Code of Practice

Acceptance of Field Compaction

RC 500.05

June 2017

1. Introduction

This Code of Practice sets down the procedures to be followed when carrying out acceptance testing of field compaction of asphalt, other pavement materials, earthworks, trench bedding and backfill.

This Code must be read in conjunction with the particular contract specification and relevant test methods. The contract specification must be checked to see whether or not acceptance is based on testing of the work in lots.

In general, VicRoads has adopted Australian Standards (prefix AS) for the testing of materials and work. Where necessary, VicRoads has developed VicRoads Test Methods (prefix RC).

2. Lot Testing

2.1. Test Lot Bounds

A test lot shall consist of a single layer as placed. It must contain only areas of work which are essentially homogeneous. This occurs when material type, general appearance, test rolling response, moisture condition during compaction, compaction technique, and state of underlying materials are substantially alike. Generally if these criteria are met, the size of a test lot need not be a consideration. Areas which fail to meet these conditions must be excluded from the lot but may be tested independently for separate assessment. Areas within 200 mm of the edges of construction or within about 2 metres of lateral construction joints should be excluded from the lot.

A lot shall not exceed a single day's production and in some cases more than one lot for a single day's production will be required, as specified under "Minimum Testing Requirements" in the job specification.

Soils and pavement materials which do not appear essentially homogeneous and are not uniform in terms of maximum size and particle size distribution may be included provided that laboratory compaction tests are performed on material from each field density test site.

There are differences from site to site in a lot. These differences should form a continuous range arising only from the influence of random factors which apply during road construction.

2.2. Selection of a Lot

The contractor will need to define the bounds of the lot and to designate any areas to be excluded from the lot on the basis of appearance or test-rolling response prior to the selection of sites.

2.3. Selection of Test Sites within a Lot

The validity of lot testing depends on there being no bias associated with the selection of test sites.

Prior to the start of the selection process, every point in the lot must have an equal chance of being selected. Sites shall be selected in accordance with RC 316.10 or AS 1289.1.4.2.

2.4. Testing in Trenches

Test sites within a trench shall be assessed as a small test lot, with test sites selected in accordance with RC 316.10.

For trenches less than 0.6m in width, the gauge shall be sited in the centre of the trench.

3. Test Depth for Field Density

The test depth for field density testing of a compacted layer shall be in accordance with Sections 3.1 to 3.4, as appropriate.

***Note** : For the nuclear gauge, the probe test depth range has been changed for direct transmission testing to improve assessment of field density.*

3.1. Pavement Materials, other than Asphalt, Concrete or Trench Bedding

3.1.1. Nuclear Gauge

For direct transmission mode, the probe shall be positioned at a depth between 10 mm and 30 mm less than the nominal layer thickness, in a hole drilled or driven in the pavement, at least 25 mm deeper than the probe position.

3.2. Asphalt Pavements

3.2.1. Nuclear Gauge

For the thin-layer asphalt gauge, with the probe at the test position, set the reading thickness at nominal layer thickness.

For direct transmission mode, the probe shall be positioned at a depth between 10 mm and 30 mm less than the nominal layer thickness, in a hole drilled in the pavement, at least 25 mm deeper than the probe position.

3.2.2. Core

Full layer thickness

3.3. Concrete Pavements

3.3.1. Nuclear Gauge

For direct transmission mode, the probe shall be positioned at a depth between 10 mm and 30 mm less than the nominal layer thickness, in a hole drilled in the pavement, at least 25 mm deeper than the probe position.

3.3.2. Core

Full layer thickness

3.4. Trench Backfill in Earthworks

3.4.1. Nuclear Gauge

For direct transmission mode, the probe shall be positioned at a depth between 10 mm and 30 mm less than either :

- 75% of the specified loose layer thickness, or
- 100% of the compacted layer thickness;

in a hole drilled or driven into the material, at least 25 mm deeper than the probe position.

When testing trench bedding immediately over pipes, the probe shall be set at a point between 40 mm and 60 mm above the top or uppermost surface of the pipe.

