Transport
Roads & Maritime
Services

Test method T111

Dry density/moisture relationship of road construction materials

OCTOBER 2012

Revision Summary

Ed/Rev Number	Clause Number	Description of Revision	Authorisation	Date
		Reformatted and Revision Summary Added	D. Dash	May 1999
	4 (c) (ii), 5.1.1 (a) (e), 5.1.2 (a)	Revised	D. Dash	Sept 1999
Ed 2/ Rev 0		Revised and reformatted. Rammer tolerance as per AS 1289.5.2.1. Method A deleted and Method B becomes the standard. Changed 'M' subscripts. Notes added and renumbered. Appendix revised.	G Donald	July 2006
Ed 2/ Rev 1	2(b) & (d); 4, 5.1(a); 6(a); 7(e)	Clarify portion. Document ref. Curing. Mould selection. Symbol for density revised.	D Hazell	Jan 2010
Ed 2/ Rev 2	2(d); 5.1(e); 7(a)	New style. Added references. Protect moisture loss. Reworded.	D Hazell	May 2011
Ed 3/ Rev 0	All	Reformatted RMS template	J Friedrich	October 2012

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

The most recent revision to Test method T111 (other than minor editorial changes) are indicated by a vertical line in the margin as shown here.

Test method T111

Dry density/moisture relationship of road construction materials

1. Scope

This Test Method sets out the procedure to determine the relationship between moisture content and dry density of road construction materials.

The method uses Standard or Modified compaction on independent sub-samples having different moisture contents.

2. General

(a) Standard compaction is to be used unless otherwise specified.

(b) The sample is the portion passing the 19 mm AS sieve except where a larger maximum sieve size is specified (e.g. the 37.5 mm portion that is applicable to T171). Separate testing of different portions from the sample may be required.

NOTE: The OMC and MDD may differ for different portions and cannot be interchanged.

(c) For road construction materials blended in the laboratory with cementitious binders, this test is amended in accordance with T130.

(d) The following documents are referred to in this Test Method:

(i) T105 Preparation of Samples for Testing (Soils)

(ii) T120 Moisture Content of Road Construction Materials (Standard Method)

(iii) T171 Modified Texas Triaxial Compression Test for Pavement Materials.

(iv) AS 1289.5.1.1 Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using standard compactive effort.

(v) AS 1289.5.2.1 Soil compaction and density tests - Determination of the dry density/moisture content relation of a soil using modified compactive effort.

3. Apparatus

(a) A cylindrical metal mould with an internal diameter and volume as specified below. A detachable base plate and a collar assembly, approximately 60 mm high, both of which can be firmly attached to and removed from the mould.

(i) An internal diameter of 105 ± 0.5 mm and a volume of 1000 ± 15 mL (i.e. one litre mould)

NOTE: A suitable design is shown in Figure 1 of AS 1289.5.1.1.

OR

(ii) An internal diameter of 148.5 ± 1.0 mm and a volume of 2000 ± 30 mL (i.e. two litre mould)

(b) A metal rammer with a 50 ± 0.4 mm face diameter and the requirements as specified below.

(i) For Standard compaction, a drop mass of 2.7 ± 0.01 kg and equipped with a suitable device to control the height of drop to a free fall of 300 ± 2.0 mm.

OR

(ii) For Modified compaction, a drop mass of 4.9 ± 0.01 kg and equipped with a suitable device to control the height of drop to a free fall of 450 ± 2.0 mm.

NOTE: A suitable form of hand apparatus is shown in Figure 2 of AS 1289.5.1.1 or AS 1289.5.2.1. Provided the essential dimensions are adhered to, mechanical forms of the apparatus may be used.

(c) A rigid foundation to compact the specimen on (e.g. a concrete floor or a concrete block of at least 100 kg) with suitable attachments for firmly holding the mould base plate assembly during compaction

(d) A balance of suitable capacity with a limit of performance not greater than ± 5 g

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

(f) A bowl and trowel, or mixing machine suitable for thoroughly mixing increments of water with the sub-sample

(g) A suitable measuring cylinder

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

(i) A 300 mm ruler marked in mm or a suitable depth gauge

(j) Dishes of suitable size

(k) Suitable brushware

4. Preparation

Prepare samples in accordance with T105. Ensure that the curing requirements for the sample have been achieved.

