

Australian Standard®

Methods of testing soils for engineering purposes**Method 5.8.4: Soil compaction and density tests—Nuclear surface moisture-density gauges—Calibration using standard blocks**

This Standard incorporates Amendment No. 1 (October 2012). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

1 SCOPE

This Standard sets out the method for the following:

- (a) The calibration of the density system of a nuclear surface moisture-density gauge using standard density blocks. The calibration equation, so derived, defines the relationship between the density count ratio and field density for direct transmission measurement (see Notes 1 and 2).

NOTES:

- 1 A nuclear surface moisture-density gauge calibrated in accordance with this method may also be used for the determination of the field density of asphalt in accordance with AS 2891.14.1.1.
 - 2 When the density and moisture systems operate independently, a gauge may be used to measure only one variable (either density or moisture).
- (b) The partial calibration of the moisture system of a nuclear surface moisture-density gauge using standard moisture blocks. The calibration equation, so derived, defines the slope of the moisture calibration equation. The intercept of the moisture calibration equation for each particular material is determined from actual measurements of field moisture content, as detailed in AS 1289.5.8.1.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- 1289 Methods of testing soils for engineering purposes
- 1289.5.8.1 Method 5.8.1: Soil compaction and density tests—Determination of field density and field moisture content of a soil using a nuclear surface moisture-density gauge—Direct transmission mode
- 1289.5.8.5 Method 5.8.5: Soil compaction and density tests—Nuclear surface moisture-density gauges—Density of a Type A or Type C Standard density block
- 1289.5.8.7 Method 5.8.7: Soil compaction and density tests—Nuclear surface moisture-density gauges—Water content of a Standard moisture block using hydrogen content of components

AS

1289.5.8.8 Method 5.8.8: Soil compaction and density tests—Nuclear surface moisture-density gauges—Water content of a Standard moisture block using proportion of water

1289.5.8.9 Method 5.8.9: Soil compaction and density tests—Nuclear surface moisture-density gauges—Water content of a Standard moisture block using comparison against primary blocks

AS/NZS

2891 Methods of sampling and testing asphalt

2891.14.1.1 Method 14.1.1: Field density tests—Determination of field density of compacted asphalt using a nuclear moisture-density gauge—Direct transmission mode

ISO/IEC

Guide 98–3 Uncertainty of measurement—Guide to the expression of uncertainty measurement

3 SAFETY PRECAUTIONS

The equipment used in this method utilizes radioactive materials that may be hazardous to health unless proper precautions are taken. Therefore, it is essential that operators receive instruction on potential hazards and precautions, together with routine safety procedures such as the use of personal radiation monitors, source leak testing and use of radiation survey meters.

4 APPARATUS

The following apparatus is required (additional items may be required for some types of gauges):

- (a) Nuclear surface moisture-density gauge, manufacturer's handbook for the gauge and the manufacturer's reference block.
- (b) Standard density blocks, Type A or Type C, complying with the following:
 - (i) The density range spanned by the blocks shall cover the range of densities that are expected to be encountered in the field. The density of the blocks shall be evenly spaced throughout the range.
 - (ii) Each block shall have minimum dimensions of 550 mm length $\times$ 450 mm width and a minimum depth of 50 mm greater than the maximum depth at which the gauge is to be calibrated. Blocks of not less than 300 mm in width may be used, provided two or more such blocks are strapped together with 50 mm thick aluminium plates on each end.
 - (iii) The top surface of each block shall be finished with an out-of-flatness not exceeding 0.5 mm. When determining the density of a block in accordance with AS 1289.5.8.5, using direct measurement of volume, each of the other surfaces of the block shall be finished with an out-of-flatness not exceeding 1 mm.
 - (iv) A direct transmission access hole of diameter not exceeding 20 mm shall be drilled in the block, normal to the top surface, at least 100 mm from the end and on the longitudinal axis of the block. The centre of the access hole shall be at least 150 mm from the sides of the block. The depth of the access hole shall be at least 50 mm greater than the calibration depth. If desired, two access holes, one near each end, may be drilled.

- (v) When the gauge probe is placed into the access hole, the gauge base shall rest entirely on the block and shall be clear of any other access holes.
- (vi) The density of a standard density block shall be re-determined at least every 10 years.
- (vii) The set of standard density blocks shall be one of the following:

(A) *Type A* Homogeneous blocks, of naturally occurring stone and of metal. Five blocks, two of natural stone and three of metal, shall be used. The stone blocks shall be of materials that bracket the mass attenuation coefficients of soils (see Note below). The density of each block shall be determined in accordance with AS 1289.5.8.5. The uncertainty of density for each block shall be not greater than 0.3%.

NOTE: Limestone and granite blocks have been found to be as satisfactory as natural stone blocks. Magnesium, aluminium and magnesium/aluminium laminate blocks have been found to form a suitable metallic series.