4. Field Density Measurement

4.1. Test Methods

The following test methods are applicable.

RC 202.02	Bulk Density of Compacted Asphalt - Pre-Saturation Method
RC 316.00	Density Ratio and Moisture Ratio - Lot Characteristics
RC 316.10	Selection of Test Sites within a Test Lot
RC 316.12	Nuclear Gauge - Offset Determinations - Field Density Testing of Asphalt Layers
RC 316.14	Moisture Ratio Determination for Assessment of Dry-Back of Granular Pavement Materials
AS 1289.1.4.2	Selection of sampling or test sites - Stratified random number method
AS 1289.2.1.1	Determination of the moisture content of a soil - Oven drying method
AS 1289.2.1.4	Determination of the moisture content of a soil - Microwave-oven drying method.
AS 1289.2.1.6	Determination of the moisture content of a soil - Hot plate method
AS 1289.5.4.1	Dry density ratio, moisture ratio and moisture variation
AS 1289.5.7.1	Hilf density ratio
AS 1289.5.8.1	Determination of field density and field moisture content of a soil using a nuclear surface moisture-density gauge - Direct transmission mode
AS 1289.5.8.4	Nuclear surface moisture-density gauges - Calibration using standard blocks
AS 2891.1	Sampling of asphalt
AS 2891.9.1	Determination of the bulk density of compacted asphalt - Waxing procedure
AS 2891.14.1.1	Determination of field density of compacted asphalt using a nuclear surface moisture-density gauge - Direct transmission mode
AS 2891.14.1.2	Determination of field density of compacted asphalt using a nuclear surface moisture-density gauge - Backscatter mode
AS 2891.14.2	Determination of field density of compacted asphalt using a nuclear thin-layer density gauge
AS 2891.14.3	Calibration of a nuclear thin-layer density gauge using standard blocks
AS 2891.14.4	Calibration of a nuclear surface moisture-density gauge - Backscatter mode
AS 2891.14.5	Density ratio of compacted asphalt
AS 2891.9.3	Determination of the bulk density of compacted asphalt - Mensuration method

4.2. Selection of Test Methods

The method used for determination of field density will depend upon the material to be tested and the equipment available. Whenever practicable, the same method shall be used for all field density testing carried out on a given material on any one job. Different methods shall not be used in the determination of field densities within a lot.

Nuclear gauges shall be used for the determination of field density except when environmental conditions are such that the results from the nuclear gauge could be affected.

Density or moisture gradients in the compacted material, the material chemical composition, the mode of use of a nuclear gauge, and the difference in geometry between different brands of nuclear gauge can influence the result obtained. Therefore, results from different brands of nuclear gauge and/or from different modes of operation can differ and are not directly comparable.

4.3. Nuclear Gauge Testing

4.3.1. General

The modes or type of gauge shall not be interchanged for the assessment of a test lot. It is preferable to use the same method of compaction assessment for a total job.

When testing with a nuclear gauge, the nuclear gauge shall be seated on either fines of the material under test, or fine sand that passes the 0.425 mm sieve. This material shall not form an added layer.

Nuclear gauges shall not be used for materials which contain more than 20 percent of material retained on the 37.5 mm sieve.

Except for thin-layer gauges, two 60 second density and moisture readings shall be obtained at each site with the gauge remaining in the same position for both readings. The average of the two readings shall be used for determination of field values.

4.3.2. Testing in Trenches

When testing in trenches, the standard counts shall be undertaken inside the trench, the gauge shall be set parallel to the sides of the trench and a set of counts shall be taken for each test site. During testing the gauge shall be sited at least 200 mm from the sides of the trench. Moisture content shall be obtained from disturbed samples oven dried according to AS 1289.2.1.1.

4.3.3. Earthworks and pavement materials, (excluding asphalt)

Nuclear gauge testing shall be performed in accordance with AS 1289.5.8.1, except that field moisture content may be determined as detailed in Clause 4.4 below.

4.3.4. Asphalt

When using a thin-layer gauge, one four-minute count shall be taken at each site.

