TECHNICAL GUIDE
L-G-002

Field density testing by using a nuclear density gauge

February 2015

About this release

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Field Density Testing by using a Nuclear Density Gauge

Preface

This guide covers Test Methods T120, T121, T173 and T180.

1. Introduction

Nuclear density gauges (NDG) are used to determine compaction acceptance of earthworks, granular and stabilised pavement materials and asphalt. This Guide provides staff undertaking general surveillance with guidance on the general aspects of field density testing as applied to earthworks and pavement materials placed and compacted for road applications in accordance with specifications and test methods.

Compliance with the specified compaction and density requirements is a key acceptance criterion for earthworks and pavements specifications. Nuclear density gauges (see Figure 1) are often used for testing on earthworks for compaction acceptance and the NDG asphalt thin-layer gauge (see Figure 2) is used for asphalt materials.

Figure 1: The NDG is seated on reference block (Source: VicRoads TN106)

Figure 2: The NDG Asphalt thin-layer gauge seated on reference plate (Source: VicRoads TN106)

Where surveillance of the field density testing reveals non-conformance, specialist surveillance personnel may need to review the detail of practices associated with the application of the test method, both in the field and in the laboratory.

This Guide is restricted to field density testing using the NDG, although other methods involving volume or sand replacement methods can be used for field density testing. The laboratory testing and the preparation of test reports associated with these other field test are not discussed in this guide.

2. Definitions

The following list of definitions is used in this Guide and does not represent a complete list of soil testing definitions.

Backscatter mode - The retractable rod with the source is lowered so that it is even with the detector but still within the instrument. The source emits radiation, which then interact with electrons in the material and lose energy and/or are redirected (scattered). Radiation that is scattered towards the detector is counted. The denser the material, the higher the probability that radiation will be redirected towards the detector. Therefore, the detector count is proportional to the density. Backscatter mode is not used for testing compacted pavement construction materials

Direct transmission mode - A test in which the Gamma source is placed into the material by means of a punched or drilled access hole. Gamma rays are transmitted from the source, through the material to be measured, to the detectors located on the surface. The average density and moisture content of the lift of material are determined. Direct transmission mode is used for testing compacted pavement construction materials.

Dry density – Mass of dry soil after drying at 105ºC to 110ºC, contained in the unit volume of undried soil

Field density - The density of earthworks or pavement material measured insitu.

NDG - Nuclear Density Gauge

Proof rolling – Subjectively assessed deformation test where the transient surface deformation under specified loading equipment is perceptible or not. Perceptible deformation may be visible or elastic deformation (springing, spongy or resilient.)

Relative compaction - The percentage ratio between the field density of a soil to the maximum density as determined by standard or modified compaction.

Wet density – Mass bulk soil, including solid particles, water and air contained in a unit volume.

Lot - A lot is based on no more than one day’s production and must only contain an area of work that is defined as a single layer, batch or area of like work which has been constructed or produced under essentially uniform conditions and is essentially homogeneous with respect to material and appearance (refer to specification Q6, Annexure Q/L).

3. Compaction and relative compaction

Road making techniques need to achieve adequate compaction of placed material during construction to prevent in-service problems, such as densification, settlement, rutting etc and to inhibit movement of water in and out of the material. The level of compaction is commonly referred in specifications as the relative compaction and expressed as a percentage. It is commonly determined by field density testing using a NDG and laboratory-based reference density testing on samples of the material.

The key density testing requirements for the assessment of field compaction are:

- field density measurements by NDG
- sampling of material for laboratory-based testing
- laboratory testing using calibrated apparatus to obtain the reference density and
- production of results and test reports.

Compaction assessment of road making materials is based on the characteristic value as determined in T166 using a number of test sites per lot (refer to specification Q6, L3). The acceptance limits for different road making materials are detailed in the relevant specifications.

Proof rolling is used in earthworks and pavement construction to verify both uniform behaviour and stability of the layer before the next layer is placed and compacted. Proof rolling is complimentary to assessment of compaction by field density testing. For more information about proof rolling refer to T198.

4. Test methods

The Roads and Maritime permits the use of the nuclear density gauge for the determination of field density. Reference density measurements using laboratory compaction methods, with standard or modified compaction effort, are carried out on material sampled from the site.

The test methods are detailed in Roads and Maritime and Australian Standard test methods, with specific application requirements detailed in the relevant specifications, (e.g. R44, R71, etc).

Laboratories carrying out the testing must be accredited for each test that is involved by the National Association of Testing Laboratories, Australia (NATA). The acceptance of work using density and compaction criteria is based on the test being performed in accordance with the relevant test methods.

