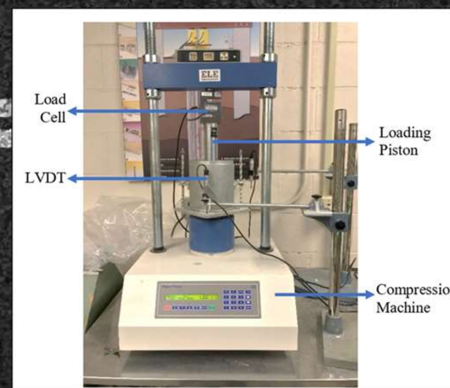
Highway Engineering Laboratory

AASHTO T 193-13

The California Bearing Ratio|
اختبار نسبة تحمل كاليفورنيا



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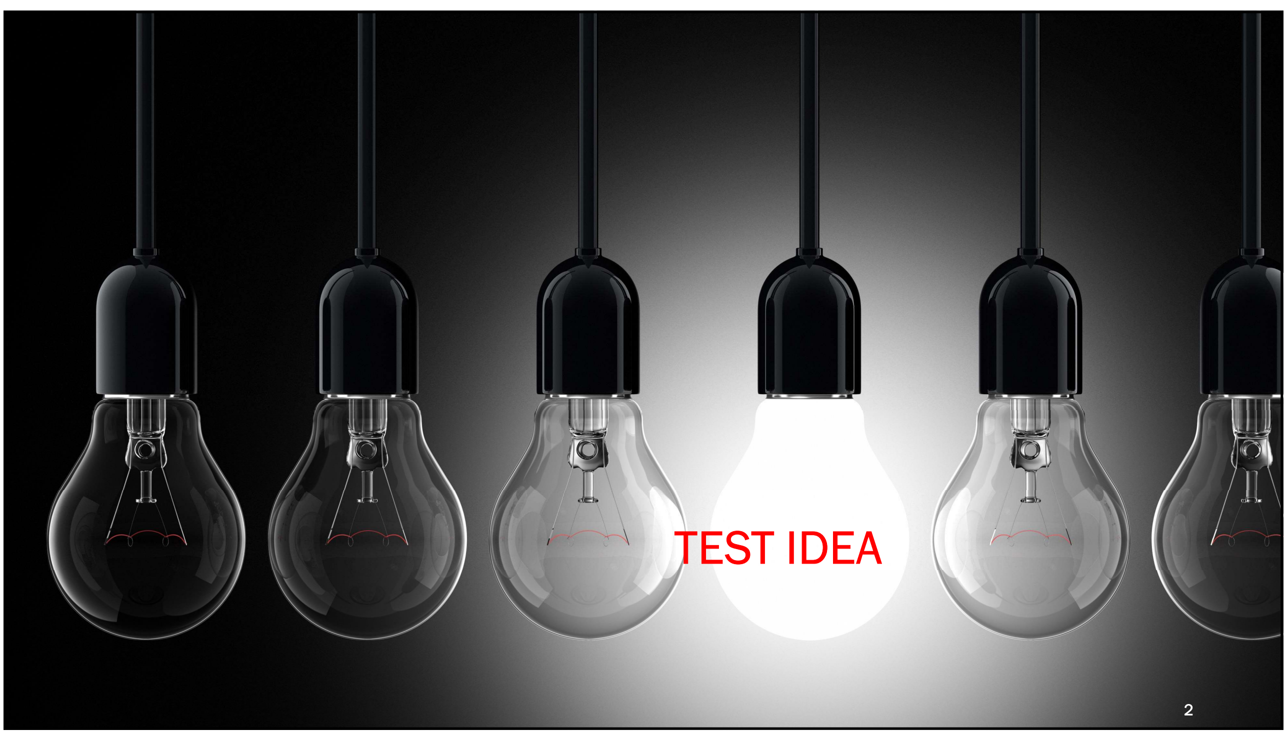

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Soils and Aggregates Characterization tests

- Characterization tests used to describe fundamental parameters of soils and aggregates
- Bearing Capacity (Strength) tests
  - *In laboratory*
    - CBR test (Most common)
    - R-value test
  - *in-situ*
    - Field CBR
    - Dynamic Cone Penetrometer (DCP) (Most common)
- Stiffness tests (Modulus of resilience, Mr)
  - *In laboratory*
    - Repeated load triaxial test
  - *in-situ*
    - Plate Load test, k value
    - Dynamic plate test using the light weight deflectometer

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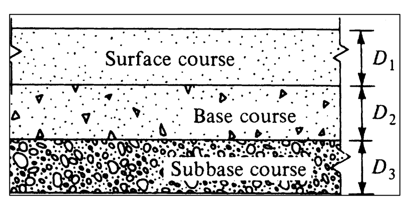
CBR

History

- The basic testing procedure employed in the determination of the CBR was developed by the California Division of Highways before World War II and was used by that agency in the design of flexible pavements.
- The basic procedures of this test were adopted by the Corps of Engineers of the U.S. Army during the early stages of the war and served as a basis for the development of design curves that were used for determining the required thickness of flexible pavements for airport runways and taxiways.
- Certain modifications were made in the test procedure, and it became a standardized test procedure



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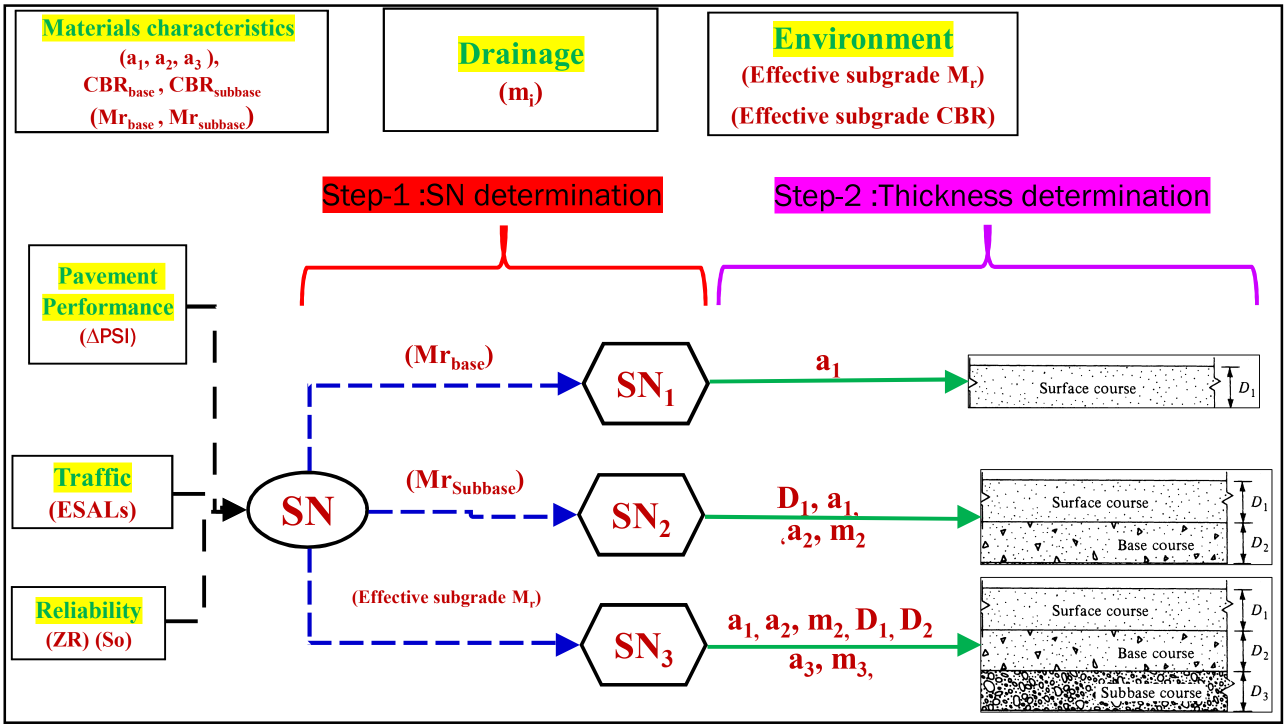

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Standard Method of Test for

The California Bearing Ratio

AASHTO Designation: T 193-13

AASHTO

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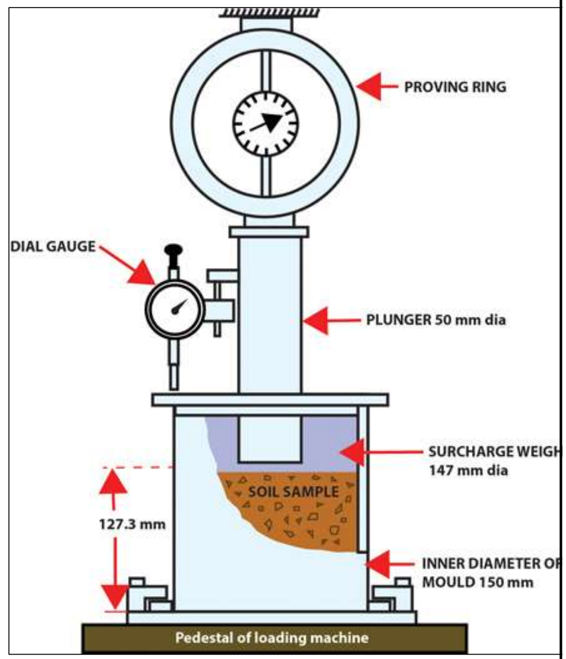
CBR (California Bearing Ratio)

Summary of Test Method

- The laboratory test uses a circular piston to penetrate material compacted in a mold at a **constant rate** of penetration.
- The CBR is expressed as the ratio of the unit load on the piston **required** to penetrate 0.1 in. (2.5 mm) and 0.2 in (5 mm) of the test soil to the unit load required to penetrate a standard material of well-graded crusted stone



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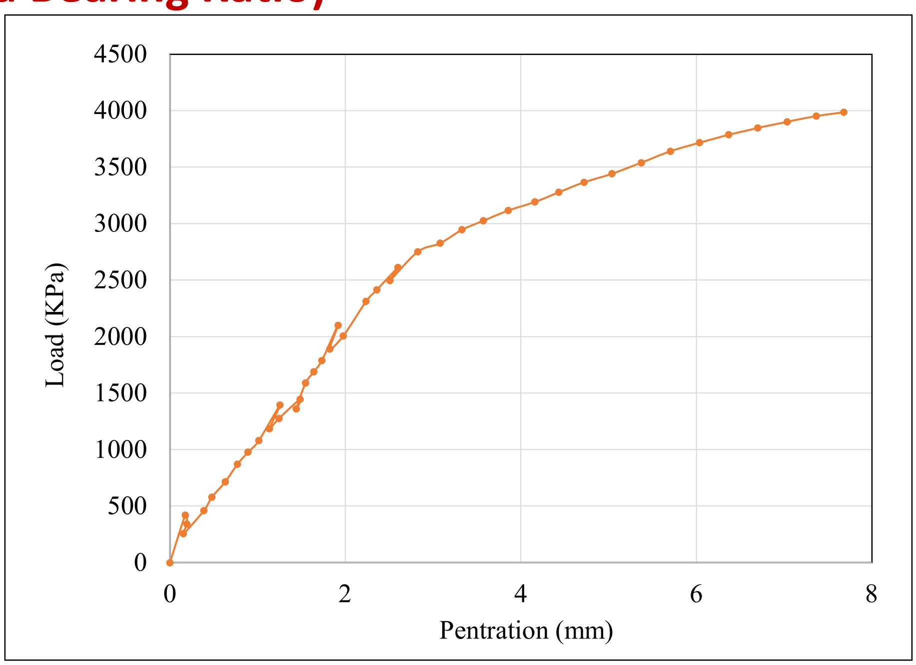
CBR (California Bearing Ratio)

