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METHODS OF TEST FOR SOILS

PART XLI MEASUREMENT OF SWELLING PRESSURE OF SOILS

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Indian Standard

METHODS OF TEST FOR SOILS

PART XLI MEASUREMENT OF SWELLING PRESSURE OF SOILS

0. FOREWORD

0.1 This Indian Standard (Part XLI) was adopted by the Indian Standards Institution on 30 December 1977, 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 has brought out this Indian Standard methods of test for soils (IS : 2720) which is published in parts. Fortyone parts of this standard have been published so far. This part IS : 2720 (Part XLI) deals with the method of test for determination of swelling pressure of soils. The main purpose of swelling pressure test is to determine the intrinsic swelling pressure of the expansive soil tested. The expansive clays increase in their volume when they come in contact with water owing to surface properties of these clay types. Light structures founded on these type of clays — popularly known in India as black cotton soil, experience severe structural damage due to the swelling of the subsoil. Since the intrinsic swelling pressure is to be associated with the design of structures against such damages, measurement of swelling pressure assumes importance.

0.3 The swelling pressure is dependent upon several factors namely (a) the type and amount of clay in the soil and the nature of the clay mineral, (b) the initial water content and dry density, (c) the nature of pore fluid, (d) the stress history of the soil including the confining pressure and (e) drying and wetting cycles to which the soils have been subjected to. Besides, the dependence of swelling pressure on volume change makes a precise measurement of swelling pressure difficult.

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*.

1. SCOPE

1.1 This standard covers the laboratory method of conducting one-dimensional swelling pressure test using either fixed or the floating rings on both undisturbed or remoulded soils in the partially saturated condition to determine the swelling pressure of the soil. Two methods, namely, consolidometer method in which the volume change of the soil is permitted and the corresponding pressure required to bring back the soil to its original volume is measured and the constant volume method in which the volume change is prevented and the consequent pressure is measured are covered.

2. TERMINOLOGY

2.0 For the pupose of this standard, the following definition shall apply.

2.1 Swelling Pressure — The pressure which the expansive soil exerts, if the soil is not allowed to swell or the volume change of the soil is arrested.

SECTION I CONSOLIDOMETER METHOD

3. APPARATUS AND EQUIPMENT

3.1 Consolidometer — A device to hold the sample in a ring either fixed or floating with porous stones (or ceramic discs) on each face of the sample. A consolidometer shall also provide means for submerging the sample, for applying a vertical load and for measuring the change in the thickness of the specimen. The provision for fixing of the dial gauge shall be rigid; in no case shall the dial gauge be fixed to a cantilevered arm. Suitable provision shall be made to enable the dial gauge to be fixed in such a way that the dial gauge records accurately the vertical expansion of the specimen.

3.1.1 *Specimen Diameter* — The specimen shall be 60 mm in diameter (specimens of diameters 50, 70 and 100 mm may also be used in special case).

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

3.1.2 *Specimen Thickness* — The specimen shall be at least 20 mm thick in all cases. However, the thickness shall not be less than 10 times the maximum diameter of the grain in the soil specimen. The diameter to thickness ratio shall be a minimum of 3.

3.1.3 *Ring* — The ring shall be made of a material which is non-corrosive in relation to the soil tested. The inner surface shall be highly polished or coated with a thin coating of silicon grease or with a low-friction material. The thickness of the ring shall be such that under assumed hydrostatic stress conditions in the sample the change in diameter of the ring will not exceed 0·03 percent under the maximum load applied during the test. The ring shall have one edge bevelled suitably so that the sample is pressed into the ring with least disturbance. The ring shall be placed with its cutting edge upwards in the consolidometer and clamped with a special clamp which should in no way damage the sharp edge. The clamp should be made circular with central hole equal in diameter of the porous stone and should be perfectly concentric with the sample. The ring shall be provided with a collar of internal diameter same as that of the ring and of effective height 20 mm. The collar shall rest securely on the specimen ring.

3.1.4 *Porous Stones* — The stones shall be of silicon carbide or aluminium oxide and of medium grade. It shall have a high permeability compared to that of the soil being tested. The diameter of the top stone shall be 0·2 to 0·5 mm less than the internal diameter of the ring. The thickness of the stone shall be a minium of 15 mm. The top stone shall be loaded through a corrosion-resistant plate of sufficient rigidity and of minimum thickness 10 mm to prevent breakage of the stone. The loading plate shall have suitable holes for free drainage of water.

3.2 Dial Gauge — accurate to 0·01 mm with a traverse of at least 20 mm.

3.3 Water Reservoir — To keep the soil sample submerged.

3.4 Moisture Room — For storing samples and for preparing samples in climates where there is likelihood of excessive moisture loss during preparation (optional).

