INTERNATIONAL

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Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils[1]

This standard is issued under the fixed designation D1883; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This test method covers the determination of the California Bearing Ratio (CBR) of laboratory compacted specimens. The test method is primarily intended for, but not limited to, evaluating the strength of materials having maximum particle size less than ¾ in. (19 mm).

1.2 When materials having a maximum particle size greater than ¾ in. (19 mm) are to be tested, this test method provides for modifying the gradation of the material so that the material used for testing all passes the ¾-in. (19-mm) sieve while the total gravel fraction (material passing the 3-in. (75-mm) sieve and retained on the No. 4 (4.75-mm) sieve) 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 database has been 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 No. 4 (4.75 mm) sieve are more variable than for finer materials. Consequently, more trials may be required for these materials to establish a reliable CBR.

1.4 This test method provides for the determination of the CBR of a material at optimum water content or a range of water contents from a specified compaction test and a specified dry unit weight. The dry unit weight is usually given as a percentage of maximum dry unit weight determined by Test Methods D698 or D1557.

1.4.1 The client requesting the CBR test may specify the water content or range of water contents and/or the dry unit weight for which the CBR is desired.

1.5 Unless specified otherwise by the requesting client, 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.

1.6 *Units*—The values stated in inch-pound units are to be regarded as standard. The SI units given in parentheses are mathematical conversions, which are provided for information purposes only and are not considered standard. Reporting of test results in units other than inch-pound units shall not be regarded as nonconformance with this test method.

1.6.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.6.2 The slug unit of mass is almost never used in commercial practice; that is, density, balances, etc. Therefore, the standard unit for mass in this standard is either kilogram (kg) or gram (g), or both. Also, the equivalent inch-pound unit (slug) is not given/presented in parentheses.

1.6.3 It is common practice in the engineering/construction profession, in the United States, to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit for mass. However, the use of balances or scales recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

1.6.4 The terms density and unit weight are often used interchangeably. Density is mass per unit volume whereas unit weight is force per unit volume. In this standard, density is given only in SI units. After the density has been determined, the unit weight is calculated in SI or inch-pound units, or both.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Strength and Compressibility of Soils.

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***A Summary of Changes section appears at the end of this standard**

1.7 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.7.1 The procedures used to specify how data are collected/recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives, and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analytical methods for engineering design.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))

D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))

D2168 Practices for Calibration of Laboratory Mechanical-Rammer Soil Compactors

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedures)

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

D6913/D6913M Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *water content of the compaction specimen, w_i, n*—water content in percent of material used to compact the test specimen.

3.2.2 *water content top 1 in. (25-mm) after soaking w_s, n*—water content in percent of upper 1 in. (25 mm) of material removed from the compacted specimen after soaking and penetration.

3.2.3 *water content after testing, w_f, n*—water content in percent of the compacted specimen after soaking and final penetration; does not include material described in 3.2.2.

3.2.4 *dry density as compacted and before soaking, ρ_{di}, n*—dry density of the as compacted test specimen using the measured wet mass and calculating the dry mass using the water content defined in 3.2.1.

4. Summary of Test Method

4.1 The California Bearing Ratio (CBR) is an index of the bearing resistance of a compacted soil by forcing a circular piston at a constant rate of penetration into the soil and measuring the force during penetration. The CBR is expressed as the ratio of the unit force on the piston required to penetrate 0.1 in. (3 mm) and 0.2 in. (5 mm) of the test material to the unit force required to penetrate a standard material of well-graded crushed stone.

4.2 This test method is used to determine the CBR of a material compacted in a specified mold. It is incumbent on the requesting client to specify the scope of testing to satisfy the client's protocol or specific design requirements. Possible scope of testing includes:

4.2.1 CBR penetration tests can be performed on each point of a compaction test specimen prepared in accordance with either Method C of Test Methods D698 or D1557. The CBR mold with the spacer disk specified in this standard has the same internal dimensions as a 6.000-in. (152.4-mm) diameter compaction mold.

4.2.2 Another alternative is for the CBR test to be performed on material compacted to a specific water content and density so as to bracket those anticipated in the field. A water content range may be stated for one or more density values and will often require a series of specimens prepared using two or three compactive efforts for the specified water contents or over the range of water contents requested. The compactive efforts are achieved by following procedures of Test Methods

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D698 or D1557 but varying the blows per layer to produce densities above and below the desired density.

5. Significance and Use

5.1 This test method can be used in a number of engineering applications such as to evaluate the potential strength of subgrade, subbase, and base course materials, including recycled materials for use in the design of flexible roads and airfield pavements.

NOTE 1—As with other laboratory test methods, the user should consider whether results from this test are appropriate for the intended design use. Considerations may include roadbed conditions, environmental conditions, soil saturation, drainage effects, seasonal effects, etc.

5.2 For applications where the effect of compaction water content on CBR is small, such as cohesionless, coarse-grained materials, or where an allowance is made for the effect of differing compaction water contents in the design procedure, the CBR may be determined at the optimum water content of a specified compaction effort. The specified dry unit weight is normally the minimum percent compaction allowed by the using client's field compaction specification.

5.3 For applications where the effect of compaction water content on CBR is unknown or where it is desired to account for its effect, the CBR is determined for a range of water contents, usually the range of water content permitted for field compaction by using the client's protocol or specification for field compaction.

5.4 The criteria for test specimen preparation of self-cementing (and other) materials which gain strength with time must be based on a geotechnical engineering evaluation. As directed by the client, self-cementing materials shall be properly cured until bearing ratios representing long term service conditions can be measured.

NOTE 2—The quality of the results produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Loading Machine*—The loading machine shall be equipped with a movable head or base that travels at a uniform (not pulsating) rate of 0.05 ± 0.01 in. (1 ± 0.2 mm)/min for use in pushing the penetration piston into the specimen over the range of forces developed during penetration.

6.1.1 *Axial Load Measuring Device*—The machine shall be equipped with a load-indicating device matched to the anticipated maximum penetration load. The axial load measuring device shall be a load ring, electronic load cell, hydraulic load cell, or any other load-measuring device with an accuracy of 1 % of the load from 0.100 in. (2.5 mm) penetration to at least 0.500 in. (13 mm) penetration or failure.

6.2 *Penetration Measuring Device*—The penetration measuring device (such as a mechanical dial indicator or electronic displacement transducer) shall be capable of reading to the nearest 0.001 in. (0.02 mm) and provided with appropriate mounting hardware. The mounting assembly of the deformation measuring device shall be connected to the penetrating piston and the edge of the mold providing accurate penetration measurements. Mounting the deformation holder assembly to a stressed component of the load frame (such as tie rods) will introduce inaccuracies of penetration measurements.

