Standard Method of Test
for

The California Bearing Ratio

AASHTO DESIGNATION: T 193-93

1. SCOPE

1.1 This test method covers the determination of the CBR (California Bearing Ratio) 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.)

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 $^3/_4$-in. sieve while the total gravel (No. 4 to 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 No. 4 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 content 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 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 weight 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.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

- M 92 Wire Cloth Sieves for Testing Purposes
- M 145 The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
- T 2 Sampling Aggregates
- T 87 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
- T 88 Particle Size Analysis of Soils
- T 89 Determining the Liquid Limit of Soils
- T 90 Determining the Plastic Limit and Plasticity Index of Soils
- T 99 The Moisture-Density Relations of Soils Using a 5.5-lb. (2.5 kg) Rammer and a 12-in. (305 mm) Drop
- T 180 Moisture-Density Relations of Soils Using a 10-lb. (4.54 kg) Rammer and an 18-in. (457 mm) Drop
- T 265 Laboratory Determination of Moisture Content of Soils

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.

3.2 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 dry unit weight specified is normally the minimum percent compaction allowed by the using agency's field compaction specification.

3.3 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 content, usually the range of water content permitted for field compaction by using agency's field compaction specification.

3.4 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 engineer, self cementing materials shall be properly cured until bearing ratios representing long term service conditions can be measured.

4. APPARATUS

4.1 *Molds*—The molds shall be cylindrical in shape, made of metal, with an internal diameter of 152.4 ± 0.66 mm (6.0 ± 0.026 in.) and a height of 177.8 ± 0.40 mm (7.0 ± 0.018 in.) provided with an extension collar apoximately 51 mm (2.0 in.) in height ıd a perforated base plate that can be .ted to either end of the mold (See gure 1). It is desirable to have at least ree molds for each soil to be tested.

4.2 *Spacer Disk*—A circular spacer sk made of metal 150.8 ± 0.8 mm ($^{15}/_{16}$ ± $^{1}/_{32}$ in.) in diameter and 61.4 ± 25 mm (2.416 ± 0.01 in.) in height ee Figure 1).

NOTE 1—When using molds having a ɜight of 177.8 mm (7.0 in.) (see Figure 1), spacer disk height of 61.37 mm (2.416 in.) needed to obtain a thickness of compacted ɔecimen that conforms to the thickness: 16.43 mm (4.584 in.) of specimens in T 99 ıd T 180.

Rammer—A rammer as speci- ːed in either T 99 or T 180.

4.4 *Apparatus for Measuring Expan- ion*—This consists of a swell plate with djustable stem (Figure 1) and a tripod upport for a dial indicator (Figure 1). 'he swell plate is made of metal, 149.2 ː 1.6 mm (5$^{7}/_{8}$ ± $^{1}/_{16}$ in.) in diameter nd is perforated with 1.6 mm ($^{1}/_{16}$ in.) iameter holes. The tripod used to sup- 'ort the dial indicator is arranged to fit ıe mold extension collar.

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

4.6 *Surcharge Weights*—One annu- ar metal weight with a center hole ap- ıroximately 54.0 mm (2$^{1}/_{8}$ in.) in diame- er and several slotted or split metal veights, all 149.2 ± 1.6 mm (5$^{7}/_{8}$ ± $^{1}/_{16}$ n ' 'n diameter and each weighing 2.27 ± .04 kg (5 ± 0.10 lb) (Figure 1) NOTE 2).

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

4.7 *Penetration Piston*—A metal ɔiston of circular cross-section having a ɟiameter of 49.63 ± 0.13 mm (1.954 ±).005 in.) (1935 mm², area = 3 in.²) and ıot less than 102 mm (4 in.) long (see Figure 1).

4.8 *Loading Device*—A compres- sion-type apparatus capable of applying a uniformly increasing load up to 10000 lb (44.5kN) at a rate of 1.3 mm (0.05 in.) per min., used to force the penetration piston into the specimen.

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

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

4.11 *Moisture Content Contain- ers*—As specified in T 265.

