 2 250 cm^3 volume and shall conform to IS : 10074-1982‡.

3.2 Sample Extruder (Optional) — It consists of a jack, lever frame or other device adopted for the purpose of extruding compacted specimens from the mould.

3.3 Balances — One of 10 kg capacity sensitive to 1 g, and other of 200 g capacity and sensitive to 0·01 g.

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

3.5 Container — Any suitable non-corrodible airtight container to determine the water content for tests conducted in the laboratory.

3.6 Steel Straightedge — A steel straightedge about 30 cm in length and having one bevelled edge.

3.7 Sieve — 4·75-mm, 19-mm and 37·5 mm IS sieves conforming to IS : 460 (Part I)-1978§.

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

†Glossary of terms and symbols relating to soil engineering (*first revision*).

‡Specification for compaction mould assembly for light and heavy compaction of soils.

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

3.8 Mixing Tools — Miscellaneous tools, such as tray or pan, spoon, trowel and spatula, or a suitable mechanical device for thoroughly mixing the sample of soil with additions of water.

3.9 Metal Rammer — Heavy compaction rammer conforming to IS : 9189-1979*.

4. SOIL SPECIMEN

4.1 A representative portion of air-dried soil material and large enough to provide about 6 kg of material passing a 19-mm IS sieve (for soils not susceptible to crushing during compaction), or about 15 kg of material passing a 19 mm IS sieve (for soils susceptible to crushing during compaction), shall be taken (*see* Note). This portion shall be sieved on a 19 mm IS sieve and the coarse fraction rejected after its proportion of the total sample has been recorded.

NOTE — The soil should be considered susceptible to crushing during compaction if the sample contains granular material of a soft nature, such as soft lime stone, sandstone, etc, which is reduced in size by the action of the 4·9-kg rammer. The procedure given in 5.2 for soils susceptible to crushing during compaction can be applied to all soils if it is convenient to do so.

4.1.1 Aggregations of particles shall be broken down so that if the sample was sieved on a 4·75-m IS sieve, only separated individual particles would be retained.

5. PROCEDURE

5.1 Soil Not Susceptible to Crushing During Compaction (***see* Note under 4.1**) — The procedure is as follows:

5.1.1 A 5-kg sample of air dried soil passing the 19-mm IS test sieve shall be taken (*see* Note 1). The sample shall be mixed thoroughly with a suitable amount of water depending on the soil type (*see* Notes 2 and 3).

5.1.2 The mould, of 1 000 cm^3 capacity with baseplate attached, shall be weighed to the nearest 1 g (m_1). The mould shall be placed on a solid base, such as a concrete floor or plinth and the moist soil shall be compacted into the mould, with the extension attached, in five layers of approximately equal mass, each layer being given 25 blows from the 4·9-kg rammer droped from a height of 450 mm above the soil. The blows shall be distributed uniformly over the surface of each layer. The operator shall ensure that the tube of the rammer is kept clear of soil so that the rammer always falls freely. The amount of soil

*Specification for compaction rammer for soil testing.

used shall be sufficient to fill the mould, leaving not more than about 6 mm to be struck off when the extension is removed (*see* Note 4). The extension shall be removed and the compacted soil shall be levelled off carefully to the top of the mould by means of the straightedge. The mould and soil shall then be weighed nearest to 1 g (m^2).

5.1.3 The compacted soil specimen shall be removed from the mould and placed on the mixing tray. The water content of a representative sample of the specimen shall be determined as in IS : 2720 (Part 2)-1973*.

5.1.4 The remainder of the soil specimen shall be broken up, rubbed through the 19-mm IS test sieve, and then mixed with the remainder of the original sample. Suitable increments of water (*see* Note 5) shall be added successively and mixed into the sample, and the above procedure from operations **5.1.2** to **5.1.4** shall be repeated for each increment of water added. The total number of determinations made shall be at least five, and the moisture contents should be such that the optimum moisture content, at which the maximum dry density occurs, is within that range.

5.2 Soil Susceptible to Crushing During Compaction (*see* **Note under 4.1**) — The procedure is as follows :

5.2.1 Five or more 2·5 kg samples of air-dried soil passing the 19-mm IS sieve, shall be taken (*see* Note 1). The samples shall each be mixed thoroughly with different amounts of water to give a suitable range of moisture contents (*see* Notes 2 and 3). The range of moisture content, at which the maximum dry density occurs, is within that range (*see* Note 5).

