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*Indian Standard*

# METHODS OF TEST FOR SOILS

## PART VII DETERMINATION OF WATER CONTENT-DRY DENSITY RELATION USING LIGHT COMPACTION

*( Second Revision )*

(Incorporating Amendment Nos. 1 & 2)

UDC 624-131.378



**BUREAU OF INDIAN STANDARDS**
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# *Indian Standard*

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## *( Second Revision )*

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# *Indian Standard*

# METHODS OF TEST FOR SOILS

## PART VII DETERMINATION OF WATER CONTENT-DRY DENSITY RELATION USING LIGHT COMPACTION

## *( Second Revision )*

### 0. FOREWORD

**0.1** This Indian Standard (Part VII) (Second Revision) was adopted by the Indian Standards Institution on 31 October 1980, after the draft finalized by the Soil and Rock Mechanics Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

**0.2** With a view to establishing uniform procedures for determination of different characteristics of soils and also for facilitating comparative studies 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. This part (Part VII) (first published in 1965 and revised in 1974) deals with the method of test for the determination of water content-dry density relation of soil using light compaction ( *see* Note below ). The 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 the 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.

NOTE — The method of test based on heavy compaction is covered in IS : 2720 (Part 8)-1983*.

**0.2.1** This revision is prepared so as to cover such cases when soil could be susceptible to crushing during compaction.

**0.3** This edition 3.2 incorporates Amendment No. 1 (October 1982) and Amendment No. 2 (July 1984). Side bar indicates modification of the text as the result of incorporation of the amendments.

**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 VII) lays down the method for the determination of the relation between the water content and the dry density of soils using light compaction. In this test a 2.6-kg rammer falling through a height of 310 mm is used.

## 2. TERMINOLOGY

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

## 3. APPARATUS

**3.1 Moulds** — It 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 capacity 10 kg sensitive to 1 g and other of capacity 200 g 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.

*Methods of test for soils: Part 8 Determination of water content-dry density relation using heavy compaction ( *second revision* ).

†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 test for soils.

**3.7 Sieve** — 4.75-mm and 19-mm IS sieves conforming to the requirements of IS : 460 (Part I)-1978*.

**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** — It shall conform to IS : 9198-1979†.

## 4. SOIL SPECIMEN

**4.1** A representative portion of air dried soil material and large enough to provide about 6 kg of material passing at 20-mm IS sieve (for soils not susceptible to crushing during compaction), or about 15 kg of material passing a 20-mm IS sieve (for soils susceptible to crushing during compaction), shall be taken ( *see* Note 1 ). This portion shall be sieved on a 20-mm IS sieve and the coarse fraction rejected after its proportion of the total sample has been recorded.

NOTE 1 — The soil should be considered susceptible to crushing during compaction if the sample contains granular material of a soft nature, such as soft limestone, sandstone, etc, which is reduced in size by the action of the 2.6 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-mm IS sieve, only separated individual particles would be retained.

## 5. PROCEDURE

**5.1 Soil not Susceptible to Crushing During Compaction ( *see* Note 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 2 ). The sample shall be mixed thoroughly with a suitable amount of water depending on the soil type ( *see* Notes 3 and 4 ).

**5.1.2** The mould, 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 three layers of approximately equal mass, each layer being given 25 blows from the 2.6-kg rammer dropped from a height of 310 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

*Specification for test sieves: Part I Wire cloth test sieves ( *second revision* ).
†Specification for compaction rammer for soil testing.

rammer always falls freely. The amount of soil 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 5 ). 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 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 II)-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 6 ) 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 range of 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 1 )** — The procedure is as follows:

a) Five or more 2.5-kg samples of air dried soil passing the 19-mm IS test sieve, shall be taken ( *see* Note 2 ). The samples shall each be mixed thoroughly with different amounts of water to give a suitable range of moisture contents ( *see* Notes 3 and 4 ). The range of moisture content, at which the maximum dry density occurs, is within that range ( *see* Note 6 ).

b) Each sample shall be treated as in **5.1.2**.

c) Each compacted specimen shall be treated as in **5.1.3**.

d) 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 ml mould should be used. A sample weighing about 6 kg and passing the 37.5-mm IS sieve is used for the test. Soil is compacted in three layers, each layer being given 55 blows of the 2.6-kg rammer. The rest of the procedure is the same as in **5.1** or **5.2**.

*Methods of test for soils: Part II Determination of water content ( *second revision* ).

NOTE 2 — The removal of small amounts of stone (up to 5 percent) retained on a 19-mm IS Sieve will affect the density obtainable only by amounts comparable with the experimental error involved in measuring the maximum dry density. The exclusion of a large proportion of stone coarse than 19 mm may have a major effect on the density obtained compared with that obtainable with the soil as a whole, and on the optimum moisture content. There is at present no generally accepted method of test or 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 ml) will avoid major errors.

NOTE 3 — 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 4 percent to 6 percent would be suitable, while with cohesive soils a moisture content about 8 percent to 10 percent below the plastic limit of the soil (plastic limit minus 10 to plastic limit minus 8) usually be suitable.

NOTE 4 — 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 5 — 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 6 — 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 percent to 2 percent are suitable for sandy and gravelly soils and of 2 percent 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** — $\gamma_m$ in g/ml, 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 ml of mould.

**6.2** The dry density, $\gamma_d$ in g/ml, 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, $\gamma_d$ 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/ml 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 nearest 0.2 for values below 5 percent to the nearest 0.5 for values from 5 percent to 10 percent, and to the nearest whole number for value exceeding 10 percent ( *see* Note 7 ).

**7.4** The amount of stone retained on the 20-mm IS Sieve shall be reported to the nearest 1 percent.

**7.5** The method of obtaining the result shall be stated, (2.6-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 7 — For some highly permeable soils such as clean gravels, uniformly graded and coarse clean sands the results of the laboratory compaction test (2.6-kg 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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