T 193

CALIFORNIA BEARING RATIO OF SOILS
FOP FOR AASHTO T 193

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02

Scope

This method of test covers the determination of the California Bearing Ratio (CBR) of soils at optimum moisture content.

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Significance

This test method is used to evaluate the potential strength of soils, including recycled materials, for use in roadway and airfield pavements. The CBR is an integral part of several flexible pavement design methods.

Where the effect of compaction water content on CBR is small, such as cohesionless, coarse-grained materials the CBR may be determined at the optimum water content of a specified compactive effort.

Where the effect of compaction water content on CBR is unknown or when its effect is to be accounted for, the CBR is determined for a range of water contents. See AASHTO T 193 for this procedure.

Apparatus

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- **Mold(s):** Cylindrical-shaped steel mold(s), 7.0 ±0.018 in. in height, inside diameter of 6.0 ±0.026 in. The mold shall be provided with a collar extension, approximately 2.0 in. in height. The mold and collar assembly shall be so constructed that it can be fastened firmly to a perforated metal base plate. Perforations in the base plate shall have a diameter not exceeding 1/16 in.

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- **Spacer-disc:** A metal disc, 2.416 ±0.01 in. in height with a diameter of $5^{15}/_{16} \pm {}^{1}/_{32}$ in., to be used as a false bottom in the mold during compaction.

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- **Compaction equipment:** Mechanical equipment suitable to compact a solid specimen in a 6-in. diameter mold according to AASHTO T 99 or T 180.
- **Scale or Balance:** Capacity of at least 11 kg. (25 lb.), sensitive to 5 g. (0.01 lb.).

07 • **Apparatus for measuring expansion:** A perforated metal swell plate with an adjustable stem, a tripod dial mount, and a dial gauge with
08 divisions of 0.001 in. The swell plate shall have a diameter of 5⅞ ±$^{1}/_{16}$ in. Perforations in the swell plate shall have a diameter not exceeding $^{1}/_{16}$ in.

09 • **Weights:** One annular metal weight with a center hole 2⅛ in. in diameter and several slotted metal weights, all 5⅞ in. in diameter and weighing 5 ±0.10 lb. The weights shall be suitable for applying a surcharge load on the surface of the soil specimen during soaking and penetration.

10 • **Penetration piston:** A metal piston of circular cross-section, at least 4 in. in length and with a diameter of 1.954 ±0.005 in. (area of 3 in^2). The piston shall be long enough to penetrate the specimen with the surcharge weights in place.

• **Soaking tank:** A soaking tank suitable for maintaining the water level 1 in. above the top of the sample.

11 • **Loading device:** A laboratory testing machine or screw jacks and frame arrangement capable of applying a uniformly increasing load up to 10,000 lb., suitable to force the penetration piston into the specimen at a uniform rate of 0.05 in. per minute.

The loading device shall be fitted with a proving ring or other load indicating equipment, suitable for reading loads in 10 lb. increments.

12 • **Drying oven:** A thermostatically controlled oven capable of maintaining a temperature of 230 ±9° F.

• **Miscellaneous:** Tools such as mixing pan, spoon, spatula, straightedge, etc.

13 ## Sampling and Sample Reduction

• Obtain a sample of sufficient size for the specified procedure according to AASHTO T 2.

• Reduce to a test sample size of at least 35 kg. (75 lb.) according to AASHTO T 248.

Sample

14 • Prepare the sample according to AASHTO T 99 or T 180 except that if material larger than 3/4 in. is present, that material shall be removed and replaced with an equal amount of material passing the 3/4 in. but retained on the No. 4 sieve. Material for replacement shall be obtained from the original representative sample. Recombine the material thus prepared and mix thoroughly.

15 ## Moisture Density Relations

- From the prepared sample, select a representative portion of approximately 11 kg. (25 lb.).

- Determine the maximum dry density and optimum moisture content of the material according to AASHTO T 99 or T 180. (Consult agency specifications for determining which method is applicable).

CBR Specimen Preparation

16 1. From the prepared material, select three or more samples of approximately 6.8 kg. (15 lb.) each, and mix with sufficient water to obtain the optimum moisture content. If the soil is clay with hard dry lumps, the moistened material shall be placed in air tight containers and allowed to cure for approximately 24 hours.