3.5 Soil Trimming Tools — Fine wire-saw, knife, spatula, etc for trimming sample to fit into the inside diameter of the consolidometer ring with minimum disturbances.

3.6 Oven — thermostatically controlled oven with interior of non-corroding material to maintain the temperature between 105 and 110°C.

3.7 Desiccator — With any desiccating agent other than sulphuric acid.

3.8 Balance — sensitive to 0·01 g.

3.9 Containers — for water content determination.

4. PREPARATION OF TEST SPECIMEN

4.1 Preparation of Specimen from Undisturbed Soil Samples — The container ring shall be cleaned and weighed empty. From one end of the undisturbed soil sample about 30 mm, or more if desired, of the soil sample, if desired shall be cut off and rejected. The specimen shall be cut off either from the undisturbed tube sample or from block sample the latter generally being more representative of the field conditions. In either case the consolidation ring should be gradually inserted in the sample by pressing with hands and carefully removing the material around the ring. The soil specimen so cut shall project as far as 10 mm on either side of the ring. The specimen shall then be trimmed smooth and flush with the top and bottom of the ring. Any voids in the specimen caused due to removal of gravel or limestone pieces, shall be filled back by pressing lightly the loose soil in the voids, care being taken to see that the specimen is not affected. The container ring shall be wiped clear of any soil sticking to the outside and weighed again with the soil. The whole process should be quick to ensure minimum loss of moisture and if possible shall be carried out in the moisture room. Three representative specimens from the soil trimming shall be taken in moisture content cans and their moisture content determined in accordance with IS : 2720 (Part II)-1973*.

4.2 Preparation of Specimen from Disturbed Soil Samples — In case where it is necessary to use disturbed soil samples the soil sample shall be compacted to the desired (field) density and water content in a standard compaction proctor mould. Samples of suitable sizes are cut from it as given in **4.1**.

NOTE 1 — Since the swelling pressure of the soil is very much influenced by its initial water content and dry density it shall be ensured that in the case of undisturbed soil samples, the specimen shall be collected from the field for test during the driest season of the year, namely, April, May and June, so that the swelling pressure recorded shall be maximum.

In the case of remoulded soil samples, the initial water content shall be at the shrinkage limit or field water content, so that the swelling pressure recorded shall be maximum.

NOTE 2 — The desiccated soil obtained from the field coupled with smaller thickness of consolidation ring make the undisturbed soil specimen always in danger of being disturbed during trimming; hence great care shall be taken to handle the specimen delicately with the least pressure applied to the soil.

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

5. PROCEDURE

5.1 Assembly

5.1.1 The porous stones shall be saturated. All surfaces of the consolidometer which are to be enclosed shall be moistened. The porous stones shall be saturated by boiling in distilled water for at least 15 minutes. The consolidometer shall be assembled with the soil specimen (in the ring) and porous stones at top and bottom of the specimen, providing a filter paper rendered wet (Whatman No. 1 or equivalent) between the soil specimen and the porous stone. The loading block shall then be positioned centrally on the top porous stone.

5.1.2 This assembly shall then be mounted on the loading frame such that, the load when applied is transmitted to the soil specimen through the loading cap. The assembly shall be so centred that the load applied is axial.

5.1.3 In the case of the lever loading system, the apparatus shall be properly counterbalanced. If a jack with load measurements by platform scales is used as the loading system, the tare weight with the empty consolidation apparatus, excluding those parts which will be on top of the soil specimen, which rest on the platform shall be determined before filling the ring with the soil and this tare weight shall be added to the computed scale loads required to give the desired pressures at the time of loading the soil specimen.

5.1.4 The holder with the dial gauge to record the progressive vertical heave of the specimen under no load, shall then be screwed in place and adjusted in such a way that the dial gauge is near the end of its release run, allowing small margin for the compression of the soil, if any.

5.1.5 An initial setting load of 50 gf/cm^2 (this includes the weight of the porous stone and the loading pad) shall be placed on the loading hanger and the initial reading of the dial gauge shall be noted.

5.1.6 The system shall be connected to a water reservoir with the level of water in the reservoir being at about the same level as the soil specimen and water allowed to flow in the sample. The soil shall then be allowed to swell.

5.2 Procedure

5.2.1 The free swell readings shown by the dial gauge under the seating load of 5 kN/m^2 (0·05 kgf/cm^2) shall be recorded at different time intervals. For the purpose of record form 1 given in Appendix A shall be used and the total readings noted at total elapsed time since starting shown therein.

