5.1 California Bearing Ratio (CBR) Test

5.1.1 Introduction

5.1.1.1 General. The test is an empirical test which gives an indication of the shear strength of a soil. The great value of this test is that it is comparatively easy to perform and because of its wide use throughout the world, there is a vast amount of data to assist with the interpretation of results. The CBR test is essentially a laboratory test but in some instances the test is carried out on the soil in-situ.

5.1.1.2 Scope. The laboratory CBR test consists essentially of preparing a sample of soil in a cylindrical steel mould and then forcing a cylindrical steel plunger, of nominal diameter 50 mm, into the sample at a controlled rate, whilst measuring the force required to penetrate the sample.

A pictorial view of the general test arrangement is shown in Figure 5.1.1.

CBR values may vary from less than 1% on soft clays to over 150% on dense crushed rock samples.

Preparation of remoulded samples for the CBR test can be made in several ways. However, commonly used methods are described here:

(1) Static compression
(2) Dynamic compaction by
   (a) using 2.5 or 4.5 kg rammer and
   (b) using vibrating hammer.

5.1.2.1 Material. The CBR test is carried out on material passing a 20mm test sieve. If soil contains particles larger than this the fraction retained on 20mm shall be removed and weighed before preparing the test sample. If this fraction is greater than 25% of the original sample the test is not applicable. The moisture content of the specimen or specimens can be adjusted as necessary following the procedure given in Chapter 4. The moisture content used is normally to the Optimum Moisture Content (OMC), but obviously this can be varied to suit particular requirements.

5.1.2.2 Mass of soil for test. When the density or air voids content of a compacted sample is specified the exact amount of soil required for the test can be calculated as described in a) or b) below. When a compactive effort is specified the mass of soil can only be estimated, as described in c) below.

a) Dry density specification. The mass of soil \( m \) (in g), required to just fill the CBR mould of volume \( V \) (in cm\(^3\)) is given by the equation

\[
m = \frac{V}{100} (100 + w) \rho_d
\]
Figure 5.1.1 Pictorial view of the CBR test setup
where, \( w \) is the moisture content of the soil (in %); and \( \rho_d \) is the specified dry density (in Mg/m\(^3\)).

b) **Air voids specification.** The dry density, \( \rho_d \), (in Mg/m\(^3\)), corresponding to an air voids content of \( V_a \) (in %) is given by the equation

\[
\rho_d = \frac{1 - \frac{V_a}{100}}{1 + \frac{w}{\rho_s}} + \frac{w}{100 \rho_w}
\]

Where,
\( V_a \) is the air voids expressed as a percentage of the total volumes of soil;
\( \rho_s \) is the particle density (in Mg/m\(^3\));
\( w \) is the soil moisture content (in %);
\( \rho_w \) is the density of water (in Mg/m\(^3\)), assumed equal to 1.

The corresponding mass of soil to just fill the CBR mould is calculated from the equation in (a) above.

c) **Compactive effort specification.** About 6kg of soil shall be prepared for each sample to be tested. The initial mass shall be measured to the nearest 5g so that the mass used for the test sample can be determined after compaction by difference, as a check.

*Note. Preliminary trials may be necessary to determine the required mass more closely.*

5.1.2.3 **Undisturbed samples.** This method is very useful for testing of fine-grained cohesive soils, but cannot be applied to non-cohesive materials or materials containing gravel or stones. Only the CBR moulds as described in 5.1.2.4(b) are suitable for undisturbed sampling.

5.1.2.4 **Apparatus.** The following apparatus is variously required to carry out the 2.5 kg, 4.5 kg and Vibrating hammer methods in Figure 5.1.2.

