IS 2720 - Methods of Tests for Soil

Indian Standard

METHODS OF TEST FOR SOILS

PART 1 PREPARATION OF DRY SOIL SAMPLES FOR VARIOUS TESTS

(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 Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 With a view to establishing uniform procedure for the determination of different characteristics of soils, Indian Standards on methods of test for soils (IS : 2720) have been formulated in various parts. This part covers method of preparation of samples for the various laboratory tests covered in the standard. This part was first published in 1966 and revised in 1972. Since then more parts of this standard have been published covering additional characteristics besides some of the published parts have been revised wherein requirements have been modified. This revised version has therefore been formulated in order to up date in this respect.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, 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 1) covers the method of preparation of dry samples from the bulk soil sample received from the field for various laboratory tests.

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

2. APPARATUS

2.1 Wooden-Mallet — for breaking soil clods.

2.2 Trays — for air drying of soil, of suitable size and of non-rusting material.

2.3 Pulverizing Apparatus — Either mortar and rubber covered pestle or a mechanical device consisting of mortar and a power-driven rubber covered pestle suitable for breaking up the aggregation of soil particles without reducing the size of the individual grains. Pestle and mortar made of soft wood may also be used.

2.4 Sampler — A suitable riffle sampler or sample splitter for quartering the samples (*see* IS : 1607-1960*).

2.5 Sieves — of sizes 75-mm, 63-mm, 37·5-mm, 19-mm, 13·2-mm, 9·50-mm, 6·7-mm, 4·75-mm, 2·00-mm and 425-micron [*see* IS : 460 (Part 1)-1978†].

2.6 Drying Apparatus

a) *Drying Oven* — Thermostatically controlled, with interior of non-corroding material to maintain the temperature between 105 and 110°C.

b) Other suitable drying apparatus.

2.7 Balances

a) Capacity 10 kg and minimum sensitivity 100 g.

b) Capacity 1 kg and minimum sensitivity 1 g.

c) Capacity 250 g and minimum sensitivity 0·01 g.

3. PREPARATION OF SAMPLE FOR TESTS

3.1 General — Soil sample as received from the field shall be dried in the air or in sun. In wet weather a drying apparatus may be used in which case the temperature of the sample should not exceed 60°C. The clods may be broken with a wooden-mallet to hasten drying. The organic matter, like tree roots and pieces of bark should be removed from the sample. Similarly, matter other than soil, like shells should also be separated from the main soil mass. A noting shall be made of such removals and their percentage of the total soil sample noted. When

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*Methods for dry sieving.

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

samples are to be taken for estimation of organic content, lime content, etc, total sample should be taken for estimation without removing shells, roots, etc.

3.2 Drying of the Sample — The amount of drying depends upon the proposed test to be conducted on the particular sample. The type, temperature and duration of drying of soil samples for different tests are given in Table 1. When oven is used for drying, the temperature in the oven shall not exceed 110°C (*see* Note). Chemical drying of samples should not be adopted for any tests.

NOTE — Soils containing organic or calcareous matter should not be dried at temperature above 60°C.

TABLE 1 QUANTITY OF SOIL SAMPLE REQUIRED FOR CONDUCTING THE TESTS

(*Clauses* 3.2, 3.3 *and* 4.1)

SL No.	TEST	TYPE, TEMPERATURE AND DURATION OF DRYING	AMOUNT OF SOIL SAMPLE REQUIRED FOR TEST	DEGREE OF PULVERIZATION (PASSING IS SIEVE SIZE)	REF TO PART OF IS : 2720[1]
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water content	Oven, 24 h	As given in Table 2	—	Part 2[2]
ii)	Specific gravity	Oven 105-110°C, 24 h	50 g for fine grained soils	2 mm	Part 3/Sec1[3]
			400 g for fine, medium and coarse grained soils	—	Part 3/Sec 2[4]
iii)	Grained size analysis	Air drying	As given in Table 3	—	Part 4[5]
iv)	Liquid limit	do	270 g	425 micron	Part 5[6]
v)	Plastic limit	do	60 g	do	do

[1] Methods of test for soils.

[2] Determination of water content.

[3] Determination of specific gravity, Section 1 Fine grained soils.

[4] Determination of specific gravity, Section 2 Fine, medium and coarse grained soils.

[5] Grain size analysis.

[6] Determination of liquid and plastic limits.

(*Continued*)

TABLE 1 QUANTITY OF SOIL SAMPLE REQUIRED FOR CONDUCTING THE TESTS — *Contd*

SL No.	TEST	TYPE, TEMPERATURE AND DURATION OF DRYING	AMOUNT OF SOIL SAMPLE REQUIRED FOR TEST	DEGREE OF PULVERIZATION (PASSING IS SIEVE SIZE)	REF TO PART OF IS : 2720[1]
(1)	(2)	(3)	(4)	(5)	(6)
vi)	Shrinkage factors	Air drying	100 g	425 micron	Part 6[2]
vii)	Compaction				
	a) Light compaction	do	6 kg (15 kg if soil is susceptible to crushing)	19 mm	Part 7[3]
	b) Heavy compaction	do	do	19 mm	Part 8[4]
	c) Constant mass	do	2 kg	4·75 mm	Part 9[5]
viii)	Unconfined compressive strength	oven 110°C ± 5°C	1 kg	—	Part 10[6]
ix)	Triaxial compression (unconsolidated)	do	1 kg/5 kg	—	Part 11[7]
x)	Triaxial compression (consolidated)	do	do	—	Part 12[8]
xi)	Direct shear	Air drying/Oven 110°C±5°C	1 kg	4·75 mm	Part 13[9]

[1] Methods of test for soils.

[2] Determination of shrinkage factors.

[3] Determination of water content dry density relation using light compaction.

[4] Determination of water content dry density relation using heavy compaction.

[5] Determination of dry density — moisture content relation by constant weight of soil method.

[6] Determination of unconfied compressive strength.

[7] Determination of shear strengh parameters of specimen tested in unconsolidated undrained triaxial compression without the measurement of pore water pressure.

[8] Determination of shear strength parameters of soil from consolidated undrained triaxial compression test with measurement of pore water pressure.

[9] Direct shear test.

(*Continued*)

TABLE 1 QUANTITY OF SOIL SAMPLE REQUIRED FOR CONDUCTING THE TESTS — *Contd*

Sl No.	Test	Type, Temperature and Duration of Drying	Amount of Soil Sample Required for Test	Degree of Pulverization (Passing IS Seive Size)	Ref to Part of IS : 2720[1]
(1)	(2)	(3)	(4)	(5)	(6)
xii)	Density index (relative density)	Oven, 105-110°C, 24 h	As per size of particle given below: 75 mm 45 kg 37·5 ,, 12 ,, 19 ,, 12 ,, 9·50 ,, 12 ,, 4·75 ,, 12 ,,	—	Part 14[2]
xiii)	Consolidation properties	Air drying/Oven 110°C ± 5°C	500 g	—	Part 15[3]
xiv)	CBR	Air drying	6 kg	19 mm	Part 16[4]
xv)	Permeability	Oven, 105-110°C, 24 h	2·5 kg (100 mm dia)/ 5 kg (200 mm dia)	9·5 mm	Part 17[5]
xvi)	Field moisture equivalent	Air drying	15 g	425 micron	Part 18[6]
xvii)	Centrifuge moisture equivalent	do	10 g	do	Part 19[7]
xviii)	Linear shrinkage	do	450 g	do	Part 20[8]
xix)	Chemical tests				
	a) Total soluble solids	Oven, 105-110°C, 24 h	10 g	2 mm	Part 21[9]
	b) Organic matter	Air drying	100 g	do	Part 22[10]

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[1] Methods of test for soils.

[2] Determination of density index (relative density) of cohesionless soils.

[3] Determination of consolidation properties.

[4] Laboratory determination of CBR.

[5] Laboratory determination of permeability.

[6] Determination of field moisture equivalent.

[7] Determination of centrifuge moisture equivalent.

[8] Determination of linear shrinkage.

[9] Determination of total soluble solids.

[10] Determination of organic matter.

(*Continued*)

TABLE 1 QUANTITY OF SOIL SAMPLE REQUIRED FOR CONDUCTING THE TESTS — *Contd*

Sl No.	Test	Type, Temperature and Duration of Drying	Amount of Soil Sample Required for Test	Degree of Pulverization (Passing IS Sieve Size)	Ref to Part of IS : 2720[1]
(1)	(2)	(3)	(4)	(5)	(6)
	c) Calcium carbonate	Oven, 105-110°C, 24 h	5 g	—	Part 23[2]
	d) Cation exchange capacity	do	80-130 g	—	Part 24[3]
	e) Silica-sesquioxide ratio	do	15 g	—	Part 25[4]
	f) *p*H value	do	30 g	425 micron	Part 26[5]
	g) Total soluble sulphates	do	30 g	—	Part 27[6]
xx)	Vane shear	Air drying/oven 110°C ± 5°C	250 g	—	Part 30[7]
xxi)	Negative pore water pressure	do	1 kg/5 kg	—	Part 35[8]
xxii)	Permeability of granular soils	do	do	—	Part 36[9]
xxiii)	Sand equivalent value	105 ± 5°C	1 500 g	4·75 mm	Part 37[10]
xxiv)	Direct shear	Air drying	up to 120 g	Above 4·75 mm	Part 39/Sec 1[11]
xxv)	Free swell index	Oven dry	20 g	425 micron	Part 40[12]
xxvi)	Swelling pressure	Air drying/ Oven dry	2 kg	2 mm	Part 41[13]

[1] Methods of test for soils.

[2] Determination of calcium carbonate.

[3] Determination of cation exchange capacity.

[4] Determination of silica sesquioxide ratio.

[5] Determination of *p*H value.

[6] Determination of total soluble sulphates.

[7] Laboratory vane shear test.

[8] Measurement of negative pore water pressure.

[9] Laboratory determination of permeability of granular soils (constant head).

[10] Determination of sand equivalent values of soils and fine aggregates.

[11] Direct shear test for soils containing gravel: Section 1 Laboratory test.

[12] Determination of free swell index of soils.

[13] Measurement of swelling pressure of soils.

3.3 Degree of Pulverization — The big clods may be broken with the help of wooden mallet. Further pulverization may be done in pestle and mortar. The pulverized soil shall be passed through the specified sieve for the particular test and the soil retained on that sieve shall be again pulverized for sieving. This procedure should be repeated until on further attempts at pulverizing very little soil passes through the specified sieve. Care should be taken not to break up the individual soil particles (*see* Table 1).

4. QUANTITY OF SAMPLE

4.1 The quantities of soil sample required for conducting various laboratory tests are given in Table 1 for guidance.

NOTE — For actual quantities, corresponding part of IS : 2720 shall be referred.

4.2 When a smaller quantity has to be taken out of a bigger soil mass the representative sampling shall be done by quartering or riffling.

NOTE — In the case of coarse gravel or gravelly soils quartering by forming a cone shall not be done. The entire sample shall be thoroughly mixed and spread on a flat surface. The sample so spread shall be divided into four quadrants and diagonally opposite quadrants mixed. This process shall be repeated till the desired quantity of sample is obtained.

TABLE 2 QUANTITY OF SAMPLE REQUIRED FOR DETERMINATION OF WATER CONTENT

SIZE OF PARTICLES MORE THAN 90 PERCENT PASSING	MINIMUM QUANTITY OF SOIL SPECIMEN TO BE TAKEN FOR THE TEST MASS IN g
425-micron IS Sieve	25
2-mm IS Sieve	50
4·75 mm IS Sieve	200
9·50 mm IS Sieve	300
19 mm IS Sieve	500
37·5 mm IS Sieve	1 000

TABLE 3 QUANTITY OF SOIL REQUIRED FOR GRAIN SIZE ANALYSIS

MAXIMUM SIZE OF MATERIAL PRESENT IN SUBSTANTIAL QUANTITIES mm	MASS TO BE TAKEN FOR TEST kg
75	60
37·5	25
19	6·5
13 2	3·5
9·5	1·5
6·7	0·75
4·75	0·4

Indian Standard
METHODS OF TEST FOR SOILS
PART II DETERMINATION OF WATER CONTENT
(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part II) (Second Revision) was adopted by the Indian Standards Institution on 22 March 1973, 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 comparative studies of the results, the Indian Standards Institution is bringing out this Indian Standard methods of test for soils (IS : 2720) which will be published in parts.

0.3 This part was first published in 1964 and revised in 1969 to include two rapid field methods for the determination of water content in soils. In this second revision, rapid determination of water content with infra-red lamp torsion balance moisture meter and rapid determination of water content from the gas pressure developed by the reaction of calcium carbide with the free water content of the soil have been included.

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*.

SECTION I OVEN-DRYING METHOD (STANDARD METHOD)

1. SCOPE

1.1 This method covers the determination of water content of soils expressed as a percentage of the oven-dry weight.

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

2. TERMINOLOGY

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

3. APPARATUS

3.1 Container — Any suitable non-corrodible air-tight container.

3.2 Balance — of sufficient sensitivity to weigh the soil samples to an accuracy of 0·04 percent of the weight of the soil taken for the test (*see* **4.1**).

3.3 Oven — thermostatically controlled, with interior of non-corroding material to maintain the temperature at 110 ± 5°C.

3.4 Desiccator — A desiccator with any suitable desiccating agent.

4. SOIL SPECIMEN

4.1 The soil specimen taken shall be representative of the soil mass. The size of the specimen selected depends on the quantity required for good representation, which is influenced by the gradation and the maximum size of particles, and on the accuracy of weighing. The following quantities are recommended for general laboratory use:

Size of Particles More Than 90 Percent Passing	*Minimum Quantity of Soil Specimen to be Taken for Test Mass in g*
‘425µm IS Sieve	25
2-mm IS Sieve	50
4·75-mm IS Sieve	200
9·50-mm IS Sieve	300
19-mm IS Sieve	500
37·5-mm IS Sieve’	1 000

‘NOTE 1 — For sizes of sieves, *see* IS: 460 (Part I)-1978†’.

NOTE 2 — **Drier the soil, the greater shall be the quantity of the soil taken.**

NOTE 3 — **Water content specimen should be discarded and should not be used in any other tests.**

5. PROCEDURE

5.1 Clean the container with lid, dry and weigh (W_1). Take the required quantity of the soil specimen in the container crumbled and placed loosely,

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

†~~Specification for test sieves (*revised*)~~. Specification for test sieves- Part I Wire Cloth Test sives (2nd revision)

and weigh with lid (W_2). Then keep it in an oven with the lid removed, and maintain the temperature of the oven at 110 ± 5°C (*see* Note). Dry the specimen in the oven for 24 h. Every time the container is taken out for weighing. Replace the lid on the container and cool the container in a desiccator. Record the final mass (W_3) of the container with lid with dried soil sample.

NOTE — Oven-drying at 110 ± 5°C does not result in reliable water content values for soil containing gypsum or other minerals having loosely bound water of hydration or for soil containing significant amounts of organic material. Reliable water content values for these soils can be obtained by drying in an oven at approximately 60 to 80°C.

6. CALCULATION

6.1 The percent of water content shall be calculated as follows:

$$w = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

where

w = water content percent,

W_2 = mass of container with lid with wet soil in g,

W_3 = mass of container with lid with dry soil in g, and

W_1 = mass of container with lid in g.

7. REPORT

7.1 The water content (w) of the soil shall be reported to two significant figures.

7.2 The results of the test shall be suitably recorded. A recommended *pro forma* for this record is given in Appendix A.

SECTION 2 SAND-BATH METHOD (SUBSIDIARY METHOD)

8. SCOPE

8.1 This method covers the determination of the water content of a soil as a percentage of its dry mass. It is intended as a rapid alternative to the method given in Section 1 but is less accurate and more suitable as a field test. The method shall not be used if it is suspected that the soil contains a large proportion of gypsum calcareous matter or organic matter.

9. APPARATUS

9.1 Container — any suitable non-corrodible air-tight container,

9.2 Heat-Resistant Tray — of suitable metal and about 5 to 7 cm deep.

9.3 Balance — of sufficient sensitivity to weigh the soil samples to an accuracy of 0·4 percent of the mass of the soil taken for the test.

9.4 Sand-Bath — of suitable size and containing clean sand to a depth of at least 3 cm.

9.5 Equipment for Heating the Sand-Bath — kerosene stove or spirit lamp.

9.6 Palette Knife or Steel Spatula — a convenient size is one having a blade 10 cm long and 2 cm wide.

9.7 Scoop — a convenient size is one about 20 cm long and 10 cm wide.

10. SOIL SPECIMEN

10.1 The mass of soil specimen taken for the test shall be in accordance with **4.1**.

11. PROCEDURE

11.1 Clean the container with lid or the tray, as the case may be, dry and weigh (W_1). Take the required quantity of the soil specimen in the container crumbled and placed loosely and weigh (W_2). Add a few pieces of white paper if necessary (*see* Note). Place the container with the lid removed or the tray on the sand-bath and heat the sand-bath. Care shall be taken not to get the sand-bath too hot. During heating, the specimen shall be turned frequently and thoroughly with the palette knife to assist the evaporation of water, care being taken to see that no soil is lost in the process. Dry the specimen to constant mass indicated by the difference between two consecutive masses of the container with lid or the tray with the dried specimen taken at suitable intervals after initial drying, being a maximum of 0·1 percent of the original mass of the soil specimen. When drying is complete, remove the container or the tray from the sand-bath, cool and weigh (W_3). The container should be weighed with lid.

NOTE — Avoid overheating. A convenient method of detecting overheating of the soil is by the use of small pieces of white paper mixed with the soil. Overheating is indicated if the paper turns brown.

12. CALCULATION

12.1 The percentage of water content shall be calculated as follows:

$$w = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

where

w = water content percent,

W_2 = mass of container with lid (or tray) with wet soil in g,

W_3 = mass of container with lid (or tray) with dry soil in g, and

W_1 = mass of container with lid (or tray) in g.

13. REPORT

13.1 The water content and the results of tests shall be reported in accordance with **7.1** and **7.2**.

SECTION 3 ALCOHOL METHOD (SUBSIDIARY METHOD)

14. SCOPE

14.1 This method covers the determination of the water content of a soil as a percentage of its dry mass. It is intended as a rapid alternative to the method given in Section 1 but is less accurate and is more suitable as a field test. Since methylated spirit is used, care shall be taken against risk of fire. The method shall not be used if the soil contains a large proportion of clay, gypsum, calcareous matter or organic matter.

15. APPARATUS

15.1 Evaporating Dish — 10 to 15 cm in diameter.

15.2 Palette Knife or Steel Spatula — having a blade 10 cm long and 2 cm wide.

15.3 Balance — of sufficient sensitivity to weigh the soil samples to an accuracy of 0·4 percent of the mass of the soil taken for the test.

15.4 Methylated Spirit

16. SOIL SPECIMEN

16.1 The soil specimen taken shall be representative of the soil mass. The size of the specimen selected depends on the quantity required for good representation, which is influenced by the gradation and the maximum size of particles, and on the accuracy of weighing. The following quantities are recommended for general use:

Size of Particles More Than 90 Percent Passing	*Minimum Quantity of Soil Specimen to be Taken for Test Mass in g*
'2-mm IS Sieve	30
19-mm IS Sieve'	300

NOTE 1 — For sizes of sieves, *see* IS : 460-~~1962*~~. (Part-I)-1978*

NOTE 2 — Drier the soil, the greater shall be the quantity of the soil taken.

NOTE 3 — Water content samples should be discarded and should not be used in any other tests.

17. PROCEDURE

17.1 Clean the evaporating dish, dry and weigh (W_1). Take the required quantity of the soil specimen in the evaporating dish and weigh (W_2). Pour over the soil methylated spirit at the rate of about one millilitre for every gram of soil taken so that the soil is well covered. Work the methylated spirit well into the soil with the palette knife and break up any large lumps of soil. Place the evaporating dish on a surface which will not be affected by heat and ignite the methylated spirit. Stir the soil constantly with the spatula or knife, care being taken to see that none of the soil is lost. After the methylated spirit has burnt away completely allow the dish to cool and weigh it with the contents (W_3).

18. CALCULATION

18.1 The percentage of water content shall be calculated as follows:

$$w = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

where

w = water content percent,
W_2 = mass of dish with wet soil in g,
W_3 = mass of dish with dry soil in g, and
W_1 = mass of dish in g.

19. REPORT

19.1 The water content and the results of tests shall be reported in accordance with **7.1** and **7.2**.

~~*Specification for test sieves (revised).~~ Specification for test sieves- Part I Wire Cloth Test sives (2nd revision)

SECTION 4 RAPID DETERMINATION OF WATER CONTENT WITH INFRA-RED LAMP TORSION BALANCE MOISTURE METER

20. SCOPE

20.1 This section describes a method for rapid determination of water content of soils employing a device providing infra-red lamp for drying and torsion balance for getting of percentage of water on wet basis from a scale, and the results obtained are convertible to water content on dry basis.

NOTE — The water estimation with this method takes 15 to 30 min depending upon the type of soil and quantity of water present. Plastic soils might take about 30 min. The reproducibility of readings is within ±0·25 percent. The probable error is about ± 0·3 percent water content in case of granular soils and about 0·8 to 1 percent in case of clays.

21. APPARATUS

21.1 Infra-red Lamp and Torsion Balance Moisture Meter — The moisture meter is illustrated in its essential details in Fig. 1 and 2.

21.1.1 The equipment should be of two main parts, the infra-red lamp, and the torsion balance. The infra-red radiation should be provided by 250 watt lamp built in the balance for use with an alternating current 220-230 V, 50 cycle, single phase mains supply. Provision should be made to adjust the input voltage to the infra-red lamp to control the heat for drying of specimen. A suitable thermometer graduated from 40 to 150°C should be provided for ascertaining the temperature of drying in the pan housing. The weighing mechanism, a torsion balance, should have a built in magnetic damper. The balance scale should be divided in terms of water percentages, from 1 to 100 percent water content in 0·2 percent divisions.