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

5. SAMPLE

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

5.1.1 If all material passes a 19 mm ($^{3}/_{4}$-in.) sieve, the entire gradation shall be used for preparing specimens for com- paction without modification. If there is material retained on the 19 mm ($^{3}/_{4}$-in.) sieve, the material retained on the 19 mm ($^{3}/_{4}$-in.) sieve shall be removed and replaced by an equal amount of material passing the 19 mm ($^{3}/_{4}$-in.) sieve and retained on the 4.75-mm (No. 4) sieve obtained by separation from portions of the sample not otherwise used for testing.

5.1.2 *Bearing Ratio at Optimum Wa- ter Content.* From a sample weighing 35 kg (75 lb.) or more, select a representa- tive portion weighing approximately 11 kg (25 lb.) for a moisture-density test and divide the remainder of the sample to obtain 3 representative portions weighing approximately 6.8 kg (15 lb.) each.

5.1.3 *Bearing Ratio for a Range of Water Content.* From a sample weighing 250 lb. (113 kg) or more, select at least 5 representative portions weighing ap- proximately 6.8 kg (15 lb) each for use in developing each compaction curve.

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 per- formed compaction test on the same ma- terial may be substituted for the compac- tion test just described, provided that if the sample contains material retained on the 19 mm ($^{3}/_{4}$-in.) sieve, soil prepared as described in Section 5.1 is used (NOTE 3).

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

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 den- sity 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 speci- men compacted shall be penetrated. Per- form all compaction in CBR molds. In cases where the specified unit weight is at or near 100 percent maximum dry unit weight, it will be necessary to include a compactive effort greater than 56- blows per layer (NOTE 4).

NOTE 4—A semilog plot of dry unit weight versus compactive effort usually gives a straight line relation when compactive effort in ft-lb/ft³ 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.

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 deter- mine the moisture content. If the un- soaked CBR is to be determined, take a moisture content sample in accordance with T 99 or T 180 if the average mois- ture content is desired.