a) Test sieves of aperture sizes 20 mm and 5 mm.
b) A cylindrical, corrosion-resistant, metal mould, i.e. the CBR mould, having a nominal internal diameter of 152±0.5 mm. The mould shall be fitted with a detachable base-plate and a removable extension. The mould is shown in Figure 4.3.3. The internal faces shall be smooth, clean and dry before each use.
c) A compression device (load press) for static compaction, (for 2.5 kg hammer). Horizontal platens shall be large enough to cover a 150mm diameter circle and capable of a vertical separation of not less than 300 mm. The device shall be capable of applying a force of at least 300 kN.
d) Metal plugs, 152±0.5 mm in diameter and 50±1.0 mm thick, for static compaction of a soil specimen (for 2.5 kg hammer). A handle which may be screwed into the plugs makes removal easier after compaction. The essential dimensions are shown in Figure 5.1.3. Three plugs are required for 2.5 kg hammer.
Figure 5.1.2  Flow chart representing sample preparation methods for the CBR test
e) A metal rammer, (for 4.5 kg hammer). This shall be either the 2.5 kg rammer or the 4.5 kg rammer, both as specified in Chapter 4, depending on the degree of compaction required. A mechanical compacting apparatus may be used provided that it also complies with the requirements of that document.

f) An electric, vibrating hammer and tamper, as specified in Chapter 4 (for vibrating hammer).

g) A steel rod, about 16mm in diameter and 600 mm long.

h) A steel straightedge, e.g. a steel strip about 300 mm long, 25 mm wide and 3mm thick, with one beveled edge.

i) A spatula.

j) A balance, capable of weighing up to 25 kg readable to 5 g.

k) Apparatus for moisture content determination, as described in Chapter 3.

l) Filter papers, 150 mm in diameter, e.g. Whatman No. 1 or equivalent.

Figure 5.1.3  Plug for use with cylindrical mould in the CBR test (in mm).

5.1.2.5 Preparation of test sample using static compression

1. Preparation of mould

   a) Weigh the mould with baseplate attached to the nearest 5 g (m<sub>2</sub>).

   b) Measure the internal dimensions to 0.5 mm

   c) Attach the extension collar to the mould and cover the base-plate with a filter paper.

   d) Measure the depth of the collar as fitted, and the thickness of the spacer plug or plugs, to 0.1 mm.

2. Preparation procedure

   a) This procedure is for 2.5 kg hammer in Figure 5.1.2.

   b) Divide the prepared quantity of soil into three portions with a mass equal to within 50 g of each other and seal each portion in an airtight container until required for use.

   c) Place one portion in the mould and level the surface. Compact to 1/3 the height of the mould in the compression device using suitably marked steel spacer discs to obtain the required depth of sample (127/3 = 42 mm). The mould is then removed from the compression device and the second portion of the material is added. This is then compressed to give a total sample depth to 2/3 the height of the mould (i.e. 85 mm). Finally, the remainder of the sample is
added and the mould is returned to the compression device until the finished sample is just level with the top of the mould. Care should be taken not to damage the press by attempting to crush the steel mould when the sample is level: always pay close attention to the load gauge. Except for some dense aggregates the force required for compaction should not be very large.

d) On completion of compaction weigh the mould, soil and base-plate to the nearest 5 g (m₃).

e) Unless the sample is to be tested immediately, seal the sample (by screwing on the top plate if appropriate) to prevent loss of moisture. With clay soils or soils in which the air content is less than 5%, allow the sample to stand for at least 24 h before testing to enable excess pore pressures set up during compression to dissipate.

5.1.2.6 Preparation of sample using dynamic compaction

1. General. This method may be used if a static compression device is not available. If it is required to compact specimens to a density and moisture content other than Maximum Dry Density and Optimum Moisture Content, it is preferable to use static compaction, as with dynamic compaction these can only be achieved by trial and error.

Note. An alternative to compacting a single sample using a specified compaction method (see 5.1.2.6(3) below) and then carrying out a CBR test on it, is to carry out a CBR test on each of the specimens made up during a normal compaction test (in CBR moulds). This procedure gives a curve of varying CBR with moisture content/dry density, an example is shown in Figure 5.1.8 at the end of this document.

2. Preparation of mould. Follow the procedure given in 5.1.2.5(1) above, with the exception of 5.1.2.5(1)(d).

3. Preparation procedure

3A. Using compaction rammers

   a) This procedure is for 4.5 kg hammer in Figure 5.1.2
   b) The procedures for use in the CBR mould are summarised in Table 5.1.1 below.