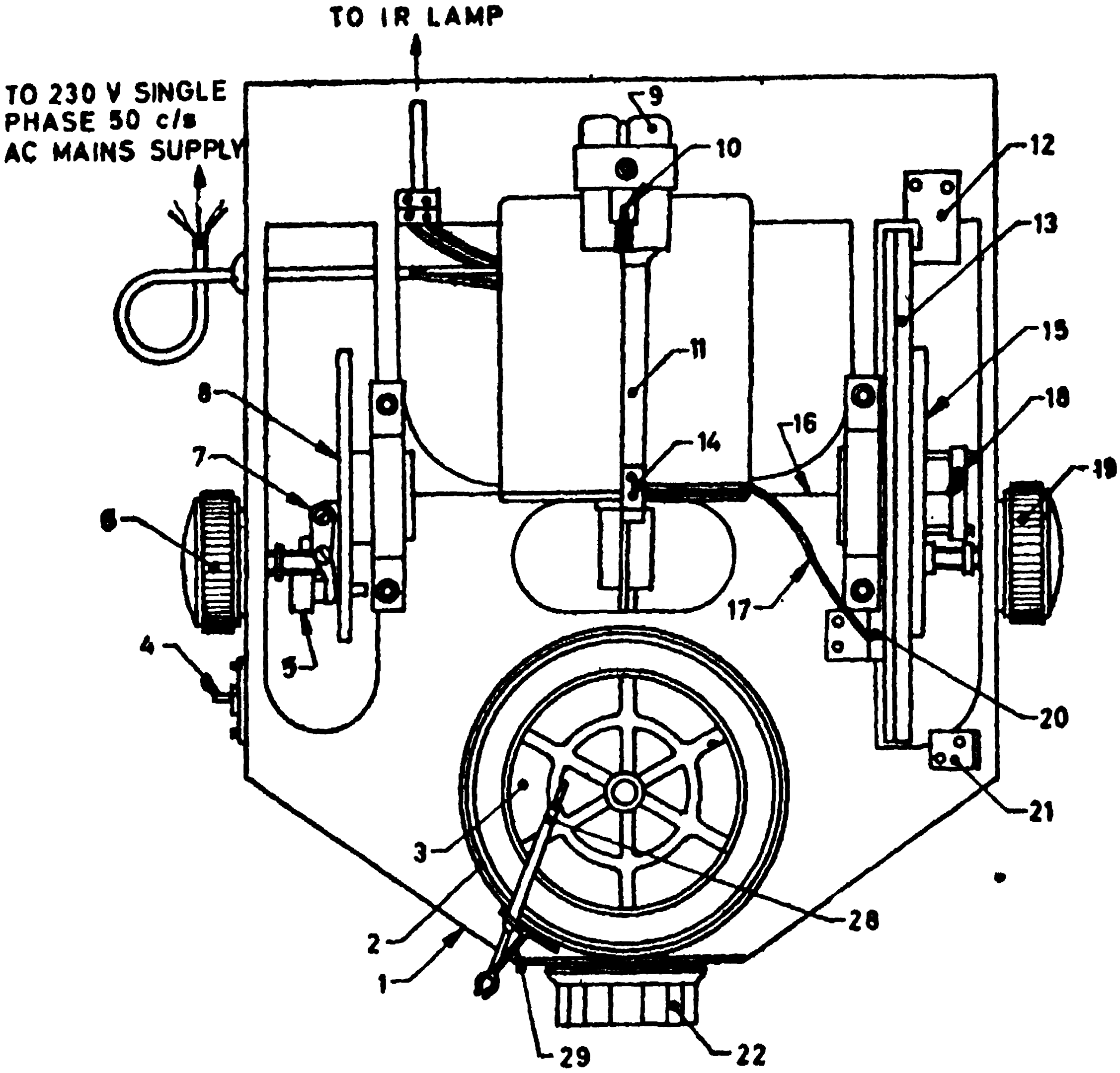
21.2 Palette Knife or Steel Spatula — having a blade 10 cm long and 2 cm wide.

22. SOIL SPECIMEN

22.1 The soil specimen taken shall be representative of the soil mass. The specimen should weigh 25 g. As this moisture meter is calibrated to use 25 g of soil, the maximum size of particle present in the specimen shall be less than 2 mm.

23. PROCEDURE

23.1 Keep the test samples always in suitable containers so that the water content to be determined is not affected by ambient conditions.



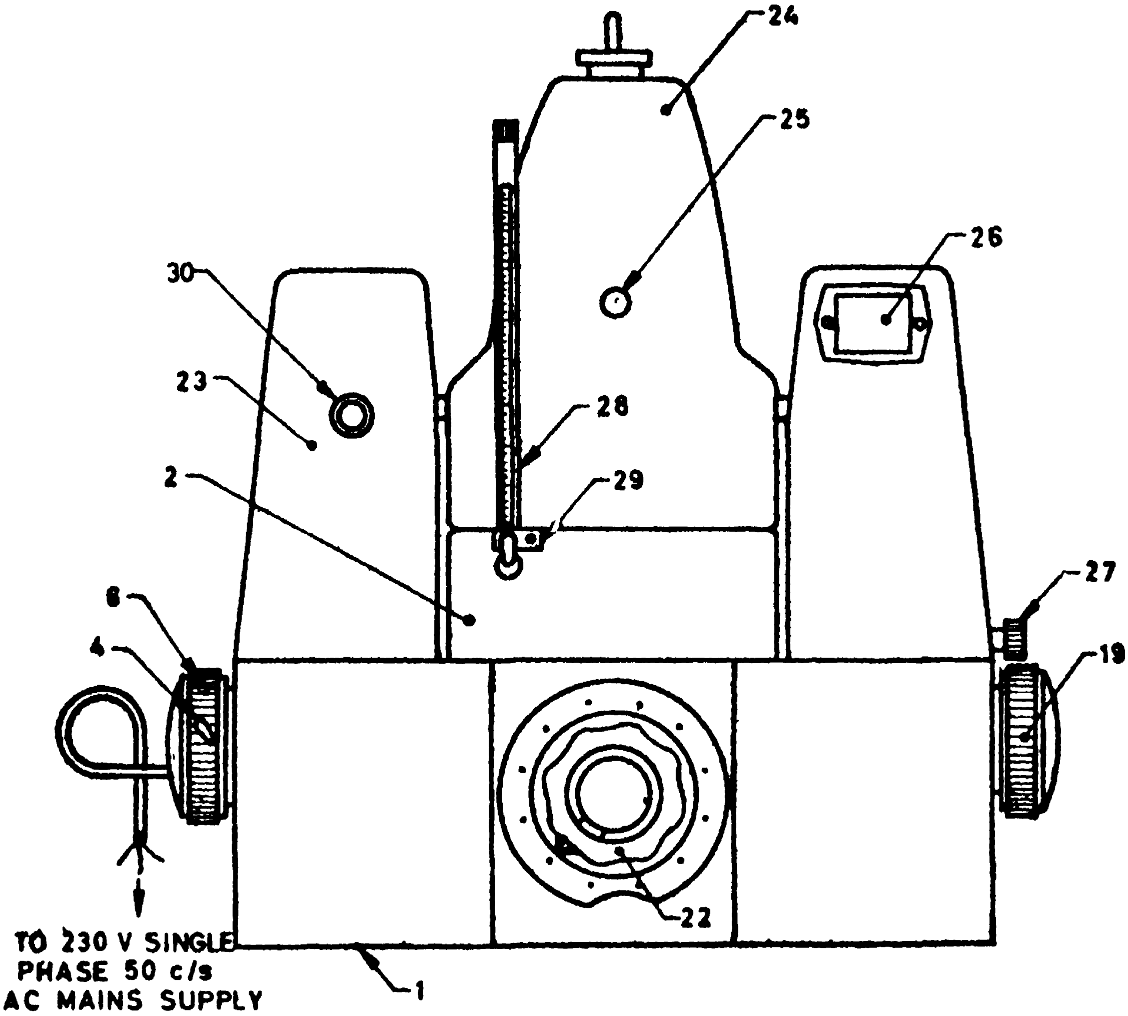
Description

1. Base
2. Pan housing
3. Pan
4. On-off switch
5. Wire tensioner
6. Initial adjustment knob
7. Left-hand wire grip
8. Gear
9. Damping magnet
10. Damping vane
11. Balance arm
12. Stopper

Description

13. Calibrated drum
14. Wire grip for balance
15. Gear
16. Torsion wire
17. Pointer
18. Right-hand wire grip
19. Drum drive knob
20. Index mark
21. Lock
22. Variac knob (for heat control)
28. Thermometer
29. Thermometer bracket

FIG. 1 TORSION BALANCE MOISTURE METER (0-100 PERCENT) — PLAN (COVER REMOVED)



	Description		*Description*
1.	Base	24.	Lamp housing
2.	Pan housing	25.	Lifting handle
4.	On-off switch	26.	Viewing lens
6.	Initial adjustment knob	27.	Locking screw
19.	Drum drive knob	28.	Thermometer
22.	Variac knob (for heat control)	29.	Thermometer bracket
23.	Cover	30.	Indicating lamp

FIG. 2 TORSION BALANCE MOISTURE METER (0-100 PERCENT) — FRONT VIEW .

23.2 Set the 100 percent scale division of the calibrated drum to align with the index mark with the help of drum drive knob.

23.3 With the pan placed on the pivot, check that the pointer is aligned with the index line and the 100 percent scale division. If not, set the pointer with the help of initial setting knob.

23.4 Rotate the drum drive knob anti-clockwise and bring the 0 percent scale division in line with the index mark, thus prestressing the wire through an amount equal to 100 percent (this represents the amount of unbalance). The pointer will now be above the index mark.

23.5 Raise the lamp housing and carefully distribute the test material evenly on the sample pan until the pointer returns to the index mark (approximately 25 g of the material will be needed in one operation).

23.6 Lower the lamp housing and switch on the infra-red lamp with the help of the switch provided on the left-hand side. Insert the thermometer in its socket and bracket. Adjust the variac control knob between 95 and 100 on the scale if it is desired that the temperature of drying is around 110°C. The sample will now begin to lose water and the pointer will rise above the index.

NOTE — Keep a watch on the column of mercury on the thermometer when the thermometer records a temperature of 105°C, control the variac in such a manner that there is no more rise in the temperature beyond 110°C and the temperature in the housing is maintained at 110 ± 5°C. If for a particular sample, the temperature is to be higher or lower than 110°C, the variac control knob can be adjusted accordingly.

23.7 To determine the percentage reduction of mass at any instant, rotate the drum scale by turning the drum drive knob until the pointer returns to the index. Read the percentage directly from the scale. The percent water which is read from the scale is the percent water based upon the initial mass of the sample, that is, the wet mass of the sample.

23.8 The criterion for taking the final reading is that the pointer should remain steady on the index mark which shows that the sample has dried to constant mass. Note the drum scale reading against the pointer which is the percent water on the total mass taken. Remove the thermometer from its bracket.

23.9 Repeat steps **23.1** to **23.8** with a fresh sample using a cool and clean pan.

24. CALCULATION

24.1 From the water content (m) as obtained on the moisture balance scale, the water content (w) on the dry weight basis shall be calculated as follows:

$$w = \frac{m}{100 - m} \times 100 \text{ percent}$$

SECTION 5 RAPID DETERMINATION OF WATER CONTENT FROM THE GAS PRESSURE DEVELOPED BY THE REACTION OF CALCIUM CARBIDE WITH THE FREE WATER OF THE SOIL

25. SCOPE

25.1 This section describes a method for rapid determination of water content from the gas pressure developed by the reaction of calcium carbide with the free water of the soil. From the calibrated scale of the pressure gauge the percentage of water on total (wet) mass of soil is obtained and the same is converted to water content on dry mass of soil.

26. APPARATUS

26.1 Metallic Pressure Vessel — with clamp for sealing cup, and a gauge calibrated in percentage water content (*see* Fig. 3).

26.2 Counterpoised Balance — for weighing sample as shown in Fig. 3.

26.3 Scoop — for measuring absorbent (calcium carbide).

26.4 One Bottle of the Absorbent (Calcium Carbide)

26.5 One Cleaning Brush

26.6 Steel Balls — three steel balls of about 12·5 mm diameter and one steel ball of 25 mm diameter.

27. SOIL SPECIMEN

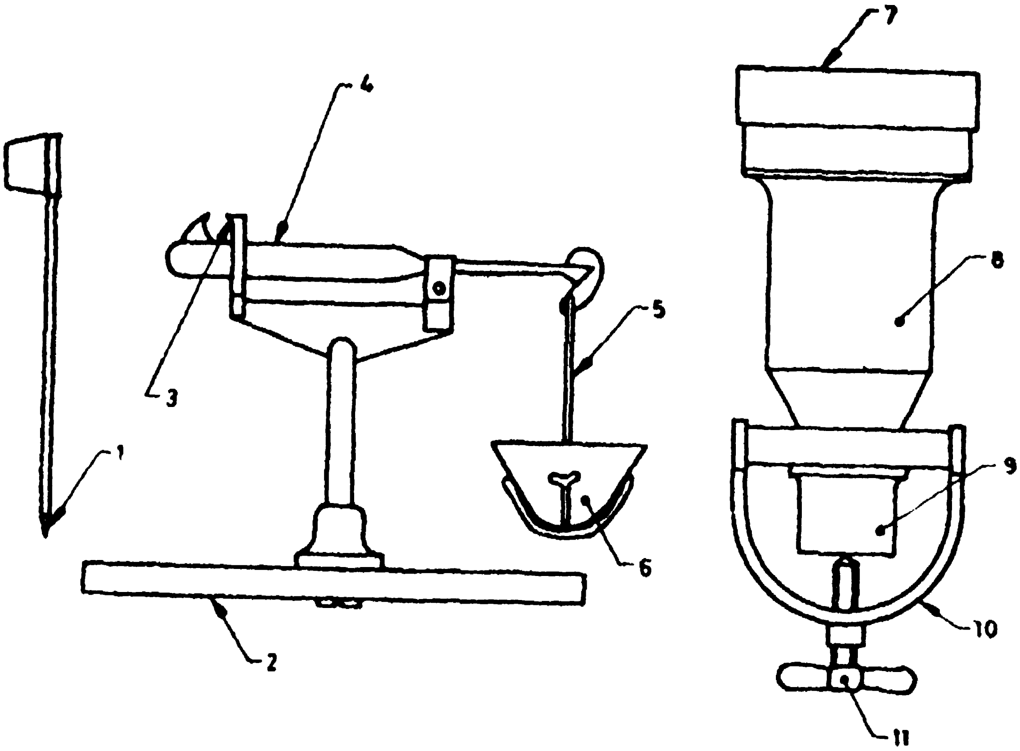
27.1 Sand requires no special preparation. Coarse powders may be ground and pulverized. Cohesive and plastic soils and material are tested with addition of steel balls in the pressure vessels. This test requires about 6 g of soil sample.

28. TEST PROCEDURE

28.1 Set up the balance. Place sample in pan till the mark on the balance arm mass lines up with the index mark.

28.2 Unclamp the clamping screw of the instrument sufficiently to move the U-clamp off the cup. Lift off the cup. Check that cup and body are clean; otherwise clean it using a brush.

28.3 Hold the body horizontal and gently deposit one level scoopful of absorbent (calcium carbide) halfway inside the chamber. Then lay the chamber down without disturbing the absorbent charge. Transfer the



	Description		*Description*
1.	Scoop	7.	Gauge 0-50%
2.	Balance base	8.	Body
3.	Index mark	9.	Cup
4.	Balance arm	10.	U-clamp
5.	Stirrup	11.	Clamp screw
6.	Pan		

FIG. 3 RAPID MOISTURE METER

soil weighed out as above from the pan to the cup. Holding cup and chamber approximately horizontal bring them together without disturbing sample or absorbent, bring the U-clamp round and clamp the cup tightly into place.

‘ NOTE — If the sample is bulky, reverse the above placement, that is, put the sample in the chamber and the absorbent in the cup. In the case of clayey soils and pastes, place the 3 smaller and one bigger steel balls in the body along with the absorbent. ’

28.4 With gauge downwards (except when the steel balls are used) shake the moisture meter up and down vigorously for 5 seconds, then quickly turn it so that the gauge is upwards, give a tap to the body of the moisture meter to ensure that all the contents fall into the cup. Hold the rapid moisture meter downwards, again shake for 5 seconds, then turn it with gauge upwards and tap. Hold for one minute. Repeat this for a third time. Once more invert the rapid moisture meter and shake up and down to cool the gas. Turn the rapid moisture meter with the gauge upwards and dial horizontal held at chest height. When the needle comes to rest take the reading. The readings on the meter are the percentages of water on the wet mass basis.

‘ NOTE — When steel balls are used, place the three smaller and one bigger balls in the body along with the absorbent and the sample in the cup and seal up the unit as usual. Hold the rapid moisture meter vertical with the cup downwards and allow the absorbent with the balls to fall into the cup. Shake the unit up and down vigorously in this position for about 15 seconds. Now invert the unit and allow the material to fall into the body. Now holding the unit horizontal rotate it for 10 seconds so that the balls rolled round the inside circumference of the body. Rest for 20 seconds. Repeat the above cycle until the gauge reading is constant (usually this takes 4 to 8 min). Note the reading as usual. ’

28.5 Finally release the pressure slowly (away from the operator) by opening the clamp screw and taking the cup out, empty the contents and clean the instrument with a brush.

29. CALCULATION

29.1 From the water content (m) obtained on the wet mass basis as the reading on the rapid moisture meter, the water content (w) on the dry mass basis shall be calculated as follows:

$$w = \frac{m}{(100 - m)} \times 100 \text{ percent}$$

NOTE — The absorbent is highly susceptible to absorption of moisture and so shall not be exposed to atmosphere; as a result the absorbent suffers deterioration and will give results on the lower side. Replace the lid of the absorbent container firmly as soon as the required amount of the absorbent for a test is taken from the bottle. The absorbent suffers deterioration with time.

APPENDIX A

(*Clause* 7.2)

PRO FORMA FOR RECORD OF RESULTS OF TEST FOR THE DETERMINATION OF WATER CONTENT OF SOIL

Details of soil sample :

Tested by :

Method of test adopted :

Oven drying :

Sand-bath :

Alcohol :

1.	Container No.	
2.	Mass of container and wet soil W_2, in g	
3.	Mass of container and dry soil W_3, in g	
4.	Mass of container W_1, in g	
5.	Mass of dry soil ($W_3 - W_1$), in g	
6.	Mass of moisture ($W_2 - W_3$), in g	
7.	Water content $w = \frac{W_2 - W_3}{W_3 - W_1} \times 100\%$	

1. SCOPE

1.1 This standard (Part 4) covers the method for the quantitative determination of grain size distribution in soils.

1.1.1 Two methods are given for finding the distribution of grain sizes larger than 75-micron IS Sieve; the first method, wet sievings shall be applicable to all soils and the second, dry sieving, shall be applicable only to soils which do not have an appreciable amount of clay.

1.1.2 For the determination of distribution of grain sizes smaller than 75-microns the pipette method is given as the standard method; the hydrometer method is given as a subsidiary method. This method shall not applicable if less than 10 percent of the material passes the 75-micron IS Sieve (determined as given in **4**).

2. TERMINOLOGY

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

3. SIEVE ANALYSIS OF SOILS FRACTION RETAINED ON 4·75 mm IS SIEVE (DRY METHOD)

3.1 Apparatus

3.1.1 *Balance* — sensitive to 0·1 percent of the weight of sample to be weighed.

3.1.2 *Sieves* — 100-mm IS Sieve, 75-mm IS Sieve, 19-mm IS Sieve and 4·75-mm IS Sieve conforming to the requirement of IS : 460 (Part 1)-1978†.

3.1.3 *Rubber Pestle and Mortar*

3.2 Preparation of Sample — The soil sample received from the field shall be prepared as specified in IS : 2720 (Part 1)-1983‡. The soil fractions retained on and passing 4·75-mm IS Sieve shall be taken separately for the analysis.

3.3 Procedure — The portion of the soil sample retained on 4·75-mm IS Sieve, selected as given in **3.2**, shall be weighed and the mass recorded

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*Glossary of terms and symbols relating to soils mechanics (*first revision*).

†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*).

as the mass of the sample uncorrected for hygroscopic moisture. The quantity of the soil sample taken shall depend on the maximum particle size contained in the soil (*see* Note 1). The sample shall be separated into various fractions by sieving through the Indian Standard Sieves specified in **3.1.2**. Other sieves may be introduced between the sieves mentioned in **3.1.2** depending upon the additional information that may be desired to be obtained from the analysis. While sieving through each sieve, the sieve shall be agitated so that the sample rolls in irregular motion over the sieve. Any particles may be tested to see if they will fall through but they shall not be pushed through. The material from the sieve may be rubbed, if necessary, with the rubber pestle in the mortar taking care to see that individual soil particles are not broken and re-sieved to make sure that only individual particles are retained. The quantity taken each time for sieving on each sieve shall be such that the maximum weight of material retained on each sieve at the completion of sieving does not exceed the values given in Note 2.

NOTE 1 — Depending on the maximum size of material present in substantial quantities in the soil, the mass of soil sample taken for analysis may be as follows:

Maximum Size of Material Present in Substantial Quantities mm	*Mass to be taken for Test* kg
75	60
40	25
25	13
19	6·5
12·5	3·5
10	1·5
6·5	0·75
4·75	0·4

NOTE 2 — Maximum weight of material to be retained on each sieve at the completion of sieving shall be as follows:

IS Sieve Designation	*450-mm Dia Sieves* kg	*300-mm Dia Sieves* kg
80-mm	15	6
20-mm	4	2
4·75 mm	1·0	0·5

The mass of the material retained on each sieve shall be recorded. If the sample appears to contain over 5 percent moisture, the water content of the material shall be determined in accordance with

IS : 2720 (Part 2)-1973* and the masses corrected accordingly. When the sample contains less than 5 percent moisture it is not necessary to determine the water content for dry weight computations and all the determinations may be made on the basis of wet weight only. If the soil contains more than about 20 percent gravel particles and the fines are very cohesive with considerable amounts adhering to the gravel after separation, the gravel shall be washed on 4·75-mm IS Sieve using sodium hexametaphosphate solution, if necessary. For further analysis a fresh portion of the fraction passing 4·75-mm IS Sieve shall be taken.

3.4 Calculations — The percentage of soil retained on each sieve shall be calculated on the basis of the total mass of soil sample taken and from these results the percentage passing through each of the sieves shall be calculated.

4. SIEVE ANALYSIS OF SOIL PASSING 4·75 mm IS SIEVE AND RETAINED ON 75-MICRON IS SIEVE

4.1 Apparatus

4.1.1 *Balance* — Sensitive to 0·1 percent of the mass of sample to be weighed.

4.1.2 *Sieves* — The following Indian Standard Sieves conforming to IS : 460 (Part 1)-1978†:

2-mm IS Sieve, 425-micron IS Sieve, and 75-micron IS Sieve.

The sieves should be periodically checked up for aperture sizes.

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

4.1.4 *Trays or Bucket* — two or more large metal or plastic watertight trays or a bucket about 30 cm in diameter and 30 cm deep (convenient sizes of the trays are in the range of 45 to 90 cm^2 and 8 to 15 cm deep).

4.1.5 *Brushes* — sieve brushes and a wire brush or similar stiff brush.

4.1.6 *Mortar with a Rubber Covered Pestle*

4.1.7 *Mechanical Sieve Shaker* (*Optional*)

4.1.8 *Riffler*

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

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

4.2 Reagents — sodium hexametaphosphate (chemically pure) or a mixture of sodium hydroxide (conforming to IS : 376-1976*) and sodium carbonate (analytical grade conforming to IS : 296-1974†) or any other dispersing agent which has been found suitable.

4.3 Procedure

4.3.1 *Analysis by Wet Sieving* — The portion of the soil passing 4·75-mm IS Sieve obtained as given in **3.2** shall be oven-dried at 105 to 110°C. The oven-dried material shall then be riffled so that a fraction of convenient mass is obtained. This shall be about 200 g if a substantial proportion of the material only, just passes the 4·75-mm IS Sieve or less if the largest size is smaller. The fraction shall be weighed to 0·1 percent of its total mass and the mass recorded. The riffled and weighed fraction shall be spread out in the large tray or bucket and covered with water.

4.3.1.1 Two grams of sodium hexametaphosphate or one gram of sodium hydroxide and one gram of sodium carbonate per litre of water used should then be added to the soil (*see* Note 1). The mix should be thoroughly stirred and left for soaking. The soil soaked specimen should be washed thoroughly over the nest of sieves specified in **4.1.2** (*see* Note 2) nested in order of their fineness with the finest sieve (75-micron IS Sieve) at the bottom. Washing shall be continued until the water passing each sieve is substantially clean. Care shall be taken to see that the sieves are not overloaded in the process (*see* Note 3). The fraction retained on each sieve should be emptied carefully without any loss of material in separate trays. Oven dried at 105 to 110°C and each fraction weighed separately and the masses recorded.