(B) *Type C* Homogeneous blocks of naturally occurring stone. A minimum of four blocks shall be used. The density of each block shall be determined in accordance with AS 1289.5.8.5. The uncertainty of density for each block shall not be greater than 0.3%.

- (c) Standard moisture blocks with water contents assigned in accordance with AS 1289.5.8.7, AS 1289.5.8.8 or AS 1289.5.8.9. The uncertainty of the water content of each block shall not be greater than 3.0%. The blocks shall have assigned water contents covering the range of water contents to be encountered in the field.

The blocks shall have minimum dimensions of 550 mm length × 300 mm width × 230 mm depth. The top surface of each block shall be finished with an out-of-flatness not exceeding 0.5 mm.

The water content of a standard moisture block shall be re-determined at least every 10 years.

The set of standard moisture blocks shall be one of the following:

- (i) Blocks prepared from quartz sand and polystyrene in various proportions, the hydrogen of the polystyrene substituting for the hydrogen of water.

A block of aluminium or magnesium alloy may be used to provide an assigned water content of 0.000 t/m³, by definition.

A minimum of three blocks shall be used.

The proportions of sand to polystyrene for the blocks shall be such that the assigned water contents are approximately evenly distributed between 0.05 t/m³ and 0.35 t/m³ (see Note below).

NOTE: For standard moisture blocks constructed from sand and polystyrene, the proportions (by mass) of the sand and polystyrene in the five blocks are not critical; however, the mass of the mix components in the blocks has to be known to calculate the assigned moisture contents. From experience, using quartz sand and commercial grade unexpanded polystyrene, the following proportions may be taken as a guide for the construction of the standard moisture blocks:

Block	Sand %	Polystyrene %	Polystyrene proportion (<i>q</i>)
1	94	6	0.06
2	86	14	0.14
3	82	18	0.18
4	70	30	0.30
5	60	40	0.40

The construction and assignment of water content to each block shall be made in accordance with AS 1289.5.8.7.

- (ii) Blocks made of a regular array of aluminium plates separated by air gaps that can be filled with water. The plates shall be vertical and normal to the line between the neutron source and detector or when the gauge is placed on the block. Plates may be added or removed to alter the assigned water content value. Any additional water around the perimeter of the array shall not influence the response as measured by the moisture counts.

A block of aluminium or magnesium alloy may be used to provide an assigned water content of 0.000 t/m^3 , by definition. A minimum of three blocks shall be used.

The assignment of water content to each block shall be made in accordance with AS 1289.5.8.8.

- (iii) Blocks made of polyethylene sheets and aluminium or magnesium alloy sheets, the hydrogen of the polyethylene substituting for the hydrogen of water.

A block of aluminium or magnesium alloy may be used to provide an assigned water content of 0.000 t/m^3 , by definition.

A minimum of two blocks shall be used.

The assignment of water content to each block shall be made in accordance with AS 1289.5.8.9.

- (d) Radiation monitoring apparatus and personal radiation monitors as required by the regulatory authority.
- (e) Thermometer, if applicable, covering a range of $0\text{--}50^\circ\text{C}$, with an uncertainty not exceeding 0.5°C .

5 PROCEDURE

5.1 Preparation for calibration

The blocks shall be stored under cover to protect them from the effects of weather.

Before a calibration is commenced, ensure that the blocks to be used are sufficiently clear of other nuclear gauges or other sources of radiation so that there is no detectable effect on the counts displayed by the gauge. In buildings that are restricted in available area, it may be necessary to provide shielding to achieve this requirement.

The location for the standard count determinations and the gauge function checks shall be at least 1 m from any vertical projection or any known neutron absorber or moderator.

There shall be a minimum clearance of 1 m from any vertical projection that is above the level of the top of the blocks.

Standard moisture blocks shall be situated at least 1 m from any significant source of hydrogen or any neutron moderator or absorber.

Ensure that the gauge is in good working order. Check that the base of the gauge, the manufacturer's reference block and the standard blocks are clean.

5.2 Gauge function check

Perform gauge function checks in accordance with procedures specified for the gauge and record the results. If the results of these checks fail to comply with the specified requirements, the function checks shall be repeated. If the results of the second function checks fail to comply with the specified requirements, the gauge shall be withdrawn from service until the reason for the fault is determined and the fault rectified.

5.3 Standard count check

Perform the check in accordance with Appendix A.

5.4 Determination of density calibration data

Initial and final standard counts together with the complete calibration data for a particular depth shall be determined in one day. If a gauge has depths calibrated on different days, additional standard counts will need to be determined, at the start and end of each day of calibration.

