

**DEPARTMENT of INFRASTRUCTURE, ENERGY and RESOURCES, TASMANIA
GENERAL SPECIFICATION**

G4 - COMPACTION ASSESSMENT

March 1995

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G4.1 SCOPE

This specification defines the methods required for the assessment of the compaction of granular and fine-grained materials for works under this Contract where the compaction to be achieved is defined in terms of minimum characteristic dry density ratio or density index.

For pavement materials, the procedures are limited to materials with a nominal size not greater than 75 mm. For other parts of the works, the methods have application to materials which have 80% or more by mass passing a 37.5 mm A.S. Sieve.

G4.2 DEFINITIONS

Unless stated otherwise below, the definitions of A.S. 1289.0 apply.

Assigned maximum dry density:	The maximum dry density for use in the calculation of dry density ratio is established by rules. Individual laboratory compaction tests are not made for each field density test. The use of an assigned value is restricted to materials where the range of MDD is within the range defined by this Specification.
Audit sample:	A sample collected either by the Contractor or the Superintendent for inspection and test by the Superintendent.
Density index, Id:	State of compactness of cohesionless material with respect to the loosest and densest state.
Dry density ratio, Rd:	The percentage ratio of the dry density of the soil to the maximum dry density (MDD) of that soil.
Hilf Density Ratio:	Percentage ratio of the field wet density to that of peak converted wet density of the soil as determined by Hilf compaction test method.
Layer:	A thickness of material placed and compacted as an entity resulting in a quantum change in the height of the works.
Lot:	An area of work which is essentially homogeneous in: material type, moisture condition, rolling effort and compaction technique and which is to be used for the assessment of the density ratio.
Nominal size:	A designation of a material which gives an indication of the largest particle present. It is expressed as a whole number above the sieve size through which nearly all the particles pass.

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- One-to-one testing (1:1): A maximum density determination is made by laboratory compaction test for each field test.
- Oversize: The fraction of a soil larger than the maximum particle size permitted by a particular test method.

G4.3 TEST METHODS

Following Australian Standards are relevant:

- AS 1289.0 - General Requirements and List of Methods
- AS 1289.2 Part - Soil Moisture Content Tests
- AS 1289.5 Part - Soil Compaction and Density Tests
- AS 1289.E5.1 - Determination of Min. and Max. Dry Density of Cohesionless Material
- AS 1289.E6.1 - Density Index Method for Cohesionless Materials
- AS 1289.E8.1 - Determination of Field Moisture Content and Field Dry Density of a Soil

The following contains provisions concerning:

- (a) Moisture content - see G4.4.2
- (b) Assigned MDD - see G4.5.3
- (c) Compaction tests - treatment of oversize material - see G4.5.2
- curing of materials - see G4.5.2

G4.4 FIELD TESTING FOR WET DENSITY AND MOISTURE CONTENT

G4.4.1 General

Field density determinations may be made by nuclear density meters in Direct Transmission mode AS 1289.E8.1 or replacement tests AS 1289.5.3.1 and AS 1289.5.3.2.

The field density and moisture determinations shall be made over the full layer depth. In the event that the layer depth is greater than the depth of view of the test method, the testing shall be done on the lowest portion of the layer but not into the underlying layer.

All tests within any particular lot shall be made with identical test procedures.

G4.4.2 Moisture Content

Moisture content shall be determined:

- (a) 1:1 testing - by drying techniques
- (b) in narrow trenches - by drying techniques
- (c) where assigned MDD is used - by drying techniques or by nuclear meter estimates of moisture content

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Nuclear meter estimates of moisture contents shall be acceptable where the MDD can be assigned (Clause G4.5.3, Assigned MDD) provided that:

- (i) An appropriate calibration is used. The calibration shall be based on at least ten (10) separate determinations over the full moisture content range likely to occur in the field for the particular material.
- (ii) The nuclear meter estimates are checked by oven dried estimates for at least 20% of field test sites.

G4.4.3 Lot Selection

Lots shall conform with the definition in Clause G4.2. Where a production unit does not satisfy the definition of a lot (Clause G4.2) it shall be divided into smaller units, each of which shall conform with the definition.

G4.4.4 Test Site Selection

- (i) **Number of Test Sites:**
The number of tests per lot shall be as follows:
 - (a) For lots comprising areas greater than 1000m², the required number of tests shall be 10 per lot, except where one-to-one testing is carried out, when the minimum number of tests shall be 5.
 - (b) For lots comprising areas less than 1000m², the required number of tests shall be 3.
- (ii) **Location of Test Sites:**
 - (a) Test sites shall be uniformly distributed along the length of lot.
 - (b) The lateral location of each test site shall be determined as follows:
 - The random numbers shall be extracted from Table G4.1 for the appropriate day of the month. The first digit from the left shall be used with the first sampling position, second with second, and so on.
 - Each test position in the transverse direction shall be calculated as an offset from the left hand side of the lot, based on the specified width of the lot at the chainage of the test as follows:
 - The digit 0 shall mean 5% of the lot width,
 - The digit 1 shall mean 15% of the lot width,
 - The digit 2 shall mean 25% of the lot width, and so on.
 - The test locations for digits 0 and 9 may be moved to no further than 0.5m from the specified edge.