Alternatively, the soaked soil specimen may be washed on the 75-micron IS Sieve until the water passing the sieve is substantially clean. The fraction retained on the sieve should be tipped without loss of material in a try, dried in the oven and sieved through the nest of sieves specified in **4.1.2** (*see* Note 2) either by hand or by using mechanical sieve shaker. The fraction retained on each sieve should be weighed separately and the masses recorded.

NOTE 1 — The amount of dispersing agent may be varied depending on the type of soil. A dispersing agent may not be required in the case of all soils; in such cases the wet sieving may be carried out without the addition of dispersing agent.

NOTE 2 — The sieves listed in **4.1.2** correspond to the limits of coarse, medium and fine sand specified in IS : 1498-1970‡. Other sieves may be introduced depending on the additional information that may be desired to be obtained from the analysis.

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*Specification for sodium hydroxide, analytical reagent (*second revision*).

†Specification for sodium carbonate, anhydrous (*second revision*).

‡Classification and identification of soils for general engineering purposes (*first revision*).

NOTE 3 — The permissible maximum mass of sample on the 200-mm diameter sieves shall be as follows:

IS Sieve Designation	*Maximum Mass of Sample* g
2-mm	200
425-micron	50
75-micron	25

4.3.2 *Analysis by Dry Sieving*

4.3.2.0 In the case of clayey soils this method shall not be used; wet sieving shall be used.

4.3.2.1 The portion of the soil passing 4·75-mm IS Sieve obtained as in **3.2** shall be oven-dried at 105 to 110°C and weighed to 0·1 percent of its total mass.

The sieve or sieves shall be agitated so that the sample rolls in irregular motion over the sieve. No particle shall be pushed through the sieve. The material retained on the sieve shall be rubbed with the rubber pestle in mortar in re-sieved to make sure that only individual particles are retained on the sieve. The amount retained on the sieve shall be weighed. The material retained in the receiver shall be transferred to a steel tray and the receiver fitted to the nest largest sized sieve. The contents of the steel tray shall then be placed on this sieve and the operations indicated above repeated. These operations shall be repeated through all the sieves specified in **4.1.3** (*see* Note 2 of **4.3.1.1**). If a mechanical shaker is available these tests may be performed in one operation. Care shall be taken to ensure that sieving is complete. A minimum of 10 minutes shaking shall be used. The soil fraction retained on each sieve shall be carefully collected in containers and the mass of each fraction determined and recorded.

4.4 Calculation — The cumulative mass of soil fraction retained on each sieve shall be calculated. The percentage of soil fraction retained on each sieve shall be calculated on the basis of the mass of the sample passing 4·75-mm IS Sieve taken for the initial analysis. The combined gradation on the basis of the total soil sample taken for analysis shall then be calculated.

5. GRAIN SIZE ANALYSIS OF THE FRACTION PASSING 75-MICRON IS SIEVE OUT OF THE PORTION PASSING 4·75-mm IS SIEVE

5.1 Pipette Method (Standard Method)

5.1.0 This method is not applicable if less than 10 percent of the material passes 75-micron IS Sieve as obtained in **4.3.1**.

5.1.1 *Apparatus*

5.1.1.1 *Sampling pipette* — of the type illustrated in Fig. 1 fitted with a pressure and suction inlet and having a capacity of approximately 10 ml. The pipette shall be so arranged that it can be inserted to a fixed depth into a sedimentation tube when the latter is immersed in a constant temperature bath (*see also* Fig. 4).

5.1.1.2 *Glass sedimentation tubes* — a minimum of two of 50 mm diameter and approximately 350 mm long marked at 500 ml volume with rubber bungs to fit.

5.1.1.3 *Weighing bottles* — required number, fitted with round stoppers or crucibles with suitable lids approximately 25 mm in diameter and 50 mm high. The bottles or crucibles shall be weighed to the nearest 0·001 gram.

5.1.1.4 *Constant temperature bath* — capable of being maintained at 27 ± 0·1°C, into which the sedimentation tube can be immersed up to 500 ml mark. The bath shall not vibrate the sample (optional).

5.1.1.5 *Stirring apparatus* — a mechanical stirring device in which a suitable mounted electric motor turns a vertical shaft at a speed of 8 000 to 10 000 rev/min when loaded. The shaft shall be equipped with a replaceable stirring paddle of either of the types shown in Fig. 2 and, made of metal, plastic or hard rubber. The shaft shall be of such length that the stirring paddle will operate neither less than 20 mm nor more than 35 mm above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 3 shall be provided to hold the sample while it is being dispersed.

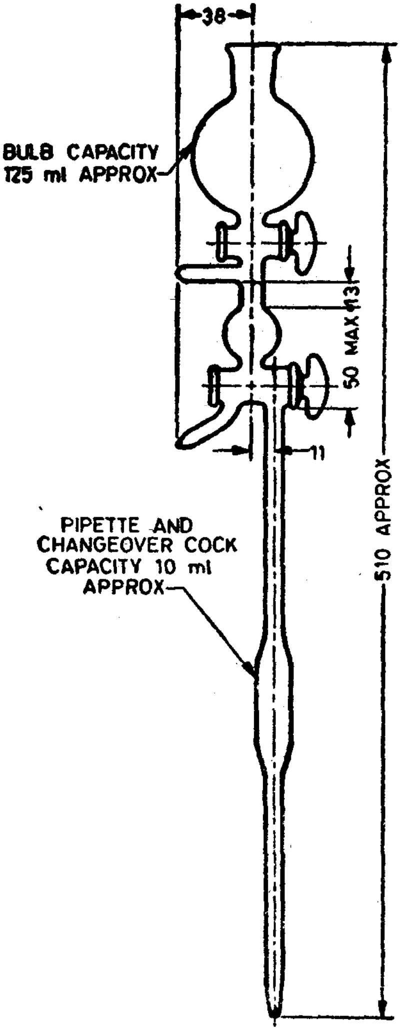
The container and baffles shall be of such material as will not be attacked by the reagents placed in the container. The motion of the soil suspension shall be sufficient to mix the contents thoroughly but it shall not be so vigorous that the particles will be crushed or lost through splashing; neither shall it be so sluggish as to leave unmixed material in the bottom of the container.

NOTE — Any other suitable dispersing device, such as mechanical bottle shaker and air-jet dispersing device which produce comparable dispersion of the soil may also be used.

5.1.1.6 *Sieves* — 2-mm, 425-micron, 75-micron IS Sieves and receiver.

5.1.1.7 *Balance* — to weigh up to 0·001 g.

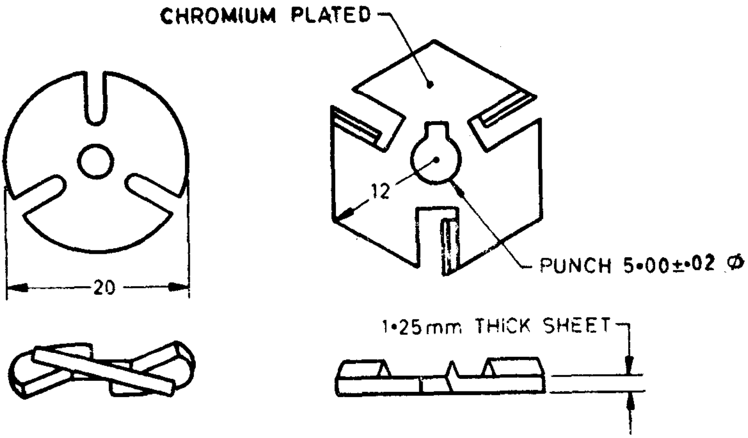
5.1.1.8 *Oven* — thermostatically controlled to maintain temperature of 105 to 110°C, will interior of non-corroding material.



Note — Bore of tube to be 4 mm ϕ where possible.

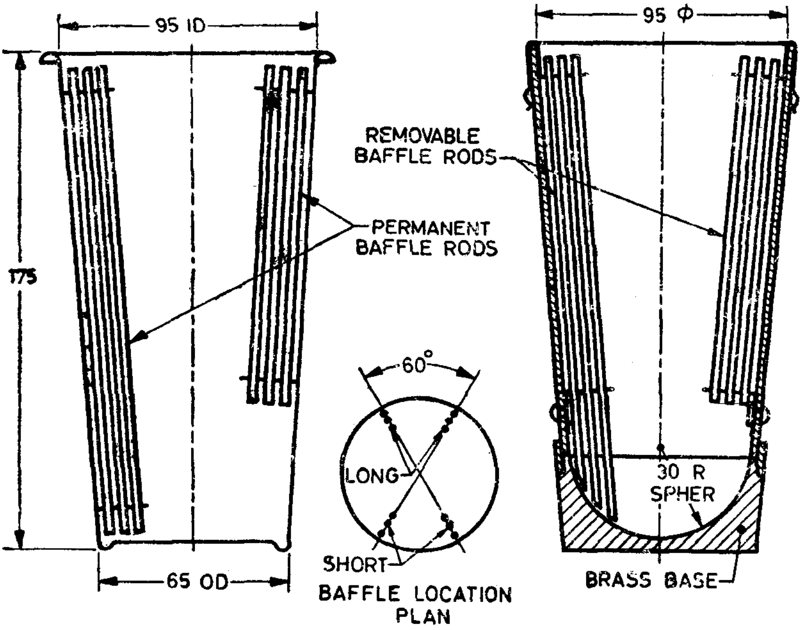
All dimensions in millimetres.

Fig. 1 Sampling Pipette



All dimensions in millimetres.

FIG. 2 STIRRING PADDLES FOR STIRRING APPARATUS



All dimensions in millimetres.

FIG. 3 DISPERSION CUPS

5.1.1.9 *Stop watch*

5.1.1.10 *Desiccator*

5.1.1.11 *Evaporating dish*

5.1.1.12 *Conical beaker* — 650 ml or one litre capacity and a cover glass to fit and a smaller beaker.

5.1.1.13 *Funnel* — Buchner or Hirch about 7 cm in diameter.

5.1.1.14 *Filter flask* — to take the funnel (about 500 ml).

5.1.1.15 *Measuring cylinder* — 100 ml capacity.

5.1.1.16 *Pipette* — 25 ml capacity.

5.1.1.17 *Glass filter funnel* — about 10 cm in diameter.

5.1.1.18 *Wash bottle* — containing distilled water.

5.1.1.19 *Filter papers*

5.1.1.20 *Blue litmus paper*

5.1.1.21 *Glass rod* — about 15 to 20 cm long, 4 to 5 mm in diameter fitted at one end with a rubber policeman.

5.1.1.22 *Thermometer* — 0 to 50°C, accurate to 0·5°C.

5.1.2 *Reagents* — The reagents shall be of analytical quality.

5.1.2.1 *Hydrogen peroxide* — 20 volume solution.

5.1.2.2 *Hydrochloric acid approximately N solution* — 89 ml of concentrated hydrochloric acid (specific gravity 1·18) diluted with distilled water to make one litre of solution.

5.1.2.3 *Sodium hexametaphosphate solution* — Dissolve 33 g of sodium hexametaphosphate and seven grams of sodium carbonate in distilled water to make one litre of solution.

NOTE 1 — This solution is unstable and shall be freshly prepared approximately once a month. The date of preparation shall be recorded on the bottle.

NOTE 2 — Solution hexametaphosphate has been found to be ineffective when dealing with certain highly flocculated soils. In such cases incomplete dispersion obtained is indicated by the formation of relatively large crumbs or flocks of soil which fall rapidly through the water leaving a sharply defined clear layer above the suspension and in such cases dispersion may be carried out by adding N sodium hydroxide solution at the rate of 4 ml per 10 g of soil.

NOTE 3 — Any other dispersing agent which has been proved suitable for dispersing soils may be used.

5.1.3 *Procedure*

5.1.3.0 If the soil fraction passing 75-micron IS Sieve during wet sieving specified in **4.3.1** has been collected, this can be oven-dried and used for pipette analysis, provided the soil has been pre-treated as specified in **5.1.3.2**. Where necessary, the oven-dried fraction shall be powdered in a mortar with a rubber covered pestle taking care that the individual grains are not crushed. 25 to 50 g (depending on the soil type) of this soil shall be used for the analysis. The other relevant portions of the procedure specified in **5.1.3, 5.1.3.1, 5.1.3.3** and **5.1.3.4**, shall be followed for further analysis.

5.1.3.1 *Calibration of sampling pipette* — The sampling pipette shall be thoroughly cleaned and dried and the nozzle shall be immersed in distilled water. The tap *B* shall be closed and the tap *E* opened (*see* Fig. 4). By means of a rubber tube attached to *C*, water shall be sucked up in the pipette until it rises above *E*. The tap *E* shall be closed and the pipette removed from the water. Surplus water drawn up into the cavity above *E'* shall be poured off through *F* into the small beaker by opening the tap *E* in such a way as to connect *D* and *F*. The water contained in the pipette and tap *E* shall be discharged into a glass weighing bottle of known mass and the mass determined. From this mass the internal volume (V_p ml) of the pipette and the tap shall be calculated to the nearest 0·05 ml. Three determinations of the volume shall be made and the average taken.

5.1.3.2 *Pre-treatment of soils* — The percentage of soluble salts in the soil shall be determined as specified in IS : 2720 (Part 21) - 1977*. In case it is more than one percent, the soil shall be washed with water before further treatment taking care to see that soil particles are not lost (*see* Note 1).

Two samples out of the soil passing 4·75-mm IS Sieve obtained as described in **3·2** weighing about 30 g shall be obtained by riffling from the bulk sample. The water content (*w*) of one sample shall be determined by the method prescribed in IS : 2720 (Part 2)-1973†.

The other sample shall be sub-divided by riffling. The actual mass of soil required may vary according to the type of soil, 50 g with a sandy soil and about 20 g with a clay soil. This sample shall be weighed to 0·001 g (W_a) and placed in the 650-ml conical beaker. 50 ml of distilled water shall be added to this and the soil suspension gently boiled until the volume is reduced to about 40 ml. After cooling 75 ml of hydrogen peroxide shall be added and the mixture allowed to stand overnight

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*Methods of test for soils: Part 21 Determination of total soluble solids (*first revision*).

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

covered with cover glass. The suspension shall then be gently heated. Care shall be taken to avoid frothing over and the contents of the beaker shall be agitated frequently either by stirring or by shaking the beaker. As soon as vigorous frothing has subsided and when there is no further reaction by the addition of fresh hydrogen peroxide, the volume shall be reduced to about 30 ml by boiling.

In the case of soils containing calcium compounds (*see* Note 2) the mixture shall be allowed to cool and about 10 ml of hydrochloric acid shall be added. The solution shall be stirred with a glass rod for a few minutes and allowed to stand for about one hour or for longer periods, if necessary. The treatment shall be continued till the solution gives an acid reaction to litmus. If the soil contains considerable amount of calcium salts, more acid may be required.

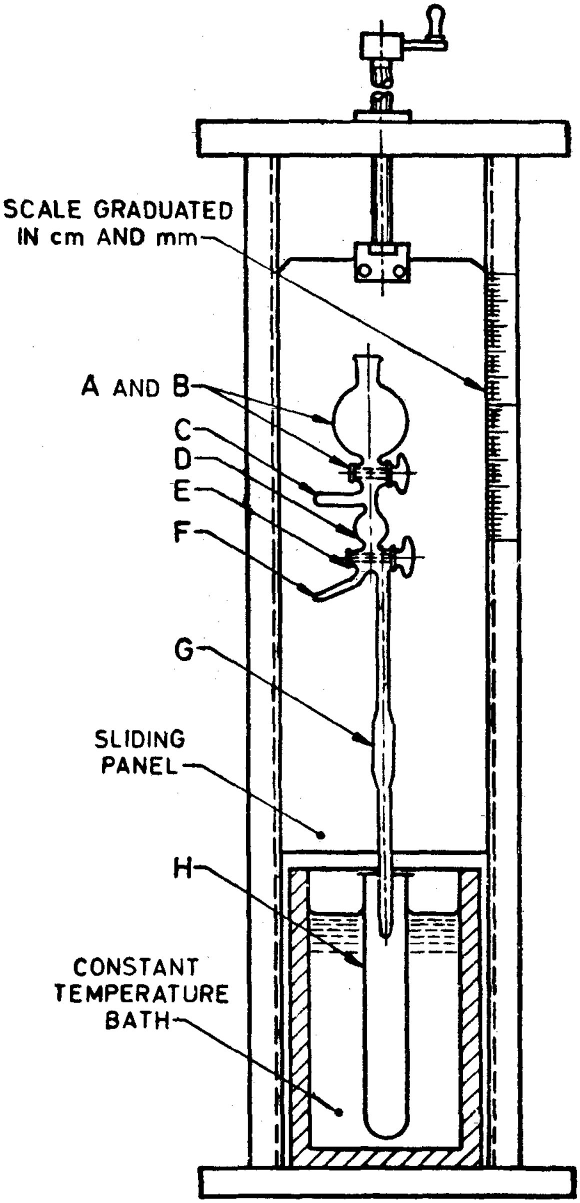
In the case of soils containing no calcium compounds or soluble salts and having a low organic content (less than 2 percent) the pre-treatment prescribed may be omitted and the dispersing agent shall be added as prescribed in **5.1.3.3** direct to the soil taken for analysis.

The mixture after pre-treatment with peroxide and acid or acid alone shall be filtered using the Buchner or Hirch funnel and washed with warm water until the filtrate shows no acid reaction to litmus. The wet soil on the filter paper and funnel shall be transferred without any loss whatsoever to the glass evaporating dish (weighed to 0·001 g) using a jet of distilled water. Only a minimum quantity of distilled water shall be used. The dish and contents shall be dried in an oven maintained at 105 to 110°C. The dish and contents shall then be cooled in a desiccator and weighed to 0·001 g. The mass of the soil remaining after pre-treatment shall be recorded (W_b).

NOTE 1 — Owing to the removal of calcium, iron, etc, by the acid during the pre-treatment of the soil, the above method is not suitable for the determination of the particle size distribution in soils predominantly containing chalk or lime and it may, therefore, be necessary to adopt different methods of treatment with these and other soils having similar special characteristics. Dispersion may be assisted by rubbing the particles of soil in the suspension against the side of the evaporating dish with a glass rod fitted with a rubber policeman. In some cases a longer mixing time may help.

Lateritic soils will also be attacked by the acid but unless they contain calcium they need not be given the acid treatment.

NOTE 2 — Acid treatment shall be carried out only for soils containing insoluble calcium salts.



NOTE — *G* — Sampling pipette, and
H — Sedimentation tube.

FIG. 4 ARRANGEMENT FOR LOWERING THE SAMPLING PIPETTE

5.1.3.3 *Dispersion of soil* — 25 ml sodium hexametaphosphate solution shall be added to the soil in the evaporating dish together with about 25 ml of distilled water and the soil brought into suspension by stirring with a glass rod. The mixture shall be warmed gently for 10 minutes and then transferred to the cup of the mechanical mixer using a jet of distilled water to wash all traces of the soil out of the evaporating dish. Any soil adhering to the dish shall be rubbed off with the rubber policeman. The amount of water used shall not exceed 150 ml. The soil suspension shall then be stirred well for 15 minutes or longer in the case of highly clayey soils (*see* Note).

The suspension shall then be transferred to 75-micron IS Sieve placed on a receiver and the soil shall be washed on this sieve using a jet of distilled water from a wash-bottle. Particular care shall be taken to wash off all traces of suspension adhering to the dispersion cup. The amount of distilled water used during the operation shall not exceed 150 ml. The suspension, that has passed through this sieve shall then be transferred to the sedimentation tube using the glass funnel and the volume of liquid is made up to 500 ml with distilled water.

The material retained on the 75-micron IS Sieve may be oven-dried and treated as prescribed in **4.3.2** and the cumulative percentages of the soil fraction retained on each sieve shall be calculated.

NOTE — Any other suitable stirring device other than the one specified in **5.1.1.5**, such as the bottle shaker, may be used and the stirring time shall be adjusted suitably.

5.1.3.4 *Sedimentation* — 25 ml of sodium hexametaphosphate solution shall be added from a pipette to a graduated 500-ml sedimentation tube (comparison tube) and diluted with distilled water to exactly 500 ml. This sedimentation tube together with the tube containing the soil suspension shall be immersed in the constant temperature bath (where used), the temperature of the bath noted (*see* Notes 1 and 2), the rubber bungs inserted and the tubes allowed to stand until they have reached the temperature of the bath. The tubes with their contents shall then be thoroughly shaken by inverting the tubes several times. They shall then be replaced in the apparatus, simultaneously starting the stop watch. The rubber bungs shall then be carefully removed without agitating the tubes.

The pipette with the tap E closed shall be lowered vertically into the soil suspension until the end is 100 ± 1 mm below the surface of the suspension. It shall be lowered with great care some 15 seconds before the sample is due to be taken. Approximately 10 seconds shall be taken to complete this operation. The tap E shall be opened and a sample (V_p ml) drawn up into the pipette. The pipette and the bore in the tap

E shall be filled with solution and tap *E* then closed. This operation shall take 10 seconds to complete.

After each sampling operation the pipette shall be withdrawn from the suspension, taking approximately 10 seconds to complete the operation.

During the sampling a small amount of the suspension may have been drawn up into the bulb *D* above the bore of the tap *E*. This surplus shall be washed away into the beaker down the outlet tube *F* by opening the tap *E* in such a way as to connect *D* and *F*. Distilled water shall then be allowed to run from the bulb funnel *A* into *D* and out through *F* until no solution remains in the system.

A tared weighing bottle shall be placed under the end of the pipette and the tap *E* opened so that the contents of the pipette are delivered into the bottle. Any suspension left on the inner walls of the pipette shall be washed into the weighing bottle by allowing distilled water from the bulb *A* to run through *B*, *D* and *E* into the pipette. This procedure shall be repeated at the end of each time corresponding to particle diameters 0·02 mm, 0·006 mm, 0·002 mm, 0·001 mm calculated on the basis of equation given in **5.1.4.3** (a). Table 1 gives the time of settling to a depth of 100 mm of particles of various diameters for temperatures ranging from 10 to 35°C for an average specific gravity of soil of 2·68. The weighing bottles and contents shall be placed in the oven maintained at 105 to 110°C and the sample evaporated to dryness. After cooling in a desiccator the weighing bottle and contents shall be weighed to the nearest 0·001 g and the mass of the solid material in the sample determined (W_1, W_2, W_3, and W_4 for each respective sampling time).

Between any of the times in which the above sampling is taking place, a sample (V_p ml) shall be taken from the tube containing the sodium hexametaphosphate solution. The mass of solid material in the sample shall be determined (W_s).

The specific gravity of the soil fraction passing the 75-micron IS Sieve shall be determined by the method specified in IS : 2720 (Part 3/Sec 1)-1980*.

NOTE 1 — If a constant temperature bath is not available for the test, the test may be performed at room temperature. The temperature shall be noted at the time of sampling and suitable correction made in the calculation of the equivalent diameter of soil grains on the basis of equation in **5.1.4.3** (a).

NOTE 2 — Asymmetrical heating of the suspension causes convection currents which affect the sedimentation process. The suspension should, therefore, be kept

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*Methods of test for soils : Part 3 Determination of specific gravity, Section 1 Fine grained soils (*first revision*).

out of direct sunlight and away from any local source of heat. Evaporation should be retarded by keeping a cover on the measuring cylinder between readings.