5. Lot testing

Road making materials for earthworks and pavements are tested in lots for acceptance. A lot is based on no more than one day's production and must only contain an area of work that is defined as a single layer, batch or area of like work which has been constructed or produced under essentially uniform conditions and is essentially homogeneous with respect to material and appearance (refer to specification Q6, Annexure Q/L).

For example, a test lot for earthworks and pavement materials may be broadly defined as those areas of work that are substantially alike for:

- material properties and source
- general appearance (for example, colour; surface texture)
- moisture condition during compaction
- compaction technique, including number of roller passes
- layer thickness, and
- state of underlying materials.

Discrete portions of a lot which are non-homogeneous with respect to material and appearance are to be excluded from the lot, as detailed in specification Q6 L1. Increasing the number of lots within a specified area will increase the cost of compliance testing but does provide a more equitable approach to the assessment of the construction work.

Each lot must be clearly identified on-site by reference points and given a unique lot number.

A test request is issued to the laboratory by the contractor to undertake field density testing. The contractor has declared the field compaction process is complete and the test lot is ready. The field testing should continue through to completion whether or not the lot is perceived during testing to become nonconforming. If the density for the lot is nonconforming (either from test results or from abandonment of testing), the compaction process as detailed by the compaction routine, and any allowance for reduced frequency of testing, must be reviewed by the contractor.

6. Test site selection

The validity of lot testing depends on and requires the random selection of test site locations. At the start of the selection process, every point in the lot must have an equal chance of being selected. Test site selection is to be in accordance with specification Q6, Annexure L3, and is to be prepared and calculated carried out by the laboratory. Laboratories must be able to demonstrate their random site selection process conforms with specification Q6, L3.

For each test lots, the number of tests must be selected, tested and assessed as specified. The minimum testing frequency is directly related to the specified ‘Relative Compaction’ as detailed in specification Q6, L3.1.

The gauge may be re-located or shifted within 0.5 m of the selected test site location if the surface at the original selected site is found to have an unsuitable surface or if there are protruding aggregates that may affect the reading. If the gauge is repositioned the cause is to be recorded.

7. Nuclear density gauge

7.1 Safety

NDG equipment uses radioactive materials which may be hazardous to health unless proper precautions are taken. Nuclear gauges must be used in accordance with the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Code of Practice and Safety Guide for Portable Density/ Moisture Gauges Containing Radioactive Sources which provides guidance on the safe use of nuclear density gauges. As a guide to site practices, the operator and the gauge must be licensed, personal radiation badges must be worn and monitored, and warning signs and vehicle placards must be used as defined in the Radiation Safety Management Plan. The NDG operator is aware of these precautions and is responsible for supervision of the testing site. Effective precautions are to keep other personnel more than 3 m from the gauge (see Figure 3) and to minimise any time close to the gauge. Vehicles and plant equipment, other than the vehicle carrying the nuclear gauges are to be kept clear of the test area to avoid accidents.

Figure 3: Staff observing NDG at top of earthworks with safe distance marked out by cones

7.2 How does the NDG work?

The radioactive sources in NDG's are always emitting radiation. When the NDG is not making readings, the source must always be retracted to the "Safe" position, with the source secured inside the tungsten shielding block.

The NDG is schematically shown in Figure 4, with the major parts identified.

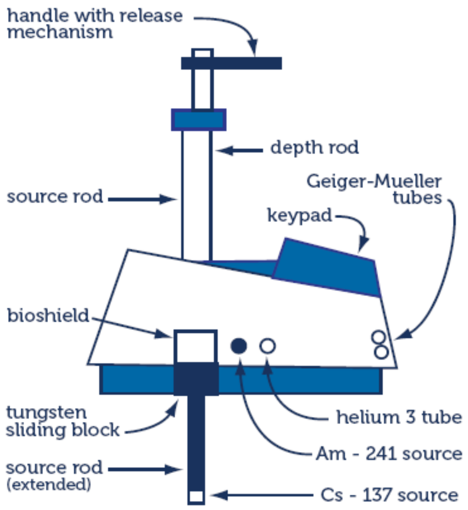

Figure 4: A diagrammatic representation of the major parts of an NDG (Source: American Portable Nuclear Gauge Association manual)

Wet density is measured using a Cesium 137 (Cs-137) gamma radiation source, a pea-sized pellet fixed in the bottom of the source rod, and two Geiger-Muller tube gamma detectors at the rear of the gauge. The Cesium gamma source is lowered to the desired test depth by releasing the handle. When the test is started, the detectors in the gauge record the count rate of the radiation transmitted directly through the soil layer, displaying wet density readings on the keypad. A more dense material absorbs more gamma radiation, resulting in a lower gamma count reading, which converts to a higher wet density value. The volume of material assessed includes the material between the source and the detectors, but the actual volume is not precisely known (refer to Figure 5).