5. Procedure

5.1 General

(a) Use a one or two litre mould. However, a two litre mould must be used if the sample has < 95% passing 19 mm sieve (i.e. more than 5% is retained on a 19.0 mm sieve).

(b) Determine the mass of the mould and record the mass (M_1).

NOTE: *In some cases, the mass of the mould (M_1) is to include the mass of the base plate and liner. The base plate may be retained to prevent some materials (e.g. fine crushed rock) slipping from the mould. Thin plastic wrap may be installed as a liner to retain moisture.*

(c) Assemble the mould, collar and base plate, and secure the assembly to the rigid foundation.

(d) Carry out testing of the sub-samples as described in Step (e), 5.3 and 5.4 until at least three test results “straddle” the Optimum Moisture Content (*OMC*). Straddling has been achieved when:

   (i) Three moisture contents lie between OMC - 2.5% and OMC + 2% with one result below OMC and one result exceeding OMC.

   (ii) The increments between the moisture contents in ascending order lie between 1% and 2.5%.

NOTE: *.Preferably results should be approximately 2% below, at OMC and 2% above OMC.*

(e) After moisture adjustments have been made, protect the sub-samples from moisture loss.

5.2 Sub-sample 1

(a) Remove the sub-sample 1 from the sealed container.

(b) Adjust the moisture content, if required, to approximate OMC.

(c) Thoroughly mix the sub-sample.

(d) Compact the sub-sample in the mould using the compaction specified in the following table (i.e. number of equal layers and each layer subject to a uniformly distributed number of blows from the required rammer falling freely from the height). Do not vary the compacted thickness of each layer by more than 5 mm.

Item	Standard Compaction	Modified Compaction
No. of layers	3	5
Rammer drop mass (kg)	2.7 ± 0.01	4.9 ± 0.01
Height of drop (mm)	300 ± 2.0	450 ± 2.0
No. of uniformly distributed blows per layer	25 for the one litre mould; or 50 for the two litre mould	25 for the one litre mould; or 50 for the two litre mould

NOTE: *Use only sufficient material to slightly overfill the mould leaving not more than 5 mm to be struck off after removing the collar. If overfilled by more than 5 mm or underfilled, the sample is to be replaced by a new sub-sample.*

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

(f) Level the specimen to the top of the mould by means of the straightedge. Patch any holes developed in the surface by replacing coarse material with smaller sized material.

(g) Remove the mould plus specimen from the base plate and determine the mass (M_3).

NOTE: *Where the base plate is retained and/or a liner used, M_3 is to include the mass of the base plate and/or liner.*

(h) Eject the specimen from the mould.

(i) Obtain a representative portion from the specimen and determine the moisture content (w) in accordance with T120.

5.3 Sub-sample 2

(a) Remove sub-sample 2 from the sealed container and adjust to appropriate moisture content.

NOTE: *If the first sub-sample was obviously above OMC, compact the remaining sub-samples at lower moisture contents. Suitable increments of moisture content range from 1% for gravels up to 3% for clays.*

(b) Repeat Steps 5.2(c) to (i).

5.4 Sub-sample 3 and additional sub-samples

(a) Remove the next sub-sample from the sealed container and adjust to appropriate moisture content.

NOTE: *If the second sub-sample was obviously above OMC, compact the remaining sub-sample(s) at lower moisture contents.*

(b) Repeat Steps 5.2(c) to (i).

(c) Where the OMC has been straddled as required in Step 5.1(d), proceed to Calculations. Otherwise, repeat Step 5.4 using additional sub-samples.

6. Calculations

(a) Calculate the Dry Density (ρ_D) of each compacted specimen as follows:

$$\rho_D = \frac{(M_3 - M_1)}{V} \times \frac{100}{(100 + w)}$$

Where:

ρ_D = Dry Density (t/m^3)

M_3 = Mass of mould and compacted specimen (g)

M_1 = Mass of mould (g)

NOTE: *ρ_D can also be designated as 'DD'.*
M_3 and M_1 are to include the mass of the base plate and/or liner if retained.

V = Volume of the mould (mL)

w = Moisture content at time of moulding (%)

(b) Plot the dry densities obtained in the series of compaction tests against the corresponding moisture contents.