5.2.2 Each sample shall be treated as in **5.1.2**.

5.2.3 Each specimen shall be treated as in **5.1.3**.

5.2.4 The remainder of each soil specimen shall be discarded.

5.3 Compaction in Large Size Mould — For compacting soil containing coarse material up to 37·5 mm size, the 2 250 cm^3 mould should be used. A sample weighing about 30 kg and passing the 37·5 mm IS sieve is used for the test. Soil is compacted in five layers, each layer being given 55 blows of the 4·9-kg rammer. The test of the procedure is the same as in **5.1** or **5.2**.

NOTE 1 — The removal of small amounts of stone (up to 5 percent) retained on a 19-mm IS sieve will effect the density obtainable only by amounts comparable

*Methods of test for soil ; Part 2 Determination of water content (*second revision*).

with the experimental error involved in measuring the maximum dry density. The exclusion of a large proporation of stone coarser than 19-mm may have a major effect on the density obtained compared with that obtainable with soil as a whole, and on the optimum moisture content. There is at present no generally accepted method of test of calculation for dealing with this difficulty in comparing laboratory compaction test results with densities obtained in the field. For soils containing larger proportions of gravel, the use of a bigger mould (2 250 cm^3) will avoid major errors.

NOTE 2 — The amount of water to be mixed with air-dried soil at the commencement of the test will vary with the type of soil under test. In general, with sandy and gravelly soils a moisture content of 3 to 5 percent would be suitable, while with cohesive soils a moisture content about 12 to 16 percent below the plastic limit of the soil should usually be suitable.

NOTE 3 — It is important that the water is mixed thoroughly and adequately with the soil, since inadequate mixing gives rise to variable test results. This is particularly important with cohesive soils when adding a substantial quantity of water to the air-dried soil. With clays of high plasticity, or where hand mixing is employed, it may be difficult to distribute the water uniformly through the air-dried soil by mixing alone, and it may be necessary to store the mixed sample in a sealed container for a minimum period of about 16 hours before continuing with the test.

NOTE 4 — It is necessary to control the total volume of soil compacted, since it has been found that if the amount of soil struck off after removing the extension is too great, the test results will be inaccurate.

NOTE 5 — The water added for each stage of the test should be such that a range of moisture contents is obtained which includes the optimum moisture. In general, increments of 1 to 2 percent are suitable for sandy and gravelly soils and of 2 to 4 percent for cohesive soils. To increase the accuracy of the test it is often advisable to reduce the increments of water in the region of the optimum moisture content.

6. CALCULATIONS

6.1 Bulk Density — Bulk density, γ_m, in g/cm^3 of each compacted specimen shall be calculated from the equation:

$$\gamma_m = \frac{m_2 - m_1}{V_m}$$

where

m_1 = mass in g of mould and base;

m_2 = mass in g of mould, base and soil; and

V_m = volume in cm^3 of mould.

6.2 Dry Density — The dry density, γ_d, in g/cm^3, shall be calculated from the equation :

$$\gamma_d = \frac{100\ \gamma_m}{100 + w}$$

where

w = moisture content of soil in percent.

6.3 The dry densities, γ_d obtained in a series of determinations shall be plotted against the corresponding moisture contents w. A smooth curve shall be drawn through the resulting points and the position of the maximum on this curve shall be determined.

7. REPORTING OF RESULTS

7.1 The experimental points and the smooth curve drawn through them showing the relationship between moisture content and dry density shall be reported.

7.2 The dry density in g/cm^3 corresponding to the maximum point on the moisture content/dry density curve shall be reported as the maximum dry density to the nearest 0·01.

7.3 The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve shall be reported as the optimum moisture content and quoted to the nearst 0·2 for values below 5 percent to the nearest 0·5 for values from 5 to 10 percent, and to the nearest whole number for value exceeding 10 percent (*see* Note under **7.5**).

7.4 The amount of stone retained on the 19-mm IS sieve shall be reported to the nearest 1 percent.

7.5 The method of obtaining the result shall be stated, (4·9-kg rammer method). The procedure used shall also be stated that is single sample or separate sample and the size of the mould used.

NOTE — For some highly permeable soils such as clean gravels, uniformily graded and coarse cleen sands the results of the laboratory compaction test (4·9-rammer method) may provide only a poor guide for specifications on field compaction. The laboratory test often indicates higher values of optimum moisture content than would be desirable for field compaction and the maximum dry density is often much lower than the state of compaction, that can readily be obtained in the field.

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