6.3 *Mold*—The mold shall be a rigid metal cylinder with an inside diameter of 6.000 ± 0.026 in. (152.4 ± 0.66 mm) and a height of 7.000 ± 0.018 in. (177.8 ± 0.46 mm). It shall be provided with a metal extension collar at least 2.0 in. (51 mm) in height and a metal base plate having at least twenty-eight 1⁄16-in. (1.59-mm) diameter holes uniformly spaced over the plate within the inside circumference of the mold. When assembled with the spacer disc placed in the bottom of the mold, the mold shall have an internal volume (excluding extension collar) of 0.0750 ± 0.0009 ft^3 (2100 ± 25 cm^3). A mold assembly having the minimum required features is shown

TABLE 1 SI Equivalents for Figs. 1-5

Inch-Pound Units, in.	SI Equivalent, mm	Inch-Pound Units, in.	SI Equivalent, mm	Inch-Pound Units, in.	SI Equivalent, mm
1.954	49.63	1¼	31.8	4½	114.3
2.416	61.37	1⅜	34.90	4¾	120.7
1⁄16	1.59	1½	38.1	5⅞	149.2
¼	6.4	1¾	44.5	5 15⁄16	150.8
⅜	9.53	1⅛	28.58	6.000	152.4
7⁄16	11.11	2	50.8	6 7⁄32	158.0
½	12.70	2⅛	53.98	7.000	177.8
⅝	15.9	2¾	69.85	7½	190.5
¾	19.1	3	76.20	8⅜	212.7
1⅛	28.58	4¼	108.0	9⅜	238.1

Inch-Pound Units, in.	SI Equivalent, mm	Inch-Pound Units, psi	SI Equivalent, MPa
0.10	2.5	200	1
0.20	5.1	400	3
0.30	7.6	600	4
0.40	10	800	6
0.50	13	1000	7
		1200	8.4
		1400	9.8

in Fig. 1. A calibration procedure shall be used to confirm the actual volume of the mold with the spacer disk inserted. Suitable calibration procedures are contained in Test Methods D698 and D1557.

6.4 *Spacer Disk*—A circular metal spacer disc (see Fig. 1) having a minimum outside diameter of $5\frac{15}{16}$ in. (150.8 mm) but no greater than will allow the spacer disc to easily slip into the mold. The spacer disc shall be 2.416 ± 0.005 in. (61.37 ± 0.13 mm) in height.

6.5 *Rammer*—A rammer as specified in either Test Methods D698 or D1557 shall be used to compact the soil specimen to the desired density.

6.6 *Expansion-Measuring Apparatus*—An adjustable metal stem and perforated metal plate, similar in configuration to that shown in Fig. 2. The perforated plate shall be 5⅞ to $5\frac{15}{16}$ in. (149.2 to 150.8 mm) in diameter and have at least forty-two $\frac{1}{16}$-in. (1.59-mm) diameter holes uniformly spaced over the plate. A metal tripod to support the dial gauge for measuring the amount of swell during soaking is also required. The expansion measuring apparatus shall not weigh more than 2.8 lbf or a mass of 1.3 kg.

6.6.1 *Swell Measurement Device*—Generally mechanical dial indicators capable of reading to 0.001 in. (0.025 mm) with a range of 0.200-in. (5-mm) minimum.

6.7 *Surcharge Weights*—These "weights" are actually "masses" converted to a force. One or two annular metal weights having a total weight of 10 ± 0.05 lbf (equivalent to a mass of 4.54 ± 0.02 kg) and slotted metal weights each having a weight of 5 ± 0.05 lbf (equivalent to a mass of 2.27 ± 0.02 kg). The annular weight shall be 5⅞ to $5\frac{15}{16}$ in. (149.2 to 150.8 mm) in diameter and shall have a center hole of approximately 2⅛ in. (53.98 mm) (see Fig. 3).

6.8 *Penetration Piston*—A metal piston 1.954 ± 0.005 in. (49.63 ± 0.13 mm) in diameter and not less than 4 in. (101.6 mm) long (see Fig. 3).

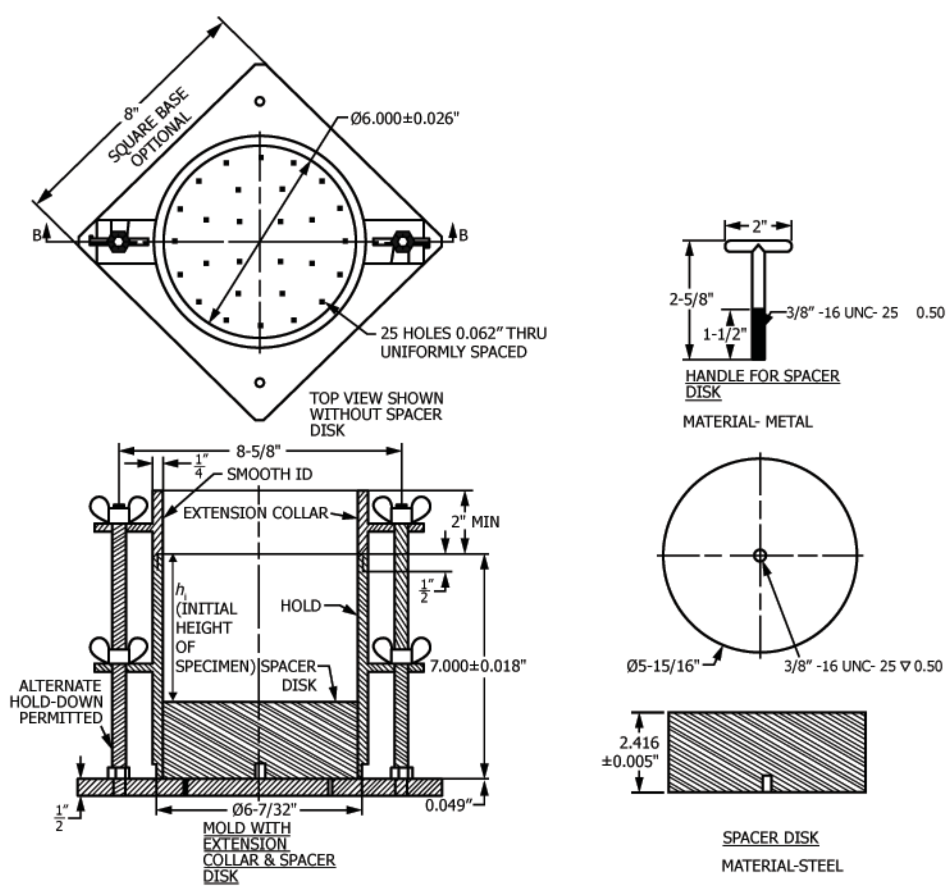
6.9 *Balance*—A class GP5 balance meeting the requirements of Specifications D4753 for a balance of 1-g readability.

6.10 *Drying Oven*—Thermostatically controlled, preferably of a forced-draft type and capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C) throughout the drying chamber.

6.11 *Sieves*—¾ in. (19 mm) and No. 4 (4.75 mm), conforming to the requirements of Specification E11.

