Project Specific Technical Specification

Transport and Main Roads Specifications PSTS116 Intelligent Compaction – Earthworks and Pavements

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Developed for: Rocklea to Darra – Stage 1 Project

Queensland Government

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1 Introduction

1.1 General

This Project Specific Technical Specification applies to the use of intelligent compaction (IC) in the construction of pavements and earthworks including stabilised materials but excluding asphalt and sprayed seals.

This Project Specific Technical Specification has been developed for the implementation of IC trials in Queensland. As the knowledge and understanding of IC is developed through these field trials, this document will be updated to reflect best practise.

The requirements of this Project Specific Technical Specification are supplementary to the relevant parent Technical Specifications, as given in Table 1. Where there are any contradictory requirements between this Project Specific Technical Specification and the respective parent Technical Specification, the requirements of this Project Specific Technical Specification shall apply where intelligent compaction is used.

Table 1 – Parent Technical Specifications

Parent Technical Specification	Application
MRTS04	*General Earthworks*
MRTS05	*Unbound Pavements*
MRTS06	*Reinforced Soil Structures*
MRTS07A	*Insitu Stabilised Subgrades using Quicklime or Hydrated Lime*
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*
MRTS07C	*Insitu Stabilised Pavements using Foamed Bitumen*
MRTS08	*Plant-Mixed Heavily Bound (Cemented) Pavements*
MRTS09	*Plant-Mixed Pavement Layers Stabilised using Foamed Bitumen*
MRTS10	*Plant-Mixed Lightly Bound Pavements*
MRTS35	*Recycled Material Blends for Pavements*

This Project Specific Technical Specification shall be read in conjunction with MRTS01 *Introduction to Technical Specifications*, MRTS50 *Specific Quality System Requirements* and other Technical Specifications as appropriate.

IC rollers used on pavement and earthworks construction are fitted with equipment to record roller passes and coverage on a lot, and measure and record the stiffness of the layer being compacted

2 Definition of terms

The terms used in this Project Specific Technical Specification shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Specifications*. Additional terms used in this Technical Specification shall be as defined in Table 2.

Table 2 – Definition of terms

Term	Definition
Geodetic Coordinates	A coordinate system used to describe a position in terms of longitude, latitude, and altitude above an imaginary ellipsoid surface (GRS80) based on a specific geodetic datum. GDA94 is the required datum to be used.
GDA94	A mathematical definition of the earth's shape, with its origin at the earth's centre of mass. GDA94 was fixed against the International Terrestrial Reference Frame 1992 (ITRF92) at epoch 1994.0, hence referred to as GDA94.
GPS	A space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth to determine the location in geodetic coordinates. In this specification, GPS is referring to all GPS-related signals including US GPS, and other Global Navigation Satellite Systems (GNSS).
GPS Base Station	A single ground-based system that consists of a GPS receiver, GPS antenna, radio and radio antenna to provide L1/L2 differential GPS correction signals to other GPS receivers within a range limited by radio signal strength and topography. Typically, 1-5 kms in radius without repeaters.
GPS Correction Service Subscription	A service that can be subscribed to receive a GPS correction in order to achieve higher accuracy GPS positioning normally via cellular wireless data services; that is, without the need for a ground-based GPS Base Station. Examples of GPS Correction Service subscriptions include Trimble VRS NOW, HxGn SmartNet, AllDayRTK, and so on
Grid Coordinate	Grid: Refer also to MGA94 in this Project Specific Technical Specification.
GUI Display	Graphical User Interface Display.
Hand-held GPS rover	A portable GPS radio/receiver for in-situ point measurements.
Intelligent Compaction (IC)	A compaction system that includes assessment of stiffness using vibration monitoring integrated with global positioning system (GPS) and displayed for the plant operator. The data can be exported to provide a complete record of compaction and for further analysis with Veta.
Intelligent Compaction Measurement Value (IC-MV)	Generic term for IC roller-integrated stiffness measurement value. Proprietary products may measure IC-MV using different terminology/units.
Light Weight Deflectometer (LWD)	Portable, non-destructive test device used to measure pavement deflections by applying a dynamic load to the pavement surface.
Network RTK	Network RTK is a system that use multiple bases in real-time to provide high-accuracy GPS positioning within the coverage area that is generally larger than that covered by a single GPS Base Station; for example, Trimble VRS NOW.
RTK-GPS	Real Time Kinematic Global Positioning Systems based on the use of carrier phase measurements of the available GPS signals where a single reference station or a reference station network provides the real-time corrections in order to achieve centimetre-level accuracy.