Plotting



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CBR (California Bearing Ratio)

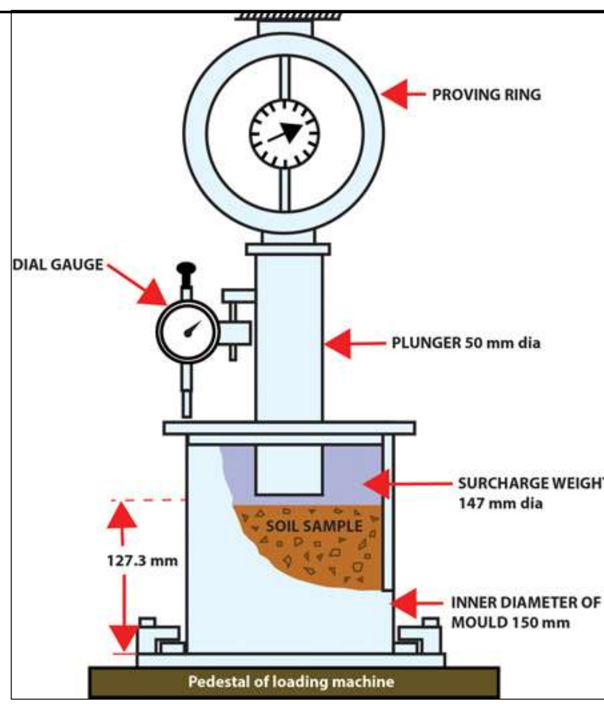
Determination

- **CBR** compares the bearing capacity of a tested material with that of obtained from an excellent coarse base material (a well-graded crushed stone)
- $CBR(\%) = \frac{Unit\ load\ of\ test\ materils}{Unit\ load\ of\ standard\ crushed\ stone}$ at <u>specific penetration</u>
- Two penetration points are used to determine CBR
  - *2.5 mm penetration*
  - *5.0 mm penetration*
- The unit load for the standard crushed stones are
  - *6.9 MPa (or 1000 psi) at 2.5 mm penetration*
  - *10.3 MPa (or 1500 psi) at 5.0 mm penetration*

CBR (California Bearing Ratio)

Significance and Use

- This test method is **<u>used to evaluate</u>** the potential strength of subgrade, subbase, and base course material, including recycled materials for use in road and airfield pavements.
- The CBR value obtained in this test forms an integral part of several flexible pavement design methods.



The California Bearing Ratio

Scope

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1. **SCOPE**

1.1. This test method covers the determination of the California Bearing Ratio (CBR) of pavement subgrade, subbase, and base/course materials from laboratory compacted specimens. The test method is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 19 mm ($^3/_4$ in.).

٥- أعمال الفرشيات :

****

٥/١- طبقة ما تحت الأساس (Sub Base) (الوجه الأول) :

تتكون المواد التي تستخدم في هذه الطبقة من ناتج تكسير الحجر الجيري أو الصخور البازلتية أو الجرانيتية أو من مواد حصمة السيل المغربلة. على أن تحقق

٣- مواد القاعدة الترابية (Topping) Sub Grade :

تعرف طبقة القاعدة الترابية في حالة الطمم بأنها الطبقة النهائية لطبقات الطمم الترابي والتي تكون صالحة لوضع طبقة فرشيات ما تحت الأساس (Sub Base) عليها والتي تعتبر نفس طبقة الـ (Topping) وبسماكة (٢٠ سم) .

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1. SCOPE

1.1. This test method covers the determination of the California Bearing Ratio (CBR) of pavement subgrade, subbase, and base/course materials from laboratory compacted specimens. The test method is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 19 mm ($^3/_4$ in.).

	Cohesive soil	Cohesionless soil
	- Fine	- Course
BS	- $d<0.06mm$	- $d>0.06mm$
	- silt clay	- sand gravel
	- exhibit platicity	- not exhibit platicity
	- high porosity	- Low porosity
	- low permeability	- high permeability

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1.2. When materials having maximum particle sizes greater than 19 mm ($^3/_4$ in.) are to be tested, this test method provides for modifying the gradation of the material so that the material used for tests all passes the 19.0-mm ($^3/_4$-in.) sieve while the total gravel 4.75-mm (No. 4) to 75-mm (3-in.) fraction remains the same. While traditionally this method of specimen preparation has been used to avoid the error inherent in testing materials containing large particles in the CBR test apparatus the modified material may have significantly different strength properties than the original material. However, a large experience base has developed using this test method for materials for which the gradation has been modified and satisfactory design methods are in use based on the results of tests using this procedure.

1.3. Past practice has shown that CBR results for those materials having substantial percentages of particles retained on the 4.75-mm (No. 4) sieve are more variable than for finer materials. Consequently, more trials may be required for these materials to establish a reliable CBR.

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1.4. This test method provides for the determination of the CBR of a material at optimum water content or a range of water content from a specified compaction test and a specified dry unit mass. The dry unit mass is usually given as a percentage of maximum dry unit mass from the compaction tests of T 99 or T 180.

1.5. The agency requesting the test shall specify the water content or range of water content and the dry unit mass for which the CBR is desired.

1.6. Unless specified otherwise by the requesting agency, or unless it has been shown to have no effect on test results for the material being tested, all specimens shall be soaked prior to penetration.

1.7. The values stated in SI units are to be regarded as the standard.

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Referenced documents

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2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 145, Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
- R 58, Dry Preparation of Disturbed Soil and Soil-Aggregate Samples for Test
- T 2, Sampling of Aggregates
- T 88, Particle Size Analysis of Soils

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Significance and use

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3. SIGNIFICANCE AND USE

3.1. This test method is used to evaluate the potential strength of subgrade, subbase, and base course material, including recycled materials, for use in road and airfield pavements. The CBR value obtained in this test forms an integral part of several flexible pavement design methods.

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٥/١- طبقة ما تحت الأساس (Sub Base) (الوجه الأول) :

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Apparatus

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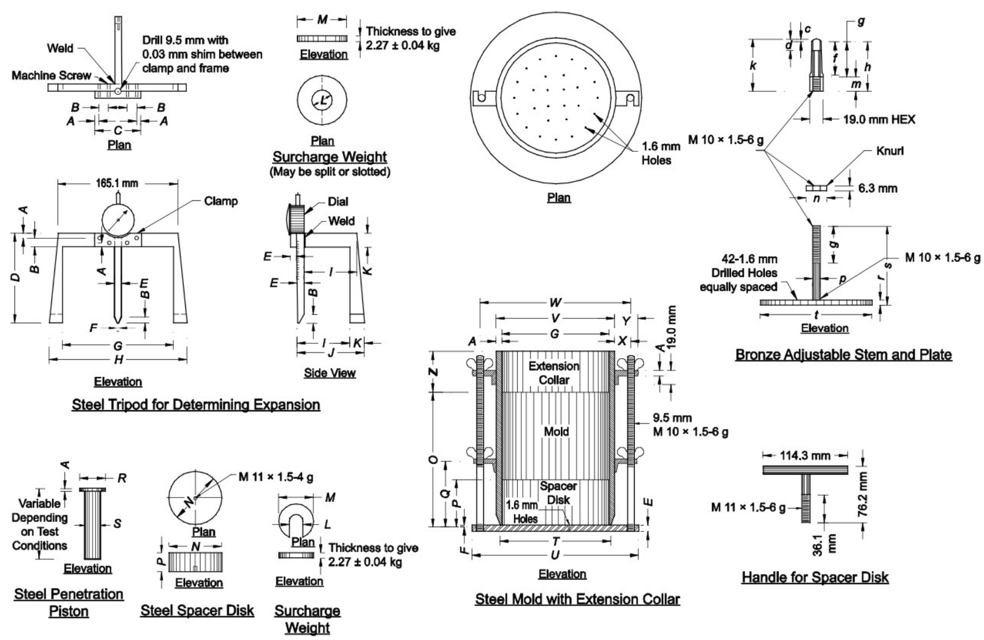

Figure 1—California Bearing Ratio Apparatus

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4. APPARATUS

4.1. *Molds*—The molds shall be cylindrical in shape, made of metal, with an internal diameter of 152.40 ± 0.66 mm (6.0 ± 0.026 in.) and a height of 177.80 ± 0.46 mm (7.0 ± 0.018 in.), and provided with an extension collar approximately 50 mm (2.0 in.) in height and a perforated base plate that can be fitted to either end of the mold. (See Figure 1.) It is desirable to have at least three molds for each soil to be tested.

Compaction Mold

Compaction Mold Collar

Mold Base

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4.2. *Spacer Disk*—A circular spacer disk made of metal 150.8 ± 0.8 mm ($5^{15}/_{16} \pm {}^{1}/_{32}$ in.) in diameter and 61.37 ± 0.25 mm (2.416 ± 0.01 in.) in height. (See Figure 1.)

Note 1—When using molds having a height of 177.80 mm (7.0 in.) (Figure 1), a spacer disk height of 61.37 mm (2.416 in.) is needed to obtain a thickness of compacted specimen that conforms to the thickness: 116.43 mm (4.584 in.) of specimens in T 99 and T 180.

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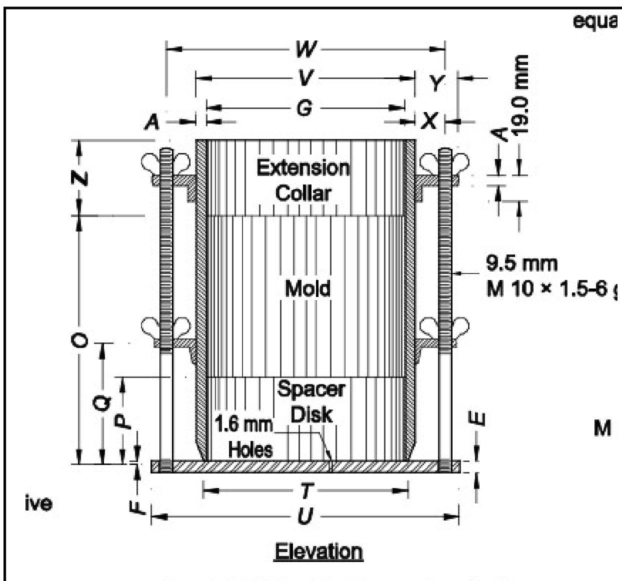

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Table of Measurements

	TRIPOD FOR DETERMINING EXPANSION											SURCHARGE		SPACER DISC	
MATERIAL	STEEL **													STEEL **	
DIMENSION	A	B	C	D	E	F	G	H	I	J	K	L*	M*	N*	P
METRIC, mm	6.3	12.7	63.5	120.6	9.5	1.6	152.4	190.5	76.2	95.2	19.0	54.0	149.2	150.8	61.37
TOLERANCE, mm													1.6	0.8	0.25
ENGLISH, in.	1/4	1/2	2 1/2	4 3/4	3/8	1/16	6	7 1/2	3	3 3/4	3/4	2 1/8	5 7/8	5 15/16	2.416
TOLERANCE, in.													1/16	1/32	0.01

	MOLD WITH EXTENSION COLLAR														PISTON		
MATERIAL	STEEL**														STEEL**		
DIMENSION	A	E	F	G*	O	P	Q	T*	U***	V*	W	X	Y	Z	A	R	S*
METRIC, mm	6.3	9.5	1.6	152.40	177.80	61.37	88.9	158.0	238.1	165.1	212.7	23.8	33.3	50.8	6.3	69.8	49.63
TOLERANCE, mm				0.66	0.46	0.25											0.13
ENGLISH, in.	1/4	3/8	1/16	6	7	2.416	3 1/2	6 7/32	9 3/8	6 1/2	8 3/8	15/16	1 5/16	2	1/4	2 3/4	1.954
TOLERANCE, in.				0.026	0.018	0.01											0.005

	ADJUSTABLE STEM AND PLATE														
MATERIAL	BRONZE														
DIMENSION			c	d	e*	f	g	h	k	m	n*	p*	r	s	t
METRIC, mm			5.6	11.9	3.2	46.04	50.8	69.8	75.4	19.0	28.6	9.5	6.3	107.9	149.2
TOLERANCE, mm															1.6
ENGLISH, in.			7/32	15/32	1/8	1 13/16	2	2 3/4	2 31/32	3/4	1 1/8	3/8	1/4	4 1/4	5 7/8
TOLERANCE, in.															1/16

Figure 1—California Bearing Ratio Apparatus (*Continued*)

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4.3. *Rammer*—A rammer as specified in either T 99 or T 180.

