Transport Roads & Maritime Services

NSW GOVERNMENT

Test method T167

Determination of the California bearing ratio of remoulded specimens of road materials (Design method)

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Revision Summary

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Note that Roads and Maritime Services is hereafter referred to as 'RMS'.

The most recent revision to Test method T167 (other than minor editorial changes) are indicated by a vertical line in the margin as shown here.

Test method T167

Determination of the California bearing ratio of remoulded specimens of road materials (Design method)

1. Scope

This test method sets out the procedure for the determination of pavement design values of the California Bearing Ratio (CBR) of soils, gravels and crushed rock materials, from specimens compacted and tested in a laboratory. The compaction and moisture condition at moulding and testing are variable. This method is applicable to that portion of the material to be tested which passes a 19.0 mm sieve.

2. Apparatus

(a) A loading machine equipped with a moveable head or base capable of controlled travel at a uniform (not pulsating) rate of 1 mm/min. The machine shall be equipped with a load-indicating device readable and accurate in accordance with the following table:

CBR	Readable and Accurate to at least
<2	10 N
2-5	25 N
5-10	50 N
10-20	100 N
>20	225 N

(b) The following items, similar to items shown in AS 1289:

(i) A metal penetration piston of 49.6 ± 0.1 mm diameter approximately 190 mm long.

(ii) A cylindrical metal mould with an internal diameter of 152 ± 0.5 mm and internal effective height of 178 ± 0.5 mm equipped with a metal extension collar 50 mm high an a perforated metal base plate 10 mm high, both of which can be firmly attached to the mould. The perforations in the base plate should not exceed 3 mm in diameter.

(iii) A metal spacer disc of 150 ± 0.5 mm diameter and 61 ± 0.25 mm high.

(iv) A perforated metal plate of 150 ± 0.5 mm diameter, 6 mm high fitted with an adjustable stem. The perforations in the plate should not exceed 3 mm in diameter.

(v) One annular metal surcharge and several slotted metal surcharges, each having a mass of 2.25 kg and a diameter of 150 ± 0.5 mm with a central hole of 55 ± 0.5mm diameter.

(c) Dial gauges with a travel of 25 mm reading to 0.02 mm.

(d) A metal rammer with a 50 ± 0.5 mm diameter face and a drop mass of 2.7 kg +10 g -25g equipped with a suitable device to control the height of drop to a free fall of 300 ± 2 mm.

(e) A cylindrical mould having an internal diameter of 105 ± 0.5 mm and a volume of 1000 ± 10 mL, fitted with a detachable base plate and a removable collar assembly approximately 60 mm high, both of which can be firmly attached to the mould. A suitable design is shown in AS 1289.

(f) 19.0 mm AS sieve.

(g) A metal mixing and quartering tray.

(h) Mixing apparatus such as a trowel and quartering apparatus such as metal plates approximately 400 mm by 125 mm and 200 mm by 125 mm.

(i) Sample divider (riffle box) of appropriate size openings (optional).

(j) A thermostatically controlled oven with good air circulation, capable of maintaining a temperature within the range of 105° C to 110°C.

(k) A balance of at least 15 kg capacity readable and accurate to 5 g within the operating range.

(l) A balance of at least 500 g capacity readable and accurate to 0.01 g within the operating range.

(m) A jack, lever and frame or other device suitable for extruding specimens from the mould.

(n) A bowl suitable for thoroughly mixing increments of water with the test sample.A mixing machine of suitable capacity to take complete sub-samples may be used.

(o) Moisture measurement tins, with slip-on lids.

(p) Soaking tank of sufficient depth to immerse the mould in water.

(q) Filter papers, coarse, 150 mm diameter.

(r) A graduated measuring cylinder, 100 mL.

(s) A porcelain mortar, approximately 180 mm diameter, with porcelain and rubber pestles.

(t) Air tight containers, suitable for curing moistened test specimens. These may be suitably clamped plastic bags.

(u) Metal dishes.

(v) A steel straightedge about 300 mm long, 25 mm wide and 3 mm thick, preferably with a bevelled edge.

