IS 2720-16 (1987): Methods of test for soils, Part 16: Laboratory determination of CBR [CED 43: Soil and Foundation Engineering]

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(Reaffirmed 2002)

Indian Standard

METHODS OF TEST FOR SOIL

PART 16 LABORATORY DETERMINATION OF CBR

(Second Revision)

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BUREAU OF INDIAN STANDARDS
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Indian Standard

METHODS OF TEST FOR SOIL

PART 16 LABORATORY DETERMINATION OF CBR

(Second Revision)

Soil Engineering Sectional Committee, BDC 23

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Indian Standard

METHODS OF TEST FOR SOIL

PART 16 LABORATORY DETERMINATION OF CBR

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 16) (Second Revision) was adopted by the Bureau of Indian Standards on 31 August 1987, after the draft finalized by the Soil Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 In order to establish a uniform procedure for determination of various characteristics of soils and also for facilitating a comparative study of the results, an Indian Standard on methods of test for soils IS : 2720 has been brought about which is published in several parts. This part (Part 16) covers the laboratory method for determination of California Bearing Ratio (CBR). This method was used by the California State Highway Department in USA until 1950 for evaluating subgrade strengths for design of flexible pavements. The ratio is used in conjunction with curves evolved through a study of the performance of the flexible pavements.

0.3 The CBR value of a soil can thus be considered to be an index which in some fashion is related to its strength. The value is highly dependent on the condition of the material at the time of testing. Recently, attempts have been made to correlate CBR values to parameters like modulus of subgrade reaction, modulus of resilience and plasticity index, with considerable success.

0.4 This standard (Part 16) was first published in 1965 and revised in 1979. The principal modifications made in this revision are in respect of loading machine, reducing the weight of the sample of the specimen and upgrading the procedure for testing based on experience gained in the use of this test by various research laboratories of the country in the past 10 years.

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‡.

*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

*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.

*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

*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

*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.

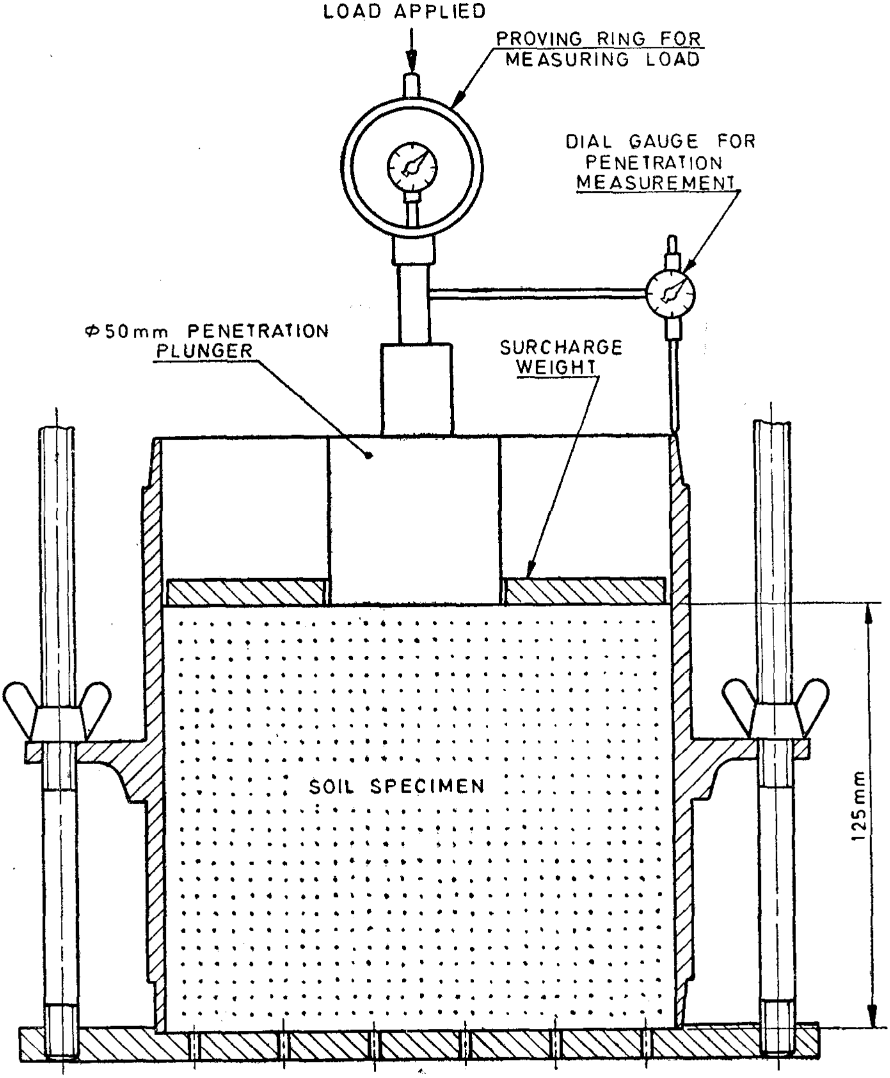


FIG. 1 SET-UP FOR CBR TEST

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

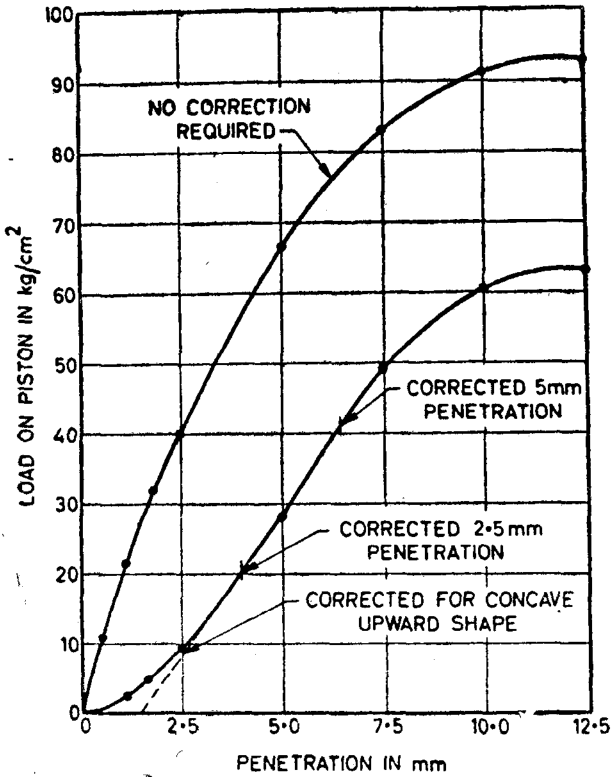
h = initial height of the specimen in mm.

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	*Unit Standard Load*	*Total Standard Load*
(1)	(2)	(3)
mm	kg/cm²	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) =

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

Remarks:

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(*Continued from page* 2)

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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