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4.5. *Indicators*—Two dial indicators: each indicator shall have a 25-mm (1-in.) throw and read to 0.02 mm (0.001 in.).

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4.6. *Surcharge Weights*—One annular metal weight with a center hole approximately 54.0 mm ($2^1/_8$ in.) in diameter and several slotted or split metal weights, all 149.2 ± 1.6 mm ($5^7/_8 \pm {}^1/_{16}$ in.) in diameter and each having a mass of 2.27 ± 0.04 kg (5 ± 0.10 lb) (Figure 1) (Note 2).

Note 2—When using split weights, the mass of the pair shall be 2.27 ± 0.04 kg (5 ± 0.10 lb).

CBR Surcharge Weight (Annular)

CBR Surcharge Weight (Slotted)

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4.7. *Penetration Piston*—A metal piston of circular cross-section having a diameter of 49.63 ± 0.13 mm (1.954 ± 0.005 in.) area = 1935 mm^2 (3 $in.^2$) and not less than 102 mm (4 in.) long. (See Figure 1.)

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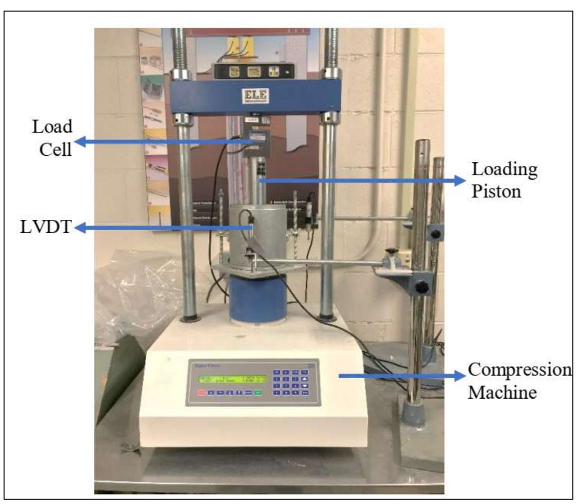
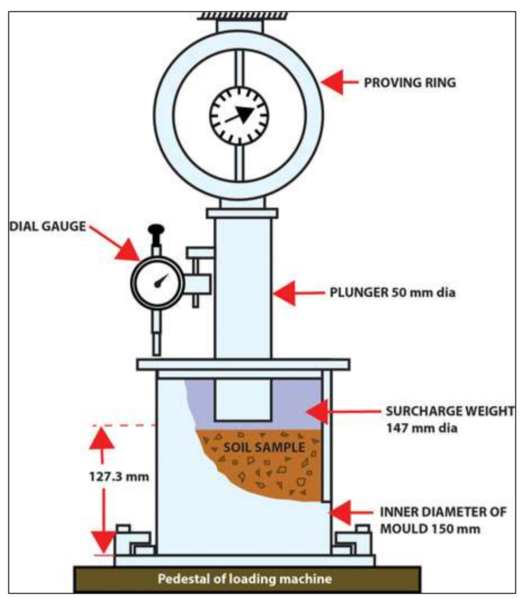
4.8. *Loading Device*—A compression-type apparatus capable of applying a uniformly increasing load up to a capacity sufficient for the material being tested at a rate of 1.3 mm/min. (0.05 in./min.), used to force the penetration piston into the specimen.





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4.9. *Soaking Tank*—A soaking tank suitable for maintaining the water level 25 mm (1 in.) above the top of the specimens.

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4.4. *Apparatus for Measuring Expansion*—This consists of a swell plate with adjustable stem (Figure 1) and a tripod support for a dial indicator (Figure 1). The swell plate is made of metal, 149.2 ± 1.6 mm ($5^7/_8 \pm {}^1/_{16}$ in.) in diameter and is perforated with 1.6-mm (${}^1/_{16}$-in.) diameter holes. The tripod used to support the dial indicator is arranged to fit the mold extension collar.

Swell Plates

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4.10. *Drying Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F) for drying moisture samples.

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4.11. *Moisture Content Containers*—As specified in T 265.

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Apparatus

CBR Paper Filters

- for separating soil from the spacer disc during compaction or to place on the top of the soil when compacting is done

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4.12. *Miscellaneous*—Miscellaneous tools such as mixing pans, spoons, straightedge, filter paper, balances, etc.

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Test Procedures

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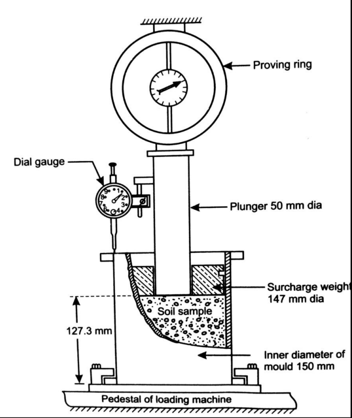
Test Procedures

9. PENETRATION TEST

9.1. *Application of One Surcharge Weight*—Place one annular weight on the specimen. Seat the penetration piston with a load of no more than 44 N (10 lb).



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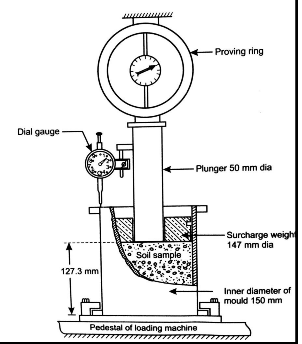
Test Procedures

9.2. *Application of the Remaining Surcharge Weight*—After seating the penetration piston, place the remainder of the surcharge weights around the piston. The total amount of surcharge weight placed on the specimen shall be equal to the surcharge weight used during soaking. Set the penetration dial indicator and the load indicator to zero.



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Test Procedures

9.3. *Application of Load*—Apply the loads to the penetration piston so the rate of penetration is uniform at 1.3 mm (0.05 in.)/min. Record the load when the penetration is 0.64, 1.27, 1.91, 2.54, 3.81, 5.08, and 7.62 mm (0.025, 0.050, 0.075, 0.100, 0.150, 0.200, and 0.300 in.). Load readings at penetrations of 10.16 and 12.70 mm (0.400 and 0.500 in.) may be obtained if desired.

- Record the load readings at penetrations of
  - *0.025 in. (0.64 mm)*
  - *0.050 in. (1.27 mm)*
  - *0.075 in. (1.91 mm)*
  - *0.100 in. (2.54 mm)*
  - *0.125 in. (3.18 mm)*
  - *0.150 in. (3.81 mm)*
  - *0.175 in. (4.45 mm)*
  - *0.200 in. (5.08 mm)*
  - *0.300 in. (7.62 mm),*
  - *0.400 in. (10.16 mm)*
  - *0.500 in. (12.70 mm)*

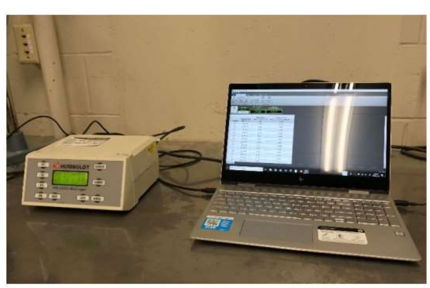
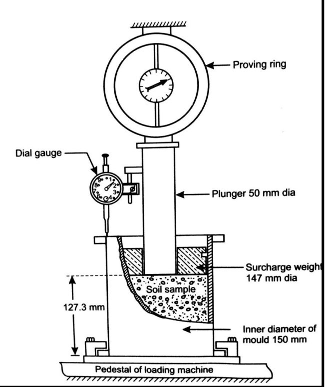


Figure 3.15 Data acquisition system for the CBR testing



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Test Outputs

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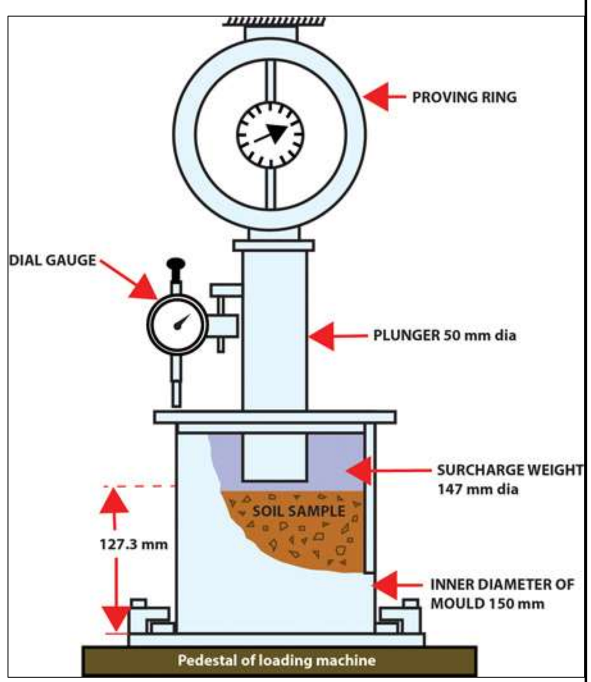
CBR (California Bearing Ratio)

Test Outputs

CBR test results	
Penetration (in)	Load on piston (psi)
0.025	70
0.05	115
0.1	220
0.2	300
0.4	320



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Calculations

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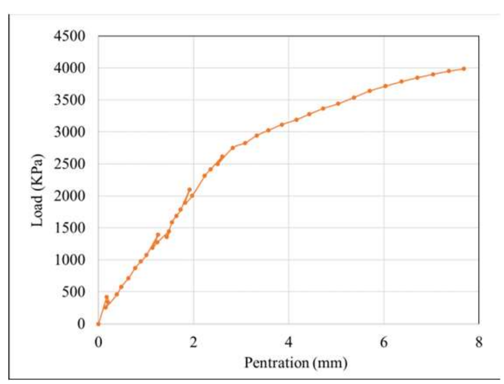
CBR (California Bearing Ratio)

Plotting

10.1. *Stress–Strain Curve*—Plot the stress–strain (resistance to penetration-depth of penetration) curve for each specimen as shown in Figure 2. In some instances, the initial penetration takes place without a proportional increase in the resistance to penetration and the curve may be concave upward. To obtain the true stress–strain relationships, correct the curve having concave upward shape near the origin by adjusting the location of the origin by extending the straight line portion of the stress–strain curve downward until it intersects the abscissa. (See dashed lines.)



