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Indian Standard

METHODS OF TEST FOR SOILS

PART 17 LABORATORY DETERMINATION OF PERMEABILITY

(First Revision)

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*Shri Verma acted as Chairman in the meeting in which this Indian Standard was finalized.

Indian Standard

METHODS OF TEST FOR SOILS

PART 17 LABORATORY DETERMINATION OF PERMEABILITY

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 30 January 1986, 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 procedures for the determination of different characteristics of soils and also for facilitating the comperative study of the results, Indian Standards Institution is bringing out Indian Standard method of test for soils (IS : 2720) being published in various parts. This part (Part 17) deals with the method for the laboratory determination of the coefficient of permeability of soils.

0.3 The knowledge of the permeability is essential in the solution of many engineering problems involving flow of water through soils such as:

a) Dewatering and drainage of excavations, back fills and subgrades;

b) Determining yield of water bearing strata;

c) Assessing seepage through the body of earth dams; and

d) Computing losses from canals.

In addition since the soil may be used to inhibit flow of water, the permeability of soil governs the type of soil to be used.

0.4 This Standard (Part 17) covers both constant head and falling head tests as used for most of the soil. The laboratory determination of permeability of granular soil by constant head method is covered in separate part (Part 36). This part was first published in 1966. Based on the experience gained in the use of this test in the past 20 years by various laboratories, this standard has been revised. The principal modifications made are deletion of details of the equipment for testing for which separate

Indian Standard has been formulated (*see* IS : 11209-1985*), giving detailed procedures for the record of the observations as well as calculations for two types of the test and revising the proforma for the record of tests by enlarging to cover more details.

0.5 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.

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1. SCOPE

1.1 This standard (Part 17) covers the methods for laboratory determination of coefficient of permeability of soils using falling head and the constant head methods. This test is recommended for soils with coefficient of permeability in the range 10^{-3} to 10^{-7} cm/s and maximum particle size of 9·5 mm.

2. TERMINOLOGY

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

3. APPARATUS

3.1 The mould assembly (including drainage base and drainage cap) shall conform to IS : 11209-1985*.

3.2 The compaction rammer shall conform to IS : 9198-1979§.

3.3 Set of Stand Pipes — Glass stand pipes for falling head (variable head) test arrangement, varying in diameter from 5 to 20 mm, suitably mounted on stand or otherwise fixed on wall.

3.4 Constant Head Tank — A suitable water reservoir capable or supplying water to the permeameter under constant head for constant head test arrangement.

*Specification for mould assembly for determination of permeability.

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

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

§Specification for compaction rammer for soil testing.

3.5 Vacuum Pump

3.6 Miscellaneous Apparatus — Such as IS sieves, mixing pan, graduated cylinder, metre scale, stop watch, 75-micron wire gauge, thermometer, and a source of de-aired water.

4. PREPARATION OF TEST SPECIMEN

4.1 Disturbed Soil Sample

4.1.1 A 2·5-kg sample shall be taken from a thoroughly mixed air-dried or oven-dried material which has been obtained in accordance with IS:2720 (Part 1)-1983*.

4.1.2 The moisture content of the 2·5-kg sample shall be determined as described in IS:2720 (Part 2)-1973†. The sample shall be placed in an airtight container. The quantity of water to be added to the stored sample to give the desired moisture content shall be computed and spread evenly over the sample, and after thoroughly mixing, the material shall again be placed in the storage container. The moisture content of the sample shall again be determined and the entire process repeated until the actual moisture content is within 0·5 percent of that desired.

4.1.3 The permeameter mould shall be weighed empty to the nearest gram. After greasing lightly the inside of the mould it shall be clamped between the compaction base plate and the extension collar. The assembly shall be kept on a solid base.

4.1.4 The dry density for remoulding of soil samples 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 IS:2720 (Part 8)-1983§] or any other density at which the permeability is desired. The moisture content used for compaction should be the optimum moisture content or the field moisture as the case may be. The compactive effort may be varied to simulate field conditions. Static compaction may also be used where necessary. After completion of compaction the collar, if attached, shall be removed and excess soil trimmed level with the top of the mould. The base shall be detached and the mould full of the compacted specimen shall be weighed.

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*Methods of test for soils: Part 1 Preparation of dry soil samples for various tests (*second revision*).

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

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

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

4.1.5 The mould with the specimen inside shall be assembled to the drainage base and cap having porous discs. The porous discs shall be saturated before assembling the mould.