NOTE 3 — It is not necessary to measure the specific gravity of every sample used for fine analysis. An average value for samples from the same area or soil type in an area may be used without loss of accuracy. It is essential that the specific gravity used is that of the fraction passing 75-micron IS Sieve.

5.1.4 *Calculations*

5.1.4.1 *Loss in mass in pre-treatment* — The loss in mass in pre-treatment of the soil in percentage shall be calculated as follows:

$$P = 100 - \frac{W_b (100 + w)}{W_a}$$

where

P = loss in mass in percentage,

W_b = mass of soil after pre-treatment,

w = air dry moisture content of the soil taken for analysis, and

W_a = mass of air dry soil used.

5.1.4.2 *Sieving* — The percent of soil sample passing each of the sieves used in the analysis shall be calculated using the mass of the pre-treated soil (W_b).

5.1.4.3 *Sedimentation*

a) *Diameter of particle* — The diameter of the particle in suspension at any sampling time t shall be calculated from the formula:

$$D = \sqrt{\frac{30\ \mu}{980 (G - G_1)}} \sqrt{\frac{H}{t}}$$

where

D = diameter of particle in suspension, in mm;

μ = coefficient of viscosity of water in poises at the temperature of suspension at the time of sampling;

G = specific gravity of the soil fraction used in the sedimentation analysis, in g/cm^3;

G_1 = specific gravity of water, in g/cm^3;

H = height of fall of the particles or sampling depth, in cm; and

t = time elapsed before sampling, in minutes.

TABLE 1 RATE OF SETTLING OF PARTICLES AT VARIOUS TEMPERATURES

(AVERAGE SPECIFIC GRAVITY OF SOIL ASSUMED AS 2·68)

(*Clause* 5.1.3.4)

TEMPERATURE °C	DIAMETER, mm																		
	·001	·002	·003	·004	·005	·006	·007	·008	·009	·01	·02	·03	·04	·05	·06	·07	·08	·09	·1
	(Time				for		a		fall		of		100		mm)				
	h				min						s								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
10	40·80	10·19	4·53	2·55	98·0	68·0	53·0	38·3	30·2	24·5	367	163	92	59	40·8	31·8	22·9	18·1	14·7
11	39·64	9·91	4·40	2·48	95·2	66·1	51·5	37·2	29·3	23·8	357	158	89	57	39·6	30·9	22·3	17·6	14·3
12	38·55	9·63	4·28	2·41	92·6	64·2	50·1	36·1	28·5	23·1	347	154	87	55	38·5	30·0	21·7	17·1	13·9
13	37·48	9·37	4·16	2·34	90·0	62·5	48·7	35·1	27·7	22·5	337	150	84	54	37·5	29·2	21·1	16·7	13·5
14	36·39	9·10	4·04	2·28	87·6	60·8	47·3	34·2	27·0	21·9	328	146	82	52	36·4	28·4	20·5	16·2	13·1
15	35·45	8·86	3·93	2·22	85·1	59.2	46·1	33·3	26·2	21·3	319	142	80	51	35·4	27·6	19·9	15·8	12·7
16	34·49	8·62	3·83	2·16	82·8	57·6	44·9	32·4	25·5	20·7	310	138	78	50	34·5	26·9	19·4	15·3	12·4
17	33·64	8·41	3·73	2·10	80·8	56·1	43·7	31·5	24·9	20·2	302	134	76	48	33·6	26·2	18·9	14·8	12·1
18	32·73	8·18	3·64	2·04	78·6	54·6	42·5	30·7	24·2	19·6	294	131	74	47	32·7	25·5	18·4	14·5	11·8
19	31·89	7·98	3·54	1·99	76·6	53·2	41·4	29·9	23·6	19·1	287	127	72	46	31·9	24·8	17·9	14·1	11·5
20	31·10	7·77	3·45	1·94	74·6	51·8	40·4	29·1	23·0	18·6	280	124	70	45	31·1	24·2	17·5	13·8	11·5
21	30·28	7·57	3·36	1·89	72·7	50·6	39·4	28·4	22·4	18·2	273	121	68	44	30·3	23·6	17·0	13·4	10·9
22	29·55	7·38	3·28	1·85	70·9	49·3	38·4	27·7	21·8	17·7	266	118	66	42	29·5	23·0	16·6	13·1	10·6
23	28.81	7·21	3·20	1·80	69·2	48·1	37·5	27·0	21·3	17·3	259	115	65	41	28·8	22·4	16·2	12 8	10·4
24	28·12	7·03	3·12	1·76	67·5	46·9	36·6	26·4	20·8	16·9	253	113	63	40	28·1	21·9	15·8	12·5	10·1
25	28·78	6·86	3·05	1·72	65·9	45·8	35·7	25·8	20·3	16·5	247	110	62	39	27·8	21·4	15·5	12·2	9·9
26	26·81	6·71	2·98	1·68	64 4	44·7	34·8	25·2	19·8	16·1	241	107	60	39	26·8	20·9	15·1	11·9	9·6
27	26·19	6·54	2·91	1·64	62·9	43·7	34·0	24·6	19·4	15·7	236	105	59	38	26·2	20·4	14·7	11·6	9·4
28	25·60	6·40	2·84	1·60	61·4	42·7	33·2	24·0	19·0	15·4	231	102	58	37	25·6	19·9	14·4	11·4	9·2
29	25·04	6·25	2·78	1·56	60·1	41·7	32·5	23·4	18·5	15·0	226	100	56	36	25·0	19·4	14·1	11·1	9·0
30	24·46	6·12	2·72	1·53	58·8	40·8	31·8	22·9	18·1	14·9	221	98	55	35	24·5	19·0	13·8	10·8	8·8
31	23·95	5·98	2·66	1·50	57·5	39·9	31·1	22·4	17·7	14·4	216	96	54	34	23·9	18·6	13·5	10·6	8·6
32	23·44	5 86	2·60	1·47	56·3	39·1	30·4	21·9	17·3	14·1	221	94	53	34	23·4	18·2	13·2	10·4	8·5
33	22·95	5·74	2·55	1·44	55·1	38·3	29·8	21·5	17·0	13·8	206	92	52	33	22·9	17·8	12·9	10·2	8·4
34	22·50	5·62	2·50	1·41	54·0	37·5	29·2	21·1	16·6	13·5	202	90	51	32	22·5	17·5	12·6	10·0	8·1
35	22·01	5·50	2·45	1·38	52·9	36·7	28·6	20·7	16·3	13·2	198	89	50	32	22·0	17·2	12·4	9·8	7·9

b) *Percentage finer than D*

1) The mass of solid material in 500 ml of suspension for each respective sampling time shall be calculated from the formula:

$$M_1 \text{ or } M_2 \text{ or } M_3 \text{ or } M_4, \text{ etc, or } M_s, \text{ in g} = \frac{W_1 \text{ or } W_2 \text{ or } W_3 \text{ or } W_4, \text{ etc, or } W_s}{V_p} \times 500$$

where

$\left.\begin{matrix} M_1 \\ M_2 \\ M_3 \\ M_4 \\ \text{etc} \end{matrix}\right\}$ = mass of material in 500 ml from respective samplings,

M_s = mass of sodium hexametaphosphate in 500 ml of solution,

$\left.\begin{matrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ \text{etc} \end{matrix}\right\}$ = mass of material in V_p ml from respective samplings,

W_s = mass of sodium hexametaphosphate in V_p ml of solution, and

V_p = volume in ml of sample pipetted for respective samplings.

2) The percentage by mass (W), of particles finer than diameter D shall be calculated from the formula:

$$W = \frac{(M_1 \text{ or } M_2 \text{ or } M_3 \text{ or } M_4, \text{ etc}) - M_s}{W_b} \times 100$$

where

$\left.\begin{matrix} M_1 \\ M_2 \\ M_3 \\ M_4 \\ \text{etc} \end{matrix}\right\}$ = mass of material in 500 ml from respective samplings,

M_s = mass of sodium hexametaphosphate in 500 ml of solution, and

W_b = mass of soil after pre-treatment.

5.1.4.4 *Combined gradation* — Combined gradation for each of the particle sizes covered by **5.1.3.4** shall be calculated on the basis of the total soil sample taken for analysis.

5.2 Hydrometer Method (Subsidiary Method)

5.2.0 This method is not applicable, if less than 10 percent of the material passes 75-micron IS Sieve.

5.2.1 *Apparatus*

5.2.1.1 *Hydrometer* — of the type illustrated in Fig. 5 and fulfilling the following requirements:

a) There shall be no abrupt changes in the cross section of the hydrometer, such as will hinder cleaning or drying or permit air bubbles to be trapped.

b) The hydrometer shall be graduated on the basis of a liquid having a surface tension of 55 dynes/cm.

c) The graduation lines shall be at intervals of 0·000 5, every alternate line shall extend beyond the shortest lines, every tenth graduation shall exceed that of all the intervening lines and shall be numbered in full. A recommended scale is shown in Fig. 5.

d) The basis of the scale shall be density (g/ml) at 27°C.

e) The maximum permissible scale error on the hydrometer is plus or minus one scale division.

f) The other general requirements shall satisfy those specified in IS : 3104-1965*.

5.2.1.2 *Glass measuring cylinders* — two of 1 000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1 000 ml volume.

5.2.1.3 *Thermometer* — to cover the range 0·50°C accurate to 0·5°C.

5.2.1.4 *Water-bath or constant temperature room (optional)* — for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature. Such a device is illustrated in Fig. 6.

5.2.1.5 *Stirring apparatus* — as specified in **5.1.1.5**.

5.2.1.6 *Sieves* — as specified in **5.1.1.6**.

5.2.1.7 *Balance* — accurate to 0·01 g.

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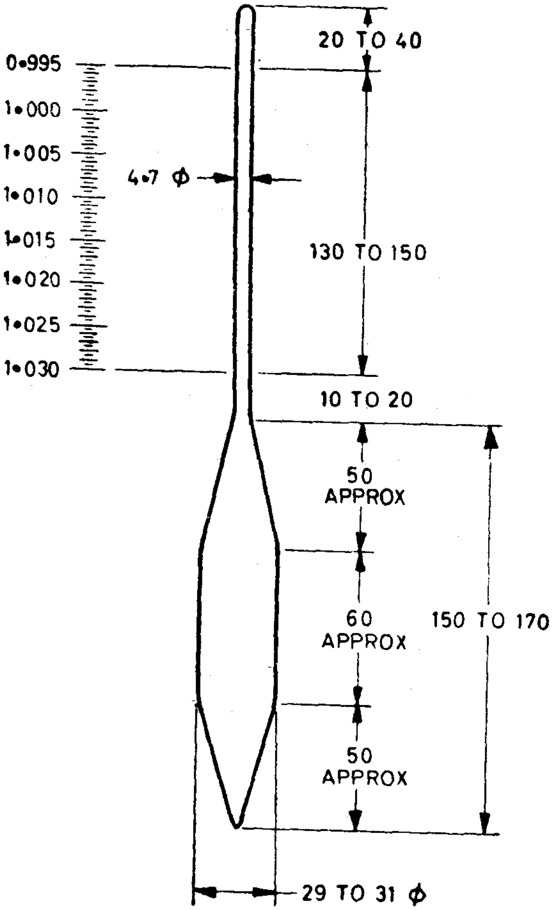
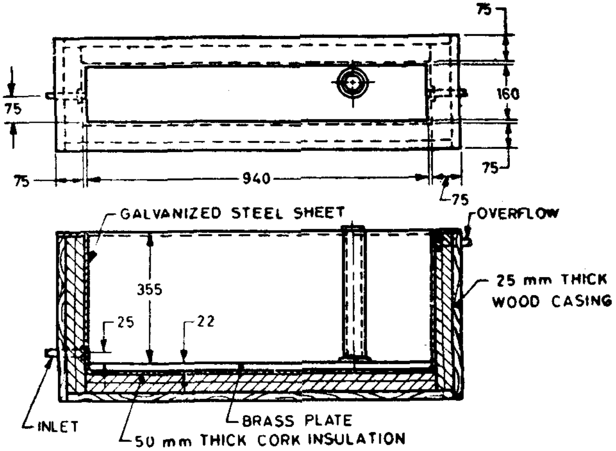
*Specification for density hydrometers.



All dimensions in millimetres.

FIG. 5 HYDROMETER



All dimensions in millimetres.

FIG. 6 ILLUSTRATED WATER BATH

5.2.1.8 *Oven* — thermostatically controlled to maintain a temperature of 105 to 110°C, with interior of non-corroding material.

5.2.1.9 *Stop watch*

5.2.1.10 *Desiccator*

5.2.1.11 *Centimetre scale*

5.2.1.12 *Porcelain evaporating dishes* — four, about 15 cm in diameter.

5.2.1.13 *Wide-mouth conical flask or conical beaker* — of 1 000 ml capacity.

5.2.1.14 *Buchner or Hirch funnel* — about 10 cm in diameter.

5.2.1.15 *Filter flask* — to take the funnel.

4.2.1.16 *Measuring cylinder* — of 100 ml capacity.

5.2.1.17 *Wash bottle* — containing distilled water.

5.2.1.18 *Filter papers*

5.2.1.19 *Blue litmus paper*

5.2.1.20 *Glass rod* — about 15 to 20 cm long and 4 to 5 mm in diameter.

5.2.2 *Reagents* — The reagents shall be of analytical quality.

5.2.2.1 *Hydrogen peroxide* — *See* **5.1.2.1.**

5.2.2.2 *Hydrochloric acid N solution* — *See* **5.1.2.2.**

5.2.2.3 *Sodium hexametaphosphate solution* — *See* **5.1.2.3** and Notes 1, 2 and 3 thereunder.

5.2.3 *Calibration of Hydrometer*

5.2.3.1 *Volume* — The volume of the hydrometer bulb (V_h) shall be determined in one of the following ways:

a) *From the volume of water displaced* — Approximately 800 ml of water shall be poured into the 1 000 ml measuring cylinder. The reading of the water level shall be observed and recorded.

The hydrometer shall be immersed in the water and the level shall again be observed and recorded.

The difference between the two readings shall be recorded as the volume of the hydrometer bulb in millilitres plus the volume of that part of the stem that is submerged. For practical purposes the error due to the inclusion of this stem volume may be neglected.

b) *From the mass of the hydrometer* — The hydrometer shall be weighed to the nearest 0·1 g.

The mass in grams shall be recorded as the volume of the hydrometer in millilitres. This includes the volume of bulb plus the volume of the stem below the 1·000 graduation mark. For practical purposes the error due to the inclusion of this stem may be neglected.

5.2.3.2 *Calibration*

a) The sectional area of the 1 000 ml measuring cylinder in which the hydrometer is to be used shall be determined by measuring the distance between two graduations. The sectional area (A) is equal to the volume included between the two graduations divided by the measured distance in centimetres between them.

b) The distance from the lowest calibration mark on the stem of the hydrometer to each of the other major calibration marks (R_h) shall be measured and recorded.

c) The distance from the neck of the bulb to the nearest calibration mark shall be measured and recorded.

d) The distance H corresponding to a reading R_h is the sum of the distances measured in (b) and (c).

e) The distance (h) from the neck to the bottom of the bulb shall be measured and recorded as the height of the bulb.

NOTE — The distance $h/2$ locates the centre of volume of asymmetrical bulb. If an asymmetrical bulb is used, the centre of volume can be determined with sufficient accuracy by projecting the shape of the bulb on to a sheet of paper and locating the centre of gravity of the projected area.

f) The effective depth (H_R) corresponding to each of the major calibration marks (R_h) shall be calculated from the following formula :

$$H_R = H_1 + \frac{1}{2}\left[h - \frac{V_h}{A}\right]$$

where

H_R = effective depth;

H_1 = length from neck of bulb, to graduation R_h, in cm;

h = twice the length from neck of bulb to its centre of volume, in cm;

V_h = volume of hydrometer bulb, in ml; and

A = area of measuring cylinder in cm^2.

NOTE — The factor $\frac{V_h}{A}$ in the above equation shall not be applied to hydrometer reading taken after periods of sedimentation of half, one, two and four minutes as specified in **5.2.4.3**(a).

g) The relationship between H_R and R_h may be plotted as a smooth curve which may be used for finding the effective depth (H_R) corresponding to hydrometer readings (R_h) obtained during test.

5.2.3.3 *Meniscus correction* — The hydrometer shall be inserted in a 1 000-ml measuring cylinder containing about 700 ml water. By placing the eye slightly below the plane of the surface of the liquid, and then raising it slowly until the surface seen as an ellipse becomes a straight line, the point where the plane intersects the hydrometer scale shall be determined. By placing the eye slightly above the plane of the surface of the liquid, the point where the upper limit of the meniscus intersects the hydrometer scale shall be determined. The difference between the two readings shall be recorded as the meniscus correction C_m. This is a constant for a given hydrometer.

5.2.4 *Procedure*

5.2.4.1 *Pre-treatment of soil* — The percentage of soluble salts shall be determined. In case it is more than one percent, the soil shall be washed with water before further treatment, taking care to see the soil particles are not lost (*see* Note 1 under **5.1.3.2**).

Two samples each of mass 50 to 100 g approximately shall be obtained by riffling from the air dried sample passing the 4·75-mm IS Sieve obtained as in **3.3**. The actual amount of soil required will vary according to the type of soil, 50 g with a clay soil and 100 g with a sand soil. The moisture content (w) of one sample shall be determined by the method given in IS : 2720 (Part 2)-1973*. The other sample shall be accurately weighed (W_a) to the nearest 0·01 g and placed in the wide mouth conical flask. 150 ml of hydrogen peroxide shall then be added and the mixture stirred gently with a glass rod for a few minutes after which it shall be covered with a cover glass and left to stand overnight. The mixture in the conical flask shall be gently heated. Care shall be taken to avoid frothing over and the contents of the dish shall be periodically stirred. As soon as vigorous frothing has subsided the volume shall be reduced to about 50 ml by boiling. With very organic soils additional peroxide may be required to complete the oxidation.

In the case of soils containing calcium compounds (*see* Note 2 under **5.1.3.2**) the mixture shall be allowed to cool and about 50 ml of hydrochloric acid added. The solution shall be stirred with a glass rod for a few minutes and allowed to stand for one hour or for longer periods, if necessary. If the soil contains a considerable amount of calcium salts more acid may be required. When the treatment is complete the solution shall have an acid reaction to litmus.

In the case of soils containing no calcium compounds or soluble salts and having a low organic content (less than 2 percent) the pre-treatment prescribed may be omitted and the dispersing agent shall be added as in **5.2.4.2** direct to the soil taken for analysis.

The mixture shall then be filtered and washed with warm water until the filtrate shows no acid reaction to litmus. The damp soil on the filter paper and funnel shall be transferred without any loss whatsoever to the evaporating dish (weighed to 0·01 g) using a jet of distilled water. Only the minimum quantity of distilled water shall be used. The dish

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

and contents shall be placed in an oven and dried at 105 to 110°C. The dish and contents shall then be transferred to the desiccator and allowed to cool. They shall then be weighed to 0·01 g, and the mass of soil remaining after pre-treatment shall be recorded (W_b).

5.2.4.2 *Dispersion of soil* — To the soil in the evaporating dish 100 ml of sodium hexametaphosphate solution shall be added and the mixture shall then be warmed gently for about 10 minutes and then transferred to the cup of the mechanical mixer using a jet of distilled water to wash all traces of the soil out of the evaporating dish. The amount of water used may be about 150 ml. The soil suspension shall then be stirred well for 15 minutes.

The suspension shall then be transferred to the 75-micron IS Sieve placed on a receiver and the soil shall be washed on this sieve using a jet of distilled water from a wash bottle. Particular care shall be taken to wash off all traces of suspension adhering to the dispersion cup. The amount of distilled water during this operation may be about 500 ml. The suspension that has passed through the sieve shall be transferred to the 1 000 ml measuring cylinder and made up to exactly 1 000 ml with distilled water. This suspension shall then be used for the sedimentation analysis.

The material retained on the 75-micron IS Sieve may be over-dried and analysed as specified in **4.3.2.1** and the cumulative percentages of the soil fraction retained on each sieve shall be calculated.

5.2.4.3 *Sedimentation*

a) A rubber bung shall be inserted in the mouth of the measuring cylinder which shall then be shaken vigorously and finally be inverted end over end. Immediately the shaking has ceased, the measuring cylinder shall be allowed to stand (in the constant temperature bath, if used) and the stop watch started. The hydrometer shall be immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings shall be taken after periods of half, one, two and four minutes. The hydrometer shall then be removed slowly, rinsed in distilled water and kept in a cylinder of distilled water at the same temperature as the soil suspension.

b) The hydrometer shall be re-inserted in the suspension and readings taken after periods of 8, 15 and 30 minutes, one, two and four hours after shaking (*see* Note). The hydrometer shall be removed, rinsed and placed in the distilled water after each reading. After 4 hours hydrometer readings shall be taken once or twice within 24 hours, the exact periods of sedimentation being noted. Finally a reading may be taken at the end of 24 hours. In taking all readings, insertion and withdrawal of the hydrometer before and after taking a reading shall be done carefully to avoid disturbing the suspension unnecessarly. Ten seconds shall be allowed for each operation. Vibration of the sample shall be avoided.

NOTE — Other suitable time intervals may be used, provided they give nearly equally spaced points on the grain size distribution curve.

c) The temperature of the suspension shall be observed and recorded once during the first 15 minutes and then after every subsequent reading. The temperature shall be read with an accuracy of at least ± 0·5°C. Hydrometer readings shall also be taken in pure distilled water at the corresponding temperatures and the temperature correction (M_t) calculated as the difference between this reading and the reading corresponding to the density of water at the calibration temperatures. A chart of such corrections for all temperatures may also be prepared for ready use.

NOTE — The temperature of the suspension over the period of the test should not differ from the mean temperature by more than ±2°C in order not to cause an error in the particle size of more than 2 percent. This requirement will generally be fulfilled if the maximum difference in room temperature is not greater than about 8°C. If the variation in temperature is likely to be greater than this the constant temperature bath should be used (*see also* Note 2 under **5.1.3.4**).

d) The correction (x) to be applied for the dispersing agent shall be ascertained by placing exactly 50 ml of the sodium hexametaphosphate solution in a previously weighed glass weighing bottle and after evaporating the water by drying at 105 to 110°C in an oven, the mass of dispersing agent (W_d) shall be calculated.

The dispersing agent correction (x) shall then be calculated from the formula:

$$X = 2\,W_d$$

This correction is independent of the temperature.

Alternatively, the correction may be obtained directly by making up a 1 000 ml cylinder full of distilled water containing the same proportion of dispersing agent and at the same temperature, and placing the hydrometer in this solution. The corrected zero reading may then be read directly. This correction shall be corrected for temperature.

5.2.5 *Calculations*

5.2.5.1 *Loss in mass in pre-treatment* — The loss in mass in pre-treatment of the soil shall be calculated using the formula given in **5.1.4.1**.

5.2.5.2 *Sieving* — The percent of soil sample passing each of the sieve used in the analysis shall be calculated using the mass of the pre-treated soil and as percentages of the total soil sample taken for analysis.