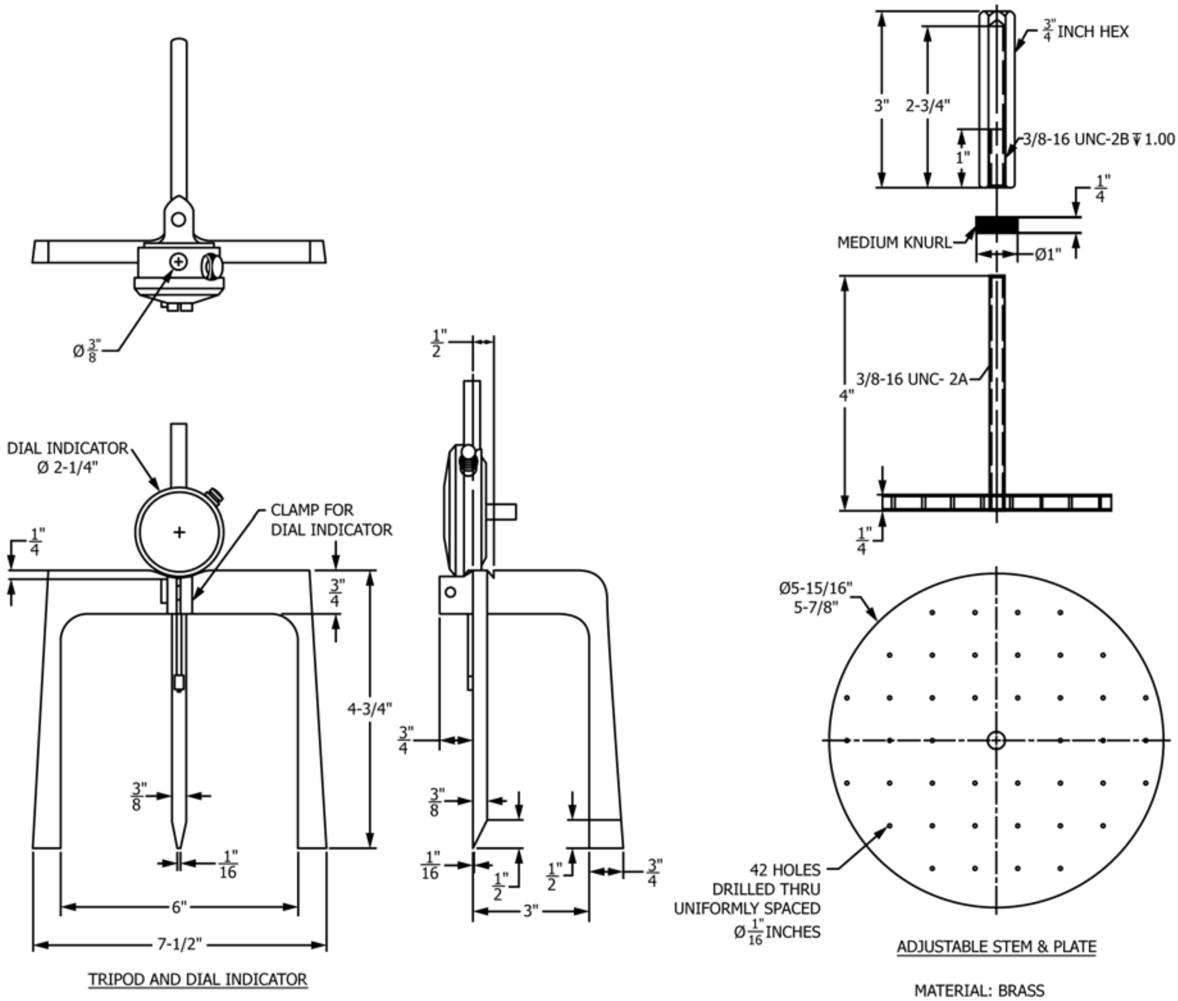
6.12 *Filter Paper*—A fast filtering, high grade hardened, low ash filter paper, 6.000 in. (152.4 mm) diameter.

6.13 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 10.0 in. (254 mm). The total



NOTE 1—See Table 1 for SI equivalents.

FIG. 1 Mold with Extension Collar and Spacer Disk



NOTE 1—See Table 1 for SI equivalents.

FIG. 2 Expansion-Measuring Apparatus

length of the straightedge shall be machined straight to a tolerance of ±0.005 in. (±0.13 mm). The scraping edge shall be beveled if it is thicker than ⅛ in. (3 mm).

6.14 *Soaking Tank or Pan*—A tank or pan of sufficient depth and breadth to allow free water around and over the assembled mold. The tank or pan should have a bottom grating that allows free access of water to the perforations in the mold's base.

6.15 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a mechanical device for thoroughly mixing the sample of soil with water.

7. Sample

7.1 Do not reuse soil that has been previously compacted in the laboratory. The reuse of previously compacted soils may yield a greater maximum dry unit weight.[3]

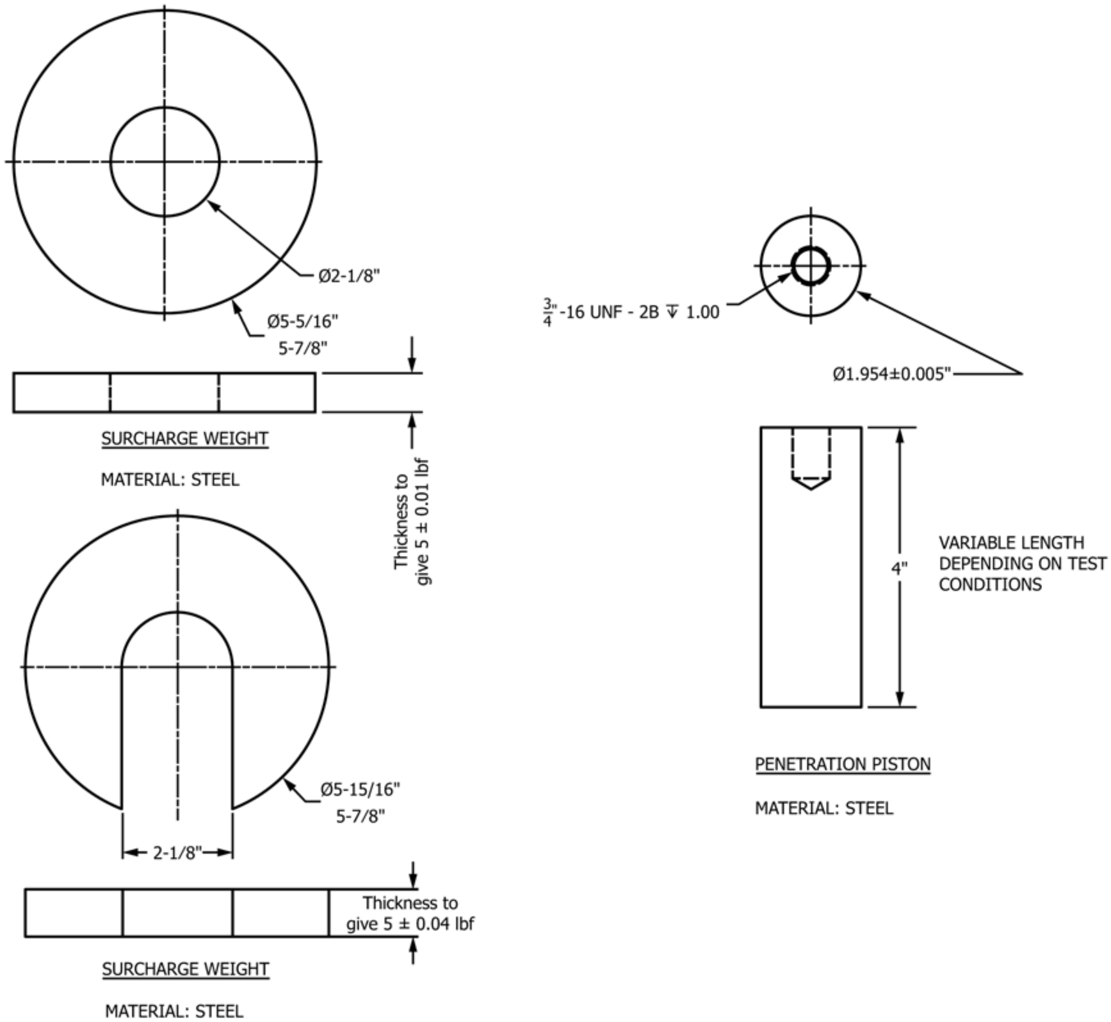
7.2 The specimen(s) for compaction shall be prepared in accordance with the procedures given in Method C of Test Methods D698 or D1557 for compaction in a 6.000-in. (152.4-mm) mold except as follows:

7.2.1 If all material passes a ¾-in. (19-mm) sieve, the entire gradation shall be used for preparing specimens for compaction without modification. If material is retained on the ¾-in. (19-mm) sieve, the material retained on the ¾-in. (19-mm) sieve shall be removed and replaced by an equal mass of material passing the ¾-in. (19-mm) sieve and retained on the No. 4 (4.75 mm) sieve obtained by separation from portions of the sample not used for testing.

8. Test Specimens

8.1 *Bearing Ratio at Optimum Water Content Only*—Using material prepared as described in 7.2, conduct a control compaction test with a sufficient number of test specimens to establish the optimum water content for the soil using the compaction method specified, either Test Methods D698 or D1557. A previously performed compaction test on the same material may be substituted for the compaction test just

[3] Johnson, A. W., and Sallberg, J.R., Factors Influencing Compaction Test Results, Highway Research Board, *Bulletin 318*, Publication 967, National Academy of Sciences-National Research Council, Washington, DC, 1962, p. 73.



NOTE 1—See Table 1 for SI equivalents.

FIG. 3 Surcharge Weights and Penetration Piston

described, provided that if the sample contains material retained on the ¾-in. (19-mm) sieve, then soil prepared as described in 7.2.1 is used for the CBR test.

NOTE 3—Maximum dry unit weight obtained from a compaction test performed in a 4.000-in. (101.6-mm) diameter mold may be slightly greater than the maximum dry unit weight obtained from compaction in the 6.000-in. (152.4-mm) compaction mold or CBR mold.

8.1.1 For cases where the CBR is desired at 100 % maximum dry unit weight and optimum water content, compact a specimen using the specified compaction procedure, either Test Methods D698 or D1557, from soil prepared to within ±0.5 percentage point of optimum water content determined in accordance with Test Method D2216.

8.1.2 Where the CBR is desired at optimum water content and some percentage of maximum dry unit weight, compact three specimens from soil prepared to within ±0.5 percentage point of optimum water content and using the specified compaction but using a different number of blows per layer for each specimen. The number of blows per layer shall be varied as necessary to prepare specimens having unit weights above and below the desired value. Typically, if the CBR for soil at 95 % of maximum dry unit weight is desired, specimens compacted using 10-blows, 25-blows, and 56-blows per layer is satisfactory. Penetration shall be performed on each of these specimens.

8.2 *Bearing Ratio for a Range of Water Contents*—Prepare specimens in a manner similar to that described in 8.1 except that each specimen used to develop the compaction curve shall be penetrated. In addition, the complete water content-unit weight relationship for the 10-blows, 25-blows, and 56-blows per layer compactions shall be developed and each test specimen compacted shall be penetrated. Perform all compaction in the CBR mold. In cases where the specified unit weight is at or near 100 % maximum dry unit weight, it will be necessary to include a compactive effort greater than 56-blows per layer.

NOTE 4—Where the maximum dry unit weight was determined from compaction in the 4.000-in. (101.6-mm) mold, it may be necessary to compact specimens as described in 8.1.2, using 75 blows per layer or some other value sufficient to produce a specimen having a unit weight equal to or greater than that required.

NOTE 5—A semi-log log plot of dry unit weight versus compactive effort usually gives a straight-line relationship when compactive effort in ft-lb/ft^3 is plotted on the log scale. This type of plot is useful in establishing the compactive effort and number of blows per layer needed to bracket the specified dry unit weight and water content range.

8.3 Take a representative sample of the material before it is soaked for the determination of water content to the nearest 0.1 % in accordance with Test Method D2216. If the compaction process is conducted under a controlled temperature range, 65 to 75°F (18 to 24°C), and the processed material is kept sealed during the compaction process, only one representative water content sample is required. However, if the compaction process is being conducted in an uncontrolled environment take two water content samples one at the beginning of compaction and another sample of the remaining material after compaction. Use Test Method D2216 to determine the water contents and average the two values for reporting. The two samples should not differ more than 1.5 percentage points to assume reasonable uniformity of the compacted specimen's water content.

8.3.1 If the compacted CBR test specimen is not to be soaked, a water content sample may be taken, after penetration testing, in accordance with Test Methods D698 or D1557 to determine the average water content. Record the water content to the nearest 0.1 %. Determine the water content in accordance with Test Method D2216.

8.4 Place the spacer disk, with the hole for the extraction handle facing down, on the base plate. Clamp the mold (with extension collar attached) to the base plate with the hole for the extraction handle facing down. Insert the spacer disk over the base plate and place a disk of filter paper on top of the spacer disk. Compact the soil-water mixture into the mold in accordance with 8.1, 8.1.1, 8.1.2, 8.2.

8.4.1 Remove the extension collar and carefully trim the compacted soil even with the top of the mold by means of a straightedge. Patch with smaller size material any holes that may have developed in the surface by the removal of coarse material. Remove the perforated base plate and spacer disk, weigh, and record the mass of the mold plus compacted soil to the nearest g. Place a disk of filter paper on the perforated base plate, invert the mold and compacted soil, and clamp the perforated base plate to the mold with compacted soil in contact with the filter paper.