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(c) The required accuracy for locations of test sites shall be:

- longitudinally, $\pm 3\text{m}$
- transversely, $\pm 0.5\text{m}$, except for tests along the edges of lots (digits 0 and 9) where it shall be $\pm 0.1\text{m}$.

TABLE G4.1 RANDOM NUMBERS FOR LOCATION OF TEST SITES
TRANSVERSE DIRECTION

Day	Number Set	Day	Number Set
1	4, 6, 3, 0, 4, 9, 7, 3, 7, 1	16	0, 7, 4, 2, 8, 6, 4, 4, 9, 1
2	9, 1, 5, 4, 7, 6, 0, 7, 2, 9	17	0, 2, 7, 6, 9, 6, 3, 0, 3, 7
3	0, 6, 7, 4, 1, 6, 3, 5, 0, 7	18	3, 8, 2, 5, 0, 6, 2, 6, 3, 8
4	6, 9, 0, 6, 8, 6, 1, 4, 9, 6	19	7, 1, 8, 2, 7, 3, 0, 9, 5, 0
5	6, 8, 1, 9, 3, 6, 9, 5, 7, 1	20	5, 8, 0, 2, 6, 1, 4, 8, 9, 7
6	2, 7, 9, 7, 4, 1, 2, 6, 0, 9	21	1, 4, 9, 6, 0, 7, 2, 5, 3, 9
7	7, 0, 5, 5, 9, 2, 0, 6, 8, 4	22	4, 4, 1, 9, 5, 2, 9, 7, 6, 0
8	7, 4, 6, 8, 7, 0, 2, 8, 3, 6	23	9, 0, 7, 4, 1, 7, 9, 4, 2, 8
9	4, 9, 3, 0, 3, 7, 3, 6, 2, 9	24	9, 8, 6, 0, 6, 9, 2, 1, 5, 1
10	8, 9, 7, 0, 4, 3, 9, 1, 8, 3	25	4, 2, 8, 4, 0, 4, 4, 7, 2, 9
11 & 31	4, 9, 4, 6, 2, 2, 1, 7, 3, 9	26	4, 9, 1, 0, 8, 6, 0, 4, 8, 1
12	8, 2, 7, 3, 4, 0, 3, 6, 2, 9	27	1, 5, 4, 9, 4, 7, 1, 7, 8, 0
13	2, 8, 5, 5, 3, 0, 7, 2, 8, 5	28	8, 0, 8, 7, 7, 2, 8, 5, 8, 0
14	4, 9, 1, 3, 3, 8, 8, 5, 0, 7	29	6, 2, 9, 2, 3, 3, 6, 6, 8, 0
15	3, 8, 3, 4, 9, 7, 3, 9, 4, 1	30	1, 5, 9, 4, 0, 1, 8, 2, 7, 1

G4.5 MAXIMUM DRY DENSITY (REFERENCE VALUE)

G4.5.1 General

The reference density used in the calculation of dry density ratio shall be determined from one of the following, but appropriate methods:

- (i) Laboratory Tests
 - (a) One-to-one testing.
 - (b) Assigned.

(ii) Roller trial

Laboratory procedures shall be used where not more than 20 percent by mass of the material is greater than 37.5 mm.

Roller trials shall be used for coarser materials up to a nominal size of 75 mm.

In the case of cohesionless materials, the laboratory reference values (maximum and minimum densities) shall be made in accordance with A.S. 1289.E5.1 and the Density Index as per A.S. 1289.E.6.2. This method shall be used for soils which contain up to 5 percent by mass of soil particles passing a 0.075 mm A.S. Sieve, except that silty sands with non plastic fines may contain up to 12 percent passing a 0.075 mm A.S. Sieve.

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One-to-one testing shall be required where the material is not controlled by closely specified limits on grading or plasticity and shall be applied to all embankments, subgrade, pipe backfilling and to all materials where the variability in MDD exceeds the range specified in Clause G4.5.3 (i), Laboratory Assigned Values. The Hilf procedure may be adopted, where appropriate, for one to one testing.