5.2.5.3 *Sedimentation*

a) *Diameter of the particles* — The diameter of the particle in suspension at any sampling time t shall be calculated from the formula:

$$D = \sqrt{\frac{30\mu}{980\,(G - G_1)}}\ \sqrt{\frac{H_R}{t}}$$

where

D = diameter of particle in suspension, in mm;

μ = coefficient of viscosity of water at the temperature of the suspension at the time of taking the hydrometer reading, in poises;

G = specific gravity of the soil fraction used in the sedimentation analysis;

G_1 = specific gravity of water;

H_R = effective depth corresponding to R_h (*see* **5.2.3.2**), in cm [*see* Note under **5.2.3.2** (f)]; and

t = time elapsed between the beginning of sedimentation and taking of hydrometer reading in minutes.

The hydrometer reading corrected for meniscus (R_h) shall be calculated from the following formula:

$$R_h = R'_h + C_m$$

where

R_h = hydrometer reading corrected for meniscus,

R'_h = hydrometer reading at the upper rim of the meniscus, and

C_m = meniscus correction.

NOTE — A nomographic chart for solving the above equation is given in Fig. 7.

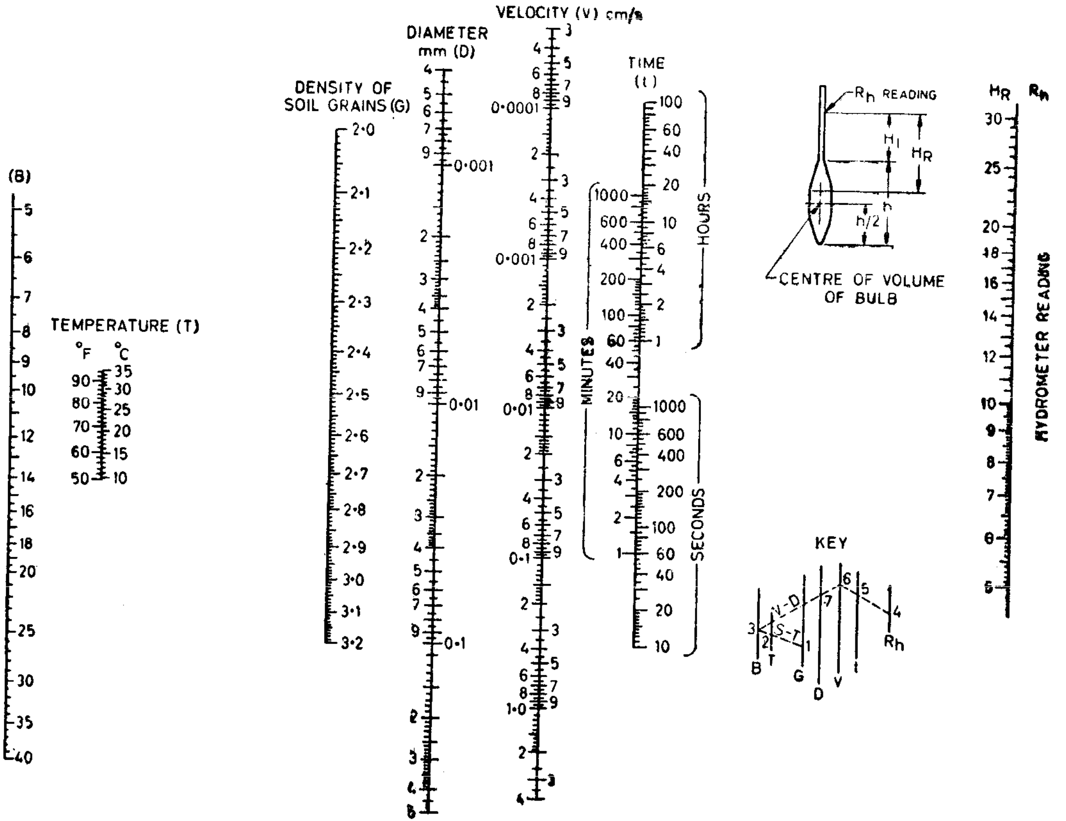

FIG. 7 NOMOGRAPHIC CHART

b) Percentage finer than D — The percentage by mass (W) of particles smaller than corresponding equivalent particle diameters shall be calculated from the formula:

$$W = \frac{100\ G_s}{W_b\ (G_s - 1)} (R_h + M_t - x)$$

where

G_s = specific gravity of soil particles,

W_b = weight of soil after pre-treatment;

R_h = hydrometer reading corrected for meniscus (for the type of hydrometer graduations illustrated in Fig. 5, R_h is obtained by reading the decimals only and placing the decimal point between the third and the fourth decimal places);

M_t = temperature correction; and

x = dispersion agent correction.

The values of W shall be calculated for all the values of D obtained and shall be expressed as percentages of particles finer than the corresponding value of D. These percentages shall then be expressed as combined percentages of the total soil sample taken for analysis.

5.3 PLUMMET BALANCE (Alternative Method)

5.3.1 *Principle* — Plummet balance is essentially a specific gravity balance and is designed on the principle that adjustment for depth of immersion of the plummet is more rapid requiring less precision than adjustment for weight. The only manipulation is adjustment of the height of the balance so that the plummet sinks to the right depth. This permits, at any time, to directly read percentage of soil in suspension with easy computation of diameter of the particle by Stoke's law.

5.3.2 *Apparatus*

5.3.2.1 *Plummet balance* — Figure 8 illustrates the basic components. The plummet balance consists of a base with three levelling screws over which an upright pillar is fixed. A light weight pointer beam mounted with the help of steel pivot and jewel bearings on to the scale arm. At the end of this scale arm a scale shall be fixed. The pointer shall be allowed on to move over the scale. The scale arm shall be fixed on two blocks acting as guides to move on the upright pillar. A pinion knob and a rack and pinion arrangement facilitates easy movement of this scale arm assembly to move up and down as desired.

The pointer has two adjusting screws allowing the adjustment of the zero reading. A plummet made of perspex with a string and hook for hanging to the pointer shall be provided. This plastic plummet shall weigh 3 gm in water. A plumb bob shall be provided on the scale arm carrier for adjustment of the level of the instrument.

5.3.2.2 *Glass measuring cylinders* — Two 1 000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1 000 ml volume.

5.3.2.3 *Thermometer* — to cover the range up to 50°C accurate up to 0·5°C.

5.3.3 *Procedure* — *see* Fig. 8.

5.3.3.1 Initial setting and adjustment level the instrument with the help of plumb bob and levelling screws. Two rider weights provided with the apparatus shall be used for checking calibration and for any adjustment. The weight marked 100 when hung on to the hook provided for hanging the plummet on the beam should read 100 and when the weight marked zero is hung the pointer should read zero. If adjustments are necessary at any time to obtain 0 and 100 readings, adjusting screws shall be used for changing the range and the other screw for setting the zero. Then the plummet shall be hooked to the beam after lowering in a container filled with distilled water. The pinion knob is then operated to bring the centre of the plummet at a depth of 9 cm or any other specified depth at which the usual readings are taken. Make a mark on the string. If the pointer does not read zero then adjust the screw. Do not tamper with the adjustment of the screw for doing this adjustment. The balance is now ready for use.

5.3.3.2 *Pre-treatment of soil* — The material retained on the 75 micron IS Sieve is oven dried and analysed as specified in **4.3.2.1**. The pretreatment is done as per the procedure as in **5.2.4**.

5.3.3.3 *Dispersion of soil* — The procedure is same as in **5.2.4.2**.

5.3.3.4 *Sedimentation* — A rubber bung shall be inserted into the mouth of the measuring cylinder which shall then be shaken vigorously and finally be inverted end over the end. Immediately after the shaking has ceased the measuring cylinder is placed on the stand of the plummet balance and the stop watch is started. This marks the beginning of sedimentation.

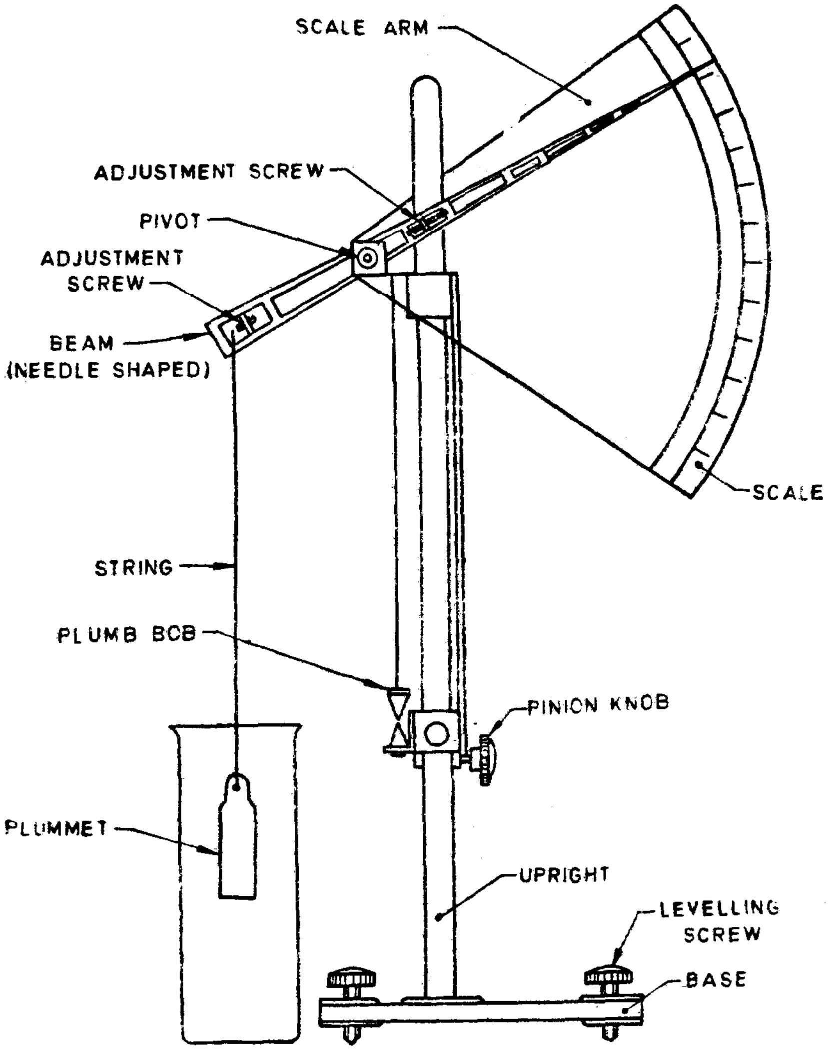

FIG. 8 DETAILS OF PLUMMET BALANCE

5.3.3.5 *Data* — The plummet then shall be lowered into the suspension and hooked on to the balance. The plummet is brought to the present depth by turning the pinion. The percentage of soil in suspension is directly read by the pointer and noted down at half, one, two, four minutes and subsequently at further intervals lasting over up to six to seven hours. The balance is sufficiently sensitive to allow readings to be made to the nearest percentage unit in 2 percent suspensions.

5.3.3.6 *Computations* — Particle diameter D in mm is computed as detailed below for each of the percentages read out by the pointer;

$$D\,(\text{ mm }) = k\sqrt{\frac{Z_c\,(\text{ cm })}{t\,(\text{ min })}}$$

where

Z_c = effective depth of immersion of the plummet which is the depth in cm, from the surface of the suspension to centre of the plummet, that is, predetermined distance (say 9 cm) from the mark on the string to centre of the plummet;

t = time in minutes when pointer readings are taken. Time intervals are adjusted such that square root of time can directly be computed; and

k = coefficient from Fig. 9 to aid in solving Stoke's equation for known temperature condition and specific gravity of particles either determined or assumed (range 2·65 to 2·8).

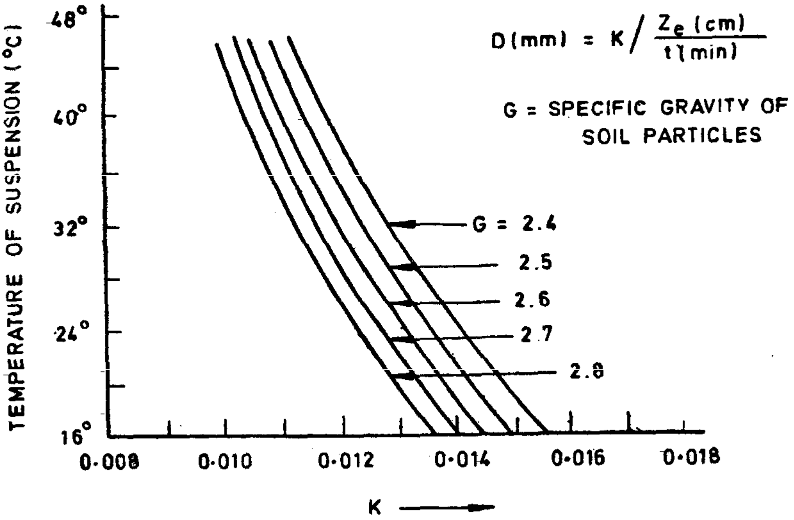

FIG. 9 CHART FOR AID IN SOLVING STOKES EQUATION

6. REPORT

6.1 The results of the grain size analysis shall be reported in a suitable form. A recommended *pro forma* is given in Appendix A. A grain size distribution curve shall be drawn on a semi-logarithmic chart, plotting particle size on the log scale against percentage finer than the corresponding size on the ordinary scale. A chart for showing grain size distribution is shown in Fig. 10.

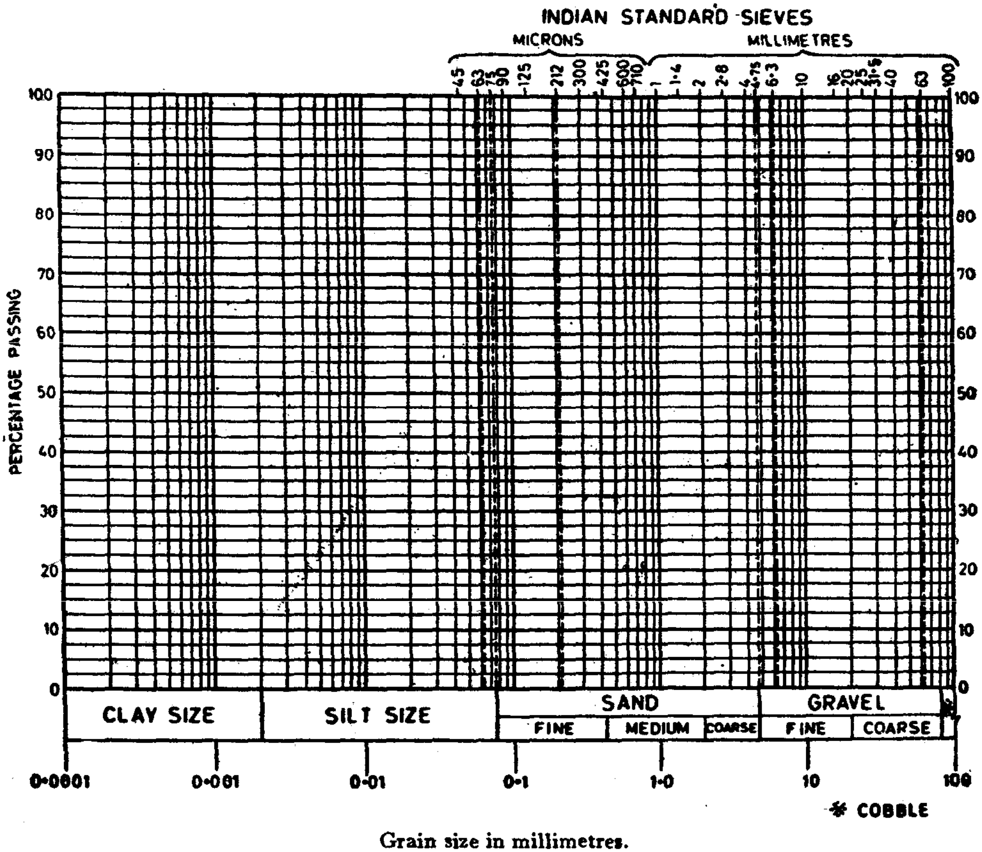

Fig. 10 Chart for Recording Grain Size Distribution

APPENDIX A

(*Clause* 6.1)

FORM FOR THE RECORD OF RESULTS OF GRAIN SIZE ANALYSIS

PROJECT . ... DETAILS OF SOIL SAMPLE..........

SIEVE ANALYSIS OF FRACTION RETAINED ON 4·75-mm IS SIEVE

Weight of total soil sample taken for analysis..

Water content..

IS Sieve Designation	Mass of Soil Retained + Mass Container	Mass of Container	Mass of Soil Retained	Cumulative Mass Retained	Soil Retained as Percentage of Soil Taken	Soil Passing as Percentage of Soil Taken	Combined Percentage Passing as Percentage of Total Soil Sample

SIEVE ANALYSIS OF FRACTION PASSING 4·75-mm IS SIEVE BUT RETAINED ON 75-MICRON IS SIEVE

Mass of partial sample taken for analysis...... ....

Water content..

IS Sieve Designation	Mass of Soil Retained +Mass of Container	Mass of Container	Mass of Soil Retained	Cumulative Mass Retained	Soil Retained as Percentage of Partial Soil Taken	Soil Passing as Percentage of Partial Soil Sample Taken for Analysis	Combined Percentage Passing as Percentage of Total Soil Sample

ANALYSIS OF SOIL PASSING 75-MICRON IS SIEVE

Mass of air dry soils (W_s) ....

Water content of air dry soil (w) ....

Mass of ovendry soil after pre-treatment (W_b) ....

Loss in mass in pre-treatment in percent ....

Pipette Analysis

Specific gravity of soil ....

Volume of suspension taken in pipette (V_p) ....

Depth at which sample was taken ....

Mass of dispersing agent in the volume of suspension sampled ....

Date	Time Elapsed Before Sampling	Temperature of Suspension	Mass of Container + Oven Dry Soil Fraction	Mass of Bottle	Mass of Solid Material in Bottle in Volume V_p	Mass of Solid Material in 500 ml	Correct Mass of Soil Material in 500 ml	Diameter D of Soil Grain in mm	Percentage Finer than D as Percentage of W_b	Combined Percentage Finer than D as Percentage of Total Soil Sample

Hydrometer Analysis

Hydrometer No. ....

Meniscus correction (C_m) ....

Temperature correction (M_t) ....

Dispersing agent correction (x) ....

Density of soil G ....

$$W = \frac{100\,G}{W_b\,(G-1)}(R_h + M_t - x)\ (\text{percent})$$

Date	Time	Temperature	Elapsed Time	Hydrometer Reading R'_h	Corrected Hydrometer Reading $R_h = R'_h + C_m$	Equipment Diameter, D (mm)	$R_h + M_t - x$	Percentage of Particles Finer than D, W Percentage	Combined Percentage of Finer than D as Percentage of Total Sample

(*Continued from page* 2)

Members	*Representing*
Assistant Research Officer (IRI)	Irrigation Department, Government of Uttar Pradesh, Roorkee
Assistant Research Officer (IRRI)	Irrigation Department, Government of Punjab, Chandigarh
Shri A. K. Chaturvedi	Ministry of Defence (Engineer-in-Chief's Branch)
Shri P. Verdarjan (*Alternate*)	
Deputy Director Research (GE-III)	Ministry of Railways
Joint Director Research (GE-I) (*Alternate*)	
Director (CSM & RS)	Central Soil and Materials Research Station, New Delhi
Deputy Director (CSM & RS) (*Alternate*)	
Shri H. K. Guha	Geologists Syndicate Private Limited, Calcutta
Shri N. N. Bhattacharya (*Alternate*)	
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Dr S. C. Handa (*Alternate*)	
Shri M. D. Nair	Associated Instruments Manufacturers (I) Private Limited, New Delhi
Prof T. S. Nagaraj (*Alternate*)	
Shri P. Jaganatha Rao	Central Road Research Institute (CSIR), New Delhi

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‡.

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*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

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*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

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*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‡.

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*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

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*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:

$$\text{Plasticity index } (I_p) = \text{liquid limit } (w_L) - \text{plastic limit } (w_p).$$

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.

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*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:

$$\text{Liquidity index } (I_L) = \frac{w_0 - w_p}{I_p}$$

where

w_0 = 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:

$$\text{Consistency index } (I_c) = \frac{w_L - w_0}{I_p}$$

where

w_L = liquid limit of the soil,
w_0 = 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 ....
Details of soil sample ....
Natural water content ....
History of soil sample ....
Period of soaking of soil sample before test ....

Date ....
Room Temperature ....

	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

AMENDMENT NO. 1 OCTOBER 1982

TO

IS:2720(Part VII)-1980 METHODS OF TEST FOR SOILS

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

(Second Revision)

Alteration

(*Page 4, clause 3.1*) - Substitute the following for the existing:

'3.1 Moulds - It shall conform to IS:10074-1982§.'

Addenda

[*Page 4, foot-note with mark*(‡)] - Add the following foot-note after the existing:

'§Specification for compaction mould assembly for light and heavy compaction test for soils.'

(BDC 23)

Reprography Unit, ISI, New Delhi, India

AMENDMENT NO. 2 JULY 1984
TO
IS:2720(Part 7)-1980 METHODS OF TEST FOR SOILS
PART 7 DETERMINATION OF WATER CONTENT-DRY DENSITY RELATION USING LIGHT COMPACTION

(Second Revision)

Alterations

(*Page 4, clause 0.2, Note*) - Substitute 'IS:2720 (Part 8)-1983*' *for* 'IS:2720(Part VIII)-1974*'.

(*Page 4, foot-note with '*' mark*) - Substitute the following for the existing:

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

(*Page 5, clause 3.7, line 1; clause 5.1.1, line 1*) Substitute '19 mm' *for* '20 mm'.

(*Page 6, clause 5.1.4, line 2; clause 5.2*(a), *line 2*) - Substitute '19 mm' *for* '20 mm'.

(*Page 6, clause 5.3, lines 2 and 3*) - Substitute '37.5 mm' *for* '40' mm at both places.

(*Page 7, Note 2, lines 2 and 4*) - Substitute '19 mm' *for* '20 mm' occurring at both places.

(*Page 7, clause 6.2, formula*) - Substitute the following for the existing formula:

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

(BDC 23)

Reprogrpahy Unit, ISI, New Delhi, India

NOTE — The method of test based on heavy compaction is covered in IS : 2720 (Part VIII)-~~1974[*]~~. 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 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 - Cylindrical Metal Moulds - shall conform to IS 10074 (1982)

~~3.1 Cylindrical Metal Mould — It shall be in accordance with relevant Indian Standards on specification of compaction mould.~~

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.

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[*] Methods of test for soils: Part VIII Determination of water content-dry density relation using heavy compaction (*first revision*).

[†] Rules for rounding off numerical values (*revised*).

[‡] Glossary of terms and symbols relating to soil engineering (*first revision*).

3.7 Sieve — 4·75-mm and ~~20~~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 a ~~20~~19-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 ~~20~~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

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

†Specification for compaction rammer for soil testing.

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 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 ~~20~~-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 ~~20~~-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 ~~40~~ mm size, the 2 250 ml mould should be used. A sample weighing about 6 kg and passing the 37.5 ~~40~~-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**.

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*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 ~~20~~ 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 ~~20~~ 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 — γ_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, γ_d in g/ml, shall be calculated from the equation:

$$\gamma_d = \frac{100\gamma_{\cancel{d}m}}{100 + w}$$

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/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.