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Mass of Rammer (Kg)</th>
<th>Height of Drop mm</th>
<th>Number of Layers</th>
<th>Blows per Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 kg rammer method</td>
<td>2.5</td>
<td>300</td>
<td>3</td>
<td>62</td>
</tr>
<tr>
<td>Intermediate compaction *</td>
<td>4.5</td>
<td>450</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>4.5 kg rammer method</td>
<td>4.5</td>
<td>450</td>
<td>5</td>
<td>62</td>
</tr>
<tr>
<td>Vibrating hammer method **</td>
<td>-</td>
<td>450</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

* Recommended procedure to obtain a specimen density between that achieved by using the 2.5 kg and 4.5 kg rammer methods.

** See Chapter 4 for specification of vibrating hammer

c) Having decided which compaction method to use from Table 5.1.2, divide the prepared quantity of soil into three (or five) portions with a mass equal to

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within 50 g of each other and seal each portion into an airtight container until required for use.

d) Stand the mould assembly on a solid base, e.g. a concrete floor.

e) Place the first portion of soil into the mould and compact it with the required number of blows of the appropriate rammer. After compaction the layer should occupy about or a little more than one-third (or one-fifth) of the height of the mould. Ensure that the blows are evenly distributed over the surface of the soil.

f) Repeat the process in (e) above using the other two (or four) portions of soil, so that the final of the soil surface is not more that 6mm above the top of the mould body.

g) Remove the collar, trim the soil flush with the top of the mould with a scraper, and check with the steel straightedge that the surface is level.

h) Weigh the mould, soil and base-plate to the nearest 5 g (m₃)

i) Seal and store the sample as described in 5.1.2.5(2)(e)

3B. Using a vibrating hammer

a) This procedure is for Vibrating Hammer in Figure 5.1.2.

b) Divide the prepared quantity of soil into three portions with a mass equal to within 50 g of each other and seal each portion in an airtight container until required for use, to prevent loss of moisture.

c) Stand the mould assembly on a solid base, e.g. a concrete floor or plinth.

d) Please the first portion of soil into the mould and compact it using the vibrating hammer fitted with the circular steel tamper. Compact for a period of 60±2 s, applying a total downward force on the sample of between 300 N and 400 N. The compacted thickness of the layer shall be about equal to or a little greater than one-third of the height of the mould.

e) Repeat 3B(d) of 5.1.2.6(3) above using the other two portions of soil in turn, so that the final level of the soil surface is not more than 6 mm above the top of the mould.

f) Remove the collar and trim the soil flush with the top of the mould with the scraper, checking with the steel straightedge.

g) Weigh the mould, soil and base-plate to the nearest 5 g (m₃).

h) Seal and store the sample as described in 5.1.2.5(2)(e) above.

3C. Preparation of undisturbed sample. Take an undisturbed sample from natural soil or from compacted fill by the procedure described in Chapter 2 using a weighed CBR mould fitted with a cutting shoe.

After removing the cutting shoe from the mould, cut and trim the ends of the sample so that they are flush with the ends of the mould body. Fill any cavities with fine soil, well pressed in.

Attach the base-plate and weigh the sample in the mould to the nearest 5 g (m₃). Unless the sample is to be tested immediately, seal the exposed face with a plate or an impervious sheet to prevent loss of moisture.

5.1.2.7 Soaking

1. General. The test sample as prepared will normally represent the material shortly after compaction in the road works. However, if the material is likely to be subjected to an increase in moisture content, either from rainfall, ground-water or ingress through the surfacing it is probable that its strength and, hence, CBR, will drop as the moisture content increases. In an attempt to estimate these effects CBR samples can be soaked in water for 4 days prior to penetration testing.
Some soils, especially heavy clays, are likely to swell during soaking and excessive swelling may indicate that the soil is unsuitable for use as a sub-grade; it is, therefore, important to record the swell during soaking.