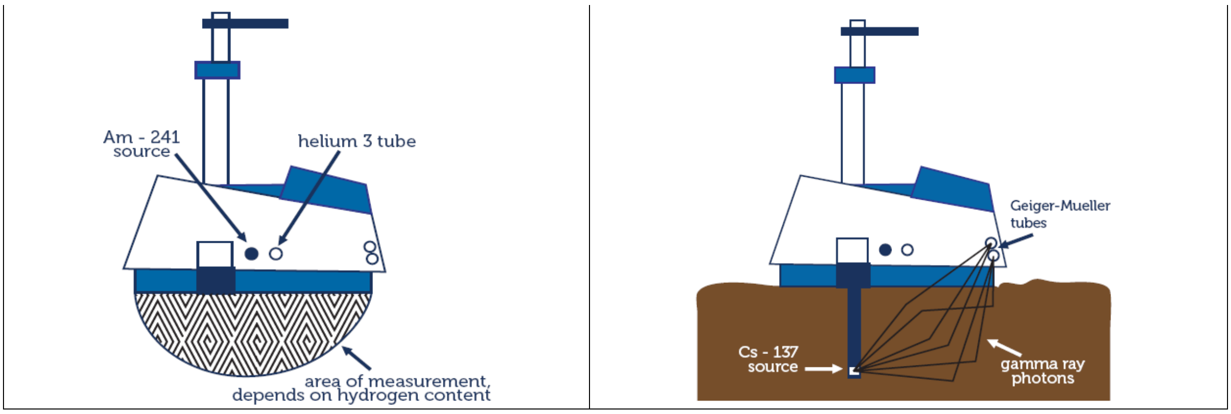

Figure 5: The NDG operating in indirect transmission (left) and (right) direct transmission mode (Source: APNGA Manual)

In direct transmission mode the NDG determines an average density from the source rod to the gauge, if the NDG is not seated properly and an air gap exists (which has a zero density) the average wet density is reduced proportionally. If the gauge cannot be seated on a flat surface, fines from the measurement layer or dry sand passing 600 µm must be used to provide a complete seal between the NDG base and the surface being tested.

Moisture content is measured using an Americium-241 /Beryllium (Am-241/Be) neutron radiation source that releases high-energy neutrons. These ‘fast’ neutrons are slowed by interaction with the hydrogen atoms. A ‘cloud’ of slow neutrons forms around the gauge, passing through a Helium 3 tube detector. This detects only the count rate of the ‘slow’ neutrons. The neutron source is fixed inside the gauge base, with the detector beside. A wetter material will slow a greater number of neutrons, and also reduce the zone of influence into the material (refer to Figure 5). Not all hydrogen atoms are in water molecules, the mineralogy of the material being testing may contain hydrogen. The moisture content determined by the NDG can be used as a guide but is not accurate and should never be used in further calculations or reporting.

Radioactive sources decay over time, producing lower raw count levels. The field counts must be standardised by comparison with the ‘Standard Count’, taken using a standard setup. All calculations and processing of results uses the count ratio, the field count divided by the standard count. This applies to both density and moisture systems.

The radiation systems of the NDG provide indirect measures of wet density and moisture content. The systems (the count ratio response) are calibrated against blocks of known wet density and moisture content, prior to use of the NDG in the field. The maximum calibration interval is two years.

7.3 Calibration and checks

It is a requirement that all NDG used are calibrated at the depth to be tested, it is recommended that all 25 mm depths be calibrated. This calibration is conducted by a facility that is NATA accredited in accordance with AS1289.5.8.4. When laboratories send their NDG away for full calibration the laboratory should check the calibration certificate and ensure there is NATA endorsement and calibrations comply with AS1289.5.8.4. This calibration must be made at intervals of no more than two years.

Monthly in-house checks must be made in accordance with AS1289.5.8.1 Appendix A, A3 Density System Consistency Checks. These checks are usually conducted on a standard density block or on a secondary block, usually of sandstone or granite. It is important that this block is stored in a dry environment. Care must be taken with the location of the standard block when used for density system consistency checks, it must be clear (1 m) from vertical projections, not be within 2 m of a wall of a building and at least 10 m from any other NDG. Checks are often carried out within a building.