Testing shall be performed in accordance with:

AS 2891.14.1.1	for direct transmission mode
AS 2891.14.1.2	for backscatter mode
AS 2891.14.2	when using a thin-layer gauge

4.3.5. In-Situ Stabilised Pavement Material of Layer Depth greater than 200mm

If required, contact VicRoads Principal Advisor – Pavements Geotech. & Materials for guidance.

4.4. Moisture Content

4.4.1. Earthworks

For earthworks, field moisture content shall be determined using AS 1289.2.1.1 or AS 1289.2.1.4.

4.4.2. Pavement materials

For pavement materials, field moisture content may be determined either by using a nuclear gauge in accordance with AS 1289.5.8.1 including Appendix B, when applicable; or by AS 1289.2.1.1, AS 1289.2.1.4 or AS 1289.2.1.6.

Moisture offsets (as intercept, bias or correction) are usually only applicable to materials to which values of maximum dry density and optimum moisture content can be assigned. Moisture offset values are determined according to AS 1289.5.8.1 Appendix B, using the paragraph appropriate to the specific nuclear gauge. A moisture offset is a value assigned to a material.

Where applicable, generally for layers of nominal compacted thickness of less than 150 mm, monitoring of moisture offset values shall be made to demonstrate that the moisture offset is consistent with a water content of ± 0.005 t/m^3, or equivalent, for the material of the layer, and if applicable for different layer thicknesses and different underlayers.

For layers where the nominal compacted thickness is 150 mm or greater, the moisture offset value may be transferred between layers.

The monitoring of moisture offset values shall be carried out following a similar process to the monitoring of assigned values to AS 1289.5.4.2. It is expected that when there is continuous production of the material, one sample per 10 000 tonne of supply or one sample per fortnight, whichever frequency produces the lesser number of samples, should be taken. Each time a sample is tested to monitor the moisture offset value, remove the oldest value from the set of six results. Using the new result and the remaining five results, recalculate the moisture offsets value for the material.

4.5. Moisture Ratio

Test results for moisture variation and moisture ratio, determined in accordance with AS 1289.5.4.1, or AS 1289.5.7.1, shall be used to determine mean, standard deviation and characteristic values in accordance with RC 316.00.

4.6. Oversize Material

If it is known or suspected that oversize material is present and assigned values for maximum dry density and/or optimum moisture content are to be used, a sample for determination of the percentage and the volume of such oversize material shall be taken from each field density site and allowance for oversize material shall be made in accordance with Clause 6 of this Code.

5. Reference Density for Calculation of Density Ratio

A Reference Density shall be established and used for the calculation of Density Ratio of compacted pavement and earthworks materials.

Different methods shall not be used in the determination of reference density within a lot.

5.1. Test Methods

The following test methods are applicable.

RC 201.01	Design of Asphalt Mixes (Marshall Method)
RC 201.12	Design of Asphalt Mixes (Gyratory Compaction Method)

RC 301.03	Preparation of Lime Stabilised Materials to Establish the Dry Density - Moisture Content Relationship.
RC 301.06	Preparation of Cement Stabilised Materials to Establish the Dry Density - Moisture Content Relationship.
RC 316.12	Nuclear Gauge – Offset Determinations - Field Density Testing of Asphalt Layers
AS 1141.3.1	Sampling - Aggregates
AS 1289.1.1	Preparation of disturbed soil samples for testing
AS 1289.5.1.1	Determination of the dry density/moisture content relation of a soil using standard compactive effort.
AS 1289.5.2.1	Determination of the dry density/moisture content relation of a soil using modified compactive effort.
AS 1289.5.4.1	Dry density ratio, moisture ratio and moisture variation
AS 1289.5.4.2	Assignment of maximum dry density and optimum moisture content values
AS 1289.5.7.1	Hilf density ratio

5.2. Asphalt

5.2.1. Reference Density

The reference density for calculation of density ratio of asphalt is the bulk density, determined for the job mix at the time that the mix was designed.

The bulk density of an asphalt mix used to determine density offsets shall be determined in accordance with the method used in RC 201.01 or RC 201.12.