G4.5.2 Laboratory Determination of Reference Density

- (i) The reference density shall be determined by:
 - (a) AS 1289.5.1.1 - Standard Compaction - as MDD
 - (b) AS 1289.5.2.1 - Modified Compaction - as MDD
 - (c) AS 1289.5.7.1 - Hilf Compaction - as Peak Converted Wet Density
- (ii) Treatment of Oversize
 - The oversize fraction shall be treated as per AS 1289.4.1, excepting that where less than 20% of material is retained on 19.0mm sieve, the Contractor may adopt the larger (152 mm diameter) mould for the compaction test.
- (iii) For earthworks control the following provision applies:
 - The test methods for curing or particle breakdown of clays may be waived, except that water additions shall be made in three (3) or more increments, each followed by thorough mixing.

G4.5.3 Assigned Maximum Dry Density

An assigned value shall be determined:

- (a) as per AS 1289.5.4.2 where long term production MDD values exist or
- (b) by the application of rules defined below.
 - (i) Laboratory Assigned Values
 - Assigned values for reference maximum dry density may be used for uniform materials where the range of laboratory maximum dry densities for a material is not greater than:
 - (a) $\pm 30 \text{ kg/m}^3$ for base.
 - (b) $\pm 40 \text{ kg/m}^3$ for sub-base and other courses.
 - The values shall be assigned to laboratory maximum dry densities corrected for oversize by use of the following procedures:
 - (a) Two (2) maximum dry densities shall be determined for independent samples taken from the first lot of each material type.
 - (b) Subsequent deliveries shall be sampled and tested at a frequency of not less than one (1) maximum dry density test for each 500 m^3 (compacted).
 - (c) The assigned value for the first lot shall be the average of the MDD of the (submitted) sample and the two (2) values determined for this lot (to the nearest 10 kg/m^3).
 - (d) Subsequent values shall be based on the moving average of the last three (3) consecutive corrected MDD determinations.
 - The Contractor shall produce and keep up to date a control chart which indicates the date of each MDD test, the corrected MDD, the moving average of the corrected value (three (3) samples) and the specified limit of acceptable variation in MDD.

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(ii) Roller Trials

- Where the nominal size of a pavement material is equal to or less than 75 mm but coarser than the requirements for laboratory tests, a roller trial, as defined in Clause G4.10, Conduct and Reporting of Roller Trial, shall be used to assign the MDD value.
- The MDD obtained in a roller trial may be assigned to a lot when the average grading of three (3) samples taken from the lot falls within an envelope defined by the average grading of the roller trial and the plus and minus limits given in Table G4.3.

G4.6 CALCULATIONS

G4.6.1 Characteristic Value

The characteristic value for a lot shall be determined by treating individual DDR determinations (or Density Index) in accordance with the following procedure:

$$\text{Characteristic value} = x - 0.9s$$

where x = mean value of the test measurements
 and s = standard deviation of the test measurements, using $(n-1)$ as the denominator

G4.6.2 Outliers

A rule for the treatment of outliers is as follows.

When x_i is the individual test result or measurement for $i = 1, 2, 3, \dots, n$

For any value of x_i where $(\bar{x} - x_i)/s$ is equal to or greater than T , taken from Table G4.2, the value x_i may be deleted in the calculation of the characteristic. The test may not be applied more than once for any lot and shall not be applied to lots with only 3 test results.

TABLE G4.2 FACTORS FOR CALCULATION OF OUTLIERS

Number of Test Measurements (n)	Outlier Test (T)
5	1.7
6	1.9
7	2.0
8	2.1
9	2.2
10	2.3

G4.6.3 Reporting

(i) Accuracy

Test results shall be reported to the following accuracy:

- (a) Dry density to the nearest 1 kg/m^3 .
- (b) Dry density ratio to the nearest 0.1 percent.
- (c) Moisture contents to the nearest 0.1 percent.
- (d) Density index to the nearest 0.1 percent.
- (e) Characteristic value to the nearest 0.5 percent.

(ii) Reporting

In addition to satisfying the specific requirements detailed in other parts of this specification, the report shall include;

- (a) Location of all tests in terms of chainage and transverse location
- (b) Individual test values of moisture content (both nuclear and oven check) and dry density at each test location
- (c) Reference density for each test location
- (d) Characteristic density ratio, average and standard deviation for the lot.

G4.7 ACCEPTANCE CRITERIA

All lots shall be compacted to a characteristic dry density ratio or density index equal to or greater than the specified value.

In the event that the characteristic value for a lot is below the specified value, retests shall be conducted over the whole lot using the site selection procedures and number of test sites defined by this Specification, after any reworking and further rolling.

G4.8 CONTROL CHARTS

The Contractor shall maintain and keep up to date charts on site as defined below:

- (i) A longitudinal section (schematic) of the works identifying the precise location and extent of all lots tested, the lot identification, the dates of all compaction tests and the date at which compliance was achieved.
- (ii) A control chart of the maximum dry density of laboratory compaction tests for each material as defined in Clause G4.5.3 (i), Laboratory Assigned Values.
- (iii) Separate control charts of the characteristic values achieved for embankment, pipe backfilling, formation, subgrade, sub-base and base tests, including failed lots. The charts shall identify the date of test and the lot identification.
- (iv) For every nuclear meter used on the site, control charts of daily standard counts (for applicable channels) and secondary block checks shall be made available to the Superintendent for inspection when requested.