Note 1: Some laboratories may prefer to test only one specimen which would be compacted to maximum dry density at optimum moisture content as determined by the FOP for AASHTO T 99/T 180.

17 2. These specimens will be used for compaction at separate compactive efforts. Consult agency specifications for the required range of compactive effort. Follow the remaining procedures for each of the specimens.

18 3. Clamp the 6-in. diameter mold to the base plate, and determine the mass of the assembly including two filter papers.

4. Insert the spacer disc. Place one filter paper on top of the disc and install the removable collar.

19 5. Compact the soil into the mold using the applicable rammer, number of layers, and number of blows required to achieve the desired level of compactive effort.

6. Obtain samples at the beginning and end of the compaction procedure to determine the moisture content according to T 265.
7. Following compaction, remove the extension collar and carefully trim the compacted soil even with the top of the mold. Release the mold from the base and remove the spacer disc. Place the second filter paper on the perforated base plate, invert the mold and specimen, and clamp the perforated base plate to the mold with the filter paper in contact with the compacted specimen.
8. Determine the mass of the specimen, filter papers, and mold with base plate. Subtract the mass of the mold, base plate, and filter papers, and record.
9. Attach the extension collar to the mold and place the perforated swell plate with adjustable stem on the surface of the specimen. Apply annular weights to produce a surcharge within 5 lb. of the anticipated mass of the base course and pavement (at least 10 lb. must be applied). Take initial measurements for swell by placing the tripod on the mold and adjustable stem and reading the dial gage.

$$\%\,\text{swell} = \frac{\text{height change (in.)}}{4.584\text{ in.}} \times 100$$

10. Immerse the assembled mold, swell plate, and annular weights in water allowing free access of water to the top and bottom of the specimen. Allow the specimen to soak for 96 hours. (See Note 2). Be sure the water level is maintained approximately 1 in. above the top of the specimen during this period. At the end of the soaking period, take final swell measurements and determine the swell as a percentage of the initial height of the specimen (4.584 in.).

Note 2: A shorter soaking period is permissible for A-1-a and A-3 soils if tests show that a shorter period does not affect the test results, but in no case shall the soaking period be less than 24 hours.

11. Remove the free water from the top of the specimen and allow draining downward for 15 minutes. Care shall be taken not to disturb the surface of the specimen during removal of water and draining.
12. Remove the extension collar, annular weights, and perforated plate. Determine the mass of the specimen and mold with base plate.
13. Immediately conduct the penetration procedure.

Penetration Procedure

27 1. Place annular weights on the surface of the specimen equal to the surcharge maintained during the soaking period. To prevent displacement of soft materials, seat the penetration piston with a 10 lb. load after one surcharge weight has been placed on the specimen. After seating the penetration piston, place the remainder of the surcharge weights around the piston.

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2. Seat the penetration piston with a 10 lb. load, and set both the stress and strain gages to zero. This initial load is required to insure satisfactory seating of the piston and shall be considered as zero load when determining the stress-strain relationship. (The mass of the penetration piston is considered negligible).

29 3. Apply the load on the penetration piston so that the rate of penetration is 0.05 in. per minute. Take load readings to the nearest 10 lb. at penetrations of 0.025, 0.050, 0.075, 0.100, 0.125, 0.150, 0.175, 0.200, and 0.300 in. (Load readings at 0.400 and 0.500 in. may also be taken if desired). Note the maximum load and penetration if it occurs before 0.300 in.

4. Remove the soil from the mold. If required,
30 determine the moisture content of the upper 1 in. soil layer according to AASHTO T 265.

Calculation

31 The California Bearing Ratio shall be calculated as follows (See examples on pages 6-7 through 6-9):

- Using the load data, plot a stress-strain curve for each specimen with the resistance to penetration (lb.) as the ordinate and the inches of penetration as the abscissa. (If the load-penetration curve is concave upward initially, the zero point shall be adjusted by extending the straight-line portion of the curve downward to the point at which it intercepts the abscissa. All penetration values shall also be adjusted accordingly).