2. **Apparatus.** The following items are required in addition to the apparatus listed in 5.1.2.4 above.

   a) A perforated base-plate, fitted to the CBR mould in place of the normal base-plate (see Figure 5.1.4).
   b) A perforated swell plate, with an adjustable stem to provide a seating for the stem of a dial gauge (see Figure 5.1.4).
   c) Tripod, mounting to support the dial gauge. A suitable assembly is shown in Figure 5.1.4.
   d) A dial gauge, having a travel of 25 mm and reading to 0.01 mm.
   e) A soaking tank, large enough to allow the CBR mould with base-plate to be submerged, preferably supported on an open mesh platform.
   f) Annular surcharge discs, each having a mass known to \(\pm 50\) g, an internal diameter of 52-54 mm and an external diameter of 145-150 mm. As an alternative, half-circular segments may be used. For practical purposes, the latter are often easier to use.
   g) Petroleum jelly.

![Figure 5.1.4 Apparatus for measuring the swelling of a sample during soaking for the CBR Test.](image)

3. **Test procedure**

   a) Remove the base-plate from the mould and replace it with the perforated base-plate.
   b) Fit the collar to the other end of the mould, packing the screw threads with petroleum jelly to obtain a watertight joint.
   c) Place the mould assembly in the empty soaking tank. Place a filter paper on top of the sample, followed by the perforated swell plate. Fit the required number of annular surcharge discs around the stem on the perforated plate.

   **Note.** One surcharge disc of 2 kg simulates the effect of approximately 70 mm of superimposed construction on the sub-grade being tested. However, the exact amount of surcharge is not critical. Surcharge discs of any convenient multiples may be used.
d) Mount the dial gauge support on top of the extension collar, secure the dial gauge in place and adjust the stem on the perforated plate to give a convenient zero reading (see Figure 5.1.4)

e) The apparatus is then placed in a tank of clean water and the sample is kept submerged for 4 days and the dial gauge is read every 24 hours. The difference between the initial and final dial gauge reading gives the swell, S. The % swell is given by:

\[
% \text{ Swell} = \frac{S}{127.0} \times 100 = \frac{S}{1.27} \%
\]

Where, S is in mm.

f) On completion of soaking surplus water is wiped from the sample which is re-weighed. The difference in weights before and after soaking is the weight of water absorbed, \( W_w \). The % of water absorbed is give by:

\[
% \text{ Water absorbed} = \frac{M_w (100 + m_2)}{W_m} \%
\]

Where \( W_m \) is original weight of sample and \( m_2 \) is original moisture content.

g) Take off the dial gauge and its support, remove the mould assembly from the immersion tank and allow the sample to drain for 15 min. If the tank is fitted with a mesh platform leave the mould there to drain after emptying the tank. If water remains on the top of the sample after draining it should be carefully siphoned off.

h) Remove the surcharge discs, perforated plate and extension collar. remove the perforated base-plate and refit the original base-plate.

i) Weigh the sample with mould and base-plate to the nearest 5 g if the density after soaking is required.

j) If the sample has swollen, trim it level with the end of the mould and reweigh.

k) The sample is then ready for test in the soaked condition.

5.1.2.8 Penetration test procedure

1. Apparatus. A general arrangement of apparatus is shown in Figure 5.1.5. The apparatus consists of:

a) A cylindrical metal plunger, the lower end of which shall be of hardened steel and have a nominal cross-sectional area of 1935 mm\(^2\), corresponding to a specified diameter of 49.65\( \pm \)0.10 mm. A convenient size would be approximately 250 mm long.

b) A machine for applying the test force through the plunger, having a means for applying the force at a controlled rate. The machine shall be capable of applying at least 45 kN at a rate of penetration of the plunger of 1 mm/min to within \( \pm 0.2 \) mm/min.

c) A calibrated force-measuring device, usually a load ring or proving ring. The device shall be supported by the cross-head of the compression machine so as to prevent its own weight being transferred to the test specimen (see Figure 5.1.1)

Note. At least three force-measuring devices should be available, having the following ranges:

- 0 to 2 kN readable to 2 N for values of CBR up to 8%
- 0 to 10 kN readable to 10 N for values of CBR from 8% to 40%

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0 to 50 kN readable to 50 N for values of CBR above 40%

d) A means of measuring the penetration of the plunger into the specimen, to within 0.01 mm. A dial gauge with 25 mm travel, reading to 0.01 mm and fitted to a bracket attached to the plunger is suitable. A general arrangement is shown in Figure 5.1.5. A dial gauge with a chisel edge to the stem anvil is easier to use than one with a pointed stem anvil.