Laboratories should find an area that conforms with the above where all in-house checks can be made. This area is usually marked with a painted rectangle so all in-house checks are conducted at the same location. Generally this location is on concrete, if not care must be taken to ensure the site is on well compacted material, loose top soil type material is not appropriate.

Every NDG comes with a reference standard block which is serialised to match the gauge and they must not be interchanged between gauges. Regular checks should be made to ensure serial numbers on the reference standard and the NDG match.

Gauge function tests are also conducted monthly and are usually done on the same day as the density system consistency checks.

The gauge function tests are:

- Stability (statistical) test – This test is a simple method of testing the short term stability of the detectors and electronic counting circuits in respect to the available radiation emitted from the source material. This check takes into account the radioactive decay of the source materials, which is constant over a long time but can fluctuate in the short term. The NDG is set up on the laboratory's standard block and a number of density and moisture counts are taken at each depth, this varies depending on the type of gauge used. Various manufacturers have different requirements and it is recommended that you consult the manufacturer's manual.
- Drift Test – The drift test consists of five standard counts taken three to eight hours after the stability (statistical) test, without moving the gauge between the standard counts. Pass and fail limits are based on the percent difference between the stability (statistical) test and drift test results. If the percent different exceeds the manufacture's recommended limits, then the gauge function test fails. If the drift test fails ensure the gauge is correctly set up and repeat the gauge function tests. If the results of the second gauge function test fail, then the gauge shall be withdrawn from service until the fault is rectified.

For Troxler gauges the density drift should not exceed 0.5% and the moisture drift should not exceed 1.0%. Humboldt gauges do not have a procedure for gauge function tests or specify limits, however to ensure correct operation of the Humboldt gauge it is recommended to perform gauge function tests and applying the same limits as the Troxler gauges. CPN gauges automatically turn off after one hour if the keyboard is not used and the gauge function test can not be performed. This can be overcome by regular use of the keyboard. To ensure correct operation of the CPN gauge it is recommended to perform the gauge function tests and applying the same limits as the Troxler gauges

7.4 Limitations

NDG are generally calibrated in the range of 1.72 to 2.76 kg/m^3 and a different test method must be used (e.g. T119) for readings taken outside this calibrated density range. The calibrated density range is stated on the external two yearly calibration certificate (see Annexure A for sample).

NDG must not be used if the oversize (+37.5 mm) material is greater than 20%. A different test method must be used (e.g. T119). If the material has more than 40% oversize (37.5 mm), the test is not valid.

In NSW the longest gauge available with calibration blocks is 300 mm and therefore, the maximum depth for testing is 300 mm in 25 mm increments.

7.5 NDG testing

Compaction testing of unbound granular pavement and earthworks material using the NDG soil meter is carried out to T173 which is based on AS 1289.5.8.1. This method can be used to a maximum test depth of 300 mm, on most materials, except when more than 20% of material is retained on the 37.5 mm sieve. The NDG soil meter determines the wet density of the material in direct transmission mode, where gamma radiation passes from the source, at the test depth, back to the detectors.

Testing carried out by VicRoads has shown that air gaps under the gauge and incorrect placing of the probe in the hole will cause unacceptable difference to the readings from the gauge as shown in Table 1.

Table 1: Changes in density readings from incorrectly seating of the gauge or probe (Walker, 2013)

Seating under block or probe alignment	Density reading (t/m3)	Relative value
Flat on block reference block	2.671	100 %
Gap 5 cent coin at one corner	2.653	99.3%
Gap $1 coin at 2 corners	2.633	98.6%
Probe to back of hole	2.562	95.9%
Hole off vertical	2.640	98.8%

7.6 Using NDG to T173

The key on-site requirements in T173 are:

- The NDG must have a current calibration certificate (maximum calibration interval of two years). NDG daily standard count must be conducted each day, prior to any testing at the same location (usually at the laboratory). The daily standard count is used to account for the changes to the source due to source radiation decay over time. This daily standard count is compared to the previous four daily standard counts for a statistical acceptance. Laboratories are required to have a record of each daily standard count and the statistical analysis to determine if the gauge is suitable for use on that day. If the gauge fails the daily standard count check, discard the result and repeat the check. If it fails again the gauge shall be removed from service until the fault is rectified. In this case the previous day's field density results need to be reviewed.