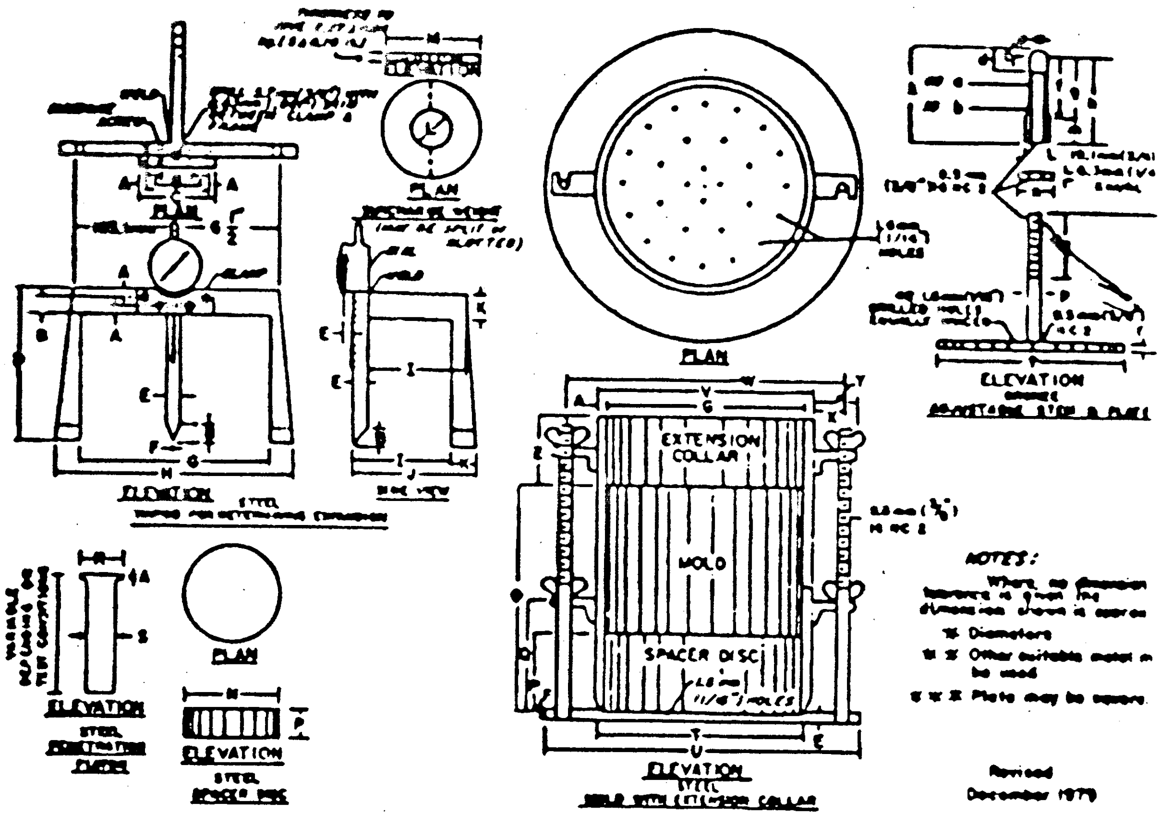


TABLE OF MEASUREMENTS

	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	61.4
TOLERANCE, mm.														0.8	0.13
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.														1/32	0.005

	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	152.4	177.8	61.4	88.9	158.0	238.1	165.1	212.7	23.8	33.3	50.8	6.3	69.8	49.6
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.				0.025	0.018	0.005											0.005

	ADJUSTABLE STEM AND PLATE														
MATERIAL	BRONZE														
DIMENSION	a	b	c	d	e *	f	g	h	k	m	n *	p *	r	s	t
METRIC, mm.	11.12	11.11	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	0.013 / 0.000	0.013 / 0.000													
ENGLISH, in.	.4378	.4375	7/32	[illegible]/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.	0.005 / 0.000	0.005 / 0.000													

FIGURE 1 California Bearing Ratio Test Apparatus

7. PROCEDURE

7.1 Bearing Ratio at Optimum Water Content.

7.1.1 Normally, 3 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.

NOTE 6—Some laboratories may prefer to test only one specimen, which would be compacted to maximum dry density at optimum moisture content as determined by T 99.

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.

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.

7.1.4 Compact one of the portions of soil-water mixture into the mold in 3 equal layers to give a total compacted depth of about 127 mm (5 in.) 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.

7.1.5 Determine the moisture content of the material being compacted at the beginning and end of the compaction procedure (2 samples). Each moisture sample shall weigh 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.

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. Weigh the mold and specimen to the nearest 5 g (0.01 lb.).

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.

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 weight is at or near 100 percent maximum dry unit weight, it will be necessary to include a compactive effort greater than 56 blows per layer.