(c) Using one of the procedures described in the Appendix A, determine the following:

(i) The Maximum Dry Density (*MDD*)

(ii) The Optimum Moisture Content (*OMC*), which is the moisture content corresponding to the Maximum Dry Density (*MDD*)

7. Reporting

Include the following data and results in the report:

(a) The percentage by mass of material retained on the 37.5 mm and 19 mm AS sieves determined while preparing the sample according to T105

(b) The nominal mould size and the fraction used for testing

(c) The compaction used (i.e. Standard or Modified)

(d) The method used from the Appendix for determining the OMC and Maximum Dry Density

(e) The Maximum Dry Density (*MDD*) to the nearest 0.01 t/m^3

NOTE: Where the result is to be used in subsequent calculations, report the MDD to the nearest 0.001 t/m^3

(f) The OMC to the nearest 0.1%

(g) Reference to this test method

Appendix A : Determination of Maximum Dry Density and Optimum Moisture Content

Determine *MDD* and *OMC* using either a mathematical or graphical procedure as described below.

A.1 Mathematical solution

The *MDD* and *OMC* may be determined by one of the following mathematical procedures: (i) Non-linear regression plot; (ii) Cubic spline function; or (iii) Solution for vertex of a parabola with vertical axis, given 3 points closest to the *OMC*.

A.2 Graphical Solution - Vertex of a Parabola with Vertical Axis Given 3 Points

(a) From the available results, denote point **B** as the result with greatest density (closest to the *MDD*).

(b) Denote point **A** as the result with moisture content just lower than that of point **B**.

(c) Denote point **C** as the result with moisture content just higher than that of point **B**.

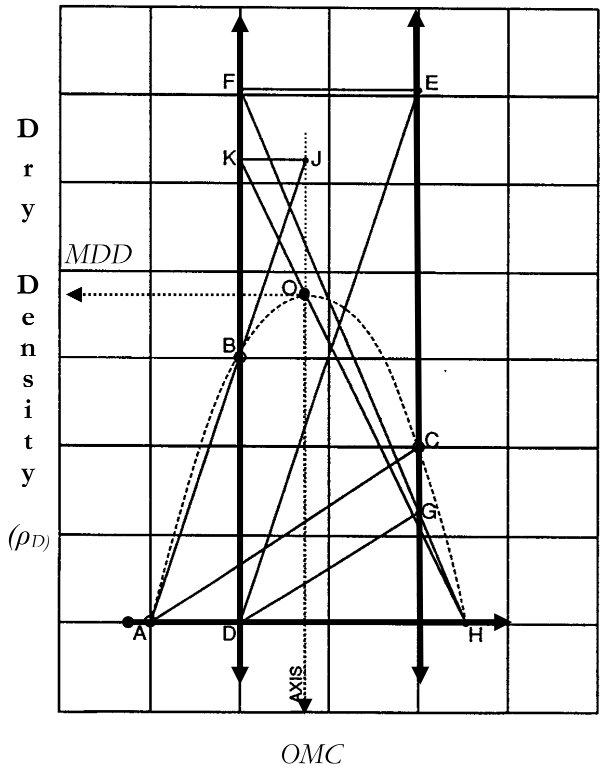
(d) Draw a horizontal base line through point **A**.

(e) If points **A**, **B** and **C** are equally spaced horizontally (i.e. equal increments of *w*):

- (i) Point **F** coincides with point **B**.
- (ii) Point **G** is halfway between the baseline and point **C**.
- (iii) Draw line **BG** to intersect the base line at **H**.

(f) If points **A**, **B** and **C** are not equally spaced horizontally.

- (i) Draw vertical lines through points **B** and **C**. Point **D** lies at the intersection of the horizontal line through A and the vertical line through **B**.



Moisture Content (*w*)

Figure 1–Graphical Solution for Peak Point of Parabola

- (ii) Draw a line **DE** parallel to **AB**. Point **E** lies on a vertical line through point **C**. Project **E** horizontally to establish point F on a vertical line through point **B**.
- (iii) Draw a line **DG** parallel to **AC**. Point **G** lies on a vertical line through **C**.
- (iv) Draw line **FG** to intersect the base line at **H**.

(g) Bisect base line **AH** to form the axis of the parabola. This defines the *OMC*.

(h) Draw line **AB** to intersect axis of parabola at **J**. Project **J** horizontally to **K**, which lies on the vertical line through **B**.

(i) Line **KH** intersects the axis at **O**, the vertex. This defines the *MDD*.