(w) A rule readable to 1 mm approximately 300 mm long.

3. Sample Size

Sufficient sample is required for a maximum of six CBR tests to be performed on the fraction passing a 19.0 mm sieve.

4. Preparation and Compaction of Specimens

4.1 For Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort

(a) Reduce the sample, as necessary, by quartering or riffling, to provide an amount sufficient to yield approximately 8000 g of material passing a 19.0 mm sieve. Reserve the remainder for possible later testing.

(b) Weigh the sample and screen on a 19.0 mm sieve. Weigh the material retained on the 19.0 mm sieve and compute the amount retained as a percentage of the mass of the sample. Discard the material retained on the 19.0 mm sieve.

(c) Split the sample to produce sub-samples of approximately 5000 g and 3000 g.

(d) Thoroughly mix the sub-samples with sufficient water, if necessary, to dampen the material (approximately 4 percent by mass for granular materials and 9 percent for clayey materials). Place the dampened sub-samples in a container and seal. Allow the samples to cure for an adequate time for the type of material. Sandy materials may by satisfactorily cured in an hour, but heavy clays may require several days or longer.

(e) Determine the optimum moisture content (W_1) on the smaller sub-sample using the procedure described in Test Method T111 Method A (Standard Compaction).

(f) Weigh the mould (M_m) and the base plate (M_b) to the nearest 5 g. Clamp a CBR mould with extension collar attached, to the base plate. Insert the spacer disc.

(g) Remove the larger cured sub-sample from its container, thoroughly mix. Add water to adjust the moisture content to 105% of the optimum moisture content, W_1, determined above.

(h) Compact the sample in the mould in three layers not varying in compacted thickness by more than 5 mm. Subject each layer to 53 uniformly distributed blows of a 2.7 kg rammer falling freely from a height of 300 mm. Use only sufficient material to slightly overfill the mould leaving not more than 5 mm to be struck off after removing the collar.

(i) Free the material from around the collar and then carefully remove the collar.

(j) Level the compacted material by means of the straight edge. Patch with smaller material any holes developed in the surface by removal of coarse material.

5. Curing of Specimens

5.1 For Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort

5.1.1 For A Design Moisture Content (D_m) (Determined By An Appropriate Method As In MR Form No. 76) Less Than The Moulding Moisture Content (i.e. 105% of Optimum M/C) And The Material Is Of Low Permeability.

(a) Remove the perforated base plate and spacer disc.

(b) Eject the sample from the mould and determine its mass (M_1). Identify the top of the specimen.

(c) Calculate the loss of moisture (g) required to dry the sample back to the design moisture content and calculate the expected final mass of the specimen at this moisture content (M_2).

(d) Allow to air dry to mass M_2.

(e) Seal the specimen for 7 days in a plastic bag or other suitable container.

(f) Remove the specimen from the plastic bag or container, weigh and record mass M_3.

(g) Replace the specimen in a CBR mould with the specimen inverted from its compacted position. Clamp the mould to the base plate ensuring that the specimen and base plate are in contact.

(h) Proceed immediately to penetration testing as described in *Penetration Testing*.

5.1.2 For A Design Moisture Content (D_m) Less Than The Moulding Moisture Content (i.e. 105% of Optimum M/C) And The Material Is Not Of Low Permeability.

(a) Remove the perforated base plate and spacer disc.

(b) Weigh the mould plus material (M_4).

(c) Calculate mass of material in mould ($M_4 - M_m$).

(d) Calculate the loss of moisture (g) required to dry the sample back to the design moisture content and calculate the expected final mass of the mould plus material (M_5).

(e) Allow to air dry in the mould, with base plate and spare disc removed, so that the mass of the mould plus material equals M_5.

(f) Seal the specimen and mould for 4 days in plastic.

(g) Remove from the sealed container and re-weigh (M_6).

(h) Replace mould in base plate inverted from its compacted position and clamp.

(i) Proceed immediately to penetration testing as described in *Penetration Testing*.