5.2.2 The dial gauge readings shall be taken till equilibrium is reached. This is ensured by making a plot of swelling dial reading *versus* time in hours, which plot becomes asymptotic with abscissa (time scale). The equilibrium swelling is normally reached over a period of 6 to 7 days in general for all expansive soils.

5.2.3 The swollen sample shall then be subjected to consolidation under different pressures as given in form 2 in Appendix A. The compression dial readings shall be recorded till the dial readings attain a steady state for each load applied over the specimen. The consolidation loads shall be applied till the specimen attains its original volume.

6. CALCULATIONS AND REPORT

6.1 The observations shall be recorded suitably. Two forms recommended for recording are given in Appendix A.

6.2 Calculations — The observed swelling dial reading recorded in form 1 of Appendix A shall be plotted with elapsed time as abscissa and swelling dial reading as ordinates on natural scale. A smooth curve shall be drawn joining these points. If the curve so drawn becomes asymptotic with the abscissa, the swelling has reached its maximum and hence the swelling phase shall be stopped, and the consolidation phase shall be started. The compression readings shall be tabulated as in form 2 of Appendix A and a plot of change in thickness of expanded specimen as ordinates and consolidation pressure applied as abscissa in semi-logarithmic scale shall be made. The swelling pressure exerted by the soil specimen under zero swelling condition shall be obtained by interpolation and expressed in kN/m^2 (kgf/cm^2).

SECTION 2 CONSTANT VOLUME METHOD

7. APPARATUS AND EQUIPMENT

7.1 Consolidometer — The consolidometer shall conform to the requirements given in **3.1**.

7.2 Dial Gauge — accurate to 0·002 mm with a traverse of at least 10 mm.

7.3 Moisture Room

7.4 Soil Trimming Tools — shall be in conformity with **3.5**.

7.5 Balance — sensitive to 0·01 g.

7.6 Oven — thermostatically controlled oven with interior if non-corroding material to maintain temperature between 105 to 110°C.

7.7 Desiccator — With any desiccating agent other than sulphuric acid.

7.8 Moisture Content Cans

7.9 Loading Unit of 5 000 kg Capacity — Strain controlled type.

7.10 High Sensitive Proving Ring of 200 kg Capacity

8. PREPARATION OF SOIL SPECIMEN

8.1 Preparation of Specimen from Undisturbed Soil Samples — as specified in **4.1**.

8.2 Preparation of Specimen from Disturbed Soil Samples — as specified in **4.2**.

9. PROCEDURE

9.1 Assembly

9.1.1 The consolidation specimen ring with the specimen shall be kept in between two porous stones saturated in boiling water providing a filter paper (Whatman No. 1 or equivalent) between the soil specimen and the porous stone. The loading block shall then be positioned centrally on the top of the porous stone.

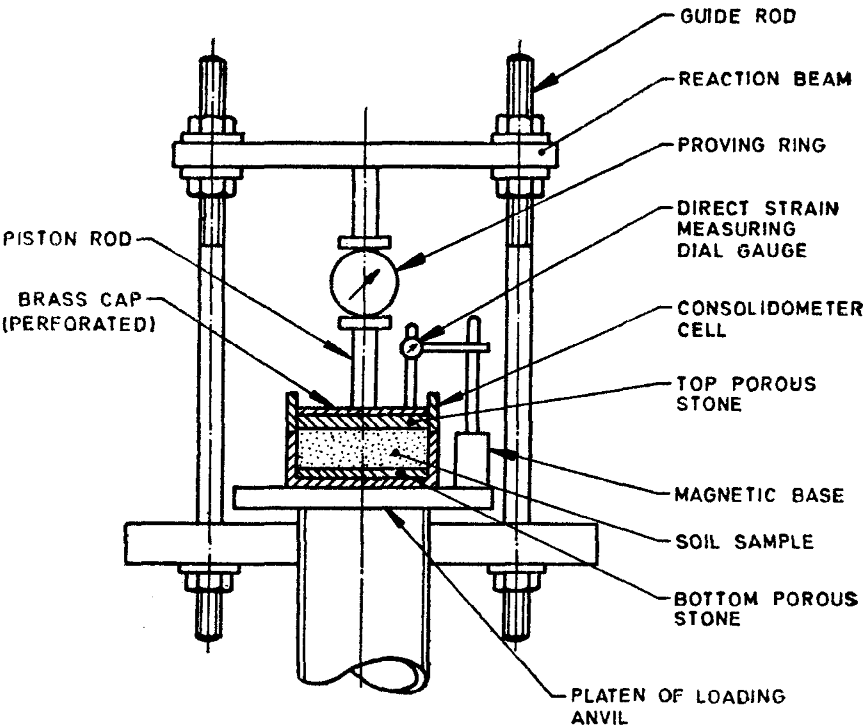
9.1.2 This assembly shall then be placed on the platen of the loading unit as shown in Fig. 1. The load measuring proving ring tip attached to the load frame shall be placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge shall be fitted to the cell. The specimen shall be inundated with distilled water and allowed to swell.

