TEST METHOD **WA 133.1 – 2022**

DRY DENSITY/MOISTURE CONTENT RELATIONSHIP: MODIFIED COMPACTION FINE AND MEDIUM GRAINED SOILS

1 SCOPE

This method describes the procedure using modified compactive effort (2703 kJ/m³), for the determination of the Dry Density/Moisture Content (DD/MC) relationship of a fine and medium grained soil. This method is applicable to soils with not more than 20% retained on the 19.0 mm sieve. However, this test method is also applicable to the DD/MC relationship determination of soils with more than 20% retained on the 19.00 mm sieve for test methods such as WA 141.1 California Bearing Ratio. The procedure uses that portion of soil which passes the 19.0 mm sieve.

2 SAFETY

This method 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 method to establish appropriate occupational health and safety practices that meet statutory regulations.

3 REFERENCED METHODS

Australian Standards

AS 1152 Specification for test sieves

AS 1289.5.2.1 Determination of the dry density/moisture content relation of a soil using modified compactive effort

Main Roads Western Australia

WA 100.1 Sampling Procedures for Soil and Granular Pavement Materials

WA 105.1 Preparation of Disturbed Soil and Granular Pavement Materials for Testing

WA 110.1 Soil and Granular Pavement Material Moisture Content: Convection Oven Method

WA 110.2 Soil and Granular Pavement Material Moisture Content: Microwave Oven Method

WA 115.1 Particle Size Distribution: Sieving and Decantation Method

WA 115.2 Particle Size Distribution: Abbreviated Method for Coarse Materials

4 APPARATUS

(a) **Cylindrical steel mould**, having internal dimensions complying with Table 1, and whose volume has been calibrated.

(b) **Steel rammer**, having essential dimensions complying with Table 1, and whose energy delivered per blow has been calibrated.

NOTE: A mechanical form of the apparatus may be used provided the essential dimensions are adhered to and the rammer has a free vertical fall of the correct height. It is also essential that the design of the machine is such that the mould rests on a solid base.

TABLE 1
DIMENSIONS AND TOLERANCES FOR COMPACTION APPARATUS

Apparatus	Value	Working Tolerance
MOULD		
Individual internal diameter, mm	105.0	± 1.0
Average internal diameter, mm	105.0	± 0.5*
Height, mm	115.5	± 0.5*
Calculated volume, cm³	1000	± 15*
RAMMER		
Diameter, mm	50.0	± 0.4
Drop, mm	450.0	± 2.0†
Mass, kg	4.90	± 0.01†
Energy delivered per blow, J	21.62	± 0.08
Number of layers	5	-
Number of blows per layer	25	-
Energy input, kJ/m³	2703	± 60

* Either but not both of the tolerances may be exceeded provided that the appropriate tolerance of volume is not exceeded.

† Either but not both of the tolerances may be exceeded provided that the appropriate tolerance of energy blow is not exceeded.

(c) A **rigid foundation** on which to compact the specimen, such as a concrete or steel block of mass at least 100 kg.

(d) **Balance** of suitable capacity, readable to 1 g, with a Limit of Performance (F) not more than 5 g.

(e) **Straightedge** approximately 300 mm long, 25 mm wide and 2 mm thick, preferably with one bevelled edge.

(f) **Sieves**—37.5 mm, 19.0 mm and 4.75 mm, in accordance with AS 1152.

(g) **Mixing apparatus**, tray, tongs, measuring cylinder, etc.

(h) **Rule**—300 mm readable to 1.0 mm.

(i) Sample extruder (recommendation only).

5 PROCEDURE

(a) Obtain a test sample taken in accordance with Test Method WA 100.1 and determine the percent of material retained on the 19.0 mm sieve in accordance with Test Method WA 115.2 or WA 115.1.

NOTE: Where it is obvious that all material passes the 19.0mm sieve (e.g. sand), testing by WA 115.1 or WA 115.2 is not necessary. It is sufficient to record that the material passes the 19.0 mm sieve by visual assessment.

(b) Obtain four or more test increments from the test sample of material passing the 19.0 mm sieve, that have been prepared in accordance with Test Method WA 105.1, of sufficient mass when wetted and compacted, to produce a volume in excess of 1 000 cm³.

NOTE 1: For most soils a mass of 2.5 kg will be adequate. However gravel may require up to 3 kg and heavy clay only 2 kg.

NOTE 2: Where the pavement material is stabilised or modified with Portland cement, the maximum dry density determinations must be commenced two (2) hours after mixing is complete and must be completed within a further two (2) hours. If Low Heat (LH) cement, bitumen or lime is used for the stabilisation or modification, these determinations must be commenced three (3) hours after mixing is complete and must be completed within a further three (3) hours.

(c) Mix each test increment thoroughly with a suitable amount of water, selecting the quantities of water to be added so that the soil optimum moisture content is straddled and the moisture content increments are not excessive for the soil type. If there are coarse particles in the test increments, screen the test increment on a 4.75 mm sieve. Wet and mix the fraction retained on the 4.75 mm sieve to ensure complete wetting of the coarse particles prior to curing. Follow by remixing with the fraction passing the 4.75 mm sieve to ensure complete wetting of the whole test increment.

NOTE: Generally moisture content increments should range from one percent for granular to three percent for clays.