Term	Definition
UTC	Coordinated Universal Time (UTC) is commonly referred to as Greenwich Mean Time (GMT) and is based on a 24 hours' time scale from the mean solar time at the Earth's prime meridian (zero degrees longitude) located near Greenwich, England.
MGA94	Cartesian coordinates from a universal transverse Mercator projection based on the Geocentric Datum of Australia 1994 (GDA94). Zone Number, Easting and Northing represents a grid coordinate.
Veta	A map-based software tool for Contractors and Administrators to standardise, display, analyse and report data collected by intelligent compaction (IC) and paver-mounted thermal profiling (PMTP) technologies during construction. Veta can import data from various IC machines and PMTP to perform editing, filtering, spot test correlation, and statistical analysis as a post-processing tool.

3 Referenced documents

Table 3 list documents referenced in this Project Specific Technical Specification.

Table 3 – Referenced documents

Reference	Title
MRTS01	*Introduction to Technical Specifications*
MRTS50	*Specific Quality System Requirements*

4 Standard test methods

Testing of all work shall be undertaken in accordance with Clause 4 of MRTS01 *Introduction to Technical Specifications*.

Unless stated elsewhere herein, the standard test methods listed in Table 4 shall be used in this Project Specific Technical Specification.

Table 4 – Standard test methods

Property to be Tested	Method No.
Random selection of sampling or test locations	Q050
Measuring deflections with a Light Weight Deflectometer (LWD)	ASTM D2583
Insitu wet density	Q141A or AS 1289.5.8.1

5 Quality system requirements

5.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are detailed in Clause 5.2 of MRTS01 *Introduction to Technical Specifications*.

The Hold Points, Witness Points and Milestones applicable to this Project Specific Technical Specification are summarised in Table 5.1.

Table 5.1 – Hold Points, Witness Points and Milestones

Clause	Hold Point	Witness Point	Milestone
5.2	1. Acceptance of construction procedures for IC		
7.2	2. Provide training for Contractors and Administrators staff		
7.3	3. Notify Administrator of any weak and/or non-homogeneous areas identified during the pre-mapping of underlying layer.		
7.4.2	4. Determine the target IC-MV prior to continuing IC works.		

5.2 Construction procedures

The Contractor shall prepare documented procedures for all construction processes in accordance with Clause 6 of MRTS50 *Specific Quality System Requirements*.

In addition to the requirements of the relevant parent Technical Specifications, the Contractor shall prepare a Construction Procedure that provides, as a minimum, the following details:

a) The number of rollers to be used in the Works and the number of these rollers equipped with IC technology, and

b) For each roller equipped with IC technology:

   i. the roller make and model, and

   ii. the IC equipment make, model and software version

c) For each roller not equipped with IC technology:

   i. the roller make and model

No works using IC shall commence until the construction procedure described in this clause has been submitted to and accepted by the Administrator. **Hold Point 1**

> Compatibility is important, mixing of IC-MV data from different systems is not currently possible in Veta. There should be only one supplier of IC equipment used in the construction of a single lot.

5.3 Lot sizes

Intelligent compaction shall be undertaken on a lot basis as specified in the relevant parent Technical Specification.

IC results shall be reported for each lot.

6 Equipment

6.1 General

The Contractor will determine the number of IC rollers required to achieve the intent of this Project Specific Technical Specification.

Not all rollers used in a lot need to be IC equipped, however sufficient IC rollers need to be provided to ensure that coverage and stiffness of the entire lot can be measured and recorded.

6.2 Intelligent compaction rollers

The IC rollers shall meet the following requirements:

a) IC rollers for use in pavements and earthworks compaction shall be self-propelled single-drum vibratory rollers equipped to measure the interactions between the rollers and compacted materials and evaluate the applied compactive effort.

b) IC rollers shall be fitted with a smooth drum

c) IC rollers shall be capable of recording and displaying

   i. real-time colour-coded maps of the IC-MV

   ii. location of the roller

   iii. number of roller passes

   iv. roller speeds, and

   v. vibration frequency and amplitude of roller drums.

d) The data output from the IC roller shall be compatible with Veta

e) The positioning system and zone settings shall comply with the requirements of Appendix A.