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- The corrected load values for each specimen will be noted at penetrations of 0.100 and 0.200 in.

- Convert the corrected load values to pounds per square inch (psi) by dividing the load (lb.) by the cross-sectional area (in^2) of the penetration piston.

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- Divide the calculated strength values for 0.100 and 0.200 in. penetration by the standard loads of 1000 and 1500 psi respectively, multiplying the ratios by 100 to convert to whole percentages.
- Generally, the CBR value at 0.100 in. penetration is selected. If the value at 0.200 in. penetration is greater than that at 0.100 in., the test must be re-run. If the retest gives similar results, the value at 0.200 in. penetration shall be reported.

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Report

- Report on standard agency forms.
- CBR percent at 0.100 or 0.200 in. penetration.
- Compactive effort (blows per layer).
- Compaction method used (AASHTO T 99 or T 180).
- Moisture content as molded.
- Swell (percent of original height).
- Soil description.
- Sample and project identification.

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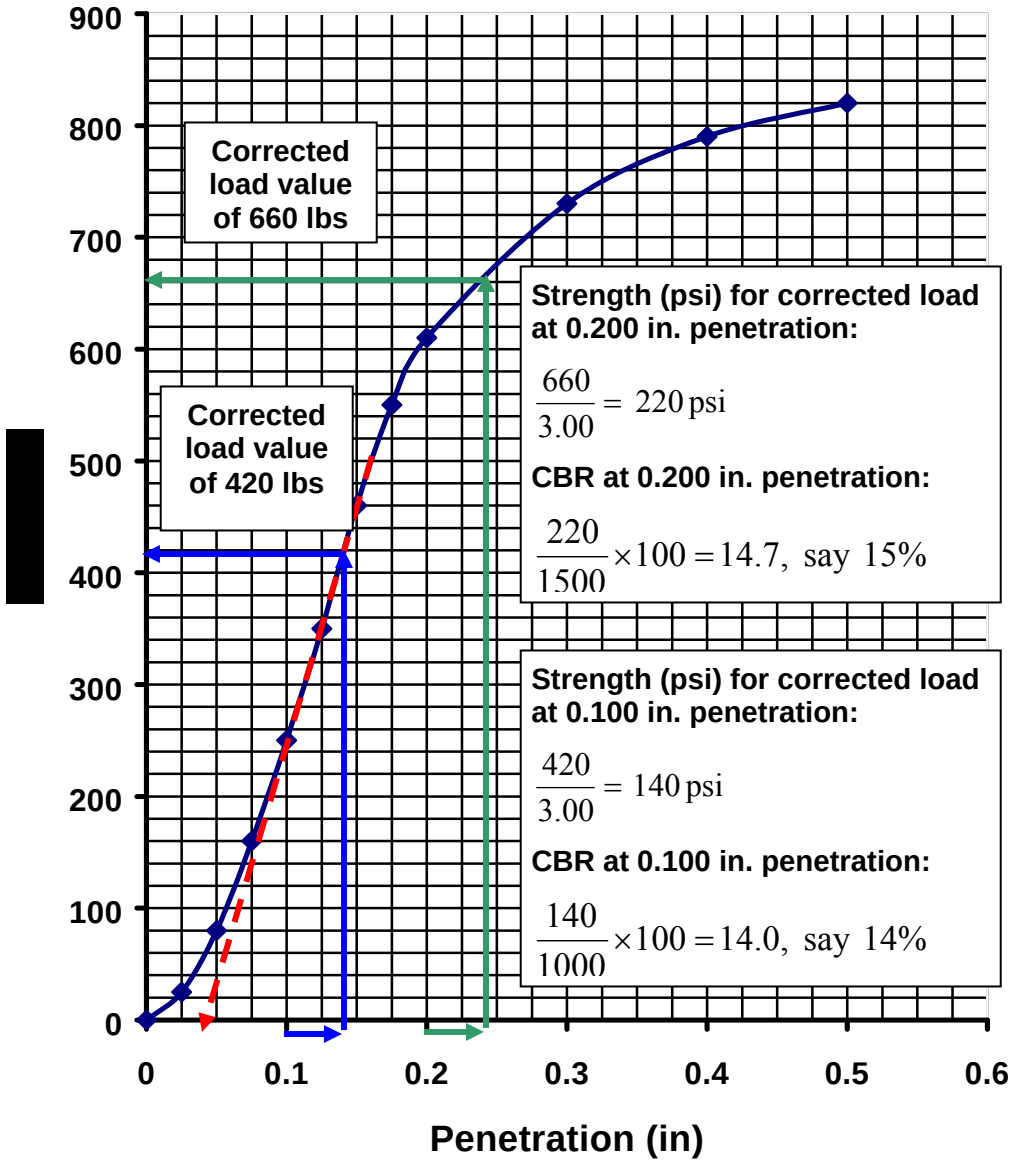
Tips!