Note. A dial gauge indicating 1 mm/revolution is convenient since the specified rate of penetration of 1 mm/min can be controlled conveniently by keeping the hand of the dial gauge in step with the second hand of a clock or watch. This is particularly convenient when using a non-motorised loading frame.

e) A stop-clock or stopwatch readable to 1 s.
f) The CBR mould as described in Chapter 4.
g) Surcharge discs as described in 5.1.2.7(2).

2. Procedure

a) Place the mould with base-plate containing the sample, with the top face of the sample exposed, centrally on the lower platen of the testing machine.
b) Place the appropriate annular surcharge discs on top of the sample.
c) Fit into place the cylindrical plunger and force-measuring device assembly with the face of the plunger resting on the surface of the sample. Make sure that the proving ring dial gauge is properly adjusted, i.e. that there is no daylight between the bottom of the stem and the proving ring anvil.

Note. It may be necessary to move the crosshead up to allow the plunger to be inserted through the surcharge discs and the stabilizer bar (if fitted). Be careful to lower the cross-head again in order to make sure that the lower platen and penetration dial gauge have enough travel left before starting the test. This must be level before starting the penetration test.

d) Apply a seating force to the plunger, depending on the expected CBR value, as follows:

For CBR value up to 5% apply 10 kN
For CBR value from 5% to 30%, apply 50 kN
For CBR value up to 30% apply 250 kN

Note. The number of proving ring dial gauge divisions corresponding to the required seating load can be found from the calibration chart for that proving ring. It is helpful to have the N/division value displayed on each load ring. It is extremely important to ensure that the maximum allowable dial gauge reading for the proving ring is never exceeded.

e) Record the reading of the force-measuring device as the initial zero reading (because the seating force is not taken into account during the test) or reset the force measuring to read zero.
f) Secure the penetration dial gauge in position. Record its initial zero reading, or reset it to read zero. Make sure that all connections between plunger, crosshead, proving ring and penetration dial gauge assembly are tight.
g) Start the test so that the plunger penetrates the sample at the uniform rate of 1±0.2 mm/min, and at the same instant start the timer.
h) Record readings of the force gauge at intervals of penetration of 0.25 mm to a total penetration not exceeding 7.5 mm (see Form 5.1.2).

Note. If the operator plots the force penetration curve as the test is being carried out, the test can be terminated when the indicated CBR value falls below its maximum value. Thus if the CBR at 2.5 mm were seen to be 6% but by 3.5 mm penetration it could be seen to have fallen below 6%, the test could be stopped and the result reported as:

CBR at 2.5 mm penetration = 6%
CBR at 5.0 mm penetration = <6%

Figure 5.1.5 General arrangement of apparatus for the CBR test

All dimensions are in millimetres.
This design has been found satisfactory, but alternative designs may be used provided that the essential requirements are fulfilled.
i) If a test is to be carried out on both ends of the sample, raise the plunger and level the surface of the sample by filling in the depression left by the plunger and cutting away any projecting material. Check for flatness with the straightedge.

j) Remove the base-plate from the lower end of the mould, fit it securely on the top end and invert the mould. Trim the exposed surface if necessary. If the sample is to be soaked make sure that a perforated base-plate is used in the correct position.

k) If the sample is to be soaked before carrying out a test on the base follow the procedure described in 5.1.2.7(3) above.

l) Carry out the penetration test on the base by repeating 5.1.2.8(2).

m) After completing the penetration test or tests, determine the moisture content of the test sample as follows:

   (a) For a cohesive soil containing no gravel-sized particles and before extruding the sample from the mould, take a sample of about 350 g from immediately below each penetrated surface, but do not include filling material used to make up the first end tested. Determine the moisture content of each sample.

   Note. If the sample has been soaked the moisture content after soaking will generally exceed the initial moisture content. Because of the possibility of moisture gradients the determination of dry density from the moisture content after soaking may have little significance. If required, the dry density after soaking can be calculated from the initial sample mass and moisture content and the measured increase in height due to swelling.