8.5 *Soaking*—Carefully place the perforated plate and adjustable stem assembly onto the surface of the compacted soil specimen in the mold. Apply sufficient surcharge weights to produce a stress equal to the weight of the subbase and base layers plus pavement within 5 ± 0.05 lbf (mass of 2.27 ± 0.02 kg), but in no case shall the total weight used be less than 10 ± 0.05 lbf (mass of not less than 4.54 ± 0.02 kg). If no surcharge weight is specified, use 10 lbf. An example of how to determine the amount of surcharge is included in Appendix X1. The mass of the Expansion Measuring Apparatus is ignored.

8.5.1 Immerse the mold and weights in water allowing free access of water to the top and bottom of the specimen. Record the initial dial reading, D_i for swell and allow the specimen to soak for 96 ± 2 hours. Maintain a constant water level above the top of the mold approximately 1 in. (25 mm) during this period. A shorter immersion period is permissible for fine grained soils or coarse grained soils that take up moisture readily, provided tests show that the shorter period does not affect the results. At the end of the immersion period, record final dial reading, D_f, for swell and determine the percent of swell to the nearest 0.1 % as a percentage of the initial height, h_i, of the specimen.

8.5.2 Remove the free water from the top surface of the specimen and allow the specimen to drain downward for at least 15 minutes. Take care not to disturb the surface of the specimen during the removal of the water. It may be necessary to tilt the specimen in order to remove the surface water. Remove the weights, perforated plate, and filter paper after draining.

NOTE 6—The user may find it convenient to set the mold's base on the rim of a shallow pan to provide the tilt and carefully using a bulb syringe and adsorbent towels to remove free water.

NOTE 7—It may be desirable to determine and record the mass of the drained specimens for computing the average wet density. Record the mass to the nearest g.

9. Procedure for Bearing Test

9.1 To prevent upheaval of soil into the hole of the surcharge weights, place the 5 ± 0.05 lbf (mass of 2.27 ± 0.02 kg) annular surcharge weight on the soil surface prior to seating the penetration piston. Place a surcharge of weights on the specimen sufficient to produce an intensity of the pavement weight or other loading specified; if no pavement weight is specified, use 10 ± 0.05 lbf (mass of 4.54 ± 0.02 kg). If the specimen has been soaked previously, the surcharge shall be equal to that used during the immersion period. The remainder of the surcharge weights shall be added after seating of the penetration piston as described in 9.2.

9.2 Seat the penetration piston with the smallest possible load, but in no case in excess of 10 lbf (444 N). This initial load is required to ensure satisfactory seating of the piston and shall be considered as the zero load when determining the load penetration relation. After seating of the penetration piston then attach the penetrating measuring device in accordance with 6.2. Set both the load and penetration gauges to zero or make provisions to subtract any initial values from all subsequently collected data.

9.3 Apply the load on the penetration piston so that the rate of penetration is approximately 0.05 in. (1.27 mm)/min. Record the load readings at penetrations of 0.025 in. (0.64 mm), 0.050 in. (1.3 mm), 0.075 in. (1.9 mm), 0.10 in. (2.5 mm), 0.125 in. (3.18 mm), 0.150 in. (3.8 mm), 0.175 in. (4.45 mm), 0.20 in. (5.1 mm), 0.30 in. (7.6 mm), 0.40 in. (10 mm) and 0.50 in. (13 mm). Note the maximum load and penetration if it occurs for a penetration of less than 0.50 in. (13 mm). With manually operated loading devices, it may be necessary to take load readings at closer intervals to control the rate of penetration. Measure the depth of piston penetration into the soil by putting a ruler into the indentation and measuring the difference from the top of the soil to the bottom of the indentation. If the depth does not closely match the depth of penetration gauge, determine the cause and test a new sample.

NOTE 8—At high loads, the penetration measuring device supports may torque and affect the reading of the penetration gauge. Checking the depth of piston penetration is one means of checking for erroneous strain indications.

9.4 If the test specimen was previously soaked, remove the soil from the mold and determine the water content to the nearest 0.1 % of the top 1-in. (25-mm) layer in accordance with Test Method D2216. If the test specimen was not soaked, take the water content sample in accordance with Test Methods D698 or D1557.

10. Calculation

10.1 *Load-Penetration Curve*—Calculate the penetration stress in pounds per square inch (psi) or megapascals (MPa) by taking the measured loading force and divide it by the cross-sectional area of the piston. Plot the stress versus penetration curve as shown in Fig. 4. In some instances, the stress-penetration curve may be concave upward initially, because of surface irregularities or other causes, and in such cases the zero point shall be adjusted as shown in Figs. 4 and 5.

NOTE 9—Figs. 4 and 5 should be used as an example of correction of load-penetration curves only. It is not meant to imply that stress on piston at the 0.2-in. penetration is always greater than the applied stress at the 0.1-in. penetration.

10.2 *Bearing Ratio*—Using either the no correction required stress on piston (SOP) values corrected stress on piston (CSOP) values taken from the stress penetration curve for 0.10 in. (2.45 mm) and 0.20 in. (5.1 mm) penetrations, calculate the bearing ratio for each by dividing either the SOP or the (CSOP) value by the standard stresses (SS) of 1000 psi (6.9 MPa) and 1500 psi (10.3 MPa) respectively, and multiplying by 100. The bearing ratio reported for the soil is normally the one at 0.10 in. (2.5 mm) penetration. When the ratio at 0.20 in. (5.1 mm) penetration is substantially greater than 0.1 in. (2.5 mm) penetration, either report both results or rerun the test if sufficient materials are available. If the rerun test gives a similar result, use the bearing ratio at 0.20 in. (5.1 mm) penetration.

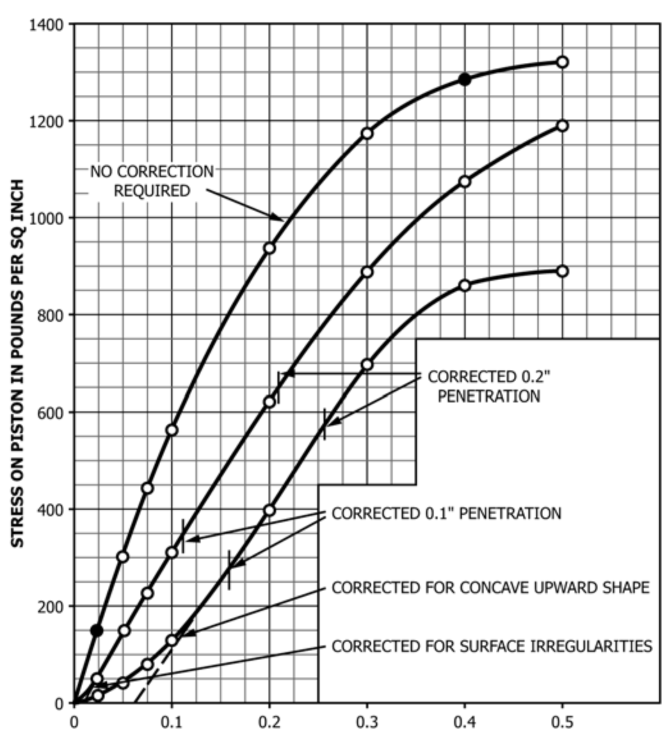
$$CBR_x = \frac{SOP \text{ or } CSOP}{SS} \times 100 \quad (1)$$