- At all times, except during processing, keep the test sample in covered containers to avoid moisture loss due to evaporation.
- Frequently change the water in the soaking tank to minimize contamination of test specimens during the soaking period.

Correction of stress-strain curve

If there is an initial concave upward portion of the curve, correction is made by extending the straight-line portion downward to where it intercepts the abscissa. The load values for 0.100 and 0.200 in. penetration are corrected accordingly.



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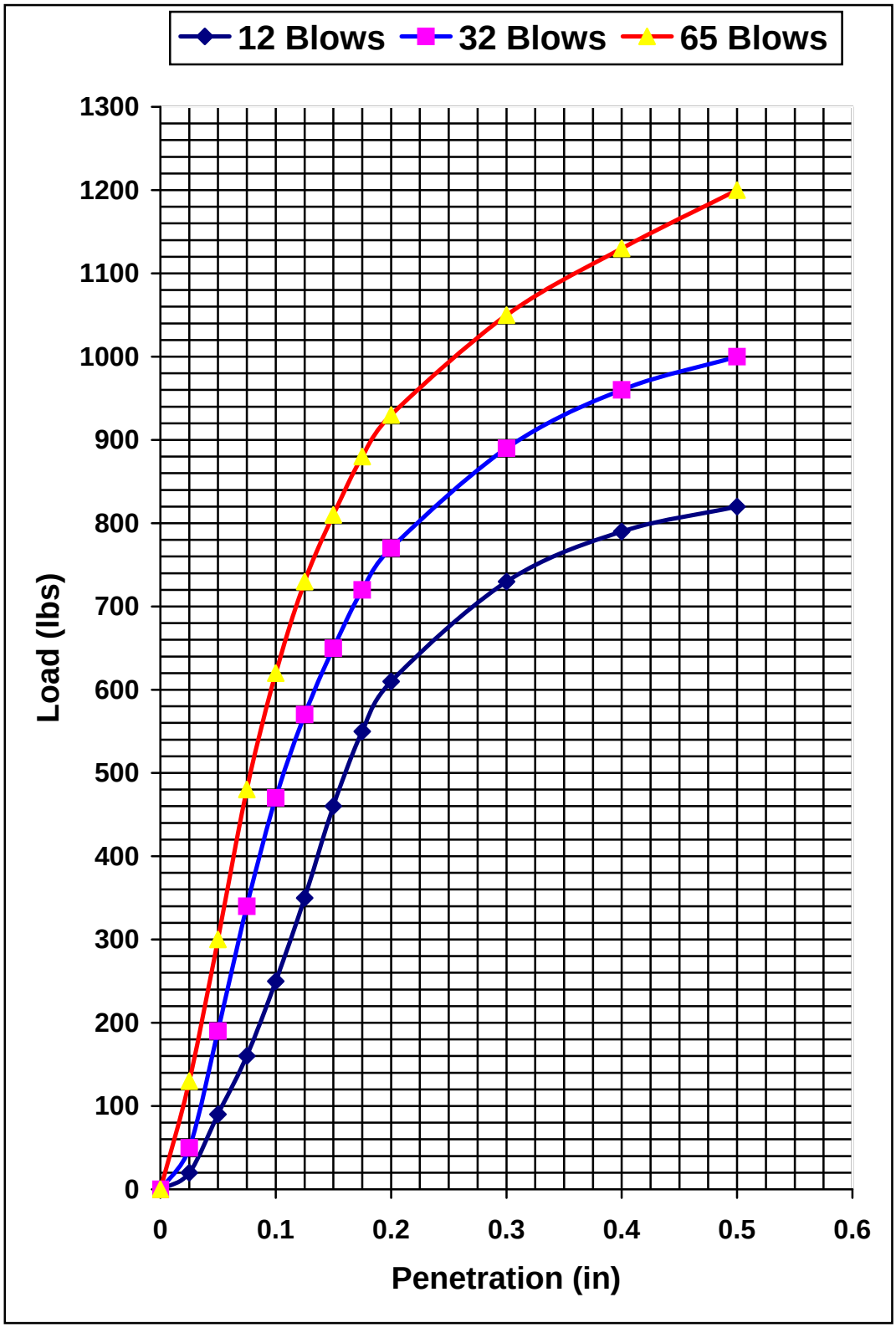
Load Penetration Values for 3 Compactive Efforts