5.2.2. Density Offset

Density offsets for each asphalt mix shall be determined after initial registration of the mix and subsequently checked at intervals in accordance with RC 316.12, for a particular thickness of asphalt.

When the density offset for the particular thickness is to be applied to asphalt of the same mix design, but of layer thickness more than 7 mm different from the particular thickness then the requirement of AS 2891.14.2, Appendix B5 (b) shall be followed.

5.3. Earthworks and Pavement Materials, other than Asphalt

The following applies to earthworks and pavement materials, other than asphalt, with not more than 20 percent retained on the AS 37.5 mm sieve after field compaction.

The reference density is obtained using the specified compactive effort in an appropriate laboratory compaction test performed on samples taken from the road-bed after compaction.

Unless otherwise specified, Standard compactive effort shall be used for Type A and Type B fill and Modified compactive effort shall be used for all granular pavement materials.

The reference density is obtained from either of the following values adjusted for oversize when appropriate:

- the maximum dry density (when field dry density is compared); or
- the peak converted wet density (when field wet density is compared using the Hilf method).

A laboratory compaction test must be performed for each individual field density test site unless an optimum moisture content and/or maximum dry density, as applicable, has been assigned to the material in accordance with AS 1289.5.4.2.

Low volume and short term supply should be assessed by other laboratory compaction methods such as AS 1289.5.1.1, AS 1289.5.2.1 or AS 1289.5.7.1.

In cases where the material used in trench bedding or backfill is of uniform grading and composition, either a reference dry density value shall be determined for each test site, or an assigned value established and maintained in accordance with AS 1289.5.4.2.

For small areas of work where limited quantities of consistent and uniform processed materials are used, when so permitted by the specification, a single reference dry density value may be used for a number of field density tests.

5.3.1. Granular Pavement Materials stabilised by Cementitous Binders

For granular pavement materials, laboratory compaction tests shall be carried out on samples taken from the field density sites within the maximum allowable working time for the binder as determined by RC 330.02 or detailed in the job specification.

Where laboratory testing is performed outside these limits, the appropriate density decay factor, as determined by RC 330.03 or from the relevant Table in VicRoads Standard Specification Section 307 shall be applied to the density ratio as detailed in RC 316.00.

Samples of cementitious treated material (crushed rock or crushed concrete) produced at a controlled mixing plant may be taken from trucks in accordance with AS 1141.3.1 and then prepared for compaction testing in accordance with AS 1289.1.1. Preparation of samples of other cementitious treated materials for compaction shall be in accordance with AS 1289.1.1 and RC 301.06.

5.3.2. Lime-Stabilised Materials

Laboratory compaction tests shall be carried out between 48-72 hours after field mixing. Laboratory compaction tests shall be carried out on samples taken from the field density sites.

5.4. Concrete

Refer to the job specification for details of requirements.

6. Allowance for Oversize Material – Reference Density Determination

Oversize material is defined as any material which is coarser than the maximum size allowable in the relevant laboratory compaction test. The percentage of oversize material for the selection of the mould for the test shall be determined at the sampled moisture content of the material. Correction for the oversize material shall be made to the reference density, assigned or determined by test, and will be determined for the condition of material for which the density ratio is to be calculated, i.e. wet or dry, in accordance with AS 1289.5.4.1 or AS 1289.5.7.1, as appropriate.

When the volume of oversize material is determined in accordance with AS 1289.5.4.1 or AS 1289.5.7.1, all solids (including residual fines) must be recovered and dried to determine the dry mass of material.

In all cases, care shall be taken to ensure that the field moisture content of the total material is used in the calculation of moisture ratio.

The test report shall be endorsed to indicate that the correction has been made and the percentage by mass of the oversize material shall be reported.

7. Calculation of Characteristic Values or Mean Values

The following test method is applicable to calculation of characteristic ratio values for lot testing:

RC 316.00	Density Ratio and Moisture Ratio — Lot Characteristics

All test results from a lot must be included in the calculations, including those markedly different from the average.