Indian Standard

METHODS OF TEST FOR SOILS

PART 10 DETERMINATION OF UNCONFINED COMPRESSIVE STRENGTH

(Second Revision)

1 SCOPE

1.1 This Standard (Part 10) describes the method for determining the unconfined compressive strength of clayey soil, undisturbed, remoulded or compacted, using controlled rate of strain.

2 REFERENCES

2.1 The following Indian Standards are the necessary adjuncts to this standard.

IS No.	*Title*
2132 : 1986	Code of practice for thin-walled tube sampling of soils (*second revision*)
2720 (Part 2) : 1973	Methods of test for soils: Part 2 Determination of water content (*second revision*)

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Unconfined Compressive Strength, q_u

It is the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compression test.

NOTE — If the axial compression force per unit area has not reached a maximum value even at 20 percent axial strain, q_u shall be taken as the value obtained at 20 percent axial strain.

4 APPARATUS

4.1 Compression Device

The compression device may be any of the following types:

a) Platfom weighing scale equipped with a screw-jack activated yoke;
b) Hydraulic loading device;
c) Screw jack with a proving ring; and
d) Any other loading device.

All these loading devices shall have sufficient capacity and strain control.

4.2 Proving Ring

The selection of the proving ring shall depend on the following:

> For relatively weak soil with q_u less than 100 KPa (1 kgf/cm^2) load shall be measurable to 1 KPa (·01 kg/cm^2). For soils with q_u equal to or greater than 100 KPa (1 kgf/cm^2) load shall be measurable to the nearest 5 KPa (0·05 kgf/cm^2). The calibration of the proving ring shall be checked frequently, at least once a year.

4.3 Deformation Dial Gauge

Axial deformation of the sample shall be measured with a dial gauge having a least count of 0·01 mm and travel to permit not less than 20 percent axial strain.

4.4 Vernier Callipers

Suitable to measure physical dimensions of the test specimen to the nearest 0·1 mm.

4.5 Timer

Timing device to indicate the elapsed testing time to the nearest second may be used for establishing the rate of strain.

4.6 Oven

Thermostatically controlled, with interior of non-corroding material capable of maintaining the temperature at 110°C ± 5°C.

4.7 Weighing Balances

Suitable for weighing soil specimens specially. Specimens of less than 100 g shall be weighed to the nearest 0·01 g whereas specimens of 100 g or larger shall be weighed to the nearest 0·1 g.

4.8 Miscellaneous Equipment

Specimen trimming and carving tools, remoulding apparatus, water content cans, data sheets, etc, as required.

5 PREPARATION OF TEST SPECIMEN

5.1 The type of soil specimen to be used for test shall depend on the purpose for which it is tested and may be compacted, remoulded or undisturbed.

NOTE — However this test specimen is not suitable for sample containing appreciable quantity of silt and sand.

5.2 Specimen Size

The specimen for the test shall have a minimum diameter of 38 mm and the largest particle contained within the test specimen shall be smaller than 1/8 of the specimen diameter. If after completion of test on undisturbed sample, it is found that larger particles than permitted for the particular specimen size tested are present, it shall be noted in the report of test data under remarks. The height to diameter ratio shall be within 2 to 2·5. Measurements of height and diameter shall be made with vernier callipers or any other suitable measuring device to the nearest 0·1 mm.

5.3 Undisturbed Specimens

Undisturbed specimens shall be prepared from large undisturbed samples or samples secured in accordance with IS 2132 : 1986.

5.3.1 When samples are pushed from the drive sampling tube the ejecting device shall be capable of ejecting the soil core from the sampling tube in the same direction of travel in which the sample entered the tube and with negligible disturbance of the sample. Conditions at the time of removal of the sample may dictate the direction of removal, but the principal concern should be to keep the degree of disturbance negligible.

NOTES

1 Three specimens obtained by trimming and carving from undisturbed soil samples shall be tested.

2 When the sample is ejected horizontally, a curved plate may be provided to butt against the sampling tube such that the ejected specimen slips over it freely. This will avoid bending of the specimen and facilitate bringing specimen to vertical position in many cases.

5.3.2 The specimen shall be handled carefully to prevent disturbance, change in cross section, or loss of water. If any type of disturbance is likely to be caused by the ejection device, the sample tube shall be split lengthwise or be cut off in small sections to facilitate removal of the specimen without disturbance. If possible carved specimen should be prepared in a humid room to prevent, as far as possible, change in water content of the soil.

5.3.3 The specimen shall be of uniform circular cross-section with ends perpendicular to the axis of the specimen.

5.3.4 Specimen of required size may be carved from large undisturbed specimens. When sample condition permits use of a vertical lathe, which will accommodate the total sample, the same may be used as an aid in carving the specimen to the required diameter. Tube specimens may be tested without trimming except for squaring of ends.

5.3.5 Where the prevention of the possible development of appreciable capillary forces is required, the specimens shall be sealed with rubber membranes, thin plastic coatings, or with a coating of grease or sprayed plastic immediately after preparation and during the entire testing cycle.

5.3.6 Representative sample cuttings taken from the tested specimen shall be used for the determination of water content.

5.4 Remoulded Specimen

The specimen may be prepared either from a failed undisturbed specimen or from a disturbed soil sample. In the case of failed undisturbed specimen, the material shall be wrapped in a thin rubber membrane and thoroughly worked with the fingers to assure complete remoulding. Care shall be taken to avoid entrapped air, to obtain a uniform density, to remould to the same void ratio as that of the undisturbed specimen, and to preserve the natural water content of the soil.

5.5 Compacted Specimen

When compacting disturbed material, it shall be done using a mould of circular cross-section with dimensions corresponding to those given in **5.3.** Compacted specimen may be prepared at any predetermined water content and density.

5.5.1 After the specimen is formed, the ends shall be trimmed perpendicular to the long axis and removed from the mould. Representative sample cuttings shall be obtained or the entire specimen shall be used for the determination of water content after the test.

6 PROCEDURE

6.1 The initial length, diameter and weight of the specimen shall be measured and the specimen placed on the bottom plate of the loading device. The upper plate shall be adjusted to make contact with the specimen.

6.2 The deformation dial gauge shall be adjusted to a suitable reading, preferably in multiples of 100. Force shall be applied so as to produce axial strain at a rate of 0·5 to 2 percent per minute causing failure with 5 to 10. The force reading shall be taken at suitable intervals of the deformation dial reading.

NOTE — Up to 6% axial strain force, readings may be taken at an interval of 0·5 mm of the deformation dial reading. After 6% axial strain, the interval may be increased to 1·0 mm and, beyond 12% axial strain it may be increased even further.

6.3 The specimen shall be compressed until failure surfaces have definitely developed, or the stress-strain curve is well past its peak, or until an axial strain of 20 percent is reached.

6.4 The failure pattern shall be sketched carefully and shown on the data sheet or on the sheet presenting the stress-strain plot. The angle between the failure surface and the horizontal may be measured, if possible, and reported.

6.5 The water content of the specimen shall be determined in accordance with IS 2720 (Part 2) : 1973 using samples taken from the failure zone of the specimen.

7 CALCULATIONS AND PLOTTING

7.1 Stress-strain values shall be calculated as follows:

a) The axial strain, e, shall be determined from the following relationship:

$$e = \frac{\triangle L}{L_0}$$

where

$\triangle L$ = the change in the specimen length as read from the strain dial indicator, and

L_0 = the initial length of the specimen.

b) The average cross-sectional area, A, at a particular strain shall be determined from the following relationship:

$$A = \frac{A_0}{1 - e}$$

where

A_0 = the initial average cross-sectional area of the specimen.

c) Compressive stress, σ_0, shall be determined from the relationship:

$$\sigma_c = \frac{P}{A}$$

where

P = the compressive force, and

A = average cross-sectional aera.

7.2 Values of stress σ_0 and strain e obtained from **7.1** shall be plotted. The maximum stress from this plot gives the value of the unconfined compressive strength q_u. In case no maximum occurs within 20 percent axial strain, the unconfined compressive strength shall be taken as the stress at 20 percent axial strain.

7.3 In the case of soils which behave as if the angle of shearing resistance $\phi = 0$ (as in the case of saturated clays under undrained conditions) the undrained shear strength or cohesion of the soil may be taken to be equal to half the unconfined compressive strength obtained from **7.2**.

8 REPORT

8.1 The observations of the test shall be suitably recorded giving details indicated in Annex A. A recommended *pro forma* for the record of observations is given in Annex A.

ANNEX A

(*Clause* 8.1)

PRO FORMA FOR RECORD OF OBSERVATIONS OF UNCONFINED COMPRESSION TEST

Project

Date:

Tested by:

A-1 Details of Soil Somples

- i) Location
- ii) Boring No.
- iii) Depth
- iv) Visual description of soil
- v) Date of sampling

A-2 Details of apparatus used

A-3 Details of load measuring device

A-3.1 Calibration factor

A-4 Details of the soil specimens:

- i) Undisturbed remoulded or compacted
- ii) Specific gravity of the soil

iii) Initial diameter, D_0 ____________________ mm

iv) Initial length, L_0 ____________________ mm

v) Initial area, A_0 ____________________ cm^2

vi) Initial volume, V_0 ____________________ cm^3

vii) Initial mass of the specimen ____________________ g

viii) Initial density ____________________ g/cm^3

ix) Initial water content ____________________ percent

x) Initial degree of saturation ____________________ percent

xi) Where test has been performed at *in situ* density, and water content/maximum dry density ____________ optimum water content

A-5 Observations of compression test

Rate of Strain:

Deformation dial reading	Axial deformation (mm)	Axial strain e	Area (cm^2) $A = \frac{A_0}{1-e}$	Proving ring dial reading	Axial force N (kgf)	Compressive stress KPa (kg/cm^2)	Remark

A-6 Sketch of failed specimen and description of failure:

A-7 Water content of the specimen after test (determined from water content samples taken from the failure zone of the specimen)

A-8 Unconfined compressive strength (q_u) ____________________ KPa

A-9 Undrained shear strength (if applicable) ____________________ KPa

A-10 Remarks

NOTE — Remarks should include observations with reference to **5.2** regarding the maximum particle size in the specimen.

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 16) covers the laboratory method for determination of California Bearing Ratio (CBR).

2. TERMINOLOGY

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

2.1 Standard Load — Load which has been obtained from the test on crushed stone which was defined as having a California Bearing Ratio of 100 percent (*see also* **7.3**).

2.2 California Bearing Ratio (CBR) — The ratio expressed in percentage of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1·25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2·5 and 5 mm. Where the ratio at 5 mm is consistently higher than that at 2·5 mm, the ratio at 5 mm is used.

3. APPARATUS

3.1 Moulds with Base Plate, Stay Rod and Wing Nut — These shall conform to **4.1**, **4.3** and **4.4** of IS : 9669 - 1980‡.

3.2 Collar — It shall conform to **4.2** of IS : 9669 - 1980‡.

3.3 Spacer Disc — It shall conform to **4.4** of IS : 9669 - 1980‡.

3.4 Metal Rammer — As specified in IS : 9198 - 1979§.

3.5 Expansion Measuring Apparatus — The adjustable stem with perforated plates and tripod shall conform to **4.4** of IS : 9669 - 1980‡.

3.6 Weights — This shall conform to **4.4** of IS : 9669 - 1980‡.

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

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

‡Specification for CBR moulds and its accessories.

§Specification for compaction rammer for soil testing.

3.7 Loading Machine — With a capacity of at least 5 000 kg and equipped with a movable head or base which enables the plunger to penetrate into the specimen at a deformation rate of 1·25 mm/min. The machine shall be equipped with a load machine device that can read to suitable accuracy.

NOTE — In the machine priming ring can also be used.

3.8 Penetration Plunger — This shall conform to **4.4** of IS : 9669 - 1980*.

3.9 Dial Gauges — Two dial gauges reading to 0·01 mm.

3.10 Sieves — 47·5 mm IS Sieve and 19 mm IS Sieve [see IS : 460 (Part 1) - 1985†].

3.11 Miscellaneous Apparatus — Other general apparatus, such as a mixing bowl, straightedge, scales, soaking tank or pan, drying oven, filter paper, dishes and calibrated measuring jar.

4. PREPARATION OF TEST SPECIMEN

4.1 The test may be performed on:

a) undisturbed specimens, and

b) remoulded specimens which may be compacted either statically or dynamically.

NOTE — The static method of compaction gives the required density but requires considerable pressure and there is a possibility of the actual density varying with depth though the mean density may be the one desired.

4.2 Undisturbed Specimens — Undisturbed specimens shall be obtained by fitting to the mould, the steel cutting edge of 150 mm internal diameter and pushing the mould as gently as possible into the ground. This process may be facilitated by digging away soil from the outside as the mould is pushed in. When the mould is sufficiently full of soil, it shall be removed by under digging, the top and bottom surfaces are then trimmed flat so as to give the required length of specimen ready for testing. If the mould cannot be pressed in, the sample may be collected by digging at a circumference greater than that of the mould and thus bringing out a whole undisturbed lump of soil. The required size of the sample to fit into the test mould shall then be carefully trimmed from this lump. If the specimen is loose in the mould, the annular cavity shall be filled with paraffin wax thus ensuring that the soil receives proper support from the sides of the mould during the penetration test.

The density of the soil shall be determined either by weighing the soil with mould when the mould is full with the soil, or by measuring the

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*Specification for CBR moulds and its accessories.

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

dimensions of the soil sample accurately and weighing or by measuring the density in the field in the vicinity of the spot at which the sample is collected in accordance with the method specified in IS : 2720 (Part 28) - 1974* or IS : 2720 (Part 29) - 1975†. In all cases, the water content shall be determined in accordance with IS : 2720 (Part 2) - 1973‡.

4.3 Remoulded Specimens — The dry density for a remoulding shall be either the field density or the value of the maximum dry density estimated by the compaction tests [*see* IS : 2720 (Part 7) - 1980§, and and IS : 2720 (Part 8) - 1983||], or any other density at which the bearing ratio is desired. The water content used for compaction should be the optimum water content or the field moisture as the case may be.

4.3.1 *Soil Sample* — The material used in the remoulded specimen shall pass a 19-mm IS Sieve. Allowance for larger material shall be made by replacing it by an equal amount of material which passes a 19-mm IS Sieve but is retained on 4·75-mm IS Sieve.

4.3.2 *Statically Compacted Specimens* — The mass of the wet soil at the required moisture content to give the desired density when occupying the standard specimen volume in the mould shall be calculated. A batch of soil shall be thoroughly mixed with water to give the required water content. The correct mass of the moist soils shall be placed in the mould and compaction obtained by pressing in the displacer disc, a filter paper being placed between the disc and the soil.

4.3.3 *Dynamically Compacted Specimen* — For dynamic compaction, a representative sample of the soil weighing approximately 4·5 kg or more for fine-grained soils and 5·5 kg or more for granular soils shall be taken and mixed thoroughly with water. If the soil is to be compacted to the maximum dry density at the optimum water content determined in accordance with IS : 2720 (Part 7) - 1980§ or IS : 2720 (Part 8)- 1983|| the exact mass of soil required shall be taken and the necessary quantity of water added so that the water content of the soi sample is equal to the determined optimum water content.

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*Methods of test for soils : Part 28 Determination of dry density of soils in-place by the sand replacement method (*first revision*).

†Methods of test for soils : Part 29 Determination of dry density of soils in-place by the core cutter method (*first revision*).

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

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

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

4.3.3.1 The mould with the extension collar attached shall be clamped to the base plate. The spacer disc shall be inserted over the base plate and a disc of coarse filter paper placed on the top of the spacer disc. The soil-water mixture shall be compacted into the mould in accordance with the methods applicable to the 150 mm diameter mould specified in IS : 2720 (Part 7) - 1980* or IS : 2720 (Part 8) - 1983†. If other densities and water contents are desired, they may be used and indicated in the report.

4.3.3.2 The extension collar shall then be removed and the compacted soil carefully trimmed even with the top of the mould by means of a straightedge. Any hole that may then develop on the surface of the compacted soil by the removal of coarse material, shall be patched with smaller size material; the perforated base plate and the spacer disc shall be removed, and the mass of the mould and the compacted soil specimen recorded. A disc of coarse filter paper shall be placed on the perforated base plate, the mould and the compacted soil shall be inverted and the perforated base plate clamped to the mould with the compacted soil in contact with the filter paper.

4.3.4 In both cases of compaction, if the sample is to be soaked, representative samples of the material at the beginning of compaction and another sample of the remaining material after compaction shall be taken for determination of water content. Each water content sample shall weigh not less than about 50 g.

If the sample is not to be soaked, a representative sample of material from one of the cut-pieces of the material after penetration shall be taken to determine the water content. In all cases, the water content shall be determined in accordance with IS : 2720 (Part 2)-1973‡.

5. PROCEDURE

5.1 Test for Swelling

5.1.1 A filter paper shall be placed over the specimen and the adjustable stem and perforated plate shall be placed on the compacted soil specimen in the mould. Weights to produce a surcharge equal to the weight of base material and pavement to the nearest 2·5 kg shall be placed on the compact soil specimen. The whole mould and weights shall be immersed in a tank of water allowing free access of water to the top and bottom of the specimen. The tripod for the expansion measuring

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

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

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

device shall be mounted on the edge of the mould and the initial dial gauge reading recorded. This set-up shall be kept undisturbed for 96 hours noting down the readings every day against the time of reading. A constant water level shall be maintained in the tank through-out the period.

5.1.2 At the end of the soaking period, the change in dial gauge shall be noted, the tripod removed and the mould taken out of the water tank.

5.1.3 The free water collected in the mould shall be removed and the specimen allowed to drain downwards for 15 minutes. Care shall be taken not to disturb the surface of the specimen during the removal of the water. The weights, the perforated plate and the top filter paper shall be removed and the mould with the soaked soil sample shall be weighed and the mass recorded.

NOTE — The swelling test may be omitted if it is unnecessary and the penetration test specified in 5.2 may be carried out directly.

5.2 Penetration Test (*see* Fig. 1) — The mould containing the specimen, with the base plate in position but the top face exposed, shall be placed on the lower plate of the testing machine. Surcharge weights, sufficient to produce an intensity of loading equal to the weight of the base material and pavement shall be placed on the specimen. If the specimen has been soaked previously, the surcharge shall be equal to that used during the soaking period. To prevent upheaval of soil into the hole of the surcharge weights, 2·5 kg annular weight shall be placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weights shall be placed. The plunger shall be seated under a load of 4 kg so that full contact is established between the surface of the specimen and the plunger. The load and deformation gauges shall then be set to zero (In other words, the initial load applied to the plunger shall be considered as zero when determining the load penetration relation). Load shall be applied to the plunger into the soil at the rate of 1·25 mm per minute. Reading of the load shall be taken at penetrations of 0·5, 1·0, 1·5, 2·0, 2·5, 4·0, 5·0, 7·5, 10·0 and 12·5 mm (The maximum load and penetration shall be recorded if it occurs for a penetration of less than 12·5 mm). The plunger shall be raised and the mould detached from the loading equipment. About 20 to 50 g of soil shall be collected from the top 30 mm layer of the specimen and the water content determined according to IS : 2720 (Part 2)-1973*. If the average water content of the whole specimen is desired, water content sample shall be taken from the entire depth of the specimen. The

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

undisturbed specimen for the test should be carefully examined after the test is completed for the presence of any oversize soil particles which are likely to affect the results if they happen to be located directly below the penetration plunger.

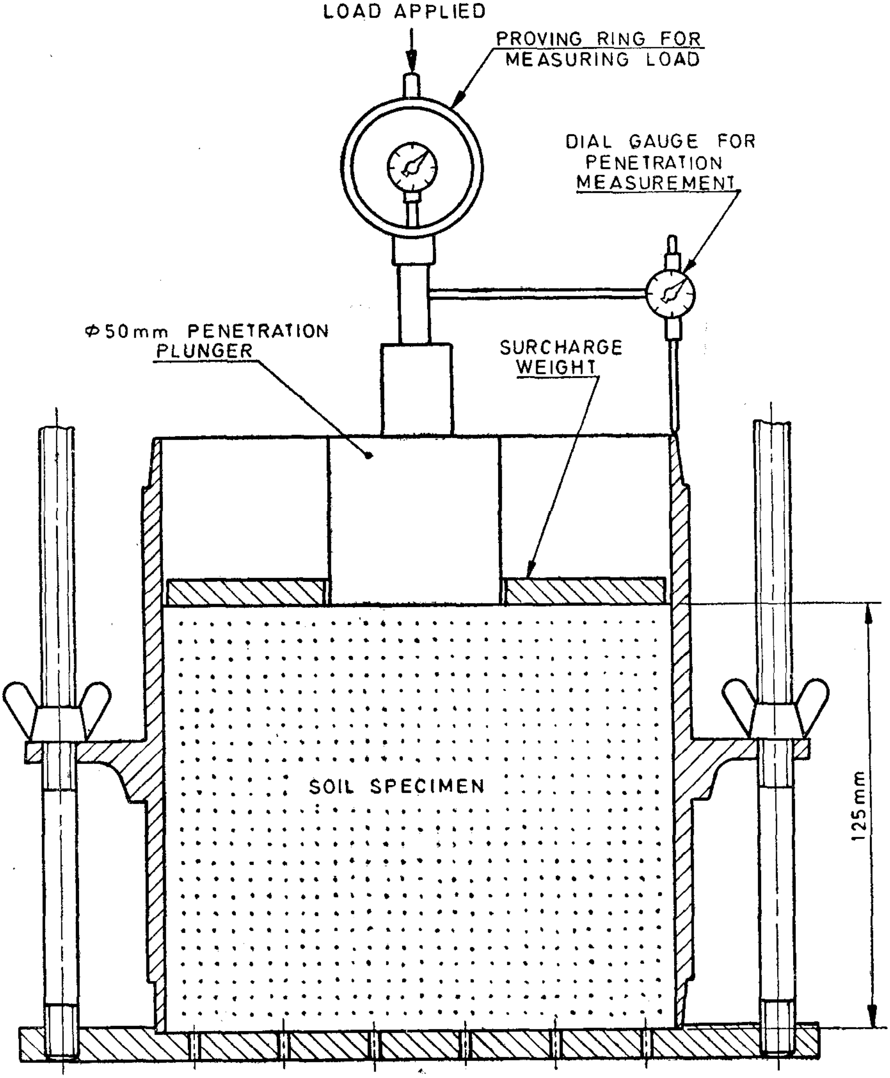


FIG. 1 SET-UP FOR CBR TEST

5.2.1 The penetration test may be repeated as a check test for the rear end of the sample.

6. RECORD OF OBSERVATIONS

6.1 Specimen Data — The specimen data shall be recorded on the data sheet as shown in Appendix A. Apart from soil identification, etc, this includes the condition of the specimen at the time of testing, type of compaction adopted, the amount of soil fraction above 20 mm that has been replaced and the water content and density determinations before and after the mould has been subjected to soaking.

6.2 Penetration Data — The readings for the determination of expansion ratio and the load penetration data shall be recorded in the data sheet as shown in Appendix B.