  Care must be taken to avoid confusion with the daily standard count taken prior to use and the (lot) standard count taken at each lot prior to testing. One (lot) standard count (as a 4 minute count) must be taken and recorded before any density measurements are taken on the material to be tested (see Annexure B for example). The gauge must be clear by 1 m from vertical projections, not be within 2 m of a building and at least 10 m from any other NDG. The (lot) standard count will take into account background radiation. To ensure that the (lot) standard count has been accepted in the gauge, use the keyboard to check the standard count in use and that it is the same as the (lot) standard count recorded prior to testing
- The test site for the gauge must be flat and is to be seated on either fines of the material under test or fine dry sand passing the 600 µm sieve (see Figure 7), to fill in any surface voids. The fines or sand must not form an added layer;
- The probe access hole, formed by drilling or spiking prior to the test, is 25 mm deeper than the required test depth (see Figure 6);
- The NDG must be used in automatic depth sensor mode.
- When measuring the density of the material the NDG must be firmly seated, without rocking on a surface essentially be flat and free of depressions and/or cracks (see Figure 6);
- The probe must be moved longitudinally so that the side of the probe nearest to the density detector is in contact with the side of the access hole.

- The test probe is to be located at the required test depth, which is generally the deepest depth available that keeps the probe in the layer being tested.
- As a minimum, at least one 60 second density measurement and density count are recorded on the material been tested at each site (see Annexure B for example)

Figure 6: The site for the NDG must be flat and the hole prepared such that it is circular

Figure 7: View of NDG seated on fine dry sand

8. Trench testing

Special requirements apply for testing in trenches, including the testing of culvert backfill. When testing in trenches, the standard counts must be taken inside the trench at each test site, it is important that the standard count site and the test site are the same distance from the trench wall. This will make allowance for rebound radiation from the trench wall at each specific site. During testing, the gauge is sited at least 200 mm from the sides, with the long side of the gauge parallel to the trench wall.

If the material to be tested is overlying a pipe, the end of the probe should be at least 50 mm above the pipe. If the trench wall is at least 600 mm from the NDG the trench effect will not be significant and if the depth of testing is greater than 100 mm the density error will also be insignificant.

9. Moisture content testing

Oven-dried moisture methods are frequently used as a laboratory-based test to determine the moisture content of granular pavement materials. Material must be sampled from each field test site in the lot and tested in accordance with the relevant test method.

The NDG moisture content must never be used for further calculations.

The presence of some chemicals, such as lime, gypsum, arsenic and cadmium, can influence the NDG moisture readings.

The moisture content of earthworks materials is determined using recognised moisture methods on samples taken from the test site in the road. The oven dried moisture content method T120 is the preferred test method, other test methods (e.g. T121 or T180) may be used. If either T121 or T180 are used the correlation method (T2105) must also be used and the corrected moisture content only can be used in further calculations.

10. Sampling for laboratory based testing

Correct sampling techniques must be followed and a sufficient quantity of material be taken to obtain both reliable moisture content and, maximum wet density results. The sand or natural fines used to seat the gauge must be swept clear of the plan area of the nuclear gauge prior to excavating for a moisture content sample.

Sampling requires that all material from a vertical-sided hole (excavated to the depth that the NDG source rod was placed) must be recovered for laboratory testing, with the hole permitted to be enlarged in plan, but no deeper than the depth of test, to obtain sufficient material for moisture content and laboratory compaction testing (e.g. T120, T162 or T111) (see Figure 8). It is extremely important to take the sample from the full depth of the test, this captures any moisture gradient in the layer being tested. Failure to take the sample properly can lead to very erroneous results.

Figure 8: The material must be taken from the site of the NDG reading (left) and be excavated to the depth of the test

An air tight container is required to hold the sample until laboratory testing commences. All samples must be labelled so that they are readily identified to the test site and the intended use of the sample.

The contractor is responsible for re-instating the test hole using material of similar quality to that removed from test holes during testing. The backfill material is to be compacted in the holes in layers with a suitable compaction device and the top of the compacted backfill should match the level of the adjoining surface.

Sufficient material should be taken when sampling at each test site to provide for all testing that is required.

Common poor practices regarding sampling from the road include:

- Excavations not vertically sided
- Large rock particles discarded from sample, upsetting the oversize correction process for density and moisture ratios
- Inclusion in samples of significant quantities of sand from gauge seating
- Samples not adequately sealed against moisture loss, or exposed to sunlight and temperature variations
- Samples not transported to the laboratory on the same day they were obtained
- Poor labelling of samples

- Loose material spilt or left in the bottom of the excavation.