(d) Cure the test increments at room temperature for a minimum period in accordance with Table 2. In the absence of known values, Liquid Limit and Optimum Moisture Content (OMC) may be estimated by visual and tactile assessment by an experienced technician. Record the period of curing.

NOTE 1: Curing time for all materials can be limited to 2 hours where used for compaction control testing if the estimated moisture condition of the material when sampled is within 4% of the estimated Optimum Moisture Content and the material is maintained in it's moist condition between sampling and testing.

NOTE 2: It is important that the water is thoroughly mixed into and uniformly distributed through the soil since inadequate mixing gives rise to variable test results. It is desirable to keep the mixed soil in a sealed container to allow the water to become uniformly distributed throughout the soil before compaction.

TABLE 2
MINIMUM CURING TIME

Plasticity	Estimated Initial Moisture Condition	
	≤2% from OMC	>2% from OMC
Sands and granular material*	2 hours	2 hours
Liquid Limit ≤ 35%	24 hours	48 hours
Liquid Limit 36% - 50%	48 hours	4 days
Liquid Limit > 50%	4 days	7 days

**These can include naturally occurring sands and gravels, crushed rocks and manufactured materials with material passing 75µm typically less than 12%.*

(e) Determine the mass of the mould plus base plate (m_1) to at least the nearest 1 g.

(f) Assemble the mould, collar and base plate and place the assembly on the rigid foundation.

(g) Take one test increment of wetted soil, mix thoroughly and compact it into the mould in five approximately equal layers, so that the compacted height of soil 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. Specimens that do not meet these tolerances must be discarded. Previously compacted soil shall not be reused.

Compact each layer by 25 uniformly distributed blows of the steel rammer falling freely from a height of 450 mm.

NOTE: It is necessary to control the total amount of soil compacted since it has been found that, if the amount of soil struck off after removing the collar is too great, test results may be inaccurate.

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

(i) Trim the surface of the specimen while the mould is still attached to the base plate as follows (the procedure depends upon the characteristics of the soil):

- For an essentially fine-grained soil: Trim the compacted soil level with the top of the mould by means of the straightedge. Use smaller size material to patch any holes developed in the surface from removal of coarse material during trimming.

- For soil containing stones: Trim the compacted soil in the mould ensuring that portions of stones protruding above the top of the mould are compensated by hollows of about the same volume below the top of the mould.

(j) Determine the mass of the mould plus base plate plus soil (m_2) to at least the nearest 1 g.

(k) Remove the soil specimen from the mould. Obtain a representative sample from the full height of the specimen and determine the moisture content (w) in accordance with Test Method WA 110.1 or WA 110.2.

NOTE: It is often desirable to use the whole specimen for the moisture content determination.

(l) Discard the used soil, clean and assemble the mould, collar and base plate ready for the next sample. Clean the steel rammer.

(m) Repeat Procedure 5(f) to 5(l) using the other wetted test increments to obtain at least four points. At least two points must be drier, and one wetter, than optimum moisture content to satisfactorily define the dry density/moisture content relationship.

NOTE: If, with increasing moisture content, the wet mass of compacted soil markedly increases and then starts to decrease, the optimum moisture content probably has been straddled adequately. For soils with low plasticity and high permeability, points wetter than optimum moisture content may not be achieved due to loss of water during compaction.

(n) If the optimum moisture content has not been straddled or is imprecisely defined, use additional test increments prepared in the same manner as in Procedure 5(a) to 5(d), and compact these at appropriate moisture contents as in Procedure 5(f) to5(l).

6 CALCULATIONS

(a) Calculate for each specimen the wet density using the formula:

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

Where:

ρ = wet density in t/m³

V =calibrated volume of mould in cm³

m_1 = mass of mould plus base plate in grams

m_2 = mass of mould plus base plate plus specimen in grams

(b) Calculate for each specimen the dry density using the formula:

$$\rho_{d/mod} = \frac{\rho \times 100}{100 + w}$$

Where:

$\rho_{d/mod}$ = modified dry density in t/m³

ρ = wet density of soil in t/m³

w = moisture content appropriate to the specimen

(c) Plot the densities obtained for the compacted specimens against their corresponding moisture contents on a linear graph with the percentage moisture content axis horizontal and the dry density axis vertical. Draw a smooth curve of best fit through the resulting points.

NOTES:

1. The discrimination of each axis should be limited to twice the reporting accuracy of the characteristic. Thus for dry density each division of the graph should less than or equal to 0.002 t/m³ and for moisture content each division of the graph should less than or equal to 0.2 percent.

2. Approved curve fitting calculations, or computer programs which plot through the point may also be used to determine the co-ordinates of the peak of the curve.

(d) Determine the dry density corresponding to the maximum point on the moisture content/dry density curve as the modified maximum dry density.

(e) Determine the percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve as the modified optimum moisture content.

7 REPORTING

Report the following:

(a) The Modified Maximum Dry Density to the nearest 0.001 t/m³.

(b) The Modified Optimum Moisture Content to the nearest 0.1%.

(c) The plot of dry density against moisture content.

(d) Percentage oversize material retained on the 19.0 mm sieve to the nearest 1 percent.

(e) The period of curing

8 ISSUING AUTHORITY

Document Owner: Pavements Manager

9 REVISION STATUS RECORD

Page No.	Section	Revision Description / Reference
2	5(b)	Note 2 added to include Specification 201 - Annexure 201A clause 1.1.1 requirements