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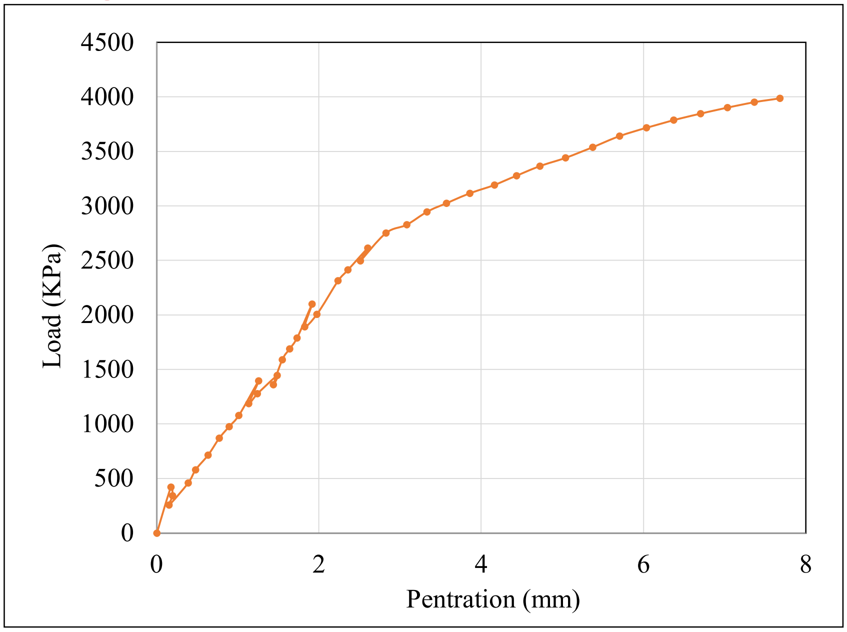
CBR (California Bearing Ratio)

Plotting

- The curve is normally concave downward



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CBR (California Bearing Ratio)

Determination

10.2. *California Bearing Ratio*—The corrected load values shall be determined for each specimen at 2.54 and 5.08 mm (0.10 and 0.20 in.) penetration. California Bearing Ratio values are obtained in percent by dividing the corrected load values at 2.54 and 5.08 mm (0.10 and 0.20 in.) by the standard loads of 6.9 and 10.3 MPa (1000 and 1500 psi), respectively, and multiplying these ratios by 100.

$$CBR = \frac{\text{corrected load value}}{\text{standard load}} \times 100 \qquad (2)$$

- **CBR** compares the bearing capacity of a tested material with that of obtained from an excellent coarse base material (a well-graded crushed stone)
- $CBR(\%) = \frac{Unit\ load\ of\ test\ materils}{Unit\ load\ of\ standard\ crush\quad stone}$ at specific penetration
- Two penetration points are used to determine CBR
  - *2.55 mm penetration*
  - *5.08 mm penetration*

- The unit load for the standard crushed stones are
  - *6.9 MPa (or 1000 psi) at 2.5 mm penetration*
  - *10.3 MPa (or 1500 psi) at 5.0 mm penetration*

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CBR (California Bearing Ratio)

Determination

$$CBR\,(\%) = \frac{\text{unit load at 2.5 mm penetration (MPa)}}{6.9\,\text{MPa}} \times 100$$

$$CBR\,(\%) = \frac{\text{unit load at 5.0 mm penetration (MPa)}}{10.3\,\text{MPa}} \times 100$$

OR

$$CBR\,(\%) = \frac{\text{Stress at 0.1 in penetration (psi)}}{1000\,\text{psi}} \times 100$$

$$CBR\,(\%) = \frac{\text{Stress at 0.2 in penetration (psi)}}{1500\,\text{psi}} \times 100$$

OR

$$CBR\,(\%) = \frac{\text{Load at 2.5mm penetration (kg)}}{1364\,\text{kg}} \times 100$$

$$CBR\,(\%) = \frac{\text{Load at 5.0mm penetration (kg)}}{2045\,\text{kg}} \times 100$$

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CBR (California Bearing Ratio)

Determination

10.2.1. The CBR is generally selected at 2.54 mm (0.10 in.) penetration. If the ratio at 5.08 mm (0.20 in.) penetration is greater, the test shall be rerun. If the check test gives a similar result, the ratio at 5.08 mm (0.20 in.) penetration shall be used.

- The CBR value is **usually based** on the load ratio for a penetration **of 2.5 mm (0.1 in).**
- however,
  - *If the CBR value at a penetration of 5.0 mm (0.2 in) is higher than the CBR value at a penetration of 2.5 mm ($CBR_{2.5} < CBR_{5.0}$)*
    - The test should be repeated.
    - If the repeated test also yields a larger value, then the CBR at 5.0 mm (0.2 in) penetration should be used.

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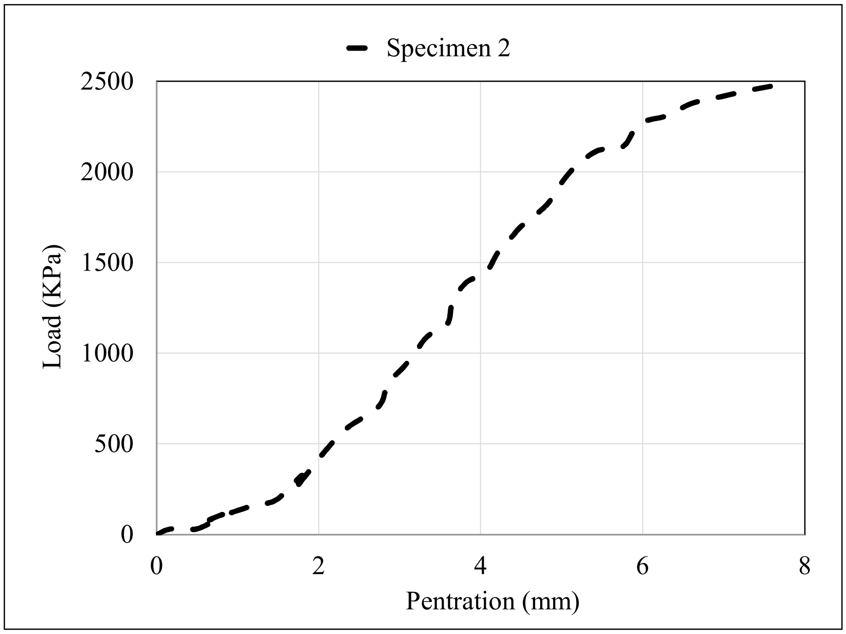
CBR (California Bearing Ratio)

Plot correction

- The initial portion might concave upward due to surface irregularity.
  - *In this case, correction should be done by drawing a tangent to the curve at the point of greatest slope.*
  - *The corrected curve will be used in all further calculations*



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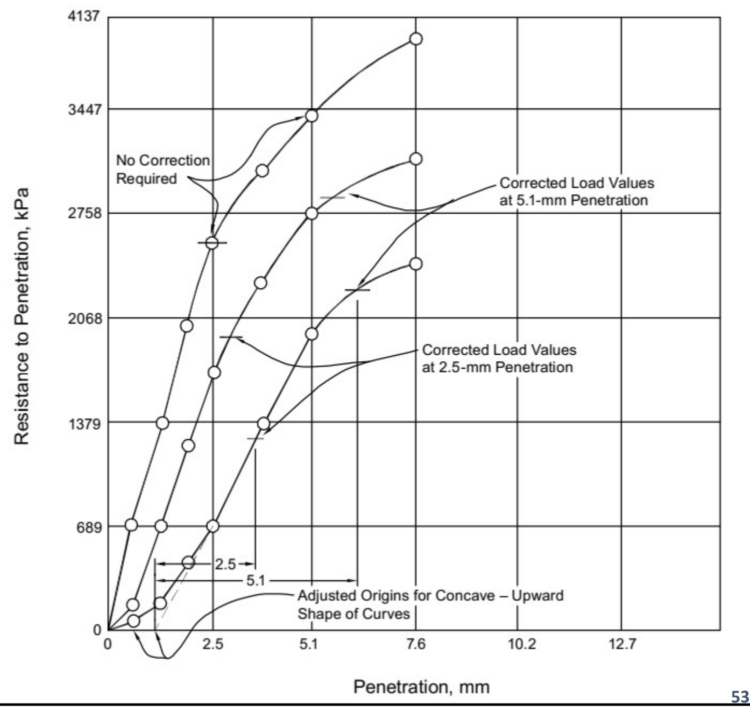
Plot correction



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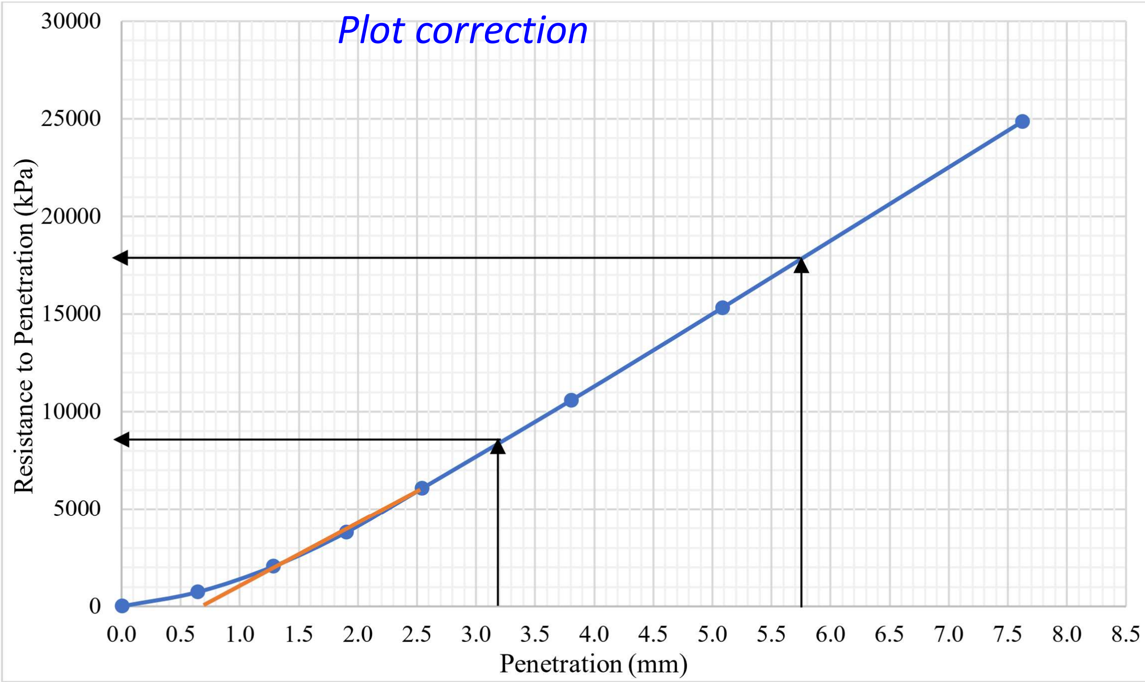

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Test Specimens preparation

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Sample Preparation

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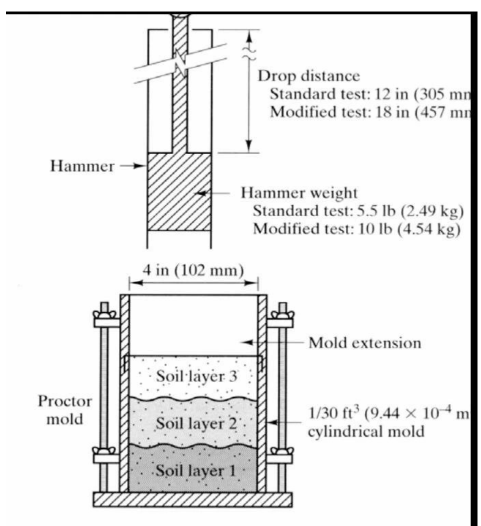
5. SAMPLE

5.1. The sample shall be handled and specimen(s) for compaction shall be prepared in accordance with the procedures given in T 99 or T 180 for compaction in a 152.4-mm (6-in.) mold except as follows:

- ❑ Proctor compaction test
- ❑ There are two tests that are used to obtain the optimum moisture content and the **corresponding maximum dry density (MDD)**.
- ❑ The tests are known as
  - ❑ *Standard Proctor test (Standard AASHTO T99)*
  - ❑ *Modified Proctor test (Modified AASHTO T180)*
- ❑ Both tests use a falling hammer to compact the material in a mould, which roughly corresponds to the compactive effort in the field.