where:

x = penetration, in. (mm),
SOP = no correction stress on piston, lbf/in.^{2} (MPa),
$CSOP$ = corrected stress on piston, lbf/in.^{2} (MPa),
SS = standard stress, lbf/in.^{2} (MPa),
-for x = 0.1 in. (2.5 mm) SS= 1,000 lbf/in.^{2} (6.9 MPa),
-for x = 0.2 in. (5.1 mm) SS= 1,500 lbf/in.^{2} (10.3 MPa).

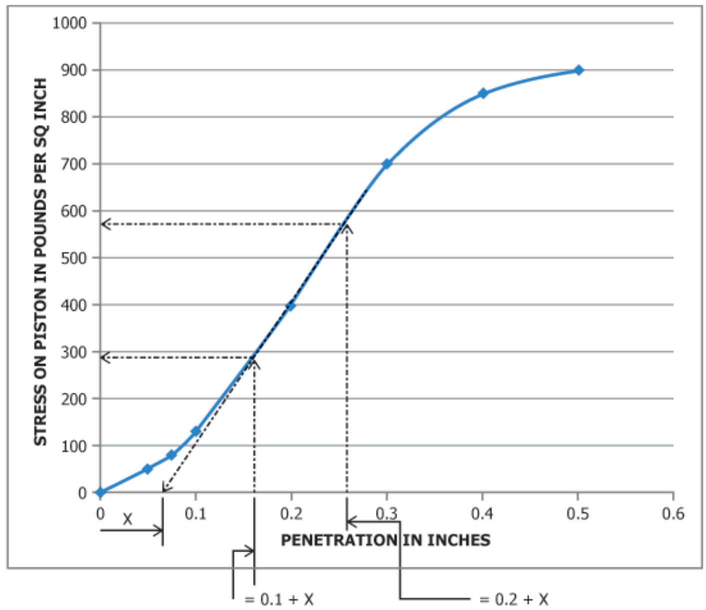
NOTE 10—On occasion the testing agency may be requested to determine the CBR value for a dry unit weight not represented by the laboratory compaction curve. For example, the corrected CBR value for the dry unit weight at 95 % of maximum dry unit weight and at optimum water content might be requested. A recommended method to achieve this value is to compact two or three CBR test specimens at the same molding water content but compact each specimen to different compaction energies to achieve a density below and above the desired value. The corrected CBR values are plotted against the dry unit weight and the desired CBR value interpreted as illustrated in Fig. 6. For consistency the corrected CBR values should be of identical origin, for example, all either soaked or un-soaked and all either at 0.1 or 0.2 corrected penetration values.

10.3 Calculate and record the dry density, ρ_d, of the compacted specimen (before soaking) to four significant figures in g/cm^3 as follows:



NOTE 1—See Table 1 for SI equivalents.

FIG. 4 Correction of Load-Penetration Curves



When adjusting a concave upward shaped curve, project a straight line through the straight-line portion of the stress-penetration curve downward until it intersects the penetration axis (see dashed lines in Figs. 4 and 5). Measure the distance (X) from the origin to the intersection. This distance (X) is then added to 0.1 and 0.2 of the penetrations and this creates a new 0.1 and 0.2 penetration. Project a straight line upward from these new penetration points until it intersects the stress-penetration curve and then select the appropriate stress values that correspond with new 0.1 and 0.2 penetrations.

FIG. 5 Method for Adjusting Concave Upward Shaped Curve

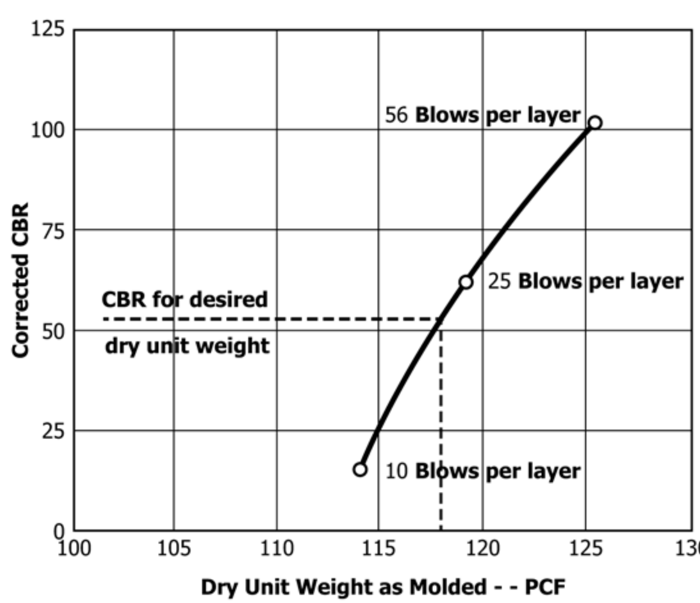


FIG. 6 Dry Unit Weight Versus CBR

$$\rho_d = \frac{M_{sas}}{V_m}$$

where:

$$M_{sac} = \frac{M_{m+ws} - M_m}{1 + \frac{w_{ac}}{100}}$$

M_{sac} = dry mass of soil as compacted, g,
M_{m+ws} = wet mass of soil as molded plus mold mass, g,
M_m = mold mass, g,
w_{ac} = water content determination of representative scraps taken during the compaction process, nearest 0.1 %,
V_m = volume of mold (area of mold × initial height), a calibrated value, cm^3, and
ρ_d = dry density of the compacted specimen, g/cm^3.

10.3.1 Calculate and record the dry unit weight to four significant figures in lbf/ft^3 or kN/m^3 as follows:

$$\gamma_d = 9.8066 \times \rho_d, \; kN/m^3$$

or,

$$\gamma_d = 62.428 \times \rho_d, \; lbf/ft^3$$

where:

γ_d = dry unit weight, kN/m^3 or lbf/ft^3,
9.8066 = conversion factor, g/cm^3 to kN/m^3, and
62.428 = conversion factor, g/cm^3 to lbf/ft^3.

10.4 If the test specimen was soaked, calculate the percent swell as follows:

$$S = \left(\frac{(D_f - D_i)}{h_i}\right) \times 100$$

where:

S = swell that occurred during soaking, to the nearest 0.1 %,
D_f = final dial reading of swell measurement, in. (mm),
D_i = initial dial reading of swell measurement, in. (mm), and
h_i = height of test specimen before swell, in. (mm).