11. Testing stabilised or bound material

Cement or lime is used in some instances to stabilise insitu material, or cement treated granular material is imported and placed prior to placement of a wearing course. The NDG soil meter is used for assessment of compaction of cement and lime stabilised materials, using the same test method as for unbound material except sampling for T120 moisture content and T162 Compaction control test are carried out prior to compaction as specified.

12. NDG testing of asphalt

Compaction testing of asphalt is often carried out using the NDG thin-layer asphalt gauge (see Figures 2 and 9) to AS 2891.14.2. Figure 9 shows the NDG being used to measure the density of a thin-layer asphalt in accordance with the requirements of Specification R116.

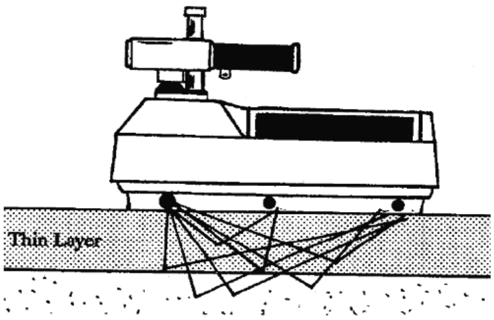

Figure 9: Thin layer NDG – backscatter gamma paths. (Source: VicRoads TN106)

The NDG asphalt gauge uses one radioactive source and two density measurement systems, operating in backscatter mode (see Figure 9) where radiation must be scattered or diverted from its original direction to reach the detectors. This method can be used on most asphalt types, except for open graded asphalt. The asphalt gauge measures the density of asphalt, when the asphalt layer thickness is in the range of 25 to 100 mm.

The key requirements for AS 2891.14.2 and to cover on-site processes for the NDG asphalt gauge are similar to those for the soil meter, except that:

- Two separate density standard counts (one for each measurement system) must be taken simultaneously at the start of each lot (see Figure 2).
- The long axis of the NDG asphalt gauge is aligned parallel to the direction of rolling.
- There is no probe access hole (reference in the checklist to probe depth does not apply).
- One 4 minute reading of layer density, with two separate density counts recorded, is required at each test site.
- Density offsets must be determined and applied for each asphalt mix as described in AS 2891.14.2, to adjust the NDG readings for backscatter effects due to aggregate chemistry. Sampling of asphalt by coring is required for establishing or checking density offsets.

13. References

General

Australian Radiation Protection and Nuclear Safety Agency, Radiation Protection Series No. 5 - Code of Practice and Safety Guide for Portable Density/ Moisture Gauges Containing Radioactive Sources (2004), link: http://www.arpansa.gov.au/publications/Codes/ rps5.cfm.

American Portable Nuclear Gauge Association manual, July 2009 http://www.apnga.com/the_manual.pdf.

VicRoads (2011) *Surveillance of Field Density Testing by Nuclear Density Gauge* Technical Note 106 (TN106), VicRoads, Kew, Victoria.

Walker, A (2013) *How do we get Nuclear Density Gauge testing RIGHT* Proceedings from Roads and Maritime Services Laboratory Forum 2013, Roads & Maritime Services, North Sydney, NSW.

Australian Standards

AS (2007) *Soil compaction and density tests – Compaction control test, Determination of field density and field moisture content of a soil using a nuclear surface moisture-density gauge - Direct transmission method* AS1289.5.8.1 Standards Australia, Sydney NSW.

AS (2007) *Soil compaction and density tests – Compaction control test – Assignment of maximum dry density and optimum moisture content values* AS1289.5.4.2, Standards Australia, Sydney NSW.

AS (1999) *Methods of sampling and testing asphalt - Field density tests - Determination of field density of compacted asphalt using a nuclear thin-layer density gauge* AS2891.14.2, Standards Australia, Sydney, NSW.

Roads and Maritime Services Test Methods

Roads and Maritime Services (2012) *Field wet density of road construction of road construction materials (Nuclear gauge in direct transmission method)* T173, Roads and Maritime Services, North Sydney NSW

Roads and Maritime Services (2012) *Moisture Content of Road Construction Materials (Standard Method)* T120, Roads and Maritime Services, North Sydney NSW

Roads and Maritime Services (2012) *Moisture Content of Road Construction Materials (Sand bath of hot plate method)* T120, Roads and Maritime Services, North Sydney NSW

Roads and Maritime Services (2012) *Relative compaction of road construction materials* T166, Roads and Maritime Services, North Sydney NSW

Roads and Maritime Services (2012) *Moisture Content of Road Construction Materials (microwave oven method)* T180, Roads and Maritime Services, North Sydney NSW

