DETERMINATION OF THE UNCONFINED COMPRESSIVE STRENGTH OF HYDRATED CEMENT TREATED CRUSHED ROCK BASE (HCTCRB)

1 SCOPE

This method sets out the procedure for determining the unconfined compressive strength of laboratory compacted specimens of Hydrated Cement Treated Crushed Rock Base (HCTCRB).

This method is applicable to the control testing of field or plant mix materials and for the assessment of the strength of materials mixed in the laboratory. The test is conducted on that portion of the material, which passes the 19.0 mm sieve.

NOTES:

• When this method is applied to quality control testing of field or plant mixes of HCTCRB the period of hydration shall be recorded.

• If testing coarse material, the exclusion of a large proportion of stone coarser than 19.0 mm may have a significant effect on the unconfined compressive strength determined in the laboratory compared with that obtainable from the material when used as a whole.

2 SAFETY

This standard does not attempt to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate occupational health and safety practices that meet statutory regulations.

3 REFERENCED METHODS

WA Methods

WA 100.1
WA 105.1
WA 110.1
WA 133.1

Australian Standards

1152 Specification for test sieves

AS 2193 Methods for calibration and grading of force-measuring systems of testing machines.

4 DEFINITIONS

For the purpose of this method, the definitions below apply.

(a) Hydrated Cement Treated Crushed Rock Base (HCTCRB) – is crushed rock base that has been mixed with water and 2% of cement and then allowed to hydrate.

(b) Hydration – the reaction between cement and water in a material that gradually bonds together individual particles to form a solid mass.

(c) Laboratory density ratio - the ratio of the dry density of a test specimen to the maximum dry density of that material as determined by testing in accordance with WA 133.1, expressed as a percentage.

(d) Laboratory moisture ratio - the ratio of the moisture content of a test specimen to the optimum moisture content of that material as determined by testing in accordance with WA 133.1, expressed as a percentage.

5 APPARATUS

(a) Balance—of sufficient capacity, readable to at least 0.1 g with a limit of performance less than or equal to 0.5 g.

(b) Base—a level rigid foundation on which to compact the specimen; for example, a sound concrete floor about 100 mm or more in thickness or a cubical concrete block of at least 100 kg mass.

(c) Dishes—metal dishes.

(d) Vernier callipers of suitable range, readable to at least 0.1 mm and having an uncertainty of less than or equal to 0.5 mm.

(e) Mixing apparatus—such as a trowel, palette knife and metal quartering plates.

(f) Cylindrical steel mould having essential dimensions as specified in Table 1 of WA 133.1.
(g) Mechanical or manual steel rammer, having essential dimensions as specified in Table 1 of WA 133.1.

(h) Rule—300 mm readable to 1.0 mm.

(i) Sample dividers (riffle boxes)—of appropriate size openings (optional).

(j) Sample extruder—jack, level and frame, or other device, suitable for extruding compacted specimens from the mould (optional if split mould is used).

(k) Sieves—19.0 mm and 4.75 mm, in accordance with AS 1152.

(l) Steel straightedge—a suitable size being about 300 mm long, 25 mm wide and 2 mm thick, preferably with a bevelled edge.

(m) Testing machine—a compression testing machine complying with the requirements for Grade C of AS 2193, with the upper bearing block of the machine having a spherical seat. The capacity of the testing machine shall be sufficient to test the strongest test specimen (a minimum capacity of 50 kN is recommended).

The testing machine shall be power operated and capable of applying the load at a uniform rate of 60±6 kN per minute or to travel at a speed of 1.0±0.2 mm per minute whilst under load.

(n) Tray—a metal mixing and quartering tray of adequate size.

(o) Cabinet—a humidity cabinet capable of maintaining a humidity of not less than 90% at a temperature within the range required by the curing regime (usually 21°C to 25°C).

Alternatively, a water bath equipped with snug-fitting lid and perforated metal false bottom with supports to provide a 50 mm space below the perforated plate and about 10 mm above the water surface.

(p) A concrete mixer with a suitable mixing capacity and a rotational speed between 25 and 35 revolutions per minute.