11. Report: Test Data Sheet(s)/Form(s)

11.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.7 and in Practice D6026. An example of data sheets is included in Appendix X2.

11.2 Record as a minimum the following general information (data):

11.2.1 Any special sample preparation and testing procedures (for example, for self-cementing materials).

11.2.2 Sample identification (location, boring number, etc.).

11.2.3 Any pertinent testing done to describe the test sample such as: as-received water content per Test Method D2216, soil classifications per Test Method D2487, visual classification per Practice D2488, Atterberg Limits per Test Method D4318, gradation per Test Methods D6913/D6913M, etc.

11.2.4 The percent material retained on the 19-mm sieve for those cases where scalping and replacement is used to the nearest 0.1 %.

11.2.5 Technician name/initials of personnel performing the test.

11.2.6 Date(s) of testing.

11.3 Record as a minimum the following test specimen data:

11.3.1 Method used for preparation and compaction of specimen: Test Methods D698 or D1557, or other, with description.

11.3.2 Condition of sample (unsoaked or soaked).

11.3.3 Dry unit weight of sample as compacted (before soaking) to the nearest 0.1 lbf/ft^3 or 0.02 kN/m^3.

11.3.4 Water content of sample to the nearest 0.1 %:

11.3.4.1 As compacted.

11.3.4.2 Top 1-in (25.4-mm) layer after soaking.

11.3.5 Swell (percentage of initial height) to the nearest 0.1 %.

11.3.6 Stress-penetration curve.

11.3.7 Corrected CBR value of sample (unsoaked or soaked) at 0.10 in. (2.5 mm) penetration or at 0.20 in. (5.1 mm) penetration, to the nearest 1 %.

11.3.8 Surcharge weight(s) used for the testing to the nearest 5 lbf.

11.3.9 Immersion period, hours.

12. Precision and Bias

12.1 *Precision*—Test data on precision is not presented due to the nature of the materials tested by this test method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. Notwithstanding this statement the following is offered for guidance:

12.1.1 Single operator, based on seven repetitions, coefficient of variation (1S%) has been found to be 8.2 % (compacted per Test Method D698) and 5.9 % (compacted per Test Method D1557). Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 23 % (compacted per Test Method D698) and 17 % (compacted per Test Method D1557).[4] See Appendix X3 for the data used.

12.1.2 Subcommittee D18.05 is seeking any data from the users of this test method that might be used to make a more thorough statement on precision.

12.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

13. Keywords

13.1 California Bearing Ratio; CBR; pavement subgrade; subbase; strength; pavement design

[4] These numbers represent the difference limit (d2s) as described in Practice C670.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE OF COMPUTATION TO DETERMINE THE AMOUNT OF SURCHARGE WEIGHT

X1.1 The following example (Fig. X1.1) presents how to determine the amount of surcharge weight, SW, to use for the CBR test to produce an intensity of the pavement weight or other loading specified.

NOTE X1.1—See Table X1.1 for SI equivalents.

X1.2 Determine the vertical stress (σ_V) at the top of the soil subgrade due to the Asphalt + Crushed Aggregate Base

$$\sigma_V = \frac{T_1 * \gamma_1}{12} + \ldots\ldots \frac{T_N * \gamma_N}{12} \quad (X1.1)$$

where:

$T_{1..N}$ = thickness of layer, in.
$\gamma_{1..N}$ = unit weight of material, lbf/ft^3

$$\sigma_V = (8/12 * 148) + (6/12 * 140) = 168.7 \text{lbf/ft}^2 \quad (X1.2)$$

X1.3 Determine the surface area, SA, of the top of the 6 in. CBR mold.

$$SA = \frac{\pi \times (D_M)^2}{4 \times 144} \quad (X1.3)$$

where:

SA = surface area, ft^2.
D_M = diameter of mold, in.

$$SA = \frac{\pi \times (D_M)^2}{4 \times 144} = \frac{\pi \times (6)^2}{4 \times 144} = 0.196 \text{ft}^2 \quad (X1.4)$$

X1.4 Determine the surcharge weight, SW, in lbf, rounded to the nearest 5 lbf.

$$SW = \sigma_V \times SA \quad (X1.5)$$

$$SW = 168.7 * 0.196 = 33 \text{lbf, Use 35 lbf} \quad (X1.6)$$

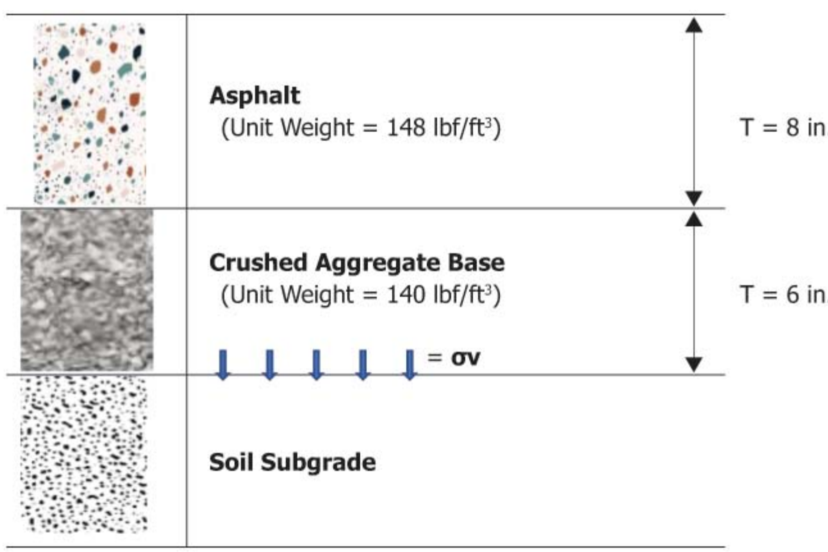


FIG. X1.1 Typical Pavement Section

TABLE X1.1 SI Equivalents

Inch-Pound Units, in.	SI Equivalent, mm	Inch-Pound Units, lbf/ft^3	SI Equivalent, kN/m^3	Inch-Pound Units, lbf	SI Equivalent, kg	Inch-Pound Units, ft^3	SI Equivalent, m^3	Inch-Pound Units, lbf/ft^2	SI Equivalent, kg/m^2
6	152	140	22	5.0	1.9	0.196	0.006	168.7	823.7
8	203	148	23	35	13.0				

X2. EXAMPLE DATA SHEETS

X2.1 Fig. X2.1 and Fig. X2.2 provide examples of data sheets.