7. CALCULATION

7.1 Expansion Ratio — The expansion ratio based on tests conducted as specified in **5.1** shall be calculated as follows:

$$\text{Expansion ratio} = \frac{d_f - d_s}{h} \times 100$$

where

d_f = final dial gauge reading in mm,

d_s = initial dial gauge reading in mm, and

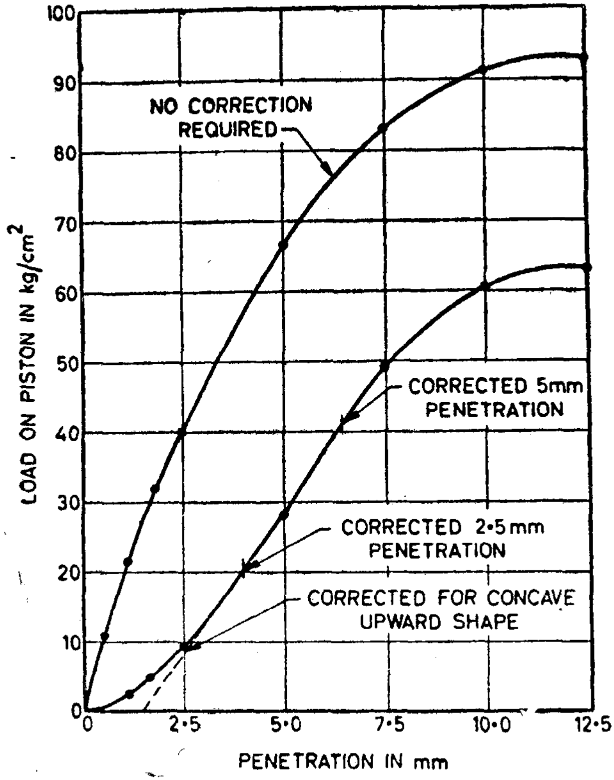
h = initial height of the specimen in mm.

The expansion ratio is used to qualitatively identify the potential expansiveness of the soil.

7.2 Load Penetration Curve — The load penetration curve shall be plotted (*see* Fig. 2). This curve is usually convex upwards although the initial portion of the curve may be convex downwards due to surface irregularities. A correction shall then be applied by drawing a tangent to the point of greatest slope and then transposing the axis of the load so that zero penetration is taken as the point where the tangent cuts the axis of penetration. The corrected load-penetration curve would then consist of the tangent from the new origin to the point of tangency on the re-sited curve and then the curve itself, as illustrated in Fig. 2.

7.3 California Bearing Ratio — The CBR values are usually calculated for penetrations of 2·5 and 5 mm. Corresponding to the penetration value at which the CBR values is desired, corrected load value shall be taken from the load penetration curve and the CBR calculated as follows:

$$\text{California Bearing Ratio} = \frac{P_T}{P_S} \times 100$$



Penetration Depth (1) mm	*Unit Standard Load* (2) kg/cm²	*Total Standard Load* (3) kgf
2·5	70	1 370
5·0	105	2 055

FIG. 2 CORRECTION LOAD PENETRATION CURVES

where

P_T=corrected unit (or total) test load corresponding to the chosen penetration from the load penetration curve, and

P_S=unit (or total) standard load for the same depth of penetration as for P_T taken from the table given in Fig. 2

Generally, the CBR value at 2·5 mm penetration will be greater than that at 5 mm penetration and in such a case, the former shall be taken as the CBR value for design purposes. If the CBR value corresponding to a penetration of 5 mm exceeds that for 2·5 mm, the test shall be repeated. If identical results follow, the CBR corresponding to 5 mm penetration shall be taken for design.

8. PRESENTATION OF RESULTS

8.1 The results of the CBR test are presented as the CBR value and the expansion ratio.

APPENDIX A

(*Clause* 6.1)

CALIFORNIA BEARING RATIO TEST

SPECIMEN DATA

PROJECT :	TEST NO. :
SAMPLE NO. :	DATE :
SOIL IDENTIFICATION :	TEST BY
CONDITION OF SPECIMEN AT TEST :	UNDISTURBED/REMOULDED/ SOAKED/UNSOAKED
TYPE OF COMPACTION :	Static/Dynamic Compaction Light/Heavy Compaction

Soil Fraction above 20 mm replaced——kg.

Water Content	Before soaking field	After test		
		Top	Centre	Bottom
Can No.				
Wt of can+wet soil (g)				
Wt of can+dry soil (g)				
Wt of water (g)				
Wt of can (g)				
Wt of dry soil (g)				
Water content (%)				

Condition of Specimen	Before Soaking	After Soaking
Wt of mould+soil (kg)		
Wt of mould (kg)		
Wt of soil (kg)		
Volume of the specimen (cc)		
Bulk density (g/cc)		
Average water content (%)		
Dry density (g/cc)		

APPENDIX B

(*Clause* 6.2)

SOIL MECHANICS LABORATORY CALIFORNIA BEARING RATIO TEST

PENETRATION DATA

Surcharge weight used = kg

	Test 1		Test 2	
Penetration	Load Measuring Device Reading	Load (kg)	Load Measuring Device Reading	Load (kg)

CBR of specimen at 2·5 mm penetration =
CBR of specimen at 5·0 mm penetration =
CBR of specimen = percent
Expansion Ratio
Surcharge Weight used (kg) =
Period of soaking (days) =
Initial height of specimen, h (mm) =
Initial dial gauge reading, d_s (mm) =
Final dial gauge reading, d_f (mm) =

$$\text{Expansion ratio} = \frac{d_f - d_s}{h} \times 100 =$$

Remarks:

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Indian Standard
METHODS OF TEST FOR SOILS
PART XXVIII DETERMINATION OF DRY DENSITY OF SOILS IN-PLACE, BY THE SAND REPLACEMENT METHOD
(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part XXVIII) (First Revision) was adopted by the Indian Standards Institution on 21 February 1974, 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 comparative studies of the results, the Indian Standards Institution is bringing out this Indian Standard methods of test for soils (IS : 2720) which will be published in parts. This part [IS : 2720 (Part XXVIII)] deals with the determination of dry density of soil, in-place, by the sand replacement method. 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.

0.2.1 This standard was originally published in 1966. In this revision the sieve size for defining fine-grained soils has been changed to 2 mm. An appendix has been added for the determination of water content and dry density of medium- and coarse-grained soils containing appreciable gravel fraction.

0.3 This standard is divided into two sections. Section 1 prescribes the method suitable for fine- and medium-grained soils using the small sand pouring cylinder; Section 2 lays down the method which uses the large sand pouring cylinder and is suitable for fine-, medium- and coarse-grained soils containing stones which make the test of Section 1 difficult to perform.

0.3.1 For the purpose of tests described in this standard soils shall be grouped as shown below:

Fine-grained soils	Soils containing not less than 90 percent passing a 2·0-mm IS Sieve (*see* IS : 460-1962*)
Medium-grained soils	Soils containing not less than 90 percent passing a 20-mm IS Sieve (*see* IS : 460-1962*)
Coarse-grained soils	Soils containing not less than 90 percent passing a 40-mm IS Sieve (*see* IS : 460-1962*)

0.4 The other standards so far published relating to the determination of density of soil in-place are as follows:

IS : 2720 (Part XXIX)-1966 Methods of test for soils: Part XXIX Determination of dry density of soils in-place by the core cutter method

IS : 2720 (Part XXXIII)-1971 Methods of test for soils: Part XXXIII Determination of density in-place by the ring and water replacement method

IS : 2720 (Part XXXIV)- 1972 Methods of test for soils: Part XXXIV Determination of density of soil in-place by the rubber-baloon method

0.5 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. This has been met by basing the standard on the following publications:

BS 1377 : 1961 Methods of testing soils for civil engineering purposes. British Standards Institution.

INDIA. MINISTRY OF IRRIGATION AND POWER. CBIP Publication No. 42. Standards for testing soils. 1963. Central Board of Irrigation and Power, New Delhi.

0.6 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†.

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*Specification for test sieves (*revised*).

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

SECTION I METHOD SUITABLE FOR FINE- AND MEDIUM-GRAINED SOILS : SMALL POURING CYLINDER METHOD

1. SCOPE

1.1 This method covers the determination, in-place, of the dry density (in g/cm^3 or kg/m^3) of natural or compacted fine- and medium-grained soils for which a small sand-pouring cylinder is used. The method is applicable to layers not exceeding 150 mm in thickness (*see* Note).

NOTE — With granular materials having little or no cohesion, particularly when they are wet, there is a danger of errors in the measurement of dry density by this method. These errors are caused by the slumping of the sides of the excavated density hole and always result in an over-estimation of the density.

2. APPARATUS

2.1 Small Sand-Pouring Cylinder — similar in essential details to that shown in Fig. 1.

2.2 Tools for Excavating Holes — suitable tools, such as a scraper tool similar to that shown in Fig. 2 to make a level surface; bent spoon, dibber shown in Fig. 3.

2.3 Cylindrical Calibrating Container — with an internal diameter of 100 mm and an internal depth of 150 mm (*see* Note 1 under **4.2.2**) of the type illustrated in Fig. 4 fitted with a flange approximately 50 mm wide and about 5 mm thick surrounding the open end. The volume of the container should be given to an accuracy of 0·25 percent.

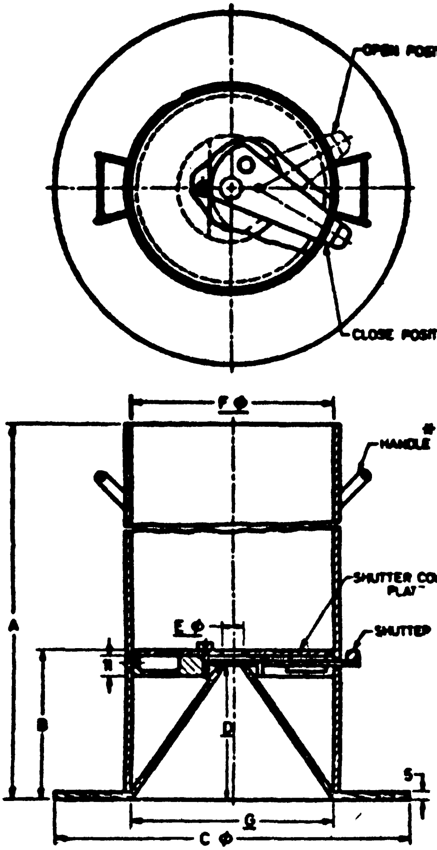
2.4 Balance — accurate to 1 g.

2.5 Plane Surface: Glass or Perspex Plate or Other Plane Surface — about 450 mm square and 9 mm thick or larger.

2.6 Metal Containers — to collect excavated soil. A convenient size is one about 150 mm diameter and 200 mm deep with a removable cover.

2.7 Cylindrical Steel Core-Cutter — of steel, 127·4 ± 0·1 mm long and 100 mm ± 0·1 mm internal diameter with a wall thickness of 3 mm bevelled at one end. One suitable type is illustrated in Fig. 5. The cutter shall be kept adequately greased.

2.8 Metal Tray with Hole — 300 mm square and 40 mm deep with a 100 mm hole in the centre.



*The handle may be required for large pouring cylinder only.

Pouring Cylinder Size	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Capacity in Litres*
Small (for fine- and medium-grained soils)	380	85	200	75	13 ±0·1	115	115	3
Large (for fine-, medium- and coarse-grained soils)	610	175	350	160	25 ±0·1	215	215	16·5

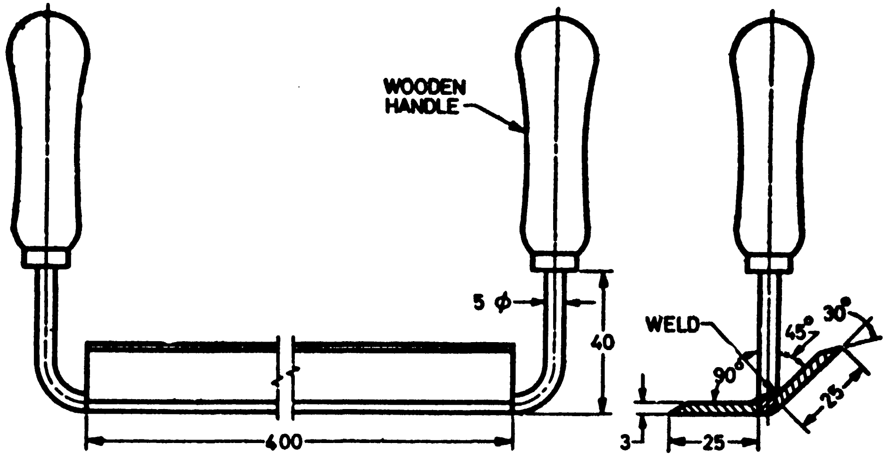
NOTE 1 — This design has been found satisfactory, but alternative designs may b employed, provided that the essential requirements are fulfilled.

NOTE 2 — Essential dimensions are underlined.

NOTE 3 — Tolerance on essential dimensions ±1 mm.

All dimensions in millimetres.

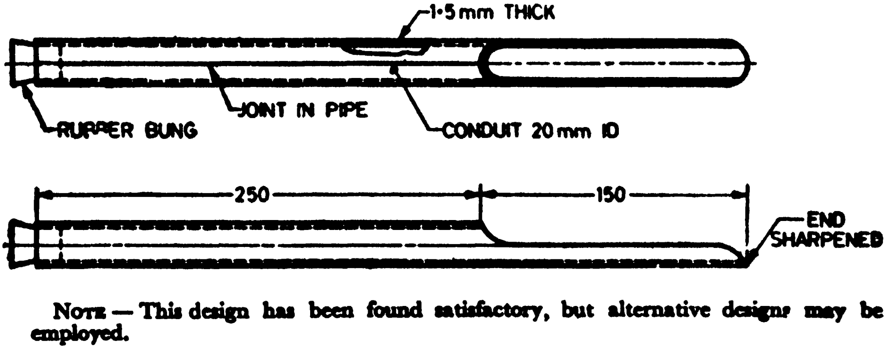
FIG. 1 SAND-POURING CYLINDER FOR THE DETERMINATION OF DENSITY



NOTE — This design has been found satisfactory, but alternative designs may be employed.

All dimensions in millimetres.

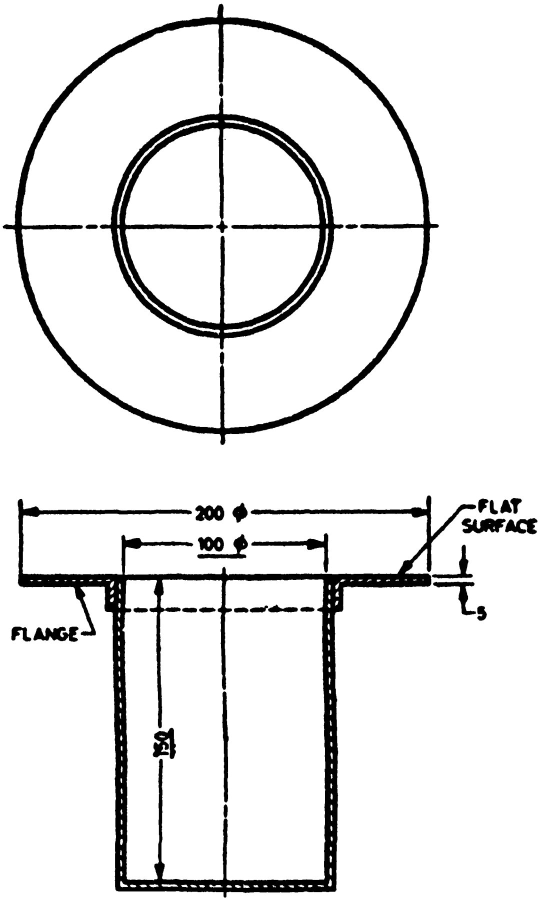
FIG. 2 SCRAPER FOR LEVELLING SURFACE OF SOIL



NOTE — This design has been found satisfactory, but alternative designs may be employed.

All dimensions in millimetres.

FIG. 3 DIBBER FOR DIGGING DENSITY HOLES



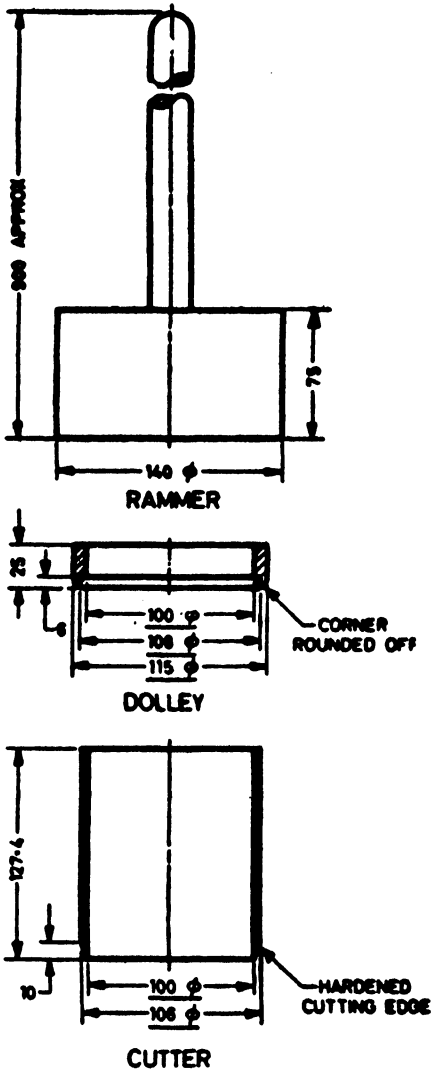
Note 1 — This design has been found satisfactory, but alternative designs may be employed, provided that the essential requirements are fulfilled.

Note 2 — Essential dimensions are underlined.

Note 3 — Tolerance on essential dimensions ± 0·1 mm.

All dimensions in millimetres.

Fig. 4 Calibrating Container for Use with Small Pouring Cylinder



All dimensions in millimetres.

NOTE 1 — These designs have been found satisfactory, but alternative designs may be employed, provided that the essential requirements are fulfilled.

NOTE 2 — Essential dimensions are underlined.

NOTE 3 — Tolerance on essential dimensions ± 0·1 mm.

FIG. 5 CORE-CUTTER APPARATUS FOR SOIL DENSITY DETERMINATION

3. MATERIAL (SAND)

3.1 Clean, uniformly graded natural sand passing the 1·00-mm IS Sieve and retained on the 600-micron IS Sieve shall be used. It shall be free from organic matter, and shall have been oven dried and stored for a suitable period to allow its water content to reach equilibrium with atmospheric humidity (*see* Note).

NOTE — Generally a storage period, after oven drying, of about 7 days is sufficient for the water content of the sand to reach equilibrium with the atmospheric humidity. The sand should not be stored in air-tight containers and should be thoroughly mixed before use. If sand is salvaged from holes in compacted soils after carrying out the test, it is advisable to sieve, dry and store this sand again before it is used in further sand replacement tests.

4. PROCEDURE

4.1 Calibration of Apparatus

4.1.1 The method given in **4.1.1.1** to **4.1.1.4** shall be followed for the determination of the weight of sand in the cone of the pouring cylinder.

4.1.1.1 The pouring cylinder shall be filled so that the level of the sand in the cylinder is within about 10 mm of the top. Its total initial weight (W_1) shall be found and shall be maintained constant throughout the tests for which the calibration is used. A volume of sand equivalent to that of the excavated hole in the soil (or equal to that of the calibrating container) (*see* Note 1 under **4.2.2**) shall be allowed to run out of the cylinder under gravity. The shutter on the pouring cylinder shall then be closed and the cylinder placed on a plane surface, such as a glass plate.

4.1.1.2 The shutter on the pouring cylinder shall be opened and sand allowed to run out. When no further movement of sand takes place in the cylinder the shutter shall be closed and the cylinder removed carefully.

4.1.1.3 The sand that has filled the cone of the pouring cylinder (that is,' the sand that is left on the plane surface) shall be collected and weighed to the nearest gram.

4.1.1.4 These measurements shall be repeated at least three times and the mean weight (W_2) taken.

4.1.2 The method described in **4.1.2.1** to **4.1.2.3** shall be followed for the determination of the bulk density of the sand (γ_s).

4.1.2.1 The internal volume (V) in ml of the calibrating container shall be determined from the weight of water contained in the container when filled to the brim (*see* Note 1 under **4.2.2**). The volume may also be calculated from the measured internal demensions of the container.

4.1.2.2 The pouring cylinder shall be placed concentrically on the top of the calibrating container after being filled to the constant weight (W_1) as in **4.1.1.1**. The shutter on the pouring cylinder shall be closed during this operation. The shutter shall be opened and sand allowed to run out. When no further movement of sand takes place in the cylinder the shutter shall be closed. The pouring cylinder shall be removed and weighed to the nearest gram.

4.1.2.3 These measurements shall be repeated at least three times and the mean weight (W_3) taken (*see* Note).

NOTE — Since variations in atmospheric humidity affect the water content of the sand, and hence its bulk density, the calibration should be made (or at least checked) during each day's work. To overcome the effects of slight variations in grading and particle shape between batches of sand, each batch should be sampled and calibrated.

4.2 Measurement of Soil Density — The following method shall be followed for the measurement of soil density.

4.2.1 A flat area, approximately 450 mm square, of the soil to be tested shall be exposed and trimmed down to a level surface preferably with the aid of the scraper tool.

4.2.2 The metal tray with a central hole shall be laid on the prepared surface of the soil with the hole over the portion of the soil to be tested. The hole in the soil shall then be excavated using the hole in the tray as a pattern, to the depth of the layer to be tested up to a maximum of 150 mm (*see* Note 1). The excavated soil shall be carefully collected, leaving no loose material in the hole and weighed to the nearest gram (W_w). The metal tray shall be removed before the pouring cylinder is placed in position over the excavated hole.

The following alternative method shall be used for fine-grained cohesionless soils:

The steel core cutter shall be pressed evenly and carefully into the soil until its top edge is flush with the levelled surface. Soil to a depth of 100 mm (*see* Note 1) within the core cutter shall then be excavated by means of suitable tools. The excavated soil shall be carefully collected and weighed to the nearest gram (W_w). The core cutter shall remain in position during the remainder of the testing procedure.

NOTE 1 — If for any reason it is necessary to excavate the holes to depths other than 150 mm, the calibrating container should be replaced by one, the depth of which is the same as the hole excavated or its effective depth should be reduced to that of the hole excavated.

NOTE 2 — Care shall be taken in excavating the hole to see that the hole is not enlarged by levering the dibber against the side of the hole, as this will result in lower densities being recorded.

4.2.3 The water content (W) of the excavated soil shall be determined by the method specified in IS : 2720 (Part II)-1973*. Alternatively the whole of the excavated soil may be dried and weighed (W_d).

4.2.4 The pouring cylinder filled to the constant weight (W_1) as in **4.1.1** shall be so placed that the base of the cylinder covers the hole concentrically. The shutter on the pouring cylinder shall be closed during this operation. The shutter shall then be opened and sand allowed to run out into the hole. The pouring cylinder and the surrounding area shall not be vibrated during this period. When no further movement of sand takes place the shutter shall be closed. The cylinder shall be removed and weighed to the nearest gram (W_4) (*see* Note).

NOTE — It is necessary to make a number of repeated determinations (at least three) and to average the results, since the dry density of the soil varies appreciably from point to point. The number of determinations should be such that an additional one would make no significant difference to the average.

5. CALCULATIONS

5.1 The weight of sand (W_a) in g, required to fill the calibrating container shall be calculated from the following formula:

$$W_a = W_1 - W_3 - W_2$$

where

W_1 = weight of pouring cylinder and sand before pouring into calibrating container in g,

W_3 = mean weight of cylinder with residual sand after pouring into calibrating container and cone in g, and

W_2 = mean weight of sand in cone in g.