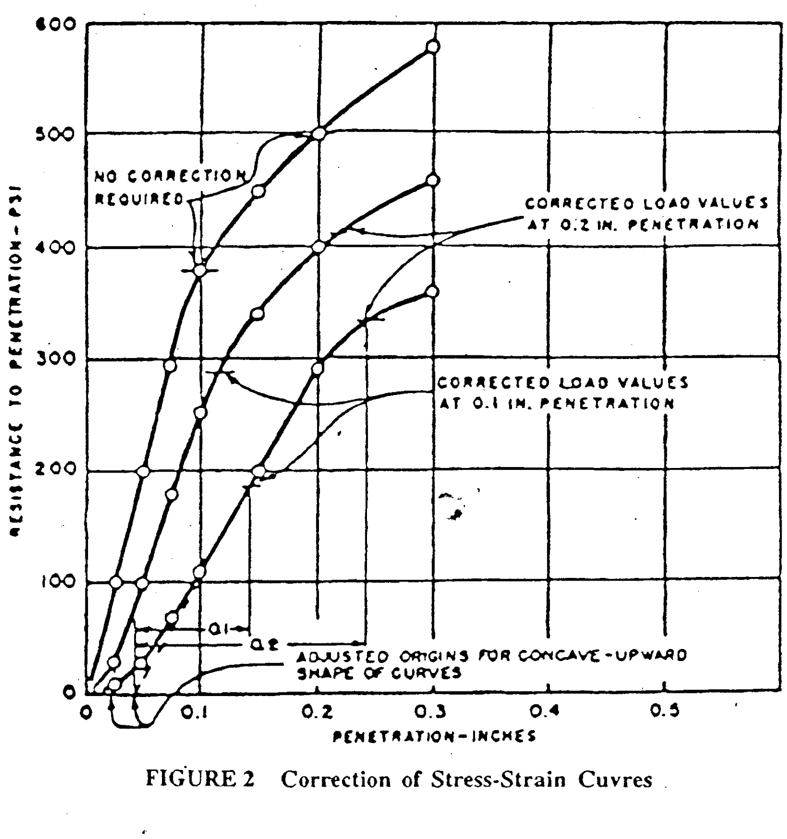


FIGURE 2 Correction of Stress-Strain Cuvres

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, 2.26 kg (± 5 lb.) but in no case shall the mass be less than 4.54 kg (10 lb.).

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 25.4 mm (1.0 in.) above the top of the specimen. Soak the specimen 96 hours (4 days).

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:

Percent swell =

$$\frac{\text{Change in length in in. during soaking}}{4.584 \text{ in.}} \times 100$$

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

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

9. PENETRATION TEST

9.1 *Application of Surcharge*—Place a surcharge of annular and slotted weights on the specimens equal to that sed during soaking. To prevent displacement of soft materials into the hole of the surcharge weights, seat the penetration piston after one surcharge weight has been placed on the specimen. After seating the penetration piston the remainder of the surcharge weights shall then be placed around the piston.

9.2 *Seating Piston*—Seat the penetration piston with a 10 lb. (44 N) load, then set both the penetration dial indicator and the load indicator to zero.

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.) per minute. Record the load when the penetration is 0.64, 1.27, 1.91, 2.54, 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.

NOTE 9—The moisture content of the upper 25 mm (1.0 in.) may be determined after testing if desired. Moisture samples shall weigh at least 100 g for fine-grained soils and 500 g for granular soils.

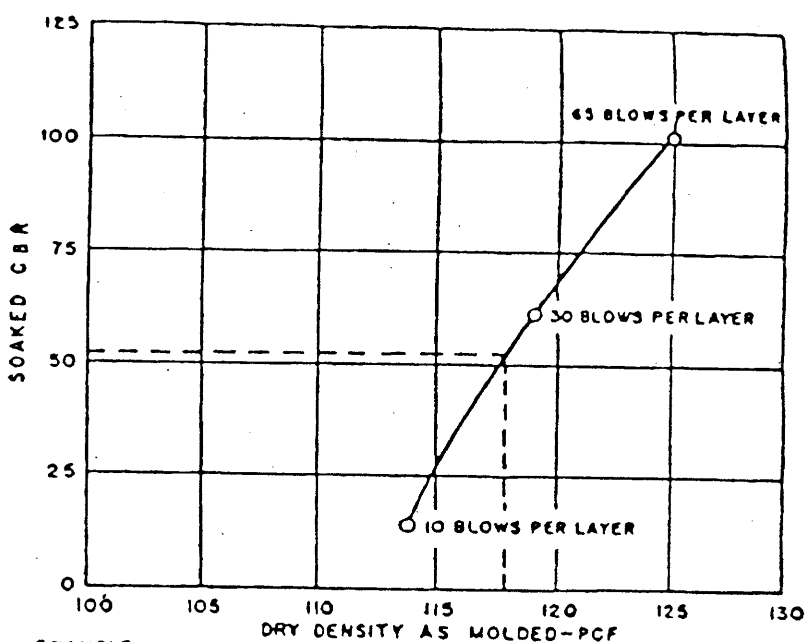
10. CALCULATIONS

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 straightline portion of the stress-strain curve downward until it intersects the abscissa (See dashed lines).