CALIFORNIA BEARING RATIO

MADE FOR: ____________________ DATE: ________

PROJECT: ____________________ PROJECT NO. ________

SOURCE: ____________________ LABORATORY NO: ________

MOLD NO: ________ DATE RECEIVED: ________ DATE TESTED: ________

MAX. DRY UNIT WEIGHT (lbf/ft^3) ________ OPTIMUM WATER CONTENT (%): ________

Test Method: ________ Hammer (lbm), ________ Drop (in), ________ Blows, ________ Layers

☐ Soaked CBR ☐ Unsoaked CBR

UNIT WEIGHT DETERMINATION			Molded Water Content (g)	Water Content Top Inch
Wgt of Mold + Wet Soil (lbf)		Wgt of Cup + Soil, Wet		
Wgt of Mold (lbf)		Wgt of Cup + Soil, Dry		
Wgt of Wet Soil (lbf)		Wgt. Of Water		
Vol. Of Mold (ft^3)		Tare Cont. Wt.		
Wet Unit Wt. (lbf/ft^3)		Tare Cont. #		
Dry Unit Wt. (lbf/ft^3)		Wgt of Dry Soil		
Percent Compaction (%)		WATER CONTENT		

Penetration (in)	Total Force (lbf)	Stress (psi)
0.00		
0.03		
0.05		
0.08		
0.10		
0.15		
0.20		
0.25		
0.30		
0.40		
0.50		

Swell:

Dial Reading after Test: ________

Dial Reading before Test: ________

Swell (in) ________

Swell (%): ________

Surcharge Load (lbs): ________

Apply Force @ 0.1 inches in 2 minutes (0.05"/min.)

% Retained #4 Sieve: ☐

Visual Description ________

USCS Classification ________

AASHTO Class. ________

Group Index: ________

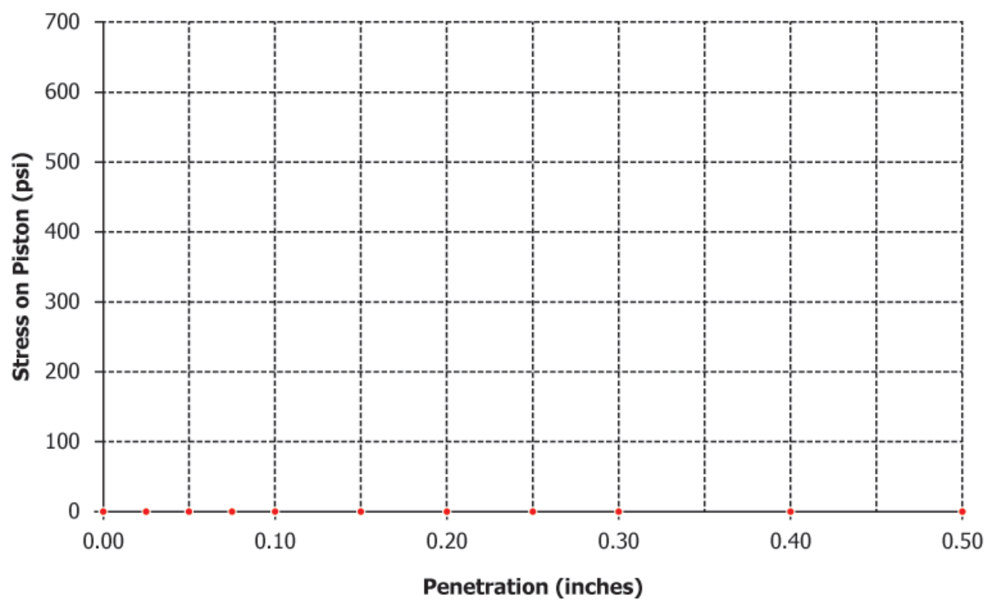
Techician:

FIG. X2.1 Data Sheet Example

California Bearing Ratio

Record #: ____________________
Client: ____________________
Project: ____________________
Location: ____________________
Lab No.: ____________________

Test Date: ____________________
Tested By: ____________________
Compaction method: ____________
_____ Soaked CBR
_____ Unsoaked CBR



CBR @ 0.1 in. or 0.2 in. penetration: ________
Swell (%): ________
Dry Unit Wgt Before Soaking (lbf/ft^3): ________
Water Content Before Soaking (%): ________
Water Content After Soak, Top in. (%): ________

Maximum Dry Unit Wgt (lbf/ft^3): ________
Optimum Water Content (%): ________

Visual Description: ____________________

% Retained No. 4 Sieve ____________________

Surcharge Load (lbs): ____________________

Reviewed By: ____________________

FIG. X2.2 Data Sheet Example

X3. PRECISION DATA FOR SINGLE OPERATOR

X3.1 See Fig. X3.1 for more information.

STANDARD (D698) — CBR

(X)	$(X - \bar{X})$	$(X - \bar{X})^2$
16.7	0.5	0.25
15.7	1.5	2.25
18.2	1	1.00
18.2	1	1.00
18.8	1.6	2.56
19.3	2.1	4.41
17.9	0.7	0.49
$\Sigma X = 124.8$		$\Sigma(X - \bar{X})^2 = 11.96$

$\bar{X} = 17.2$

$$S = \frac{11.96}{6} = 1.99$$

$$1S \text{ (one sigma)} = \sqrt{1.99} = 1.41$$

$$1S\% = \frac{1.41 \times 100}{17.2} = 8.2\%$$

$$D2S\% = 22.6\%$$

MODIFIED (D1557) — CBR

(X)	$(X - \bar{X})$	$(X - \bar{X})^2$
77.0	3.0	9.00
70.2	3.8	14.44
80.8	6.8	46.24
68.2	5.8	33.64
76.7	2.7	7.29
71.7	2.3	5.29
73.3	0.7	0.49
$\Sigma X = 517.9$		$\Sigma(X - \bar{X})^2 = 116.39$

$\bar{X} = 74.0$

$$S = \frac{116.39}{6} = 19.39$$

$$1S = \sqrt{19.39} = 4.4$$

$$1S\% = \frac{4.4 \times 100}{74} = 5.9\%$$

$$D2S\% = 16.7\%$$

NOTES:
- All Materials passed the #10 sieve
- Over 90% of all materials passed the #40 sieve
- Method A of AASHTO T99 & T180 used
- Unit weights were 110 PCF ± (D698) and 122 PCF ± (D1557)
- 7 test repetitions
- The above data is from one user
- The (1S) and (D2S) limits represent the limits as described in ASTM Practice C670.

FIG. X3.1 Compactive Effort

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2016) that may impact the use of this standard. (November 15, 2021)

(1) Corrected several typos.
(2) Updated the Referenced Documents.
(3) Updated the significant digits throughout the Test Method.
(4) Revisited the use of Shall and Should throughout the Test Method.
(5) Added the International caveat to Section 1.
(6) Revised Section 3 to be in accordance with D18 SPM
(7) Added Note 1 to Section 5.
(8) Edited 6.1 and 6.1.1 to define Axial Load-Measuring Device and removed Table 1.
(9) Corrected Fig. 5 to change line type to a dashed line.
(10) Reworded sentence structure to clarified wording throughout the standard.
(11) Corrected equation in 10.3.
(12) Added additional calculations into 10.4.
(13) Added Example X1.1 to Appendixes and rearranged and renumbered the Appendixes.