   (b) For a cohesionless soil or a cohesive soil containing gravel-sized particles, extrude the complete sample, break it in half and determine the moisture contents of the upper and lower halves separately.

5.1.2.9 Calculation and expression of results

1. Force-penetration curve

   a) Calculate the force applied to the plunger from each reading of the force-measuring device observed during the penetration test.

   Note. Alternatively, readings of the force-measuring device may be plotted directly against penetration readings. Forces are then calculated only at the appropriate penetration values as in 5.1.2.6(1)(c).

   b) Plot each value of force as ordinate against the corresponding penetration as abscissa and draw a smooth curve through the points.

   The normal type of curve is convex upwards as shown by the curve labeled Test 1 in Figure 5.1.6 and needs no correction. If the initial part of the curve is concave upwards as for Test 2 (curve OST) in Figure 5.1.6, the following correction is necessary. Draw a tangent at the point of greatest slope, i.e. the point of inflexion, S, and produce it to intersect the penetration axis at Q. The corrected curve is represented by OST, with its origin at Q from which a new penetration scale can be marked.
If the graph continues to curve upwards as for Test 3 in Figure 5.1.6, and it is considered that the penetration of the plunger is increasing the soil density and therefore its strength, the above correction is not applicable.

c) **Calculation of California Bearing Ratio.** The standard force-penetration curve corresponding to a CBR value of 100% is shown by the heavy curve in Figure 5.1.7, and forces corresponding to this curve are given in Table 5.1.2. The CBR value obtained from a test is the force read from the test curve (after correction and calculation if necessary) at a given penetration expressed as a percentage of the force corresponding to the same penetration on the standard curve. Curve representing a range of CBR values is included in Figure 5.1.7.

Penetrations of 2.5mm and 5mm are used for calculating the CBR value. From the test curve, with corrected penetration scale if appropriate, read off the forces corresponding to 2.5 mm and 5 mm penetration. Express these as a percentage of the standard force at these penetrations, i.e. 13.2 kN and 20 kN respectively. Take the higher percentage as the CBR value.

If the force-penetration curve is plotted on a diagram similar to Figure 5.1.7 the CBR value at each penetration can be read directly without further computation if the correction described in 5.1.2.9(1)(b) for test 2 is not required. The same diagram can be used for small forces and low CBR values if both the force scale (ordinate) and the labeled CBR values (abscissa) are divided by 10 as shown in brackets in Figure 5.1.7.

### Table 5.1.2 Standard force-penetration relationships for 100% CBR

<table>
<thead>
<tr>
<th>Penetration (mm)</th>
<th>Force (kN)</th>
<th>Force (kgf*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>11.5</td>
<td>1172</td>
</tr>
<tr>
<td>2.5</td>
<td>13.2</td>
<td>1345</td>
</tr>
<tr>
<td>4</td>
<td>17.6</td>
<td>1793</td>
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</tr>
<tr>
<td>8</td>
<td>26.3</td>
<td>2680</td>
</tr>
</tbody>
</table>

*Standard force in kilonewton converted using factor of 9.807

**Note.** Older equipment may be calibrated in imperial units, in which case

\[
\text{CBR at 0.1 inches penetration} = \frac{\text{Test load (1bf)}}{3000} \times 100\%
\]

\[
\text{CBR at 0.2 inches penetration} = \frac{\text{Test load (1bf)}}{4500} \times 100\%
\]

2. **Density calculations**

a) Determine the internal volume of the mould, \(V_m\) (in cm\(^3\)).

b) **Bulk density.** The initial bulk density, \(\rho\) (in kg/m\(^3\)), of a sample compacted with a specified effort (preparation methods 4.5 kg and vibrating hammer); see Figure 5.1.2, or of an undisturbed sample, is calculated from the equation:
Figure 5.1.6  Typical CBR test result curves
Figure 5.1.7 Force penetration curves for a CBR value of 100% and other CBR values.
\[ \rho = \frac{m_1 - m_2}{V_m} \]

where,
- \( m_2 \) is the mass of soil, mould and base-plate (in g);
- \( m_3 \) is the mass of the mould and base-plate (in g);
- \( V_m \) is the volume of the mould body (in \( \text{cm}^3 \)).