Table 1: Recommended Mixer Volumes

<table>
<thead>
<tr>
<th>Mixer Volume</th>
<th>Sample Increment Size (kg)</th>
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<tbody>
<tr>
<td>&lt; 0.06m³</td>
<td>&lt; 10</td>
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<tr>
<td>&gt; 0.06m³</td>
<td>&gt; 10</td>
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6 SAMPLING

(a) Samples shall be obtained from the field in accordance with WA 100.1.

(b) Field Samples shall be taken after the completion of the designated hydration period and prior to field compaction.

(c) The samples shall be placed in an airtight container and transported to the laboratory for testing.

(d) Record the following:

- Cement type
- Date and time of addition of cement
- Date and time of sampling
- Hydration Period

(e) Samples prepared in the laboratory shall be placed in an airtight container after mixing and hydrated for the specified period.

7 PREPARATION OF HCTCRB TEST PORTIONS

(a) Obtain a sample in accordance WA 105.1.

(b) Prepare at least two test portions for each Unconfined Compressive Strength (UCS) test.

7.1 Laboratory Prepared Samples

(a) Obtain a representative test portion for determining maximum dry density/optimum moisture content and UCS by sample division.

(b) Calculate the dry mass of the test portion using the equation

\[ DM_{TI} = \frac{WM_{TI} \times 100}{100 + WH1} \]

Where:

- \( DM_{TI} \) = dry mass of test specimen in grams
- \( WM_{TI} \) = wet mass of test specimen in grams
- \( WH1 \) = hygroscopic moisture content as a percentage

(c) Calculate the required mass of cement to be added to the test specimen using the equation.

\[ m_c = \frac{Rc \times DM_{TI}}{100} \]

Where:

- \( m_c \) = total mass of cement to be added to the test specimen in grams
- \( DM_{TI} \) = dry mass of test specimen in grams
- \( Rc \) = percentage of cement required

(d) Calculate the quantity of water to achieve between 90% to 120% of the optimum moisture content of the CRB

Note – If historical maximum dry density / Optimum moisture content data of source CRB is not available then a MDD/OMC
(e) Add the required amount of water to the cement and mix thoroughly.

(f) Add the water/cement mixture to the CRB test portion and mix thoroughly to achieve an even distribution. All mixing shall be completed within 5 minutes of the water being added to the cement.

(g) Immediately place the test portion in a sealed container and allow it to hydrate for the specified period. Record the date and time to nearest 30 minutes of the completion of the mixing process.

(h) The maximum dry density of the HCTCRB test portions shall be hydrated for the same period of time as the UCS with the same percentage, by dry mass, of Type GP cement and with sufficient water to achieve moisture content between 90 and 120 percent of optimum moisture content of the source CRB.

The maximum dry density and optimum moisture content of the HCTCRB shall be determined in accordance with WA 133.1 on the test portion that has been tumbled in a cement mixer conforming to Table 1 for 20 minutes.

(i) One day prior to the completion of the hydration period, determine the moisture content in accordance with WA 110.1 on each UCS test increment.

(j) Determine the amount of water required to adjust the increments to optimum moisture content using the equation:

\[
m_{w2} = \frac{omc - wh2}{100} \times DM_{CTI}
\]

Where:
- \(m_{w2}\) = mass of water to be added to the test specimen in grams
- \(omc\) = optimum moisture content of the HCTCRB, as a percentage
- \(wh2\) = hygroscopic moisture content, as a percentage, as determined in 6.2.1(j)
- \(DM_{CTI}\) = dry mass of test specimen and cement, in grams, as used in 6.2.1(h)

7.2 Field Sampled Material

(a) Testing shall only commence after the appropriate period of hydration has been completed.

(b) Prior to the preparation of the test specimens, the material shall be tumbled in a concrete mixer conforming to Table 1 for 20 minutes.

(c) Test portions are obtained by reducing the sample by quartering or riffling to provide at least 6000 g of material that would pass a 19.0 mm sieve.

(d) Screen on a 19.0 mm sieve and determine mass of material passing and retained on the sieve. Determine the amount of material retained as a percentage of total (wet) mass. Discard material retained on the sieve.

(e) Thoroughly mix all material passing the 19.0 mm sieve.

(f) Obtain by quartering or riffling two test portions, each of about 3000 g mass.

(g) Determine the moisture content \(w_{hi}\) on a representative portion of each test portion in accordance with WA 110.1.

(h) Determine the maximum dry density and optimum moisture content in accordance WA 133.1.