Where insufficient test results are obtained, either because test(s) are invalid due to the presence of excessive oversize material (material of nominal size >40 mm), or because individual test(s) have been found to contain errors and become invalid, the modifications to calculation of lot characteristics apply, as detailed in RC 316.00, and summarised as follows:

(i) for 6 test site lot (where characteristic values cannot be determined)

If the set of six test results includes one or two invalid results, calculate the mean value of the valid individual tests. If there are less than 4 valid samples, the test report shall record that characteristic values and mean values cannot be determined.

(ii) for 3 test site lot (where mean values cannot be determined)

If the set of three test results includes any invalid results, the test report shall record that a mean value cannot be determined.

8. Moisture Control for Materials of Nominal Size greater than 40 mm

When specifications related to earthworks and pavement construction require materials having more than 20 percent retained on the 37.5 mm sieve to be compacted while the moisture content of the fraction of material which passes the 19 mm sieve is within a certain range of the relevant optimum moisture content, samples for moisture content and optimum moisture content determination shall be taken from three sites selected within the test lot in accordance with RC 316.10 or AS 1289.1.4.2.

9. Re-Testing of Work

The lot testing scheme used by VicRoads is based on the objective that VicRoads and the Contractor equally share the risk that the mean or characteristic relative compaction calculated for a lot will differ from the true quality of the lot. Repeat testing should not be undertaken merely because, on the basis of the results of the first testing, the lot was deemed to have failed. Repeat testing can be expected always to provide results which differ from the first result, but there is no valid reason to accept the second result in preference to the first. Further, it will also bias the distribution of risk away from an equal sharing between the two parties.

Retesting of work should be undertaken only if an error is known to have occurred in the testing procedures, in which case the first set of test results should be discarded completely and the second set of test results should be adopted to determine the acceptability of the lot concerned. Selection of the second set of site locations should be carried out by the same method as used for the first set.

Values of Maximum Dry Density and/or Optimum Moisture Content assigned in accordance with AS 1289.5.4.2 shall be checked in accordance with that method if material has been reworked.

Where an individual result may be in error or missing, e.g. material spilt before weighing, a replacement result may be obtained by random selection of a test site within the same section of the lot.

10. Specifications not based on Lot Testing

Some job specifications may simply stipulate that the material must be compacted to not less than a certain percentage of density ratio based on the Standard or Modified compactive effort. In these cases the Superintendent must be consulted as to the number of test sites required and to the manner in which they are to be located.

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VicRoads Code of Practice - Revision Summary

RC 500.05 - Acceptance of Field Compaction

Date	Clause	Description of Revision	Authorised by
June 2017	2.1 3.4 4.4 4.4(b) 5.3.1 6 7 8	Test lot bounds re-defined to 2 m of lateral construction joints Re-titled Refers to pavement materials, and corrected appendix of AS 1289.5.8.1 Requirements for monitoring of moisture intercept Re-titled Re-titled. Removed paras 3-5 as now covered in AS 1289.5.4.1 Re-titled and included actions where results for test sites in the test lot are invalid - detail test procedure in RC 316.00, Clause 3 Re-titled	Principal Advisor – Pavement Geotech. & Materials
March 2014	Revision Summary	Correct date is 24 May 2013	Principal Advisor – Pavement & Materials
~~March 2012~~ May 2013	Full document Cl 3 Cl 4.3.5 & Cl 5.3 Cl 5.3 Cl 6	Re-styled with some re-positioning of a small amount of text, re-numbering of clauses and minor corrections made. New Clause 3 – Test Depth Subsequent Clauses re-numbered as consequence. Nuclear gauge test depth altered to be between 5 mm and 25 mm less than nominal layer depth, to improve assessment of field density. Reference to IPCAD and KVD tests and AS 1289.5.3.2 removed – methods not now used. Reference to VicRoads Test Method RC316.11 has been discontinued – this method has been previously used for purposes not intended and has been withdrawn. Change to reference density requirements for testing of trench bedding – to comply with testing accreditation. Reference to equation in AS 1289.5.7.1 clarified	Principal Advisor – Pavement & Materials