The procedure shall be as follows:

- (a) Record an initial standard density count for the gauge on the manufacturer's reference block in accordance with the procedure specified by the manufacturer. Use a counting period of at least 4 min.
- (b) Place the gauge on a standard density block and position the probe above an access hole, orienting the gauge so that its longitudinal axis is parallel to the longitudinal axis of the block. Lower the probe to the required depth, and pull the gauge towards the centre of the block to ensure that the probe is in contact with the side of the access hole.
- (c) Without shifting the gauge, obtain and record four 1 min counts or one 4 min count, in accordance with the manufacturer's instructions for direct transmission measurement.
- (d) Repeat Step (c) with the gauge in the same position or where the block contains two access holes, repeat Steps (b) and (c) with the probe located in the other access hole.
- (e) Repeat Steps (b) to (d) for the remaining standard density blocks.
- (f) Repeat Steps (b) to (e) for each required depth of the probe.
- (g) Record a final standard density count of the gauge in accordance with, and at the same location as, Step (a). If this value falls outside the limits determined in accordance with Step (d) of Appendix A, the values determined from Steps (a) to (f) shall be rejected and the calibration shall not proceed until the reason for the standard count being outside the limits is determined and the fault rectified.

5.5 Determination of moisture calibration data

Initial and final standard counts together with the complete calibration data shall be determined in one day.

The procedure shall be as follows:

- (a) If applicable, fill the standard moisture blocks with water, ensuring that entrapped air is removed. The vertical plates shall be just submerged. Leave the blocks for at least 30 min to allow temperatures to become stable. Record the water temperature of each block and determine the corresponding water density from Table 1.

- (b) Record an initial standard moisture count for the gauge on the manufacturer's reference block in accordance with the procedure specified by the manufacturer. Use a counting period of at least 4 min.
- (c) Place the gauge on a standard moisture block so that it is clear of any access holes.
- (d) Without shifting the gauge, obtain and record four 1 min counts or one 4 min count, in accordance with the manufacturer's instructions for moisture measurement.
- (e) Repeat Step (d) with the gauge in the same position or, if desired, rotate the gauge 180° about its vertical axis and repeat Steps (c) to (d).
- (f) Repeat Steps (c) to (e) for the remaining standard moisture block(s).
- (g) Record a final standard moisture count of the gauge in accordance with, and at the same location as, Step (b). If this value falls outside the limits determined in accordance with Step (d) of Appendix A, the values determined from Steps (b) to (f) shall be rejected and the calibration shall not proceed until the reason for the standard count being outside the limits is determined and the fault rectified.

TABLE 1
DENSITY OF WATER AT VARIOUS TEMPERATURES

°C	t/m ³	°C	t/m ³
15	0.9991	23	0.9975
16	0.9989	24	0.9973
17	0.9988	25	0.9970
18	0.9986	26	0.9968
19	0.9984	27	0.9965
20	0.9982	28	0.9962
21	0.9980	29	0.9959
22	0.9978	30	0.9956

6 CALCULATIONS

6.1 Density data

Calculate the following:

- (a) The mean of the initial and final Standard density counts obtained at Steps 5.4(a) and (g), respectively.
- (b) The mean of the density counts for each probe depth on each Standard density block obtained at Steps 5.4(c) and (d).
- (c) The density count ratio (*DCR*) for each probe depth on each Standard density block by dividing each mean density count obtained at Step (b) by the mean standard density count obtained at Step (a).

6.2 Density calibration constants

6.2.1 Type A blocks

The density calibration constants for Type A blocks shall be calculated from the following equation:

$$DCR = Ae^{-B\rho} - C \quad \dots 6(1)$$

A1

where

- DCR = density count ratio
 ρ = density, in t/m³
 e = natural logarithm base
 A, B, C = calibration constants for the particular gauge

For each probe depth, the procedure shall be as follows:

- Solve the above equation for A and C using the density count ratio (DCR) and the known density (ρ) of each metal block.
- Calculate the value of B for one of the stone blocks using the A and C constants so derived and the data obtained for that block.
- Repeat Step (b) for the remaining stone block.
- Calculate the average value of B derived from the stone blocks.
- The A and C constants derived on the metal blocks and the average value of B derived from the stone blocks define the density calibration equation.
- For field use, density calibration constants for Type A blocks shall be calculated from the following equation:

$$\rho = \frac{\ln A}{B} - \frac{\ln(DCR + C)}{B} \quad \dots 6(2)$$

where

- ρ = density, in tonnes per cubic metre (obtained in the field)
 DCR = density count ratio (obtained in the field)
 $\ln$ = natural logarithm
 A, B, C = calibration constants for the particular gauge

6.2.2 Type C blocks

The density calibration constants for Type C blocks shall be calculated from the following equation:

$$\rho = P - Q \ln(DCR) \quad \dots 6(3)$$

where

- DCR = density count ratio (obtained in the field)
 ρ = density, in tonnes per cubic metre (obtained in the field)
 $\ln$ = natural logarithm
 P, Q = calibration constants for the particular gauge

For each probe depth, the procedure shall be as follows:

- Solve the equation for P and Q using the density count ratio (DCR) and the known density (ρ) of each block.
- For field use, the calibration equation shall be expressed in the following form:

$$\rho = P - Q \ln(DCR) \quad \dots 6(4)$$

where

- ρ = density, in tonnes per cubic metre (obtained in the field)