5.1.3 For A Design Moisture Content (D_m) Higher Than The Moulding Moisture Content (i.e. 105% of Optimum M/C).

(a) Remove perforated base plate and spacer disc.

(b) Invert mould, and replace and clamp on base plate.

(c) Weigh assembled mould specimen and base plate (M_7).

(d) Calculate mass of material in mould i.e $M_7 - (M_m + M_6)$

(e) Calculate the increase in moisture (g) required to bring the material in the mould to the required moisture content (D_m) and calculate the final mass of mould plus specimen and base plate at the moisture content.

(f) Soak the assembly so as to reach the design moisture content or as close to it as possible. Reweigh at selected intervals to check the moisture content.

(g) When the assembly has reached the desired mass, or as close to it as possible, record this mass (M_8).

(h) Cure the specimen for an appropriate period to obtain uniformly of moisture content through the specimen, in an air-tight environment.

(i) Proceed to penetration testing as described in *Penetration Testing*.

6. Preparation and Compaction of Specimens

6.1 For Determination of the Sensitivity of CBR to Variation in Moisture Content and Degree of Compaction

If the sample is considered critical to the pavement design the sample is tested as set out in this section.

(a) Prepare sufficient material passing the 19.0 mm sieve from the remainder of the sample (see Preparation and compaction of specimens for determination of CBR Value of Material at Design Moisture Content with standard compactive effort (a)) to carry out the procedure described in Test Method T111, Preparation of samples , Method A, and five CBR determinations. If sufficient material is not available retesting of the same sub-samples is allowable provided that recompaction does not significantly after the materials characteristics. However, retesting will cause time delays.

(b) Split the sample to produce one sub-sample of 3000 g and 5 of 5000 g.

(c) Thoroughly mix the sub-samples with sufficient water, if necessary, to dampen the material as in Preparation and Compaction of Specimens for Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort (d) .

(d) Determine the optimum moisture content (W_2) of the 3000 g sub-sample prepared by the procedure described in Test Method T111, *Preparation of Samples* , Method A, but using a reduced compactive effort (i.e. 12 blows of the 2.7 kg rammer per layer in a three layer system).

(e) Remove a cured sub-sample (5000 g) from its container and thoroughly mix. Add water to adjust the moisture content to 105% of the optimum moisture content (W_2) determined above.

(f) Pre-weigh the mould (M_m) and the base plate (M_b) to nearest 5 g. Clamp a CBR mould with extension collar attached to the base plate. Insert the spacer disc and place a coarse filter on top of the disc.

(g) Compact the sub-sample in the mould in three layers not varying in compacted thickness by more than 5 mm. Subject each layer to reduced compactive effort of 25 uniformly distributed blows of a 2.7 kg rammer falling freely from a height of 300 mm. Use only sufficient material to slightly overfill the mould leaving not more than 5 mm to be struck off after removing the collar.

(h) Free the material from around the collar and then carefully remove the collar.

(i) Level the compacted material by means of the straight edge. Patch with smaller material any holes developed in the surface by removal of coarse material.

(j) Repeat Preparation and Compaction of Specimens for Determination of the Sensitivity of CBR to Variations in Moisture Content and Degree of Compaction (f) to (i) to produce a total of three moulded specimens.

(k) Adjust the moisture contents of the specimens as follows:

(i) If the design moisture content (D_m) is less than 90% of W_1 adjust the moisture content of the moulded specimens and cure by appropriate methods from *Curing of Specimens for Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort to* give three different moisture contents as follows:
Mould 1: Moisture content equal to D_m.

Mould 2: Moisture content from 95 to 100% of W_1.
Mould 3: Moisture content from 105 to 110% of W_1.

(ii) If the design moisture content (D_m) is equal to or greater than 90% of W_1 but less than 100% of W_1 adjust moisture contents of the moulded specimens and cure by appropriate methods from *Curing of Specimens for Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort* to give three different moisture contents as follows:
Mould 1: Moisture content equal to D_m.
Mould 2: Moisture content from 105°C to 110°C of W_1.
Mould 3: Moisture content less than 90% of W_1.