7 Construction

7.1 Coverage

Where not all rollers used in the Works are fitted with IC equipment, the Contractor shall ensure that the full extent of each lot is mapped with an IC equipped roller at the following points during the Works:

a) for the first lot, at the completion of compaction (final roller pass) in order to determine the target IC-MV (refer to Clause 7.4), and

b) for subsequent lots, at the completion of the compaction process (final roller pass) in order to report the IC data (refer to Clause 8.2).

7.2 On-site training

The Contractor shall coordinate and provide on-site training for their own and the Administrators personnel on the operation of the IC technology, prior to the commencement of the Works.
Hold Point 2

The Contractor's personnel shall include the Contractor's Project Manager, Project Engineer(s), Quality Representative, Works Supervisors(s) and roller operator(s).

The Administrators personnel are to be nominated by the Administrator.

Minimum training topics shall include:

a) Background information for the specific IC system(s) to be used

b) setup and checks for IC system(s), GPS receiver, base-station and hand-held GPS rovers

c) operation of the IC system(s) on the roller; that is, setup data collection, start/stop of data recording, and on-board display options

d) transferring raw IC data from the roller(s), that is, via USB or mobile/wireless connections, and

e) operation of vendor's software to open and view raw IC data files and exporting all passes and final coverage data files in a Veta-compatible format.

~~f) operation of Veta software to import the IC data files, inspect IC maps, input point test data, analyse the data and produce reports.~~

7.3 Pre-mapping of underlying layer

Prior to the construction of each lot of earthworks and/or pavements, the Contractor shall undertake pre-mapping of the underlying layer.

Pre-mapping shall involve making a single pass over the lot area with the IC roller and mapping the IC-MV results.

Where the underlying lot was constructed by the Contractor using IC, the construction records themselves are adequate for pre-mapping.

Where pre-mapping identifies weak and/or non-homogeneous areas, the Administrator shall be notified prior to the commencement of the Works. **Hold Point 3**

Where the underlying layer has been constructed by the Contractor as part of the Works, the Contractor would typically be responsible for ensuring the overlying layer can be constructed to meet the specified compaction standards, and may need to undertake dry-back and/or rework of the underlying layer accordingly.

Where the underlying layer was not constructed as part of the Contract, the Contractor and Administrator should consider what/if any additional work is required to achieve compaction of the overlying earthworks or pavement. In some circumstances the Contractor and Administrator may undertake additional investigation of the weak and/or non-homogenous underlying area (for example, proof rolling, DCP, test pit and so on).

7.4 Determine the target IC-MV

7.4.1 General

The target IC-MV shall be used by the Contractor as a guide to indicate when the required compaction standard has been achieved, and to report the uniformity of each lot.

Achieving the target IC-MV for a lot does not circumvent nonconformances recorded against the compaction requirements specified in the relevant parent Technical Specification.

The Contractor shall initially determine the target IC-MV on the first lot of the Works. The target IC-MV shall be determined using:

- the compaction equipment nominated in the Contractor's construction procedure, and

- the procedure given in Clause 7.4.2.

The target IC-MV shall be established for each combination of the following and re-established for any change thereafter:

- material type
- layer thickness, and/or
- nominal moisture content.

Regular revisions of the IC-MV shall be undertaken in accordance with Clause 7.5.

Typically, the Contractor would develop a rolling pattern to achieve the specified compaction standard. The use of IC allows the Contractor to assess the compaction of a lot with each roller pass and at completion of compaction. By doing so the rolling pattern can be optimised in real time to help ensure that the specified compaction standard is achieved.

7.4.2 Procedure

The target IC-MV shall be determined using the following procedure.

Where each roller pass during compaction is being undertaken by an IC equipped roller (or non-IC equipped roller of the same make, model and configuration), follow steps 1 – 7.

Where only the final roller passes is being undertaken by an IC equipped roller (for example where a padfoot roller is being used for the primary compaction), follow steps 4 -7.

Table 7.4.2 – Procedure for determining the target IC-MV

Step	Description	Responsibility	Notes
Step 1	Commence compacting the lot using the nominated rollers and rolling pattern. Undertake the first roller pass. Pause the compaction process to allow for the testing specified in Step 2.	Contractor	
Step 2	At a minimum of 10 locations within the lot measure: • The stiffness of the layer using a Light-Weight Deflectometer (LWD), and • The insitu wet density of the layer using a Soil Density / Moisture (nuclear) Gauge.	Transport and Main Roads	Each testing locations shall be determined using Test Method Q050, unless otherwise directed by the Administrator. The location of all stiffness and density tests shall be recorded using a hand-held GPS rover that complies with the positioning requirements given in Appendix A. These test locations shall be input into Veta.