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Laboratory Soil Compaction Tests

Proctor test procedures

Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop

AASHTO Designation: T 99-01 (2004)

1. SCOPE

1.1. These methods of test are intended for determining the relation between the moisture content and density of soils compacted in a mold of a given size with a 2.5-kg (5.5-lb) rammer dropped from a height of 305 mm (12 in.). Four alternate procedures are provided as follows:

- *Method A*—A 101.60-mm (4-in.) mold: Soil material passing a 4.75-mm (No. 4) sieve Sections 4 and 5.
- *Method B*—A 152.40-mm (6-in.) mold: Soil material passing a 4.75-mm (No. 4) sieve Sections 6 and 7.
- *Method C*—A 101.60-mm (4-in.) mold: Soil material passing a 19.0-mm ($^3/_4$-in.) sieve Sections 8 and9.
- *Method D*—A 152.40-mm (6-in.) mold: Soil material passing a 19.0-mm ($^3/_4$-in.) sieve Sections 10 and 11.

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Proctor test procedures

METHOD D

10. SAMPLE

10.1. Select the representative sample in accordance with Section 8.3 except that it shall have a mass of approximately 11 kg (25 lb).

11. PROCEDURE

11.1. Follow the same procedure as described for Method C in Section 9, except for the following: Form a specimen by compacting the prepared soil in the 152.4-mm (6-in.) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances given in Section 3.1.2, and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 471, and record the result as the wet density, W_1, in kilograms per cubic meter, of compacted soil. For molds conforming to tolerances given in Section 3.1.2, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, and record the result as the wet density, W_1, in pounds per cubic foot, of the compacted soil. For used molds out of tolerance by not more than 50 percent (Section 3.1.3), use the factor for the mold as determined in accordance with T 19M/T 19.

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TABLE 5.1 Specifications for the Two Proctor Laboratory Compaction Tests

Test	Standard Effort (ASTM Test Method D 698)			Modified Effort (ASTM Test Method D 1557)		
Method	A	B	C	A	B	C
Rammer weight	5.5 lbf (24.4 N)	5.5 lbf (24.4 N)	5.5 lbf (24.4 N)	10 lbf (44.5 N)	10 lbf (44.5 N)	10 lbf (44.5 N)
Height of drop	12 in. (305 mm)	12 in. (305 mm)	12 in. (305 mm)	18 in. (457 mm)	18 in. (457 mm)	18 in. (457 mm)
Mold diameter	4 in. (102 mm)	4 in. (102 mm)	6 in. (152 mm)	4 in. (102 mm)	4 in. (102 mm)	6 in. (152 mm)
Mold volume	0.0333 ft^3 (944 cm^3)	0.0333 ft^3 (944 cm^3)	0.075 ft^3 (2124 cm^3)	0.0333 ft^3 (944 cm^3)	0.0333 ft^3 (944 cm^3)	0.075 ft^3 (2124 cm^3)
Material	Passing No. 4 (4.75 mm) sieve	Passing 3/8 in. (9.5 mm) sieve	Passing 3/4 in. (19 mm) sieve	Passing No. 4 (4.75 mm) sieve	Passing 3/8 in. (9.5 mm) sieve	Passing 3/4 in. (19 mm) sieve
Layers	3	3	3	5	5	5
Blows per layer	25	25	56	25	25	56
Compactive effort	12 400 ft-lbf/ft^3 (600 kN-m/m^3)	12 400 ft-lbf/ft^3 (600 kN-m/m^3)	12 400 ft-lbf/ft^3 (600 kN-m/m^3)	56 000 ft-lbf/ft^3 (2700 kN-m/m^3)	56 000 ft-lbf/ft^3 (2700 kN-m/m^3)	56 000 ft-lbf/ft^3 (2700 kN-m/m^3)
Use	≤25% by mass retained on No. 4 sieve	≤25% by weight retained on 9.5 mm sieve	≤30% by weight retained on 19 mm sieve	≤25% by mass retained on No. 4 sieve	≤25% by mass retained on 9.5 mm sieve	≤30% by weight retained on 19 mm sieve

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Laboratory Soil Compaction Tests

Proctor test procedures

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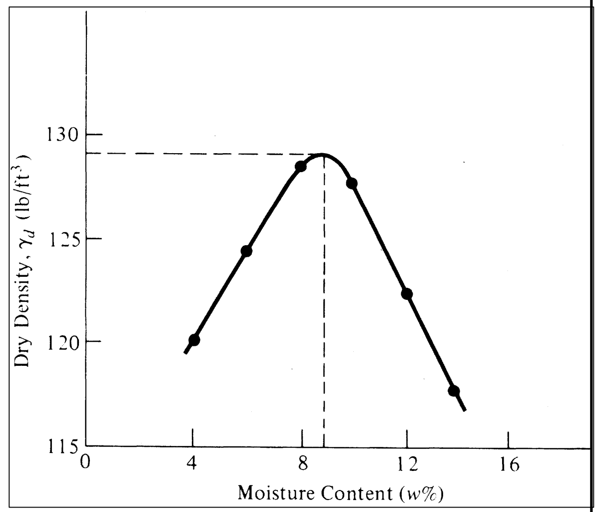
Proctor test output

Compaction curve

- The output of Proctor test is the compaction curve
- Compaction curve
  - *is the curve of the dry densities of each specimen plotted versus their respective water contents*
  - Each-data point on the curve represents a single compaction test
- The peak point of the compaction curve is an important point, which represent
  - *The maximum dry density (MDD)*
  - *Optimum water content*
    - The water content corresponding to the maximum dry density



Dry unit wt. = Wet unit wt. / (1+ω%)

This curve is unique

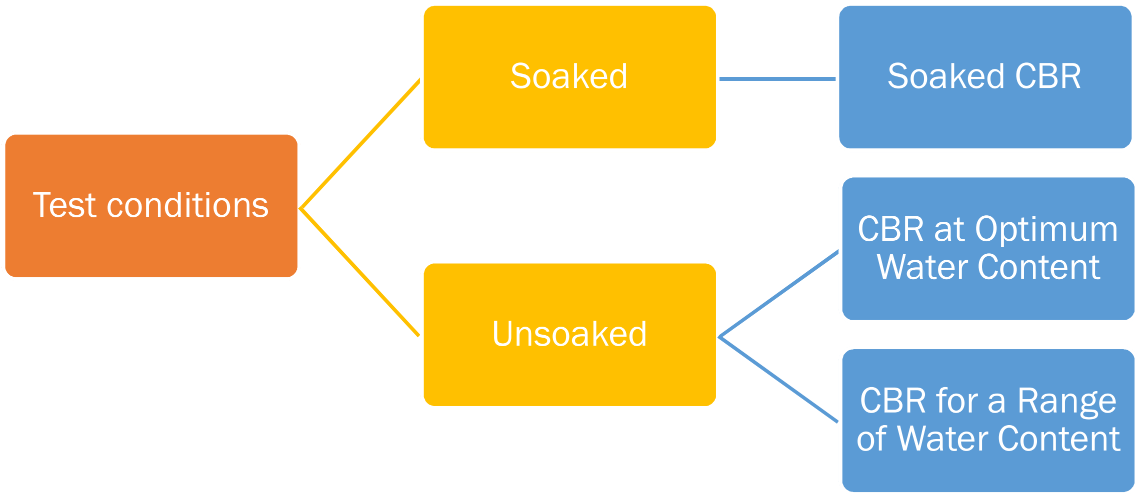
for a given soil type, method of compaction, and (constant) compactive effort

AASHTO T 193

Testing Conditions

Test Specimens Preparation

Conditions



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AASHTO T 193-13

Test Specimens preparation

Condition 1: Bearing Ratio (CBR) at Optimum Water Content

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CBR at Optimum Water Content

5. Sample

5.1.2. *Bearing Ratio at Optimum Water Content*—From a sample having a mass of 35 kg (75 lb) or more, select a representative portion having a mass of approximately 11 kg (25 lb) for a moisture-density test and divide the remainder of the sample to obtain three representative portions having a mass of approximately 6.8 kg (15 lb) each.

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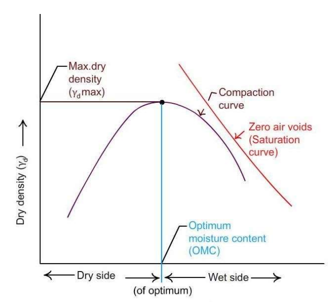
CBR at Optimum Water Content

6. Moisture-Density Relation

6. MOISTURE-DENSITY RELATION

6.1. *Bearing Ratio at Optimum Water Content*—Using the 11-kg (25-lb) portion prepared as described in Section 5.1, determine the optimum moisture content and maximum dry density in accordance with the compaction method specified, either T 99 or T 180. A previously performed compaction test on the same material may be substituted for the compaction test just described, provided that if the sample contains material retained on the 19.0-mm ($^3/_4$-in.) sieve, soil prepared as described in Section 5.1 is used (Note 3).

Note 3—Maximum dry unit mass obtained from a compaction test performed in a 101.6-mm (4-in.) diameter mold may be slightly greater than the maximum dry unit weight obtained from compaction in the 152.4-mm (6-in.) compaction mold or CBR mold.



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CBR at Optimum Water Content

7. Procedures

7. PROCEDURE

7.1. *Bearing Ratio at Optimum Water Content*:

7.1.1. Normally, three specimens must be compacted so that their compacted densities range from 95 percent (or lower) to 100 percent (or higher) of the maximum dry density determined in Section 6.1.

Note 5—Generally about 10, 30, and 65 blows per layer are suitable for compacting specimens 1, 2, and 3, respectively. More than 56 blows per layer are generally required to mold a CBR specimen to 100 percent of the maximum dry density determined by T 99 (Method D); this is due to the sample for the moisture-density test being reused, while the sample for the CBR specimen is mixed and compacted only once.