(iii) If the design moisture content (D_m) is greater than or equal to 100% of W_1 adjust moisture content of the moulded specimens (and cure by appropriate methods from *Curing of Specimens for determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort*) to give at least three moisture contents so as to give one at D_m and the other two at suitable intervals for assessing the sensitivity of CBR to moisture.

(l) Proceed immediately to penetration testing as described in *Penetration Testing.*

(m) Remove another cured sub-sample from its container, thoroughly mix. Add water to adjust the moisture content to 105% of the optimum moisture content W_1 determined in *Preparation and Compaction of Specimens for Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort.*

(n) Weigh the mould (M_m) and the base plate (M_b) to nearest 5 g. Clamp a CBR mould, with extension collar attached, to the base plate. Insert the spacer disc and place a coarse filter paper on top of the spacer disc.

(o) Compact the sample in the mould in three layers not varying in compacted thickness by more than 5 mm. Subject each layer to a 53 uniformly distributed blows of a 2.7 kg rammer falling freely from a height of 300 mm. Use only sufficient material to slightly overfill the mould leaving not more than 5 mm to be struck off after removing the collar.

(p) Free the material from around the collar and then carefully remove the collar.

(q) Level the compacted material by means of the straight edge. Patch with smaller material any holes developed in the surface by removal of coarse material.

(r) Repeat Preparation and Compaction of Specimens for Determination of the Sensitivity of CBR to Variation in Moisture Content and Degree of Compaction (m) to (q) to produce another moulded specimen.

(s) Adjust the moisture contents of the two moulded specimens to the values, other than D_m, required in Preparation and Compaction of Specimens for Determination of the Sensitivity of CBR to Variation in Moisture Content and Degree of Compaction (k).

(t) Proceed immediately to penetration testing as described in *Penetration Testing.*

7. Penetration Testing

(a) Place a 2.25 kg surcharge on the surface of the specimen, and place the mould assembly in position beneath the penetration piston. Commence the penetration test immediately, using the loading machine fitted with a suitable proving ring as specified in *Apparatus (a)* for the expected CBR value. Seat the penetration piston with the smallest possible load not exceeding 45 N. Replace other surcharges to provide a total surcharge of 4.5 g. Read, or set to zero, the load indicator and penetration gauge.

(b) Apply the load uniformly so that the rate of penetration is approximately 1 mm/min. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0 and 7.5 mm. If a penetration up to, or including 2.5 mm cannot be achieved, the CBR test is not appropriate and must be abandoned. If any of the penetrations listed above, in excess of 2.5 mm cannot be achieved, the test must be terminated at that point to avoid damage to the apparatus. The maximum penetration obtained is then recorded.

(c) Remove the mould assembly from the machine and eject the specimen from the mould. Determine the moisture content of the top 30 mm layer M_T also determine the moisture content of the entire depth of the specimen M_A.

(d) Plot the load-penetration curve. In some instances, the load-penetration curve may concave up initially, because of surface irregularities or other causes, and in such cases the zero point is adjusted. Draw a tangent through the steepest part of the curve to intersect the horizontal scale. This point is the corrected zero point. Examples of corrections are given in AS 1289.

(e) Using the corrected values determine the load corresponding to penetrations of 2.5 mm and 5.0 mm and calculate the percentage ratio of these loads to the standard loads of 13.3 kN and 20.0 kN respectively. These percentage ratios are the CBR values.