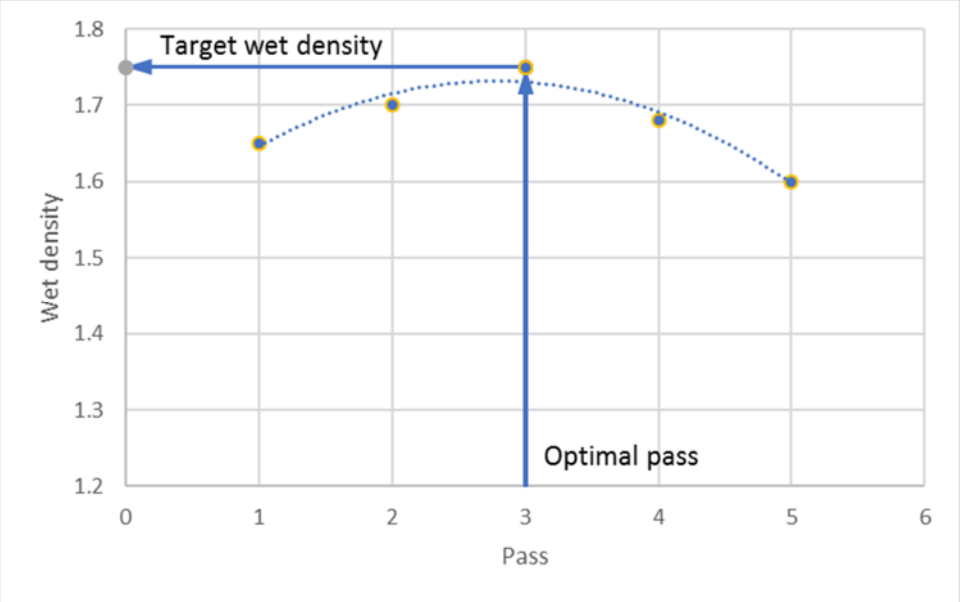
Step	Description	Responsibility	Notes
Step 3	Undertake subsequent roller passes repeating Steps 1 and 2 until it is deemed that the specified compaction standard has been achieved in accordance with the parent Technical Specification.	Contractor for roller passes and coverage (Step 1) Transport and Main Roads for testing (Step 2)	Testing to be undertaken at the same locations determined in Step 2.
Step 4	At the completion of compaction, use the IC equipped roller to map the stiffness of the entire lot (if not already done).	Contractor	
Step 5	After the final pass with the IC equipped roller, undertake a final suite of LWD and insitu wet density testing as per Step 2.	Transport and Main Roads	Testing to be undertaken at the same locations determined in Step 2.
Step 6	**Undertake a plateau analysis of the compaction data**. Analyse the compaction data by plotting the number of roller passes against the stiffness and insitu wet density results.	Contractor and Transport and Main Roads	This process will assess what amount of compactive effort is required to achieve the minimum specified compaction standard. The optimum compactive effort is the number of passes required to reach the peak of the stiffness and/or density results, whichever is the greater.
Step 7	**Determine the target IC-MV**. **Hold Point 4** Upload all IC data into Veta for analysis. Use Veta to perform a correlation analysis between the IC-MV and stiffness/wet density results using a linear regression. This analysis should include all locations where there is corresponding IC-MV and stiffness/density data (for example, each pass where IC equipped rollers are used throughout compaction of the lot).	Contractor and Transport and Main Roads	Where the coefficient of determination (R^2) of the linear regression is greater than 0.5, the target IC-MV would be the value corresponding to the t target wet density on the correlation chart. The correlation between IC-MV and stiffness should be checked for consistency. If the coefficient of determination (R^2) is less than 0.5, the homogeneity of the materials (for example, gradation, thickness and moisture content) shall be examined to determine its suitability for use and this procedure repeated on the next lot until a target IC-MV can be determined.

This procedure has been developed for the purpose of undertaking trials.