4.2 Undisturbed Soil Sample — For testing undisturbed soils, undisturbed specimen shall be trimmed in the form of a cylinder not larger than about 85 mm in diameter and having a height equal to that of the mould. The specimen shall be placed centrally over the porous disc of the drainage base fixed to the mould. The annular space between the mould and the specimen shall be filled with an impervious material such as cement slurry or a mixture of 10 percent dry powdered bentonite and 90 percent fine sand by weight to provide sealing between the soil specimen and the mould against leakage from the sides. When using the cement slurry the mould shall be kept on a flat surface other than the porous discs. The mixture shall be compacted using a small tamping rod. The drainage cap shall then be fixed over the top of the mould.

4.3 Saturation — In the case of soils of medium to high permeability the specimen shall be subjected to sufficient head, flow or immersion so as to obtain full saturation. Soils of low permeability require flow under a high head for periods ranging from a day to a week depending upon the permeability and the head. Alternatively, in the case of soils of low permeability the specimen shall be subjected to a gradually increasing vacuum with bottom outlet closed so as to remove to form the soil voids. The vacuum shall be increased to at least 70 cm of mercury which shall be maintained for 15 minutes or more depending upon the soil type. The evacuation shall be followed by a very slow saturation of the specimen with de-aired water from the bottom upwards under full vacuum. When the specimen is saturated both the top and bottom outlets shall be closed.

5. CONSTANT HEAD TEST

5.1 For a constant head test arrangement, the specimen shall be connected through the top inlet to the constant head water reservoir. The bottom outlet shall be opened and when the steady state of flow has been established, the quantity of flow for a convenient time interval shall be collected and weighed or measured. Alternatively, the inlet may be at the bottom and water may be collected from the outlet at the top. The collection of the quantity of flow for the same time interval shall be repeated thrice.

5.2 The linearity (of Darcy's law) between the hydraulic gradient and the average velocity of flow for the soil under test should be established by performing the test over a range of hydraulic gradients. The hydraulic gradients in the permeability test should preferably include the hydraulic gradient likely to occur in the field and any deviation from linearity observed should be noted.

5.3 Record of Observation

5.3.1 The inside diameter and the height of the permeameter are measured and recorded as diameter D and length L of the specimen in Appendix A. The heights H_1 and H_2 are measured to determine the head loss h. The temperature of water T is also measured and recorded.

5.3.2 During the test, observations are made of volume of water, Q collected in a graduated jar in time t and are recorded in col 2 and 3 of Appendix A respectively. The permeability is calculated and recorded in col 4 of Appendix A. Remarks, if any, are entered in col 5 of Appendix A.

5.3.3 For the purpose of getting a quantitative description of the state of the sample, after the test, the weight of wet soil specimen W_t is measured and recorded. Its dry weight W_s is measured after drying for 24 hours. The water content, w is computed and noted. From the knowledge of the specific gravity G_s of specimen and water content w, void ratio e and degree of saturation S are determined.

5.4 Calculations

5.4.1 The permeability k_T at temperature T is calculated as:

$$k_T = \frac{Q}{A\,i\,t}$$

$$k_{27} = k_T \frac{\gamma_T}{\gamma_{27}}$$

in which

k_{27} = permeability at 27°C,

γ_T = coefficient of viscosity at T°C,

γ_{27} = coefficient of viscosity at 27°C,

Q = quantity in cm^3,

A = area of speceimen in cm^2,

i = hydraulic gradient, and

t = time in seconds.

5.4.2 The parameters water content, void ratio and degree of saturation shall be calculated according to IS : 2720 (Part 2)-1973*.

5.4.3 A data sheet with observed data, calculation and result is presented in Appendix A.

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

5.5 Presentation of Results — The values of permeability at T°C and 27°C are reported as a number with units of cm/s. Also reported are corresponding void ratio, degree of saturation and water content.

6. FALLING HEAD TEST

6.1 For a falling head test arrangement the specimen shall be connected through the top inlet to selected stand-pipe. The bottom outlet shall be opened and the time interval required for the water level to fall from a known initial head to a known final head as measured above the centre of the outlet shall be recorded. The stand-pipe shall be refilled with water and the test repeated till three successive observations give nearly same time interval; the time intervals being recorded for the drop in head from the same initial to final values, as in the first determination. Alternatively, after selecting the suitable initial and final heads, h_1 and h_2 respectively, time intervals shall be noted for the head to fall from h_1 to $\sqrt{h_1 h_2}$ and similarly from $\sqrt{h_1 h_2}$ to h_2. The time intervals should be the same; otherwise the observation shall be repeated after refilling the stand-pipe.

6.2 Record of Observation — (*see* Appendix B).

6.2.1 The dimensions of specimen, length L and diameter D, are measured and recorded in Appendix B. Area a of stand-pipe is recorded. The temperature T, of water is also measured and recorded.