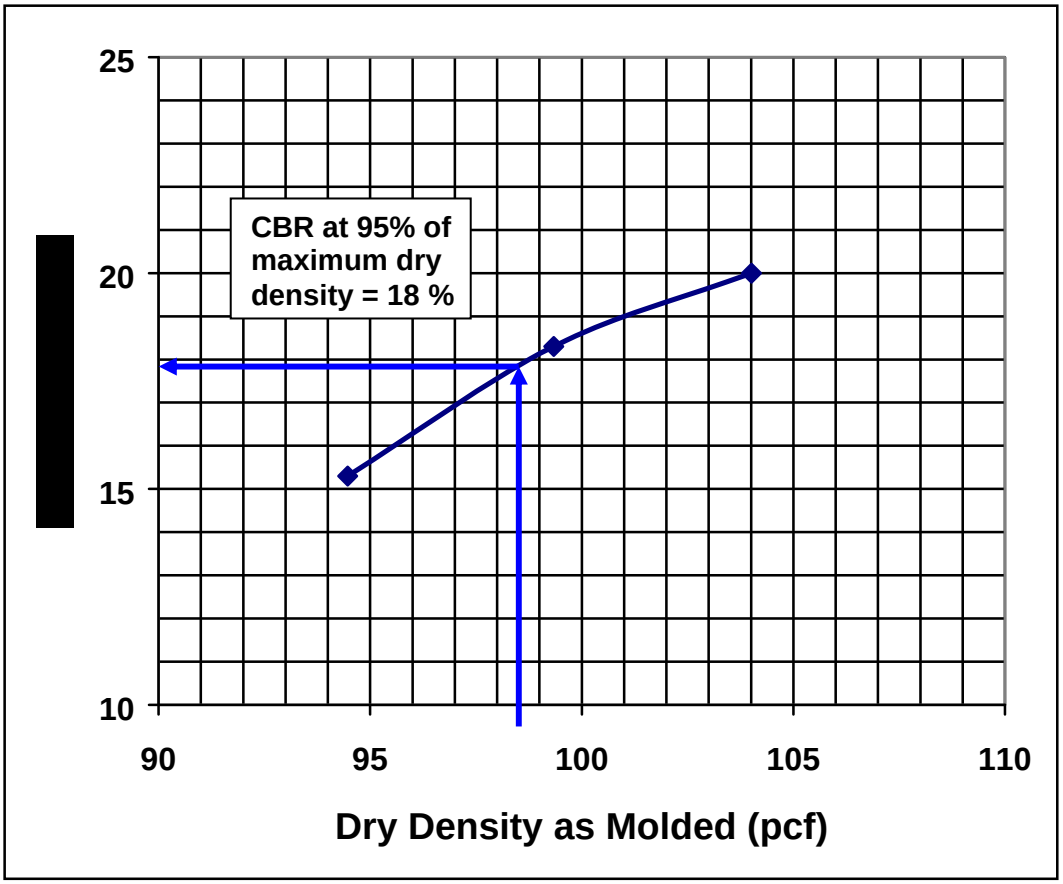
Dry Density vs. CBR for 3 Compactive Efforts

Moisture Density Relations:

Maximum Dry Density: 103.5 pcf
Optimum Moisture Content: 18.6 %

Compactive Effort

12 Blows per Layer – 94.5 pcf (91.3 % of max)
32 Blows per Layer – 99.3 pcf (95.9 % of max)
65 Blows per Layer – 104.0 pcf (100.5 % of max)



REVIEW QUESTIONS

1. If material larger than ¾ inch is present in the sample obtained for performing the CBR, what must be done?

2. According to this FOP, how many different compactive efforts are evaluated?

3. How much surcharge is applied to the sample? What does it represent?

4. For how long are samples usually soaked? Is a shorter soaking period allowed? Explain.

5. Describe the penetration procedure.

6. At what penetration is the CBR usually reported? Are there any exceptions? Explain.

PERFORMANCE EXAM CHECKLIST

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Participant Name:_____ Exam Date:_____

Procedure

Sampling

1. Sample of sufficient size obtained according to FOP for AASHTO T 2? _____
2. Sample reduced to testing size of approximately 35 kg according to FOP for AASHTO T 248? _____

Sample Preparation

1. If all material passes ¾ inch sieve, entire sample used? _____
2. If materials larger than ¾ inch present, oversize replaced with equal mass of ¾ inch to No. 4 material from the original representative sample? _____
3. Representative portion of initial sample, weighting approximately 11 kg (25 lb), selected for moisture-density test? _____
4. Sample tested according to AASHTO T 99 or T 180 using 6 in mold? _____
5. Remainder of sample divided to obtain at least 3 representative portions weighing approx. 6.8 kg (15 lb) each? _____
6. Compactive effort(s) selected (frequently 10, 30, and 65 blows per layer) according to agency standards? _____

Procedure

1. Mold clamped to base plate and extension collar attached? _____
2. Mold, base, 2 filter papers weighed to nearest 5 g (0.01 lb)? _____
3. Spacer disc placed in mold and filter paper placed on disc? _____
4. Each sample mixed with water to obtain optimum water content, and compacted in mold according to desired method? _____
5. Moisture samples obtained at beginning and end of compaction according to AASHTO T 265? _____
6. Extension collar removed, and compacted soil trimmed even with top of mold using straightedge. _____
7. Mold loosened from base and spacer disk removed? _____
8. Filter paper placed on perforated base plate? _____
9. Mold inverted and placed on filter paper (compacted soil contacts paper)? _____
10. Base plate clamped to mold? _____
11. Mass determined to nearest 5 g (0.01 lb)? _____

Soaking

1. Swell plate placed on sample in mold? _____
2. Sufficient annular weights, at least 10 lb, placed on swell plate load? _____
3. Tripod and dial indicator placed on top of mold and initial reading taken? _____

4. Mold immersed in water, allowing free access of water to top and bottom of specimen? _____
5. Water level in mold and tank maintained approximately 1 in above the top of specimen during soaking? _____
6. Specimen soaked for 96 hours (4 days)?
   Note: A shorter immersion period (not less than 24 hours) may be used for materials that drain readily, if tests show that shorter period doesn't affect test results. Soaking period greater than 4 days may be required for some clays. _____
7. Final dial reading taken and percent swell calculated? _____
8. Specimen removed from tank, water poured off top, and allowed to drain downward for 15 minutes? _____
9. Surcharge weights, perforated plate removed after draining? _____
10. Mass of specimen determined (optional)? _____

Penetration Test

1. Penetration test conducted immediately after draining down? _____
2. Same number of surcharge weights placed on specimen as during soaking period (weight with circular hole at bottom)? _____
2. Soaked sample placed in testing apparatus with piston installed? _____
3. Piston seated with 10 lb load? _____
4. Penetration dial indicator and load indicators set to zero? _____
5. Loads applied to piston so penetration rate is uniform at 0.05 in per minute? _____
6. Loads recorded at penetrations of 0.025, 0.050, 0.075, 0.100, 0.150, 0.200, and 0.300 inch (0.400 and 0.500, if desired)? _____
7. Water content of upper 1 inch of sample determined (optional)? _____
8. Stress-strain curve prepared, correction made if necessary? _____
9. CBR values obtained correctly? _____

Comments: First attempt: (Pass/Fail) ___ Second attempt: (Pass/Fail) ___

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Signature of Examiner_____.