CBR at Optimum Water Content

7. Procedures

7.1.2. Clamp the mold to the base plate, attach the extension collar and weigh to the nearest 5 g (0.01 lb). Insert the spacer disk into the mold and place a coarse filter paper on top of the disk.




CBR at Optimum Water Content

7. Procedures

7.1.3. Mix each of the three 6.8-kg (15-lb) portions prepared in Section 5.1.2 with sufficient water to obtain the optimum moisture content determined in Section 6.1.

CBR at Optimum Water Content

7. Procedures

7.1.4. Compact the first of the three portions of soil-water mixture into the mold, using three equal layers and appropriate rammer, if maximum density was determined by T 99, or five equal layers if maximum density was determined by T 180, to give a total compacted depth of about 125 mm, compacting each layer with the lowest selected number of blows in order to give a compacted density of 95 percent or less of the maximum density.

7. PROCEDURE

7.1. *Bearing Ratio at Optimum Water Content*:

7.1.1. Normally, three specimens must be compacted so that their compacted densities range from 95 percent (or lower) to 100 percent (or higher) of the maximum dry density determined in Section 6.1.

Note 5—Generally about 10, 30, and 65 blows per layer are suitable for compacting specimens 1, 2, and 3, respectively. More than 56 blows per layer are generally required to mold a CBR specimen to 100 percent of the maximum dry density determined by T 99 (Method D); this is due to the sample for the moisture-density test being reused, while the sample for the CBR specimen is mixed and compacted only once.

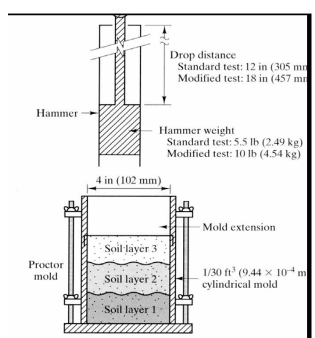

TABLE 5.1 Specifications for the Two Proctor Laboratory Compaction Tests

Test	Standard Effort (ASTM Test Method D 698)			Modified Effort (ASTM Test Method D 1557)		
Method	A	B	C	A	B	C
Rammer weight	5.5 lbf (24.4 N)	5.5 lbf (24.4 N)	5.5 lbf (24.4 N)	10 lbf (44.5 N)	10 lbf (44.5 N)	10 lbf (44.5 N)
Height of drop	12 in. (305 mm)	12 in. (305 mm)	12 in. (305 mm)	18 in. (457 mm)	18 in. (457 mm)	18 in. (457 mm)
Mold diameter	4 in. (102 mm)	4 in. (102 mm)	6 in. (152 mm)	4 in. (102 mm)	4 in. (102 mm)	6 in. (152 mm)
Mold volume	0.0333 ft^3 (944 cm^3)	0.0333 ft^3 (944 cm^3)	0.075 ft^3 (2124 cm^3)	0.0333 ft^3 (944 cm^3)	0.0333 ft^3 (944 cm^3)	0.075 ft^3 (2124 cm^3)
Material	Passing No. 4 (4.75 mm) sieve	Passing 3/8 in. (9.5 mm) sieve	Passing 3/4 in. (19 mm) sieve	Passing No. 4 (4.75 mm) sieve	Passing 3/8 in. (9.5 mm) sieve	Passing 3/4 in. (19 mm) sieve
Layers	3	3	3	5	5	5
Blows per layer	25	25	56	25	25	56
Compactive effort	12 400 ft-lbf/ft^3 (600 kN-m/m^3)	12 400 ft-lbf/ft^3 (600 kN-m/m^3)	12 400 ft-lbf/ft^3 (600 kN-m/m^3)	56 000 ft-lbf/ft^3 (2700 kN-m/m^3)	56 000 ft-lbf/ft^3 (2700 kN-m/m^3)	56 000 ft-lbf/ft^3 (2700 kN-m/m^3)
Use	≤25% by mass retained on No. 4 sieve	≤25% by weight retained on 9.5 mm sieve	≤30% by weight retained on 19 mm sieve	≤25% by mass retained on No. 4 sieve	≤25% by mass retained on 9.5 mm sieve	≤30% by weight retained on 19 mm sieve

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CBR at Optimum Water Content

7. Procedures

7.1.5. Determine the moisture content of the material being compacted at the beginning and end of the compaction procedure (two samples). Each moisture sample shall have a mass of at least 100 g for fine-grained soils and 500 g for coarse-grained soils. Determination of moisture content shall be done in accordance with T 265, Laboratory Determination of Moisture Content of Soils.

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CBR at Optimum Water Content

7. Procedures

7.1.6. Remove the extension collar, and using a straightedge, trim the compacted soil even with the top of the mold. Surface irregularities should be patched with small-sized material. Remove the spacer disk, place a coarse filter paper on the perforated base plate, invert the mold and compacted soil, and place on the filter paper so the compacted soil is in contact with the filter paper. Clamp the perforated base plate to the mold and attach the collar. Determine the mass of the mold and specimen to the nearest 5 g (0.01 lb).

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CBR (California Bearing Ratio)

Specimen Compaction

https://www.youtube.com/watch?v=6pjladw_0a4

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CBR at Optimum Water Content

7. Procedures

7.1.7. Compact the other two 6.8-kg (15-lb) portions in accordance with the procedure in Sections 7.1.4 through 7.1.6, except that an intermediate number of blows per layer should be used to compact the second specimen and the highest number of blows per layer shall be used to compact the third specimen.

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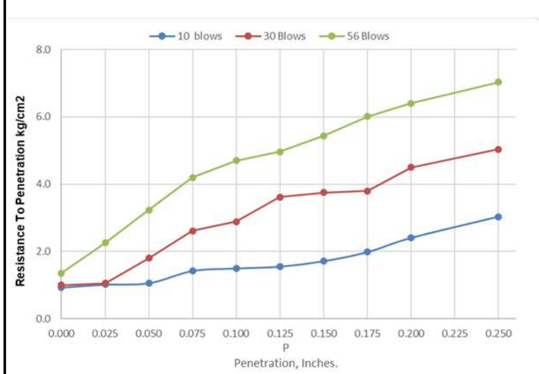
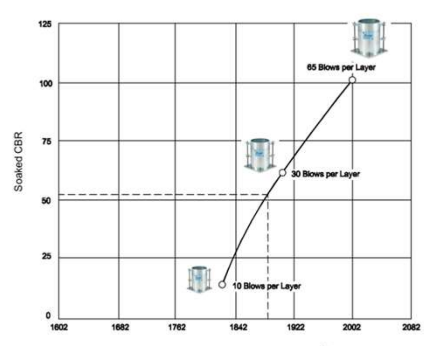
CBR at Optimum Water Content

Calculations

Design CBR for One Water Content Only—Using the data obtained from the three specimens, plot the CBR-Dry Density as Molded relation as shown in Figure 3. The design CBR may then be determined at the desired percentage of the maximum dry density, normally the minimum percentage compaction permitted by the agency's compaction specifications.





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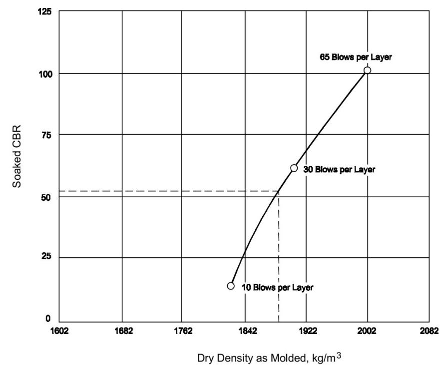
CBR at Optimum Water Content

Calculations

Design CBR for One Water Content Only—Using the data obtained from the three specimens, plot the CBR-Dry Density as Molded relation as shown in Figure 3. The design CBR may then be determined at the desired percentage of the maximum dry density, normally the minimum percentage compaction permitted by the agency's compaction specifications.



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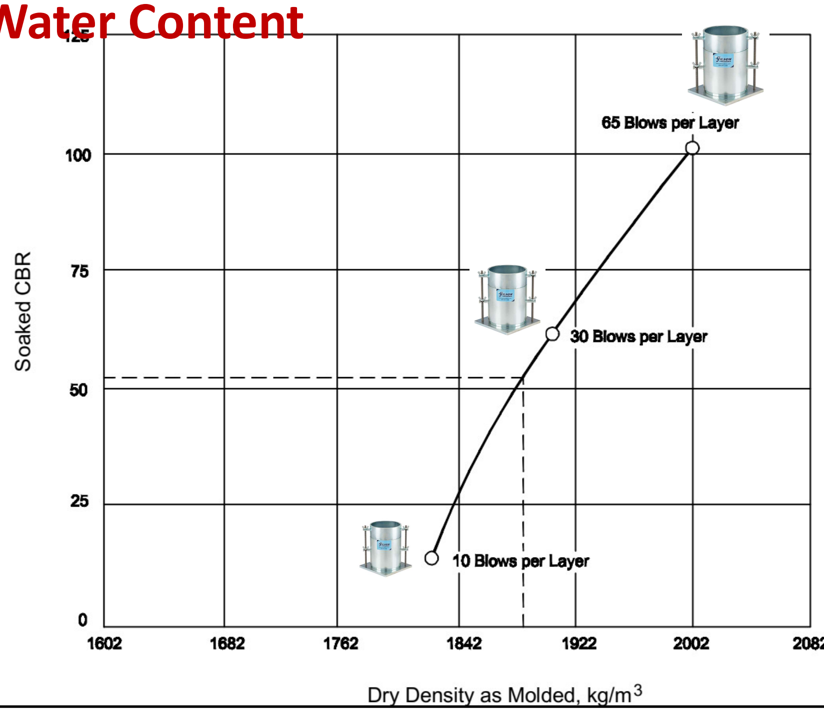
CBR at Optimum Water Content

Calculations



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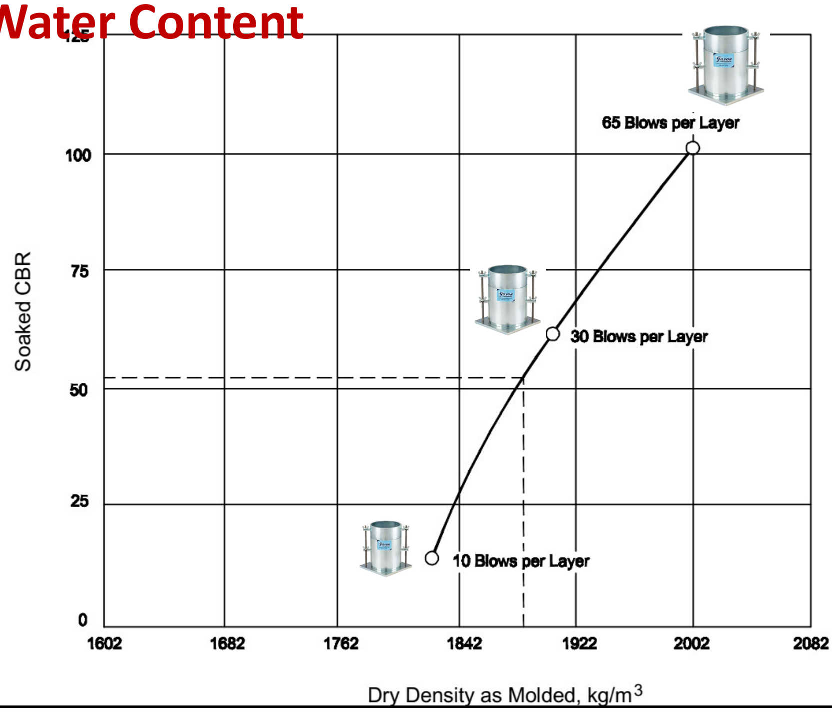
CBR at Optimum Water Content