(i) Select the dry density \(\rho_d\) / moisture content \(w_c\) condition at which the test portions are to be moulded as per MRWA Specification 501.

(j) Calculate the dry mass of the test specimen using the equation:

\[
DM_{TI} = \frac{WM_{TI} \times 100}{100 + w_h}
\]

Where:
- \(DM_{TI}\) = dry mass of test specimen in grams
- \(WM_{TI}\) = wet mass of test specimen in grams
- \(w_h\) = hygroscopic moisture content as a percentage

(k) Calculate the total mass of water required to bring the test specimen to the desired moisture content using the equation:

\[
m_w = \frac{w_c \times DM_{TI}}{100}
\]

Where:
- \(m_w\) = total mass of water to bring test specimen to the required moisture content in grams
- \(w_c\) = moisture content at compaction as a percentage
- \(DM_{TI}\) = dry mass of test specimen in grams

(l) Calculate the mass of hygroscopic water in the test specimen using the following equation:
m_H = \frac{w_H \times DM_{TI}}{100}\\

Where:
- m_H = mass of hygroscopic water in grams
- w_H = hygroscopic moisture content as a percentage
- DM_{TI} = dry mass of test specimen in grams

Calculate the mass of water to be added to bring the test specimen to the desired moisture content using the equation:

m_{WR} = m_W - m_H\\

Where:
- m_{WR} = mass of water to be added to the test specimen in grams
- m_W = total mass of water in test specimen in grams
- m_H = mass of hygroscopic water in test specimen in grams

Add the water required (m_{WR}) and thoroughly mix the sample.

8 TEST PROCEDURE

(a) Calculate the desired wet density of the test specimen using the following equation:

\rho = \frac{\rho_d \times (100 + w_c)}{100}\\

Where:
- \rho = desired wet density of test specimen in t/m³
- \rho_d = dry density of test specimen in t/m³
- w_c = moulding moisture content of the test specimen as a percentage

(b) Calculate the wet mass of each layer that is to be compacted in the mould using the equation:

m_L = \frac{m_{TS}}{5}\\

Where:
- m_L = wet mass of soil per layer in grams
- m_{TS} = wet mass of test specimen in grams

(c) In all cases, the laboratory density ratio shall be within 1.0 percent of the specified ratio and the moisture ratio shall be between 95% and 105% of OMC.

(d) Determine the mass (m_2) of the mould and base plate.

(e) Bring the test portion to the specified moisture ratio. Calculate the amount of material required to fill the mould when the material is compacted to the required laboratory density ratio.

(f) Compact using modified compactive effort.

Take one portion of material, mix it thoroughly and compact it into the mould in five layers, so that the compacted height of the material in the mould is 23 mm to 28 mm in the first layer, 47 mm to 52 mm in the second layer, 70 mm to 75 mm in the third layer, 93 mm to 98 mm in the fourth layer and 116 mm to 120 mm in the fifth layer.

NOTE: The calculated mass of material to be placed in each layer should be measured to ensure uniform compaction.

(g) Free the material from around the inside of the collar then carefully remove the collar. If required, trim the surface of the specimen level with the top of the mould by means of the straightedge. Use material passing a 2.36mm sieve to patch any holes developed in the surface from removal of coarse material during trimming.

(h) Determine the mass (m_2) of the mould and compacted material.

(i) Carefully remove the compacted specimen from the mould and examine it for any cracking. If the specimen has cracked, discard it, prepare and compact a replacement specimen.

(j) Record the time of completion of compaction.

(k) Determine the moisture content of the remaining material in the test portion in accordance with WA 110.1.

(l) Repeat Procedures 6.3(a) to 6.3(j) for the second test sample.

8.1 CURING OF TEST SPECIMENS

Stand the compacted specimen in a Humidifier capable of maintaining a humid atmosphere for the curing period specified in MRWA Specification 501.

On completion of the period of curing, immerse each test specimen in water at room temperature for 4 hrs.

8.2 COMPRESSION TESTING

Each test specimen shall be tested in compression as follows:

(a) Remove the specimen from the water and allow to drain for 15 min. Examine the specimen for any defects. If the specimen has cracked at the compaction layer or
on any of the surfaces discard it and report as “Sample not suitable for testing”

Note - End surfaces shall be plane and be at right angles to the axis of the cylinder

(b) Determine the average diameter (Dav) of the test specimen to the nearest 0.5 mm from two diameters measured at right angles to each other near the centre of the height of the cylinder.