Roads and Maritime Services (2012) *Proof rolling test* T198, Roads and Maritime Services, North Sydney NSW

Roads and Maritime Services *Specification Q6 Quality Management System* Type 6, Roads and Maritime Services, North Sydney NSW

Annexure A – Sample NDG Certificate

[redacted]

[redacted]

NUCLEAR MOISTURE DENSITY GAUGE CALIBRATION REPORT

CLIENT & ADDRESS [redacted]

TEST REPORT No. [redacted]
JOB No. [redacted]
GAUGE SERIAL No. [redacted]
MODEL [redacted]
TEST METHOD Calibration Procedures CP1, AS 1289.5.8.4 - Calibration of Nuclear Moisture Density Gauge using type 'A' blocks - 5 block method

DATE CALIBRATED [redacted]

STANDARD BLOCK DATA

Density

Serial no.	7	7	7	7	7
Type (Type A).	magnesium	mag/alum	aluminium	limestone	granite
Equiv. den. (kg/m3)	1777	2239	2713	2208	2640

These blocks were calibrated using references traceable to national standards of measurement.

Moisture

Serial no.	7	7
Type	magnesium	mag/poly
Equiv. moist. (kg/m3)	0	588

Note: If the gauge is to be used in the moisture mode a separate moisture intercept is required for each material in accordance with AS1289.5.8.1

CALIBRATION RANGE (DENSITY)

This calibration is valid for the density range of 1727 to 2763kg/m³ (AS 1289.5.8.4 point 8)

CALIBRATION EQUATIONS

Density (kg/m3) = (1/B*1000) X Ln(A/((Count/Standard Count) + C))
Moisture(kg/m3) =(Count/Standard Count-E)/(F*1000)

VALIDATION:

The calibration constants, entered into the micro processor, have been validated, at all depths for which the gauge has been calibrated. [redacted]

RECALIBRATION:

It is recommended the gauge shall be recalibrated after any major repairs or component replacement.

UNCERTAINTY

Based on a 95% confidence level with a K factor of 2, the estimated uncertainty (Up) of predicted density for each calibrated depth is shown in the "Density Performance" table under the heading RMSE shown on Page 2.
The terms PREC and CE refer to Ucal and Uce respectively, given in kg/m³. [Up=√((Z Ucal)²+(Uce)²)].
The uncertainty of predicted water content (Uw) is recorded in the "Moisture Performance" table under the heading RMSE on Page 2, given in kg/m³.

NATA Accredited for compliance with ISO/IEC 17025. The results of tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
NATA Accreditation number [redacted]

[redacted] [redacted]

[redacted] Page 1 of 2 [redacted]

[redacted]

UNITS: SI [redacted] [redacted]
GAGE MODEL: [redacted]
SOURCE TYPE: [redacted] STD COUNT: DENSITY: 2976
SERIAL: [redacted] MOISTURE: 459

** DENSITY CALIBRATION DATA **

DEPTH (mm)	MAGNESIUM 1777	MAGN/ALUM 2239	ALUMINUM 2713	LIMESTONE 2208	GRANITE 2640
BS	1171.0	846.0	618.0	758.0	621.0
50	4368.0	3054.5	2038.5	2733.0	2019.0
75	4252.0	2808.0	1749.0	2518.0	1755.5
100	4021.0	2529.0	1495.5	2241.5	1470.5
125	3690.5	2210.5	1245.0	1943.0	1223.5
150	3290.0	1900.5	1001.5	1658.5	1001.0
175	2861.0	1560.0	798.5	1362.5	796.5
200	2420.0	1264.0	621.0	1110.5	629.0
225	2000.0	1028.0	487.0	874.0	493.5
250	1637.5	805.5	383.5	679.0	387.5
275	1311.5	622.5	305.0	528.5	309.0
300	1052.0	488.5	262.0	417.5	257.0

** DENSITY PERFORMANCE at 2000 kg/m^3 [125 pcf] **

DEPTH (mm)	A	B*1000	C	CR	PREC	CE	RMSE
BS	1.64802	0.89814	-0.04632	1.54	10.5	62.68	66.11
50	5.74195	0.67414	0.33230	1.38	4.89	46.76	47.77
75	6.77263	0.79470	0.28064	1.47	4.36	43.33	44.20
100	7.75586	0.93154	0.20059	1.57	4.08	37.15	38.04
125	8.76700	1.07228	0.13352	1.67	3.91	36.22	37.06
150	8.39191	1.08840	0.16593	1.69	3.90	39.26	40.03
175	10.16788	1.32202	0.06275	1.89	3.87	35.69	36.52
200	10.43376	1.43628	0.04045	2.00	3.98	35.06	35.95
225	8.75575	1.44027	0.04628	2.00	4.29	42.18	43.05
250	9.90376	1.65966	0.00607	2.22	4.54	42.66	43.62
275	11.13469	1.88249	-0.01791	2.47	4.92	41.52	42.68
300	14.40069	2.21443	-0.04044	2.90	5.51	32.95	34.75