Calculations

- ❑ Given: Maximum dry density by AASHTO T99 = 1986 kg/m^3
- ❑ Find: The CBR at 95% of the above maximum dry density



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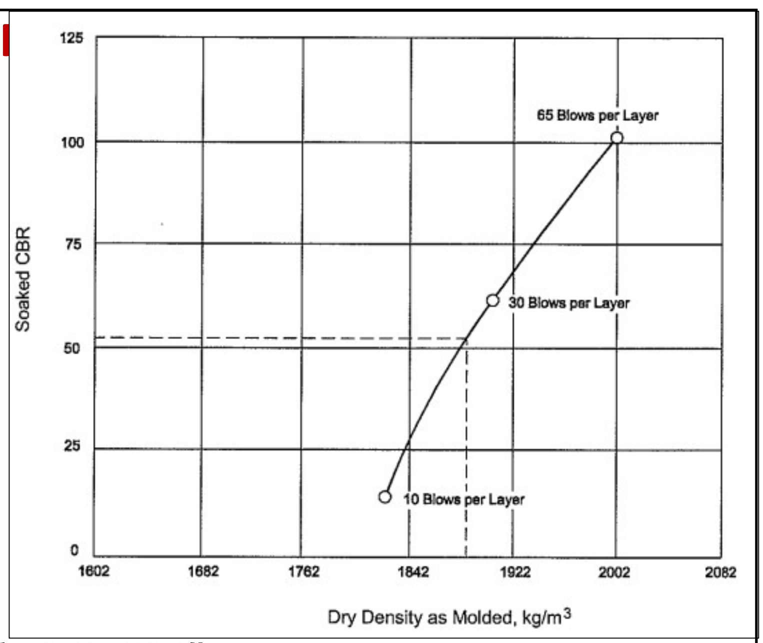
CBR (California Bearing I

Example



Solution: 95 percent of 1986 kg/m^3 = 1887 kg/m^3
At 1887 kg/m^3 > the CBR is 52.

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AASHTO T 193-13

Test Specimens preparation

Case 2: Bearing Ratio (CBR) for a Range of Water Content

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CBR for a Range of Water Content

5. Sample

5.1.3. *Bearing Ratio for a Range of Water Content*—From a sample having a mass of 113 kg (250 lb) or more, select at least five representative portions having a mass of approximately 6.8 kg (15 lb) each for use in developing each compaction curve.

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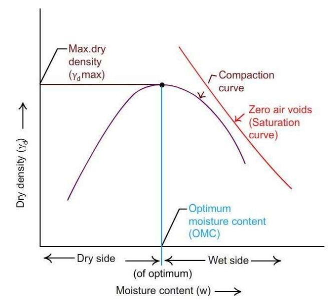
CBR for a Range of Water Content

6. Moisture-Density Relation

6.2. *Bearing Ratio for a Range of Water Content*—Using the 6.8-kg (15-lb) specimens prepared as described in Section 5.1, determine the optimum moisture content and maximum dry density in accordance with the compaction method specified, either T 99 (Method D) or T 180 (Method D), except that the CBR molds shall be used and each specimen shall be penetrated for CBR determination. In addition, the complete moisture-density relationship for 25-blow and 10-blow per layer compactions shall be developed and each test specimen compacted shall be penetrated. Perform all compaction in CBR molds. In cases where the specified unit mass is at or near 100-percent maximum dry unit mass, it will be necessary to include a compactive effort greater than 56 blows per layer (Note 4).



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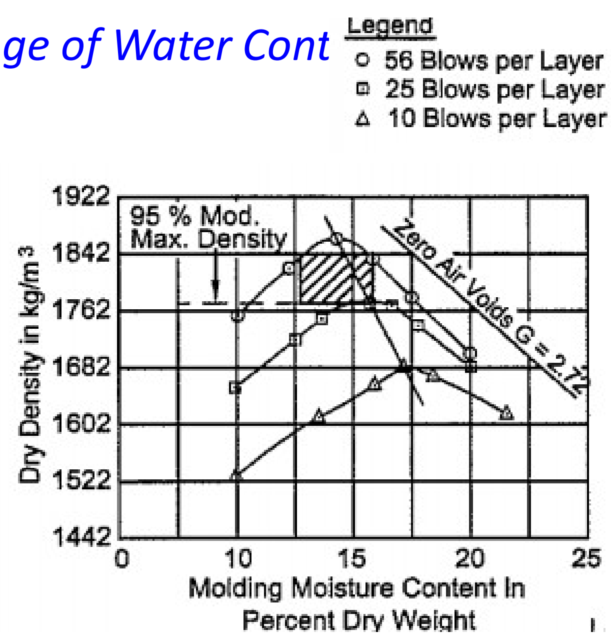
Moisture-Density Relation

Case 2: Bearing Ratio for a Range of Water Cont

- ❑ The following complete moisture-density relationship shall be developed for
  - ➢ *10-blow per layer compactions*
  - ➢ *25-blow per layer compactions*
  - ➢ *56-blow per layer compactions*
- ❑ Each test specimen compacted shall be penetrated.
- ❑ Perform all compaction in CBR molds.



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CBR for a Range of Water Content

7. Procedures

7.2. *Bearing Ratio for a Range of Water Content*:

7.2.1. Prepare specimens in accordance with Section 6.2. Perform all compaction in the CBR molds. Each specimen used to develop the compaction curves for the 10-blow, 25-blow, and 56-blow per layer compactive efforts shall be penetrated. In cases where the specified unit mass is at or near 100 percent maximum dry unit mass, it will be necessary to include a compactive effort greater than 56 blows per layer.

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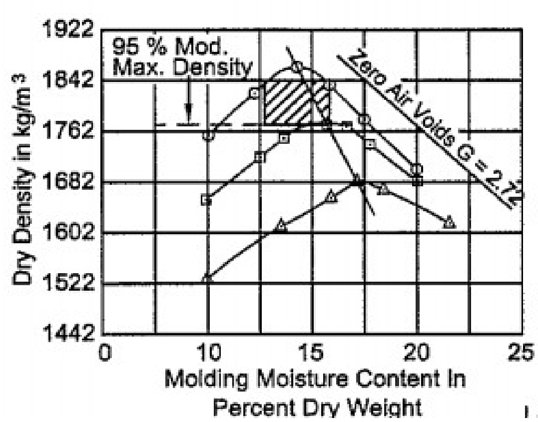
CBR at Optimum Water Content

Calculations

10.4. *Design CBR for Water Content Range*—Plot the data from the tests at the three compactive efforts as shown in Figure 4. The data plotted as shown represent the response of the soil over the range of water content specified. Select the CBR for reporting as the lowest CBR within the specified water content range having a dry unit mass between the specified minimum and the dry unit mass produced by compaction within the water content range.



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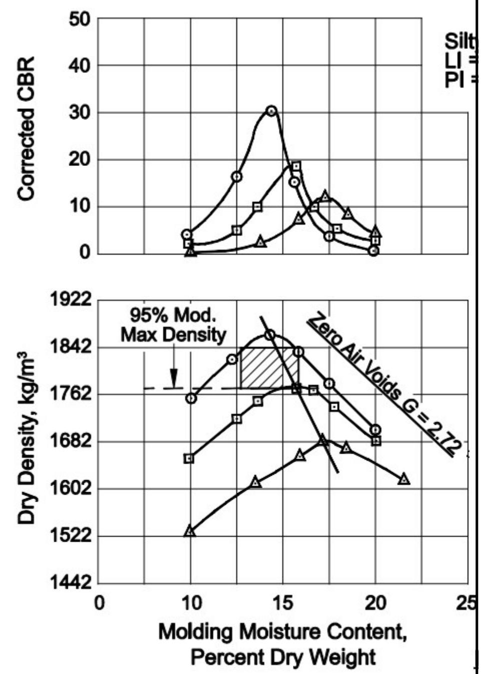
CBR (California Bearing Ratio)

Determination

Legend
- ○ 56 Blows per Layer
- ⊡ 25 Blows per Layer
- △ 10 Blows per Layer



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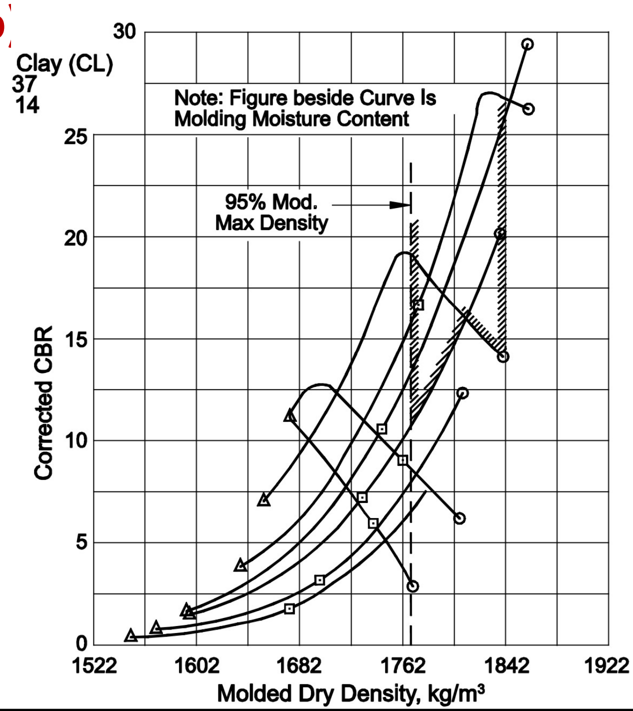
CBR (California Bearing Ratio)

Determination

Legend
- ○ 56 Blows per Layer
- ⊡ 25 Blows per Layer
- △ 10 Blows per Layer



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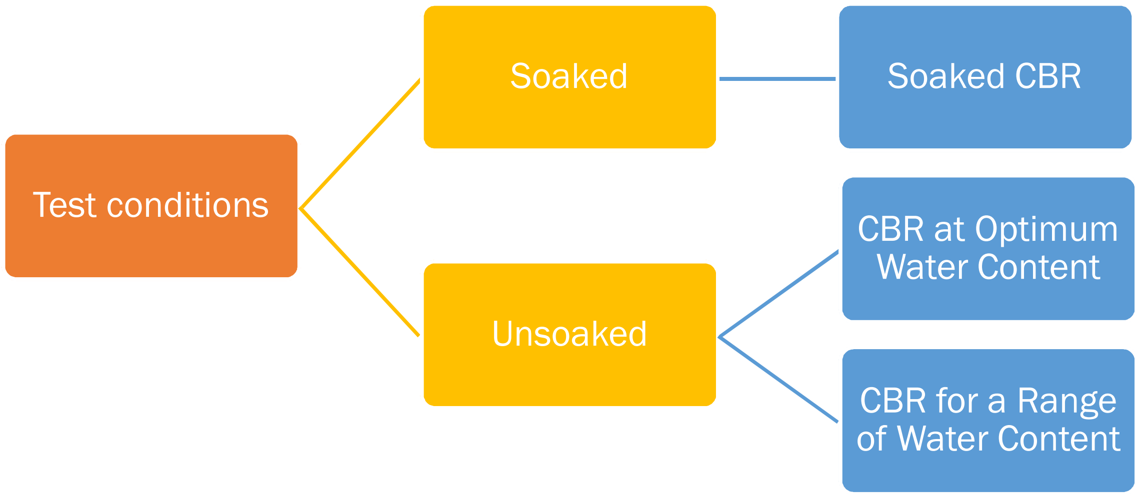
Test Specimens Preparation

Conditions



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AASHTO T 193

SOAKING

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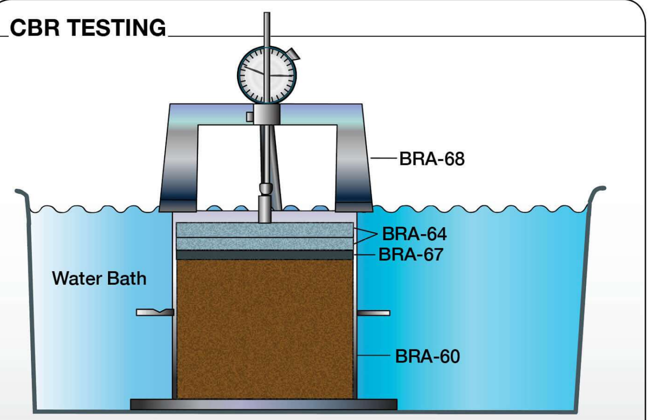
Soaking

Sample preparation for Soaked CBR

- Soaking accounts for adverse moisture conditions from potential rainfall or flooding, and most CBR tests use this procedure.
- In addition to the compaction process, preparation usually involves soaking each specimen in water for 96 hours before the penetration test



Compacted specimens in the mold are immersed in water for soaking. Surcharge weights are placed on top and the molded specimen is monitored to determine swell.