6.2.2 During the test, observations are made of initial time t_i, final time t_f, initial head h_1, final head h_2 in stand-pipe and are recorded in col 2 to 5 of Apppndix B respectively. h_1/h_2 and $\log_{10}(h_1/h_2)$ are claculated and recorded in col 6 and 7 of Appendix B respectively. The permeability k_T is calculated and recorded in col 8 of Appendix B. Remarks, if any, are entered in col 9 of Appendix B.

6.2.3 At the end of the test, the weight of wet soil specimen W_t is measured and recorded. Then the sample is dried in the oven for 24 hours and the dry weight W_s is measured and recorded. The water content, W is computed and noted. Void ratio, e, and degree of saturation S are calculated using specific gravity G_s of the specimen and water content, W.

6.3 Calculations

6.3.1 At temperature T of water, the permeability k_T is calculated as

$$k_T = 2{\cdot}303 \frac{aL}{A(t_f - t_i)} \log_{10} \frac{h_1}{h_2}$$

and the permeability at 27°C is given by

$$k_{27} = k_T \frac{\gamma_T}{\gamma_{27}}$$

Other parameters to be calculated are the water content, w, void ratio e and degree of saturation s, shall be determined according to IS : 2720 (Part 2)-1973*.

6.3.2 A data sheet with observation data, calculation and result is presented in Appendix B.

6.4 Presentation of Results

6.4.1 The permeability values at temperatures T and 27°C are reported as numbers with units as cm/s. The state of the sample is also reported in terms of water content, void ratio and degree of saturation.

APPENDIX A

(*Clauses* 5.3 *and* 5.4.2)

RECORD OF OBSERVATION WITH EXAMPLE FOR CALCULATION OF PERMEABILITY BY CONSTANT HEAD METHOD

Project _____ Test No. _____

Sample No. _____ Date _____

Soil Identification _____ Tested by _____

Diameter of specimen (D) _____ cm

Length of specimen (L) _____ cm

Area of specimen (A) = _____ cm^2

Volume of specimen (V) = _____ cm^3

Head Loss $h = H_1 - H_2$ = _____ cm

Hydraulic Gradient $i = h/L$ _____

Temperature of water T = ____ °C

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

Sl No.	Quantity Q cm^3	Time, t seconds	Permeability $k_T = \frac{Q}{A\,i\,t}$ cm/s	Remarks
(1)	(2)	(3)	(4)	(5)

Weight of wet soil specimen after test, W_t = _____ g

Weight of dry soil specimen, W_s = _____ g

Water content, $W = \frac{W_t - W_s}{W_s} \times 100$ = _____ percent

Specific gravity of specimen G_s = _____

Void ratio $e = \frac{VG_s - W_s}{W_s}$ = _____

Degree of saturation $S = \frac{G_s . W}{e}$ = _____ percent

Permeability at 27°C, $k_{27} = \frac{k_T \gamma_T}{\gamma_{27}}$ = _____ cm/s

APPENDIX B

(*Clauses* 6.2 *and* 6.3.2)

RECORD OF OBSERVATION WITH EXAMPLE FOR CALCULATION OF PERMEABILITY BY FALLING HEAD METHOD

Project _____ Test No. _____

Sample No. _____ Date _____

Soil Identification _____ Tested by _____

Diameter of specimen (D) _____ cm

Length of specimen (L) _____ cm^2

Area of specimen (A) = _____ cm^2

Volume of specimen (V) = AL = _____ cm

Area of stand-pipe (a) = _____ cm^2

$$C = 2{\cdot}303 \frac{aL}{A} = \text{\_\_\_\_\_ cm}$$

Temperature of water $T = 34°C$

Sl No.	Initial Time t_1 (seconds)	Final Time t_f (seconds)	Initial Head h_1 (cm)	Final Head h_2 (cm)	h_1/h_2	$\log_{10} \frac{h_1}{h_2}$	$K_T = \frac{\log_{10} \frac{h_1}{h_2}}{C} \frac{}{(t_f - t_1)}$ cm/s	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

Weight of wet soil specimen after the test, W_t = _____ g

Weight of dry soil specimen, W_s = _____ g

Water content, $W = \frac{W_t - W_s}{W_s} \times 100$ = _____ percent

Specific gravity of specimen, G_s = _____

Void ratio, $e = \frac{VG_s - W_s}{W_s}$ = _____

Degree of saturation, $S = \frac{G_s W}{e}$ = _____ percent

Permeability at 27°C, $k_{27} = \frac{k_T \gamma_T}{\gamma_{27}}$ = _____ cm/s

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INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg. m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2