(c) Place the test specimen on the lower bearing block of the compression testing machine, making sure that the vertical axis of the test specimen is aligned with the centre of the thrust of the bearing block. Gently bring the bearing block to bear on the test specimen and ensure that uniform seating is obtained.

(d) Apply the load at a constant rate by setting the moveable platen to travel at a speed of 1.0 ±0.2 mm/min or increase the load at a uniform rate of 60 ±6 kN/min. Record the load at failure (P) of the test specimen to the nearest 0.5 kN.

(e) Determine the moisture content (w) by drying the whole specimen as specified in WA 110.1.

9 CALCULATIONS

For each test specimen the following calculations shall be made as required:

(a) The wet density ($\rho_w$) of the test specimen as compacted from the following equation:

$$\rho_w = \frac{m_2 - m_1}{V}$$

where:

$\rho_w$ = wet density, in tonnes per cubic metre

$m_2$ = mass of the mould plus compacted specimen, in grams

$m_1$ = mass of mould, in grams

V= volume of the mould, in cubic centimetres.

(b) The dry density ($\rho_d$) of the test specimen as compacted from the following equation:

$$\rho_d = \frac{\rho_w \times 100}{w + 100}$$

Where

$\rho_d$ = dry density of the specimen, in tonnes per cubic metre

$\rho_w$ = wet density, in tonnes per cubic metre

w = moisture content of the specimen, in percent.

(c) The unconfined compressive strength (UCS) of the test specimen, in MPa, from the equation:

$$UCS = \frac{P \times 1273}{(D_{av})^2}$$

Where

UCS = unconfined compressive strength, in MPa

$P$ = load at failure, in kilonewtons

$D_{av}$ = average diameter, in millimetres.

NOTE: $1273 = \frac{4}{\pi} \times 1000$ and $1 \text{kN/mm}^2 = 1000 \text{MPa}$.

(d) The mean value of the two determinations of UCS. The results shall be rejected if the difference between the two results is greater than 20 % of the mean value.

10 REPORTING

The following data for the two test specimens shall be reported:

(a) Unconfined compressive strength, as the average of the strengths of the two test specimens, to the following precision:

- For UCS less than 1.0 MPa, to the nearest 0.05MPa
- For UCS between 1.0 and 2.0 MPa, to the nearest 0.1 MPa
- For UCS greater than 2.0 MPa, to the nearest 0.2 MPa.

(b) The curing time of the test specimens, in days taken from the time of compaction of the specimens to the time of testing, in days.

(c) Moisture content of each specimen on completion of testing, in percent to the nearest 0.5.

(d) Dry density of each specimen as compacted, to the nearest 0.001 t/m³ or, if required, the laboratory density ratio to the nearest 0.1%.

(e) If required, the laboratory moisture ratio of the material prior to compaction and after compression testing to the nearest 0.1%

(f) Compactive effort applied (i.e. Standard or Modified) and, if not in accordance with either WA 133.1 or 132.1, the method of compaction and number of layers.

(g) Description of the stabilized soil.

(h) Details of curing.

(i) If applicable, the amount of material retained on the 19.0 mm sieve as a percentage of the moist mass in the original sample, to the nearest 1.

(j) Hydration Time
(k) The elapsed time between addition of the Cement and compaction of the specimens

(l) The method of preparation of the test sample.

(m) Reference to this Test Method, i.e., WA 143.2

11 PRECISION AND BIAS

(a) Precision: Test data on precision is not presented due to the nature of the soil or rock materials tested by this test method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation.

(b) Bias: There is no accepted reference value for this test method, therefore, bias cannot be determined.

(a) ISSUING AUTHORITY

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<td>Manager Materials Engineering</td>
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(b) REVISION STATUS RECORD

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<td>3</td>
<td>REFERENCED METHODS Primary reference to Main Roads WA standards from previous reference to Australian Standards.</td>
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<td>1</td>
<td>4</td>
<td>DEFINITIONS (a) Hydrated Cement Treated Crushed Rock Base (HCTCRB) – is crushed rock base that has been mixed with water and 2% of cement and then allowed to hydrate.</td>
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