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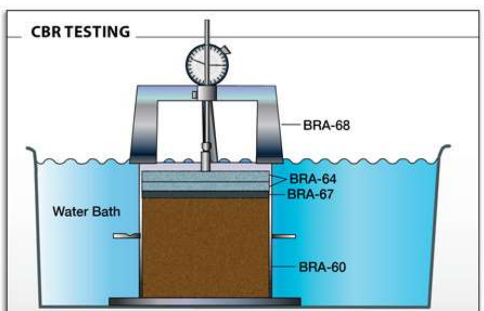
Soaking

6.2.1. If the soaked CBR is to be determined, take a representative sample of the material, for the determination of moisture, at the beginning of compaction of each specimen and another sample of the remaining material after compaction of each specimen. Use T 265 to determine the moisture content. If the unsoaked CBR is to be determined, take a moisture content sample in accordance with T 99 or T 180 if the average moisture content is desired.



Compacted specimens in the mold are immersed in water for soaking. Surcharge weights are placed on top and the molded specimen is monitored to determine swell.

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Soaking

8. SOAKING

8.1. Place the swell plate with adjustable stem on the soil sample in the mold and apply sufficient annular weights to produce an intensity of loading equal to the mass of the subbase and base courses and surfacing above the tested material. The total mass shall be a minimum of 4.54 kg. Additional mass shall be added in increments of 2.26 kg.

8.2. Place the tripod with dial indicator on top of the mold and make an initial dial reading.

8.3. Immerse the mold in water to allow free access of water to top and bottom of the specimen. During soaking, maintain the water level in the mold and the soaking tank approximately 25 mm (1 in.) above the top of the specimen. Soak the specimen 96 hours (4 days).

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Soaking

Note 7—A shorter immersion period (not less than 24 hours) may be used for soil-aggregate materials that drain readily if tests show that the shorter period does not affect the test results. For some clay soils, a soaking period greater than 4 days may be required.

8.4. At the end of 96 hours, make a final dial reading on the soaked specimens and calculate the swell as a percentage of the initial sample length:

$$\text{percent swell} = \frac{\text{change in length in mm during soaking}}{116.43\text{ mm}} \times 100 \qquad (1)$$

8.5. Remove the specimens from the soaking tank, pour the water off the top and allow to drain downward for 15 min. Care shall be taken not to disturb the surface of the specimens during removal of the water. After draining, remove the surcharge weights, perforated plates, and top filter paper.

Note 8—The mass of the specimens may be determined after draining when it is desired to determine the average wet density of the soaked and drained material.

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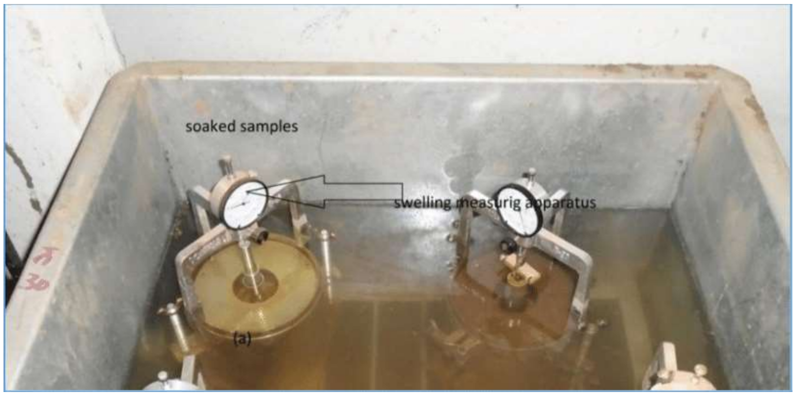
CBR

Sample preparation for Soaked CBR



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General Notes

- **Unsoaked CBR** is carried out to
  - *Simulate the natural field condition*
- **Soaked CBR** is carried out to
  - *simulate the extreme condition which can be resulted from the moisture variation*
    - *Implemented by MPW&H*
- The CBR at unsoaked conditions is always higher compared to soaked CBR values

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AASHTO T 193

Results reporting

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CBR

Results reporting

11.	**REPORT**
11.1.	*The report shall include the following information for each specimen*:
11.1.1.	Compaction effort (number of blows per layer).
11.1.2.	Dry density as molded, percent.
11.1.3.	Moisture content as molded, percent.
11.1.4.	Swell (percent of original length), percent.
11.1.5.	California Bearing Ratio, percent.

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AASHTO T 193

Specifications

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CBR typical values

General Soil Type	USC Soil Type	CBR Range
Clean gravels	GW	40 – 80
	GP	30 – 60
Gravels with fines	GM	20 – 60
	GC	20 – 40
Clean sands	SW	20 – 40
	SP	10 – 40
Sands with fines	SM	10 – 40
	SC	5 – 20
Silts and clays	ML	15 or less
	CL	15 or less
	OL	5 or less
	MH	10 or less
	CH (LL>50%)	15 or less
	OH	5 or less

Table source: https://www.slideserve.com/nishi/california-bearing-ratio-cbr-method

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Jordanian National Building council

Specifications for highway and bridge construction

٣/٢/٢– في حالة القطع وعند الوصول الى منسوب القاعدة الترابية (Topping)
وكانت التربة ذات C.B.R أكبر من ١٥٪ , وبعد التأكد من أن الطبقة
(وبسماكة ٢٠سم) أسفل القاعدة الترابية تحقق نسبة C.B.R لا يقل عن
١٠٪ وتصنيف لا يقع تحت A-6 أو A-7 , فانه يتم تنظيف الأرض من
الجذور والنباتات وحرث ٢٠سم من الأرض ورشها بالماء ودحلها الى
درجة رك بحد أدنى ٩٨٪ من كثافة بروكتور المعدل (يتم محاسبة المقاول
بالمتر المربع) ويتم بعدها وضع طبقة مواد الفرشيات, وفي حال كون المواد
للطبقة أسفل القاعدة الترابية وبسماكة ٢٠سم لا تحقق المواصفات المذكورة
أعلاه (C.B.R< ١٠, تصنيف لا يقع تحت A-6 أو A-7) فان العمل يتم
حسب البند ٣/٢/٣ أدناه .

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٤- أعمال الطمم :

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٤/١- الطمم الترابي الناتج عن القطعيات :

في حالة القطع الترابي الناتج عن أعمال الحفريات تستخدم هذه المواد لأعمال الردم على طبقات بحيث تحقق المواصفات التالية :

١- أن لا تزيد سماكة الطبقة عن ٢٠سم بعد الدحل .

٢- درجة الرك لا تقل عن ٩٥٪ من كثافة بروكتور المعدل لأخر طبقتين من الطمم وبسماكة ٢٠ سم لكل طبقة بعد الدحل أسفل طبقة القاعدة الترابيـــــــــــــة (Sub Grade) وذات CBR لا تقل عن ١٠ ٪ .

٣- درجة الرك لا تقل عن ٩٠٪ من كثافة بروكتور المعدل للطبقات السفلى بحيث لا تكون المواد ذات تصنيف A-6 أو A-7 وC.B.R أكبر من ٨٪ .

٤- الكثافة الجافة العظمى لا تقل عن ٧ر١ غم/سم٣ .

٥- المواد العضوية لا تزيد عن ٥٪ حسب طريقة AASHTO (T267) .

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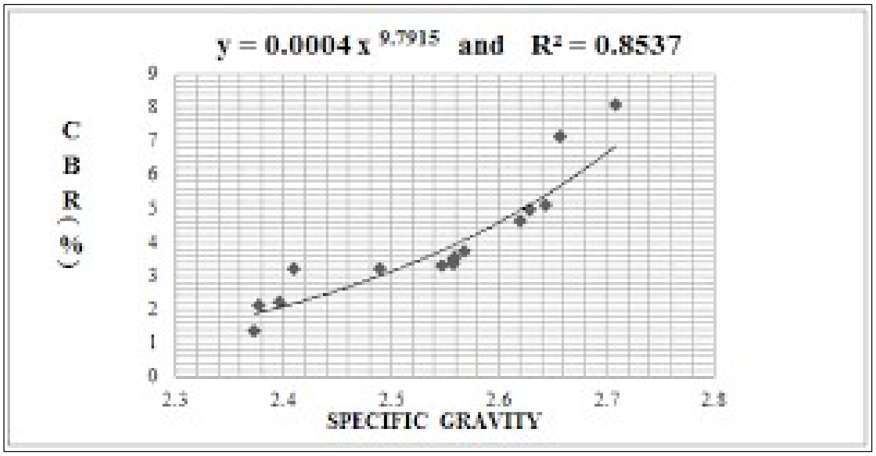
TABLE (1):
SUBGRADE (TOPPING):-

ITEM OF WORK	SUBGRADE MATERIAL		
	TESTS	LIMIT	REFERANCE STANDARD
SUB GRADE LAYER	- MAX. STONE SIZE	3"	
	- LAYER THICKNESS (cm.)	20 CM AFTER COMPACTION	
	-MAX.TOLERANCE IN LEVEL	(+10)OR(-30) MM.	
	- PASS. # 200 (%)	20 % MAX.	AASHTO T11
	- C.B.R (%)	15 % MIN.	AASHTO T193 , ASTM D-1883
	- P.I (%)	10 MAX.	AASHTO T89,T90
	- MAX. DRY DINSITY (GM/CM3)	1.7 MIN.	AASHTO T180
	- COMPACTION (%)	98% MIN.	AASHTO T191
	- ORGANIC MATERIALS %	5 % MAX.	AASHTO T267

CBR vs. S.G



y = 0.0004 x 9.7915 and R² = 0.8537
C B R (%)
0
1
2
3
4
5
6
7
8
9
2.3
2.4
2.5
2.6
2.7
2.8
SPECIFIC GRAVITY

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