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 1000 and 1500 psi (6.9 and 10.3 MPa), respectively, and multiplying these ratios by 100.

$$\text{CBR} = \frac{\text{Corrected load value}}{\text{Standard Load}} \times 100$$

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



EXAMPLE

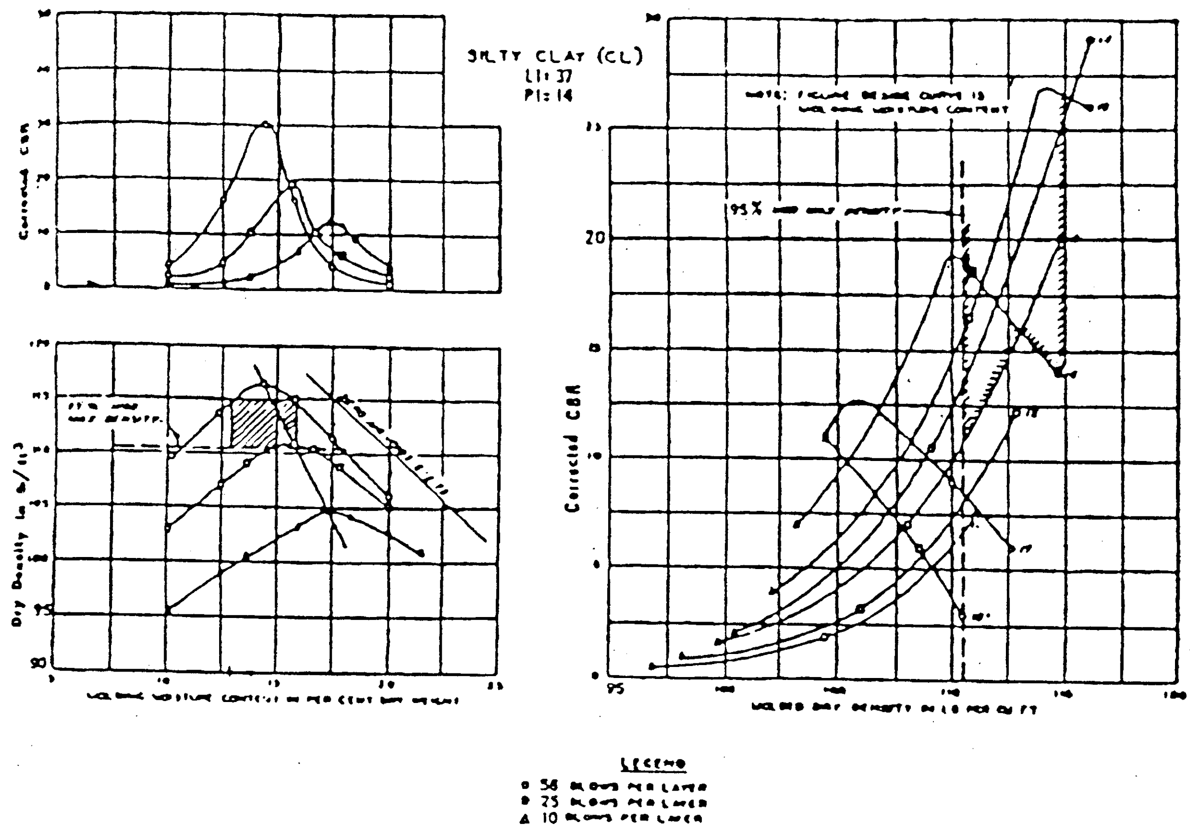
GIVEN: MAXIMUM DRY DENSITY BY T 99-57 (METHOD D) = 124 P.C.F.

FIND: THE C B R AT 95 PERCENT OF THE ABOVE MAXIMUM DRY DENSITY.

SOLUTION: 95 PERCENT OF 124 P.C.F. = 117.8 P.C.F.

AT 117.8 P.C.F., THE C B R IS 52

FIGURE 3 Dry Density Versus C B R



Note 10—Surcharge = 50 lb. soaking and penetration. All samples soaked top and bottom four days. All samples compacted in 5 layers, 10-lb. hammer, 18-in. drop in CBR mold.

FIGURE 4 Determining CBR for Water Content Range and Minimum Dry Unit Weight

ratio at 5.08 mm (0.20 in.) penetration shall be used.

10.3 *Design CBR for One Water Content Only*—Using the data obtained from the 3 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.

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 represents 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 weight between the specified minimum and the dry unit weight produced by compaction within the water content range.

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 pct.

11.1.3 Moisture content as molded pct.

11.1.4 Swell (percent of original length) pct.

11.1.5 California Bearing Ratio pct.