### Dry density

The initial dry density, \( \rho_d \) (in \( \text{kg/m}^3 \)), of the sample is calculated from the equation:

\[ \rho_d = \left( \frac{100}{100 + w} \right) \rho \]

where, \( w \) is the moisture content of soil (in %).

If the dry density, \( \rho_{ds} \) (in \( \text{Mg/m}^3 \)), of the soaked soil is required, calculate it from the equation:

\[ \rho_{ds} = \frac{\rho_d}{1 + \frac{Ax}{1000 V_m}} \]

where,
- \( A \) is the area of cross section of the mould (in \( \text{mm}^2 \))
- \( x \) is the increase in sample height after swelling (in mm).

Examples of completed calculations are given in Forms 5.1.1, 5.1.2 and 5.1.3.

### 5.1.10 Report

The test report shall affirm that the test was carried out in accordance with this Part of this standard. The results of tests on the top and bottom ends of the sample shall be indicated separately.

The test report shall contain the following information:

a) the method of test used;
b) force-penetration curves, showing corrections if appropriate;
c) the California Bearing Ratio (CBR) values, to two significant figures. If the results from each end of the sample are within \( \pm 10\% \) of the mean value, the average result may be reported;
d) the initial sample density and the moisture content and dry density if required;
e) the method of sample preparation;
f) the moisture contents below the plunger at the end of each test, or the final moisture contents of the two halves of the sample;
g) whether soaked or not, and if so the period of soaking and the amount of swell.
h) the proportion by dry mass of any over-size material removed from the original soil sample before testing;
i) information on the description and origin of the sample, as detailed on the test forms.
BANGLADESH ROAD RESEARCH LABORATORY

CBR TEST

DENSITY DATA

Sample No. 1
Date of sample 5/5/2000
Date of preparation

Mould area factor (F) = 58.10 sq m
Mould height factor (H) = 127.0 mm
Mould factor ratio (MFR) = 0.4336
Volume of mould (V_m) = 2304 cm^3

Test method : STP 5.1

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<thead>
<tr>
<th>Sample</th>
<th>Moisture Content</th>
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<td>W_i</td>
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</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td>142.4</td>
<td>140.9</td>
<td>1.5</td>
<td>39.1</td>
<td>102.3</td>
<td>1.5</td>
<td>2.2</td>
<td>1.3</td>
</tr>
<tr>
<td>93.3</td>
<td>147.9</td>
<td>145.5</td>
<td>2.4</td>
<td>39.4</td>
<td>167.1</td>
<td>2.2</td>
<td>14.8</td>
<td>14.9</td>
</tr>
<tr>
<td>207</td>
<td>159.2</td>
<td>143.7</td>
<td>15.5</td>
<td>39.7</td>
<td>105.0</td>
<td>14.8</td>
<td>14.9</td>
<td>15.0</td>
</tr>
<tr>
<td>221</td>
<td>150.8</td>
<td>136.1</td>
<td>14.7</td>
<td>37.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Testing

Mass of mould + base plate + compacted soil = 9332 g
Mass of mould + baseplate = 4740 g
Mass of compacted soil = 4592 g

Compaction

Static Compaction

No. of layers
No. of blows
Mass of rammer
Each layer vibrated for seconds

Static Compaction

Mass of mixed material required

\[ M = \frac{V_i}{A_i} \times 100 \times w_i \times d \]

\[ M = 692 \text{ g} \]

Soak time 4 days

Mass of soil + soil before soak 9332 g
Mass of soil + soil after soak 9481 g
Mass of water absorbed \( M_w \) 149 g
\% of water absorbed \( \frac{M_w}{M_i} \times 100 \) 3.37%

Swell data

<table>
<thead>
<tr>
<th>Time Soaking hrs</th>
<th>Swell gauge reading mm</th>
<th>% Swell</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>2.89</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>4.60</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>4.60</td>
<td>0.00</td>
</tr>
<tr>
<td>120</td>
<td>144</td>
<td></td>
</tr>
</tbody>
</table>