8. Reporting

(a) Tabulate the results of all sub-samples tested under Preparation and Compaction of Specimens for Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort of this method showing:

(i) Sample No. and location

(ii) Design moisture content (D_m)

(iii) Optimum moisture content for standard compactive effort (W_1)

(iv) Moisture content at compaction

(v) Moisture content of top 30 mm at Test (M_T)

(vi) Moisture content of total sample at Test (M_A)

(vii) CBR at 2.5 mm penetration

(viii) CBR at 5.0 mm penetration

(ix) Indicate which results refer to the critical samples

(b) Tabulate the results of all sub-samples tested under Preparation and Compaction of Specimens for Determination of the Sensitivity of CBR to Variation in Moisture Content and Degree of Compaction of this method showing:

(i) Sample No. and location

(ii) Design moisture content (D_m)

(iii) Optimum moisture content for the reduced compactive effort (W_2)

(iv) Optimum moisture content for standard compactive effort (W_1)

(v) Moisture content at compaction using standard compactive effort

(vi) Moisture content at compaction using reduced compactive effort

(vii) Moisture content at each test in top 30 mm (M_T)

(viii) Moisture content at each test in total sample (M_A)

(ix) CBR ratios at 2.5 mm for each test

(x) CBR ratios at 5.0 mm for each test

(c) For samples tested under Curing of Specimens for Determination of CBR Value of Material at Design Moisture Content with Standard Compactive Effort For samples tested, Part 2 of this method plot graphs of CBR at 2.5 mm penetration versus moisture content (M_A) at testing, drawing two smooth curves through points of equal compactive effort as shown in Fig 1. Note on the moisture axis the design moisture content.

(d) Similarly construct a graph of CBR at 5.0 mm penetration versus moisture content.

9. Techniques

The various compactive efforts may be expressed in terms of energy input. Because the CBR mould is slightly larger than 2 L there is a slight difference in the effort applied to the 1 litre mould to determine the optimum moisture content and the compactive effort applied in the CBR test. The compactive efforts are given in Table 1.

TABLE 1 Comparison of Various Compactive Efforts used in this Procedure

Compactive Effort	One Litre Mould	CBR Mould
STANDARD No. of Blows / Layer No. of Layers Energy	25 3 596 MJ/m^3	53 3 594MJ?m^3
REDUCED No. of Blows / Layer No. of Layers Energy	12 3 286MJ/m^3	25 3 280MJ/m^3

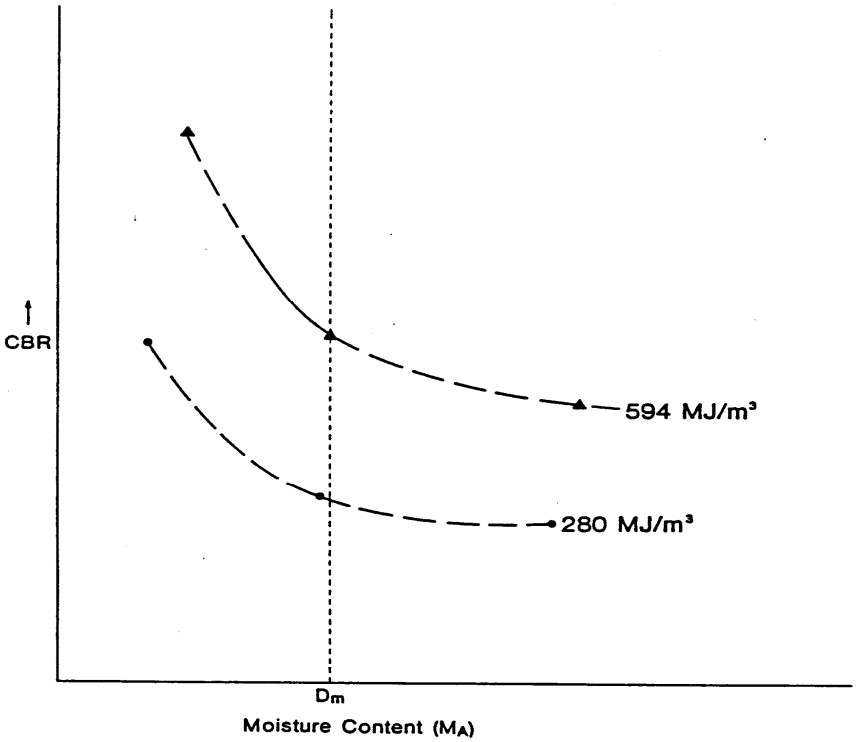

Fig. 1 Example CBR vs Moisture Content Curves