The Superintendent shall be given access to the secondary block as required.

G4.9 REDUCTION IN ROADWORKS TESTING FREQUENCY

Where the Contractor can demonstrate consistent conformance with the Specification requirements for a given test or group of tests, to the satisfaction of the Superintendent, then the Contractor may apply to the Superintendent to reduce the testing frequency to no less than half that defined in the Specification for the relevant test or group of tests.

A minimum of 4 consecutive lots or batches of work tested in accordance with the Specification shall be taken to assess consistency.

Where acceptance testing is based on statistical techniques applied to lots, then the reduction in test frequency may be applied as a reduction in the number of lots tested or the number of tests per lot, provided in the latter case that the validity of the statistical compliance scheme is maintained. For other control testing, the reduction in test frequency may be applied as a reduction in the number of tests, provided that they are distributed throughout the materials or work being tested.

If, when the testing frequency has been reduced, a subsequent test by the Contractor or audit test by the Superintendent accepted by the Contractor under Clause G2.4 shows a departure from the consistent conformance, then the Contractor shall return to full testing frequency as defined in the Specification. The Contractor shall likewise return to a full testing frequency if the materials, methods of work or conditions of application alter.

Notwithstanding the provision for reduced frequency of testing, the Superintendent may direct the Contractor to test a particular lot.

G4.10 CONDUCT AND REPORTING OF ROLLER TRIAL

G4.10.1 General

The trial shall be at least 20 m long and 5 m wide. It shall be located on a completed and proven section of the immediately underlying course. The average thickness of the compacted layer shall not exceed the maximum thicknesses specified for the particular layer. The minimum thickness of the compacted layer shall not be less than 1.5 times the nominal particle size. The range of the compacted thickness in four (4) test positions shall not exceed 20 percent of the average thickness.

The material used in the trial shall be representative of the intended supply.

The material shall be maintained throughout the trial at the appropriate optimum moisture content for compaction. The moisture shall be evenly distributed. The calculated air voids content at the end of the trial shall be less than 5 percent.

The grading of all three (3) samples shall fall within an envelope defined by their average value, expressed as the percent passing nominated sieve sizes, and the plus and minus limits given in Table G4.3.

TABLE G4.3 ROLLER TRIAL - MATERIAL UNIFORMITY GRADING ENVELOPE LIMITS

A.S. Sieve Size (mm)	Percent Passing Limits (±)
37.5	8
19.0	8
4.75	8
0.425	6
0.075	4

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G4.10.2 Equipment and Operation

Compaction of the trial shall be by either:

- (i) twenty (20) coverages of a static roller of Class No. SR12 or greater, as defined in AS 2868, or
- (ii) twelve (12) coverages of a variable frequency vibrating roller of Class No. VR24 or greater as defined in AS 2868, followed by up to four (4) coverages of a pneumatic tyred roller of Class No. PR15 or greater, as defined in AS 2868.

Rolling shall be made parallel to the longitudinal axis of the trial.

A coverage shall be three (3) parallel runs of the roller (in vibrating mode for vibratory rollers) with a minimum of 200 mm overlaps between each run.

G4.10.3 Testing

The testing shall be confined to the central 15 m x 2 m portion of the trial and shall comprise:

- (i) Four (4) or more density and moisture content measurements after each four (4) coverages and eight (8) density and moisture content measurements at the end of rolling.
- (ii) The compacted depth at four (4) locations at the end of rolling along the centre of the test strip.
- (iii) Moisture content (by oven drying) at the end of rolling for four (4) locations.
- (iv) Particle density of one (1) representative sample (plus 4.75 mm fraction).
- (v) Particle size distribution of three (3) samples.

G4.10.4 Reporting

The report of the trial shall include:

- (i) Description of the rollers (brand, model, mass, linear pressure, diameter, operating frequency for vibrating roller), and their classification according to AS 2868.
- (ii) Average moisture contents throughout the trial.
- (iii) Compacted depths at the end of the trial.
- (iv) Plot of average wet density against number of coverages. The plot shall show the range of wet densities recorded at each set of density readings.
- (v) Evidence of the calibration of the nuclear meter, if used.
- (vi) Particle size distribution of each sample and the average grading of the three (3) samples.

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- (vii) Calculated air voids at the end of the test.
- (viii) The compliance of the materials with respect to the uniformity requirements (thickness and materials).
- (ix) Assigned maximum dry density which shall be the maximum average dry density as determined from the plot of wet density against number of passes.
- (x) The grading and plasticity index limits (lot mean and individual values) for the assigned maximum dry density.

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