SURCHARGE

Dry density of soaked soil

\[ \rho_d = \frac{\rho_i}{1 + \frac{\Delta V}{1000V_i}} \]

\[ \rho_d = 1730 \text{ Kg/m}^3 \]

<table>
<thead>
<tr>
<th>Sample retained 48/20 mm</th>
<th>Nil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replaced by 19.45 mm sand</td>
<td></td>
</tr>
</tbody>
</table>

Name and Designation

Operator
Clerked
Approved

MAY 2001  Page 5.17
## California Bearing Ratio & Dynamic Cone Penetrometer

### Standard Test Procedures

**Form 5.1.2**

**BANGLADESH ROAD RESEARCH LABORATORY**

**CRR TEST PENETRATION**

**Contact:** BRRI Test Staff

**Sample date:** 5/5/2000

**Origin of sample:** BRRI Test Staff

**Sample no.:** 1

**Soil description:** Reddish Silty Clay

**Pit no.:** Total Pav

**Test method:** STP 5.1

**Depth:** 0.305 m

**Force measuring device no.:**

---

**Penetration of plunger (mm) / Force gauge reading (div) / Force on plunger (KN / kgf)**

<table>
<thead>
<tr>
<th>Penetration of plunger (mm)</th>
<th>Force gauge reading (div)</th>
<th>Force on plunger (KN / kgf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td>Bottom</td>
<td>Top</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.50 (0.025)</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>1.25 (0.050)</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>1.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.00 (0.075)</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>2.50 (0.100)</td>
<td>26</td>
<td>40</td>
</tr>
<tr>
<td>2.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.00</td>
<td>31</td>
<td>52</td>
</tr>
<tr>
<td>3.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.50</td>
<td>35</td>
<td>62</td>
</tr>
<tr>
<td>3.75 (0.150)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Delete as appropriate

---

**Moisture content after test**

<table>
<thead>
<tr>
<th>Container No.</th>
<th>Mass of wet soil + container (m&lt;sub&gt;w&lt;/sub&gt;)</th>
<th>Mass of dry soil + container (m&lt;sub&gt;d&lt;/sub&gt;)</th>
<th>Mass of container (m&lt;sub&gt;c&lt;/sub&gt;)</th>
<th>Mass of moisture (m&lt;sub&gt;m&lt;/sub&gt;)</th>
<th>Mass of dry soil (m&lt;sub&gt;d&lt;/sub&gt;)</th>
<th>Moisture content, w = ( \frac{m_3 - m_2}{m_3 - m_1} ) (in %)</th>
<th>CBR value %</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.0</td>
<td>161.0</td>
<td>176.9</td>
<td>38.3</td>
<td>20.6</td>
<td>g 101.5</td>
<td>115.4</td>
<td>20.5</td>
</tr>
<tr>
<td>312.0</td>
<td></td>
<td></td>
<td>38.5</td>
<td>23.0</td>
<td>t 101.5</td>
<td></td>
<td>19.9</td>
</tr>
</tbody>
</table>

**Penetrn. CBR value %**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Penetrn. CBR value %**

<table>
<thead>
<tr>
<th>Top</th>
<th>Bottom</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**

- **Accepted CBR:** 7.7% from the penetration force on plunger.
- **Average Moisture Content %:** 20

---

**Name and Designation**

<table>
<thead>
<tr>
<th>Operator</th>
<th>Checked</th>
<th>Approved</th>
</tr>
</thead>
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</tbody>
</table>

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EXAMPLE OF DRY DENSITY / MOISTURE CONTENT / CBR RELATIONSHIP

Figure 5.1.8

Note. Penetration of specimens carried out immediately after compaction, i.e. unsoaked.

Compaction: 5 Layers x 62 Blows x 4.5 kg
Maximum Dry Density = 2.1 Mg/m³
Optimum Moisture Content = 9.3%
CBR @ MDD & OMC = 50%

KEY
T x Top of Mould
B x Bottom of Mould
• Average Value