** MOISTURE CALIBRATION DATA **

LOW W 0.0	HIGH W 588.0
22.0	314.0

** MOISTURE PERFORMANCE at 160 kg/m^3 [10pcf] **

NATA

E	F*1000	CR	PREC	RMSE
0.04685	1.08191	2.95	5.1	11.3

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Annexure B – Typical recording form for density counts

COMPANY
LABORATORY
RTA T173 - Field Dry Density of Construction Materials (Nuclear Gauge in Direct Transmission Method)

Registration ID: S2110. ☑ Checked for Currency — Lates Issue Date 2012 (Year)

Tested by: AB. Date: 25.3.13
Checked by: EB Date: 26.3.13

Project : Roadway Upgrade.

Sampling Method:	AS1289.1.2.1 6.4(a) Uncompacted Pavement ☐ 6.4(b) Compacted Pavement ☑				
Section Represented:	23 A				
Material Type / Description:	DGB20 Limestone. SM2.				
Nuclear Gauge Equipment ID:	3959				
Lot Field Standard Density Count:	2938				
QA Specification Requirements.	102.0				
Lot / Sample Number:	25/07	25/08	25/09	25/10	25/11
Location (Chainage m)	46.498	46.526	46.554	46.582	46.610.
Offset (m)	0.2	1.8	5.4	3.6	7.2.
Depth of test probe (mm)	175	175	175	175	175
Time of Test:	0900	0910	0920	0930	0940.
Gauge Field Wet Density - t/m^3 1	2.273	2.313	2.470	2.473	2.538
2	–	–	–	–	–
Gauge Field Density Count 1	1286	1210	946	942	848
2	–	–	–	–	–
Depth of layer (mm).	175	175	175	175	175.
Moisture Content Test Method RTA T120	Balance No:	#59	Oven No:	#05	
Container No:	6	130	97	94	50.
Mass of Container (g)	500.8	510.2.	505.0	546.8	533.3
Wet mass + Container (g)	2367.1	2167.9.	2345.8	2508.7	2221.9
Dry mass + Container (g) - 1st Weigh	2326.0	2142.2	2290.0	2460.1	2170.2
Dry mass + Container (g) - 2nd Weigh	2326.0	2142.3	2290.0	2460.2	2170.2
Dry mass + Container (g) - ConMass.	2326.0	2142.3.	2290.0.	2460.2.	2170.2.
Field Moisture Content FMC (%)	2.3	1.6	3.1	2.5	3.2.
Field Wet Density - t/m^3	2.273	2.313	2.470	2.473	2.538.
Field Dry Density - t/m^3	–	–	–	–	–
T162 Max. Con. Wet Density (t/m^3) where all material passes 37.5mm sieve.	2.317	2.319	2.336	2.331	2.381.
T162 Max. Wet Bulk Density (t/m^3) where no more than 20% retained on the 37.5mm sieve.					
T111 / T112 Max. Dry Density (t/m^3)					
Optimum Moisture Content OMC % For OMC from T162 only = FMC+(1+(FMC/100) x Zm	6.5	5.8	5.7	7.0	5.7.
FMC / OMC Ratio (%)	35	28	54	36	56
RTA T166 Relative Compaction **RC** (%)	98.1	99.7	105.7.	106.1	106.6.
Statistical Calculation for Conformity of lot. QA Specification Q6. Ed #. Rev #. Date ##/##/##.	Q_{upper} = Mean **RC** + (Constant **K** x Standard Deviation) = 105.9				
	Q_{lower} = Mean **RC** - (Constant **K** x Standard Deviation) = 100.6.				
Acceptance Constant (k). 3 tests = 0.52, 4 = 0.62, 5 = 0.67, 6 = 0.72, 7 = 0.75, 8 = 0.78, 9 = 0.81, 10-14 = 0.83, 15-19 = 0.90, 20+ = 0.95	If Q_{lower} is ≥the specified lower limit (Minimum Specified Relative Compaction), the lot will achieve conformity. ***Conforms?*** ***YES*** ***NO***				

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