5.2 The bulk density of the sand (γ_s) in kg/m^3 shall be calculated from the formula:

$$\gamma_s = \frac{W_a}{V} \times 1\,000$$

where

V = volume of calibrating container in ml.

5.3 The weight of sand (W_b) in g, required to fill the excavated hole shall be calculated from the following formula:

$$W_b = W_1 - W_4 - W_2$$

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

where

W_1 = weight of cylinder and sand before pouring into hole in g,

W_4 = weight of cylinder and sand after pouring into hole and cone in g, and

W_2 = mean weight of sand in cone in g.

5.4 The bulk density γ_b, that is, the weight of the wet soil per cubic metre shall be calculated from the following formula:

$$\gamma_b = \frac{W_w}{W_b} \times \gamma_s \text{ kg/m}^3$$

where

W_w = weight of soil excavated in g,

W_b = weight of sand required to fill the hole in g, and

γ_s = bulk density of sand in kg/m^3.

5.5 The dry density γ_d, that is, the weight of the dry soil shall be calculated from the following formula:

$$\gamma_d = \frac{100\,\gamma_b}{100 + w} \text{ kg/m}^3$$

or

$$\gamma_d = \frac{W_d}{W_b} \times \gamma_s \text{ kg/m}^3$$

where

w = water content of the soil in percent,

W_d = weight of dry soil from the hole in g, and

W_b = weight of sand required to fill the hole in g.

6. REPORTING OF RESULTS

6.1 The following values shall be reported:

a) Dry density of soil in kg/m^3 to the nearest whole number. The dry density may also be calculated and reported in g/cm^3 correct to the second place of decimal.

b) Water content of the soil in percent reported to two significant figures.

6.2 The method used for obtaining the test results shall be stated as the small pouring cylinder method. The use of steel core cutter, if made, shall also be mentioned.

6.3 The results of the test shall be recorded suitably. A recommended pro forma for the record of the test results is given in Appendix A.

SECTION 2 METHOD SUITABLE FOR FINE-, MEDIUM- AND COARSE-GRAINED SOILS: LARGE POURING CYLINDER METHOD

7. SCOPE

7.1 This method covers the determination, in-place, of the dry density (in g/cm^3 or kg/m^3) of natural or compacted soil containing stones which make the test of Section 1 difficult to perform. This is an alternative method of test to Section 1 for fine- and medium-grained soils and should be used instead of that test for layers exceeding 150 mm but not exceeding 250 mm in thickness (*see* Note under **1.1**).

8. APPARATUS

8.1 Large Sand-Pouring Cylinder — similar in the essential details to that shown in Fig. 1.

8.2 Tools for Excavating Holes — suitable tools, such as bent spoon, dibber (*see* Fig. 3), large screw driver, pointed steel rod about 300 mm long and 5 to 10 mm dia with a wooden handle.

8.3 Cylindrical Calibrating Container — with internal diameter of 200 mm and an internal depth of 250 mm (*see* Note 1 under **4.2.2**) of the type illustrated in Fig. 6 fitted with a flange 75 mm wide and about 5 mm thick surrounding the open end. The volume of the container should be given to an accuracy of 0·15 percent.

8.4 Balance — accurate to 1 g.

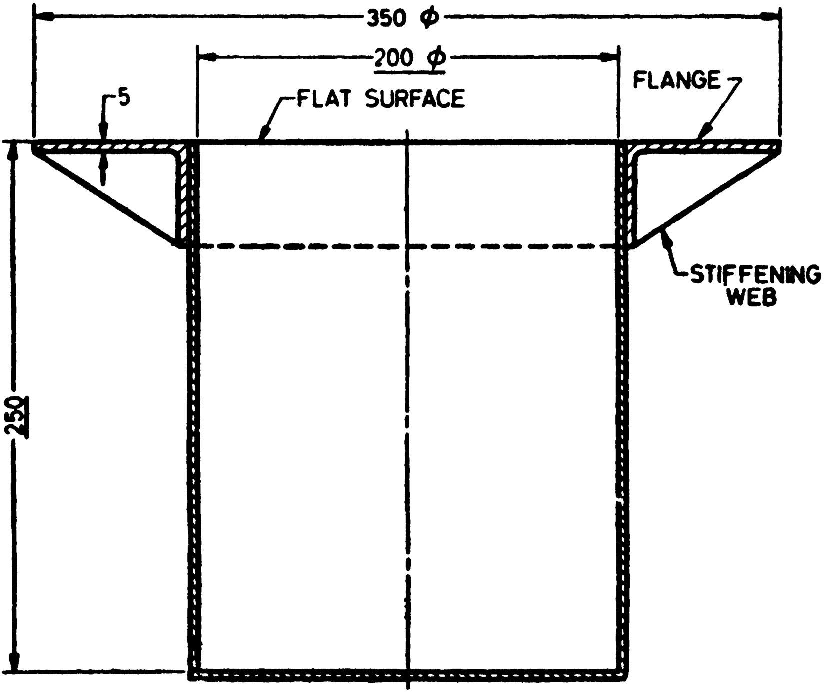
8.5 Plane Surface — a glass plate or other plane surface about 600 mm square and 10 mm thick or larger.

8.6 Metal Containers — to collect the excavated soil and to take the supply of sand to fill the pouring cylinder. This may be provided with a suitable cover.

8.7 Metal Tray with Central Hole — a metal tray 450 mm square and 50 mm deep with a 200 mm dia hole in the centre.

9. MATERIAL (SAND)

9.1 Clean, uniformly graded natural sand passing the 1·00-mm IS Sieve and retained on the 600-micron IS Sieve shall be used. It shall be free from organic matter, and shall have been oven dried and stored for a suitable period to allow its water content to reach equilibrium with atmospheric humidity (*see* Note under **3.1**).



NOTE 1 — This design has been found satisfactory, but alternative designs may be employed, provided that the essential requirements are fulfilled.

NOTE 2 — Essential dimensions are underlined.

NOTE 3 — Tolerance on essential dimensions ±0·1 mm.

All dimensions in millimetres.

FIG. 6 CALIBRATING CONTAINER FOR USE WITH LARGE POURING CYLINDER AND IN THE HAND SCOOP METHOD

10. PROCEDURE

10.1 Calibration of Apparatus

10.1.1 The method described in **10.1.1.1** to **10.1.1.4** shall be followed for the determination of the weight of sand in the cone of the pouring cylinder.

10.1.1.1 The pouring cylinder shall be filled with a given initial weight of sand (W_1). This weight shall be maintained constant throughout the tests for which the calibration is used (*see* Note). A volume of sand equivalent to that of the excavated hole in the soil (or equal to that of the calibrating container) shall be allowed to run out of the pouring cylinder under gravity. The shutter on the pouring cylinder shall then be closed and the cylinder placed on the plane surface.

NOTE — The total weight of the pouring cylinder and sand is large, so that the method of filling and weighing is to weigh the sand in two or three containers and tip it into the pouring cylinder before using. Care shall be taken to see that the same constant initial weight as is used in calibrating the apparatus is used for each density measurement. Sufficient sand should be used to leave about 4 to 5 kg of sand in the pouring cylinder after the test is completed.

10.1.1.2 The shutter on the pouring cylinder shall be opened and sand allowed to run out. When no further movement of sand takes place in the cylinder the shutter shall be closed and the cylinder removed carefully.

10.1.1.3 The sand that has filled the cone of the pouring cylinder shall be collected and weighed to the nearest 0·1 percent of its total weight.

10.1.1.4 These measurements shall be repeated at least three times and mean weight (W_2) taken.

10.1.2 The method described in **10.1.2.1** to **10.1.2.3** shall be followed for the determination of the bulk density of the sand (γ_s).

10.1.2.1 The internal volume (V) in ml of the calibrating container shall be determined by the weight of water contained in the container when filled to the brim (*see* Note under **10.2.2**).

10.1.2.2 The calibrating container should stand on a large tray during the procedure to collect the sand overflowing from the cone when the cylinder is removed. The pouring cylinder shall be placed concentrically on the top of the calibrating container and filled with the constant weight of sand (W_1) as in **10.1.1.1**. The shutter on the pouring cylinder shall be closed during this operation. The shutter shall be opened and the sand allowed to run out. When no further movement of the sand takes place in the cylinder the shutter shall be closed. The pouring cylinder shall be removed and the sand remaining in it weighed to the nearest 0·1 percent of its initial weight.

10.1.2.3 These measurements shall be repeated at least three times, and the mean weight (W_3) taken (*see* Note under **4.1.2.3**).

10.2 The method given in **10.2.1** to **10.2.4** shall be followed for the measurement of soil density.

10.2.1 A flat area, approximately 60 cm^2, at the place at which the soil is to be tested shall be exposed and trimmed down to a level surface.

10.2.2 The metal tray with a central hole shall be laid on the prepared surface of the soil with the hole over the portion of the soil to be tested. The hole in the soil shall then be excavated using the hole in the tray as a pattern, to the depth of the layer to be tested up to a maximum of 250 mm

(*see* Note). The excavated soil shall be carefully collected, leaving no loose material in the hole, and weighed to the nearest gram (W_w). The metal tray shall be removed before the pouring cylinder is placed in position over the excavated hole.

> Note — *If for any reason it is necessary to excavate holes to depths other than 250 mm the calibrating container should be replaced by one, the depth of which is the same as the hole excavated or its effective depth reduced to that of the hole excavated.*

10.2.3 A representative sample of the excavated soil shall be placed in an air-tight container and its water content (w) determined by the method specified in IS : 2720 (Part II)-1973*.

10.2.4 The pouring cylinder filled with the constant weight of sand (W_1) as in **10.1.1.1**, shall be placed so that the base of the cylinder covers the hole concentrically. The shutter on the pouring cylinder shall be closed during this operation. The shutter shall then be opened and sand allowed to run out. When no further movement of the sand takes place the shutter shall be closed. The cylinder shall be removed and the sand remaining in it weighed to the nearest 0·1 percent of its initial weight (W_4) (*see* Note under **4.2.4**).

11. CALCULATIONS

11.1 The calculations shall be done as laid down in **5**.

11.2 For medium- and coarse-grained soils containing appreciable gravel fraction (plus 4·75-mm IS Sieve) the water content and dry density shall be determined as given in Appendix B.

12. REPORTING OF RESULTS

12.1 The results shall be reported as specified in **6** except that the method used for obtaining the test results shall be stated as large pouring cylinder method.

12.2 The results of the test shall be recorded suitably. A recommended pro forma for the record of test results is given in Appendix A.

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

APPENDIX A

(*Clauses* 6.3 *and* 12.2)

DETERMINATION OF DRY DENSITY OF SOIL, IN-PLACE, BY SAND REPLACEMENT

(Small Pouring Cylinder/Large Pouring Cylinder)

A-1. The test results for the two methods, namely, small pouring cylinder and large pouring cylinder may be tabulated as given below using the appropriate symbols and words in each case:

Project:	Tested by:
Location:	Date:

State whether steel core cutter was used.

Calibration

1. Mean weight of sand in cone (of pouring cylinder) (W_2), in g	
2. Volume of calibrating container (V), in ml	
3. Weight of sand (+ cylinder) before pouring (W_1), in g	
4. Mean weight of sand (+ cylinder) after pouring (W_3), in g	
5. Weight of sand to fill calibrating container ($W_a = W_1 - W_3 - W_2$), in g	
6. Bulk density of sand $\gamma_s = \frac{W_a}{V} \times 1\,000$ kg/m^3	

Measurement of Soil Density

1. Determination No.
2. Weight of wet soil from hole (W_w), in g
3. Weight of sand (+ cylinder) before pouring (W_1), in g
4. Weight of sand (+ cylinder) after pouring (W_4), in g
5. Weight of sand in hole ($W_b = W_1 - W_4 - W_2$), in g
6. Bulk density $\gamma_b = \frac{W_w}{W_b} \times \gamma_s$ kg/m^3
7. Water content container No.
8. Weight of soil for water content determination, in g
9. Weight of oven dried soil, in g
10. Water content (w), percent
11. Dry density $\gamma_d = \frac{100\gamma_b}{100+w}$ kg/m^3

APPENDIX B

(*Clause* 11.2)

DETERMINATION OF WATER CONTENT AND DRY DENSITY OF MEDIUM- AND COARSE-GRAINED SOILS CONTAINING APPRECIABLE GRAVEL FRACTION (PLUS 4·75-mm IS SIEVE)

B-1. IN-PLACE BULK DENSITY

B-1.1 The in-place bulk density (γ_b) of the soil shall be determined as described in Section 2.

B-2. PROCEDURE FOR DETERMINATION OF VOLUME AND WATER CONTENT

B-2.1 After obtaining the wet weight (W_w) of the total material removed from the hole, the soil shall be separated into plus 4·75-mm fraction

(gravel) and minus 4·75 mm fraction by the 4·75-mm IS Sieve. This should be done rapidly to avoid loss of water.

Note — If this test is for construction control, the fraction passing the 4·75-mm IS Sieve should be placed in an air-tight container for further tests.

B-2.2 The fraction retained on the 4·75-mm IS Sieve (gravel) shall be washed on the sieve using a minimum of water, blotted dry with a towel to a wet surface-dry condition and weighed (W_g).

B-2.3 The volume of the gravel (V_g) in a wet surface-dry condition, shall then be determined by displacement of water from a siphon-container from which the over-flow can be measured, or by weighing in air and in water. The specific gravity (G_g) of the gravel particles should then be computed.

Note — For construction control, the volume of gravel need not be measured every time a test is made. After several tests have shown that the specific gravity of the gravel from a particular source is virtually constant, the specific gravity may be assumed and the volume computed.

B-2.4 The wet gravel (W'_g) shall be placed in an oven and the oven-dry weight W'g and water content (w_g) shall be determined.

B-2.5 The water content (w_s) in percent of the soil fraction passing the 4·75-mm IS Sieve shall also be determined by oven-drying a representative sample.

B-3. CALCULATIONS

B-3.1 Further calculations should be carried out as follows:

a) In-place bulk density γ_b $= \dfrac{W_w}{\text{Volume of hole}}$

b) Wet weight of minus 4·75-mm soil $= W_w - W_g$

c) Volume of minus 4·75-mm soil $= \text{Volume of hole} - V_g$

d) Wet density of minus 4·75-mm soil $= \cancel{\dfrac{(a)}{(b)}}$ (b) / (c)

e) Dry weight of minus 4·75-mm soil $= \dfrac{\cancel{(a)}\,(b)}{1 + w_s/100}$

f) Dry density of minus 4·75-mm soil $= \dfrac{\cancel{(c)}\,(d)}{1 + w_s/100}$

g) Dry weight of total material (soil + gravel) $= W'_g + \cancel{(d)}\,(e)$

h) Water content (w_T) of total material, percent $= \dfrac{W_w - (g)\cancel{(f)}}{\cancel{(f)}\,(g)} \times 100$

j) Percentage of gravel in the material on a dry weight basis $= \dfrac{W'_g}{\cancel{(f)}\,(g)} \times 100$

k) Dry density of the total material $= \dfrac{\gamma_b}{1 + w_T/100}$

Indian Standard

METHODS OF TEST FOR SOILS

PART XXIX DETERMINATION OF DRY DENSITY OF SOILS IN-PLACE BY THE CORE-CUTTER METHOD

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part XXIX) (First Revision) was adopted by the Indian Standards Institution on 22 September 1975, 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 establishing uniform procedure for the determination of different characteristics of soils and also for facilitating comparative studies of the results, the Indian Standards Institution has brought out this Indian Standard methods of test for soils (IS:2720) which is published in parts. This part [IS:2720 (Part XXIX)-1975] deals with the determination of dry density of soil in-place by using a core-cutter. The in-place density of soil is needed for stability analysis, for the determination of the degree of compaction of compacted soil, etc. The core-cutter method covered by this part is suitable for fine-grained soils free from aggregations. It is less accurate than the sand-replacement method and is not recommended, unless speed is essential or unless the soil is well compacted. Other parts relating to in-place determination of density of soils are:

Part XXVIII Determination of dry density of soils in-place by the sand replacement method

Part XXXIII Determination of the density in-place by the ring and water replacement method

Part XXXIV Determination of density of soil in-place by the rubber-baloon method

0.2.1 This standard was first published in 1966. In this revision, the test has been made applicable to soil 90 percent of which passes the 4·75-mm IS Sieve. The dimensions and requirements of the core-cutter have been modified. Detailed requirements for the steel rammer required for the test have been spelt out.

0.3 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. This has been met by basing the standard on the following publications:

BS 1377:1974 Methods of testing soils for civil engineering purposes. British Standards Institution.

INDIA. MINISTRY OF IRRIGATION AND POWER. CBIP Publication No. 42. Standards for testing soils, 1963. Central Board of Irrigation and Power, Delhi.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, 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 XXIX) covers the method for the determination of the in-place density of fine-grained natural or compacted soils free from aggregates using a core-cutter.

1.1.1 For the purpose of the tests described in this standard, a soil shall be termed as fine-grained soil if not less than 90 percent of it passes a 4·75-mm IS Sieve.

2. APPARATUS

2.1 Cylindrical Core-Cutter — of seamless steel tube, 130 mm long (*see* Note 1) and 10 cm internal diameter, with a wall thickness of 3 mm, bevelled at one end, of the type illustrated in Fig. 1. The cutter shall be kept properly greased or oiled.

NOTE 1 — *Length of Cutter* — If the average density over a smaller depth is required then the appropriate length of cutter should be used.

NOTE 2 — Where situations permit, for quality control purposes smaller size cutters have also been used.

2.2 Steel Dolley — 2·5 cm high and 10 cm internal diameter with a wall thickness of 7·5 mm with a lip to enable it to be fitted on top of the core-cutter (*see* Fig. 1).

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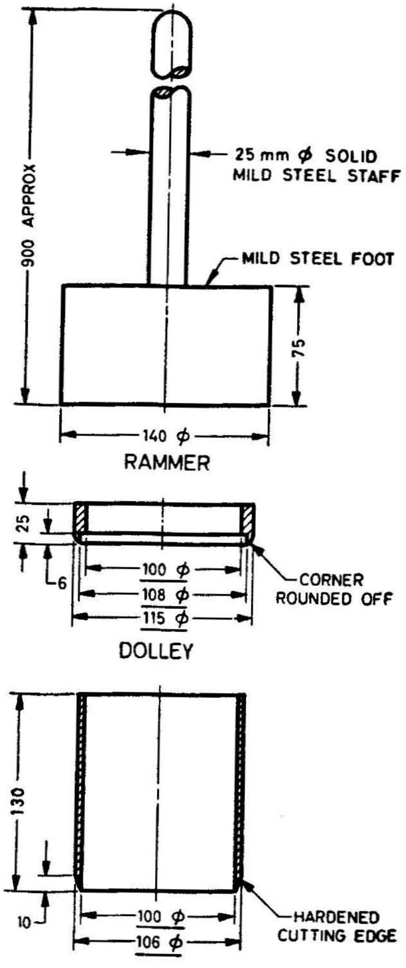
*Rules for rounding off numerical values (*revised*).



NOTE 1 — These designs have been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled.

NOTE 2 — Essential dimensions are underlined. (Tolerance on all essential dimensions shall be ±0·25 mm).

All dimensions in millimetres.

FIG. 1 CORE-CUTTER APPARATUS FOR SOIL DENSITY DETERMINATION

2.3 Steel Rammer — With solid mild steel foot 140 mm diameter and 75 mm height with a concentrically screwed 25 mm diameter solid mild steel staff. The overall length of the rammer including the foot as well as the staff should be approximately 900 mm. The rammer (foot and staff together) should weigh approximately 9 kg (*see* Fig. 1).

2.4 Balance — Accurate to 1 g.

2.5 Palette Knife — A convenient size is one having a blade approximately 20 cm long and 3 cm wide.

2.6 Steel Rule

2.7 Grafting Tool or Spade or Pick Axe

2.8 Straight Edge — A steel strip about 30 cm long, 2·5 cm wide and 3 to 5 mm thick, with one bevelled edge will be suitable.

2.9 Apparatus for Extracting Samples from the Cutter — Optional.

2.10 Apparatus for Determination of Water Content — In accordance with IS : 2720 (Part II)-1973*.

3. PROCEDURE

3.1 The internal volume (V_c) of the core-cutter in cubic centimetres shall be calculated from its dimensions which shall be measured to the nearest 0·25 mm.

3.2 The cutter shall be weighed to the nearest gram (W_c).

3.3 A small area, approximately 30 cm square of the soil layer to be tested shall be exposed and levelled. The steel dolly shall be placed on top of the cutter and the latter shall be rammed down vertically into the soil layer until only about 15 mm of the dolly protrudes above the surface, care being taken not to rock the cutter (*see* Note). The cutter shall then be dug out of the surrounding soil, care being taken to allow some soil to project from the lower end of the cutter. The ends of the soil core shall then be trimmed flat to the ends of the cutter by means of the straight edge.

NOTE — The cutting edge should be kept sharp. The cutter should not be used in stony soils.

3.4 The cutter containing the soil core shall be weighed to the nearest gram (W_s).

3.5 The soil core shall be removed from the cutter and a representative sample shall be placed in an air-tight container and its water content (w) determined as in IS:2720 (Part II)-1973*.

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

NOTE — It is necessary to make a number of repeat determinations (at least three) and to average results, since the dry density of the soil varies appreciably from point to point. The number of determinations should be such that an additional one would not alter the average significantly.

4. CALCULATIONS

4.1 The bulk density γ_b; that is, the weight of the wet soil per cubic centimetre shall be calculated from the following formula:

$$\gamma_b = \frac{W_s - W_c}{V_c}, \text{ g/cm}^3$$

where

W_s = weight of soil and core-cutter in g,

W_c = weight of core-cutter in g, and

V_c = volume of core-cutter in cm^3.

4.2 The dry density γ_d, that is, the weight of the dry soil per cubic centimetre shall be calculated from the following formula:

$$\gamma_d = \frac{100 \ \gamma_b}{100 + w}, \text{ g/cm}^3$$

where

γ_b = bulk density (*see* **4.1**), and

w = water content of the soil (percent) to two significant figures.

5. REPORTING OF RESULTS

5.1 The results of the test shall be recorded in a suitable form. A recommended *proforma* for the record of the results of this test is given in Appendix A.

5.2 The following values shall also be reported:

a) Dry density of the soil to second place of decimal in g/cm^3, and

b) Water content of the soil (percent) to two significant figures.

APPENDIX A

(*Clause* 5.1)

DETERMINATION OF DRY DENSITY OF SOIL IN-PLACE (CORE-CUTTER METHOD)

A-1. The test results shall be tabulated as follows:

PROJECT: TESTED BY:

LOCATION: DATE:

1. Determination No.	1	2	3
2. Weight of core-cutter + wet soil (W_s), in g			
3. Weight of core-cutter (W_c), in g			
4. Weight of wet soil ($W_s - W_c$), in g			
5. Volume of core-cutter (V_c), in cm³			
6. Bulk density ($\gamma_b = \frac{W_s - W_c}{V_c}$), in g/cm³			
7. Water content container No.			
8. Weight of container with lid (W_1), in g			
9. Weight of container with lid and wet soil (W_2), in g			
10. Weight of container with lid and dry soil (W_3), in g			
11. Water content (w), in percent $w = \frac{W_2 - W_3}{W_3 - W_1} \times 100$			
12. Dry density ($\gamma_d = \frac{100\ \gamma_b}{100 + w}$), in g/cm³			