9.2 Detailed Procedure for the Test — The initial reading of the proving ring shall be noted. The swelling of the specimen with increasing volume shall be obtained in the strain measuring load gauge. To keep the specimen at constant volume, the platen shall be so adjusted that the dial gauge always show the original reading. This adjustment shall be done at every 0·1 mm of swell or earlier. The duration of test shall conform to the requirements given in **5.2.2.** The assembly shall then be dismantled and the soil specimen extracted from the consolidation ring to determine final moisture content in accordance with IS : 2720 (Part II)-1973*.

10. CALCULATIONS AND REPORT

10.1 The observations shall be recorded suitably in the form given in Appendix B.

*Determination of water content (*second revision*).



NOTE — The above is only an illustrative set up. Any suitable apparatus which minimises volume changes may be preferred.

FIG. 1 SET-UP FOR MEASURING SWELLING PRESSURE IN THE CONSTANT VOLUME METHOD

10.2 Calculations — The difference between the final and initial dial readings of the proving ring gives total load in terms of division which when multiplied by the calibration factor gives the total load. This when divided by the cross-sectional area of the soil specimen gives the swell pressure expressed in kN/m² (kgf/cm²).

$$\text{Swelling pressure in kN/m}^2\text{ (kgf/cm}^2\text{)} = \frac{\left(\text{Final dial reading} - \text{Initial dial reading}\right)}{\text{Area of the specimen}} \times \text{Calibration factor of proving ring}$$

APPENDIX A

(*Clauses* 5.2.1, 5.2.3, 6.1 *and* 6.2)

SWELLING PRESSURE TEST BY CONSOLIDOMETER METHOD

FORM 1

Project: Dated:

Tested by:

1. Details of soils sample
   i) Location
   ii) Boring No.
   iii) Depth
   iv) Visual description of soil
   v) Liquid limit
      Plasticity index
   vi) Percentage of soil fraction below 0·002 mm

2. Details of soil specimen
   i) Undisturbed or remoulded
   ii) Specific gravity of the soil

NATURAL DENSITY			MOISTURE CONTENT		
Description	Test I	Test II	Description	Before Test	After Test
Weight of container-ring + wet specimen			Weight of container + wet soil		
Weight of container			Weight of container + dry soil		
Diameter of container			Weight of container		
Initial thickness of soil sample			Weight of water		
Wet density in g/ml			Weight of dry soil		

Dry density in g/ml

Moisture content in percent

Date

Time of starting

Elapsed time in hours	Swelling dial reading
0	
0·5	
1	
2	
4	
8	
12	
16	
20	
24	
36	
48	
60	
72	
96	
120	
144	

FORM 2

DATA SHEET FOR SWELL - COMPRESSION TEST

Pressure Increment		Compression	Change in Thickness of Expanded Specimen
in kgf/cm²	in kN/m²		
(0·0-0·05)	0-5		
(0·05-0·10)	5-10		
(0·10-0·25)	10-25		
(0·25-0·50)	25-50		
(0·50-1·00)	50-100		
(1·00-2·00)	100-200		
(2·00-4·00)	200-400		
(4·00-8·00)	400-800		
(8·00-16·00)	800-1 600		

APPENDIX B

(*Clause* 10.1)

SWELL PRESSURE TEST BY CONSTANT VOLUME METHOD

Project: Dated:

Tested by:

1. Details of soil samples
   i) Location
   ii) Boring No.
   iii) Depth
   iv) Visual description of soil
   v) Liquid limit
      Plasticity index
   vi) Percentage of soil fraction
      below 0·002 mm

2. Details of the soil specimen
   i) Undisturbed of remoulded
   ii) Specific gravity of the soil

NATURAL DENSITY			MOISTURE CONTENT		
Description	Test I	Test II	Description	Before Test	After Test
Weight of container ring + wet specimen			Weight of container + wet soil		
Weight of container			Weight of container + dry soil		
Diameter of container			Weight of container		
Initial thickness of sample			Weight of water		
Wet density in g/ml			Weight of dry soil		
Dry density in g/ml			Moisture content in percent		

SWELL PRESSURE DATA

Date	Time	Strain Dial Gauge Reading Before Adjustment	Proving Ring Reading	Differences	Load in kg	Swell Pressure in kg/cm²	Remarks

(*Continued from page* 2)

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