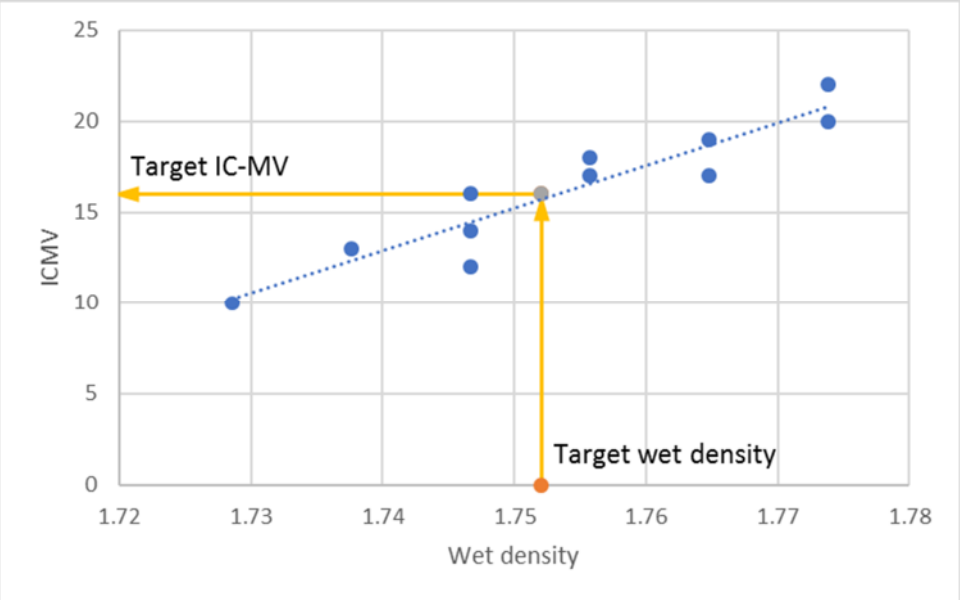
The responsibility for each step may be altered on a case by case basis.

Using the target IC-MV determined from the procedure detailed in Table 7.4.2, the Contractor and Administrator shall use this value for subsequent IC lots and IC data reporting (refer to Clause 8.2).

Example of plateau testing analysis



Example of Target IC-MV analysis



- Similar plots can be drawn up to analyse the LWD data with respect to insitu wet density and IC-MV.

7.5 Revision of the target IC-MV

The target IC-MV shall be checked at the frequencies shown in Table 7.5.

Table 7.5 – Frequencies for the revision of the target IC-MV

Interval	Action
1st Lot	Determine target IC-MV as per the procedure detailed in Clause 7.4.2.
Monthly	Review target IC-MV in accordance with the procedure detailed in Clause 7.4.2.
Intermediate lots	Use the most recently determined target IC-MV to report the IC data of each lot (refer to Clause 8.2).

For the purpose of the initial IC trials, revision of the target IC-MV may need to occur more frequently than shown in Table 7.5 to help develop the trial.

8 IC data reporting requirements

The intent of this specification for compliance and reporting of each IC lot is as follows:

- The Contractor shall be responsible for the compliance of each lot in accordance with its parent Technical Specification.
- The Contractor will record the IC data for each lot and provide it to the Administrator (as per Clause 8.2).
- The Contractor will undertake an analysis of the IC data for each lot using Veta and report the analysis to the Administrator (as per Clause 8.2).
- As the understanding and confidence in the IC process grows, a reduced level of compliance testing (for example, reduced number of relative compaction tests) may be considered by the Administrator in conjunction with the submission of conforming IC analysis.

8.1 Compliance test locations

The Contractor shall record the locations of all compliance testing undertaken in accordance with the parent Technical Specification using a hand-held GPS rover that complies with the positioning requirements given in Appendix A.

These test locations shall be input into Veta and reported with the IC results.

8.2 IC data analysis

In addition to the requirements of the relevant parent Technical Specifications, for each lot where IC is used, the Contractor shall use Veta to analyse the IC data for:

- **Coverage** – the number of roller passes made and coverage of the lot (applicable if the entire compaction effort was completed using IC equipped roller(s)), and
- **Compaction Value** – percent of the lot area meeting or exceeding the target IC-MV determined in accordance with Clause 7.4 and subsequently revised in accordance with 7.5.

The Veta software is freely available on the website www.intelligentconstruction.com

For each lot, the Contractor shall provide to the Administrator all input files necessary to analyse the data in Veta and a report of the Veta analysis (which can be output directly from Veta). The report shall include the locations and values of compliance test results. All data and files must be clearly linked to the construction lot which they relate to.

9 Supplementary requirements

The requirements of this Project Specific Technical Specification are varied by the supplementary requirements given in Clause 1 of Annexure PSTS116.1.

Appendix A – Positioning requirements

A.1 Positioning system

A.1.1 General

The Contractor shall provide a positioning system that meets the following requirements. The goal of the positioning system requirements is to achieve accurate and consistent position measurements among all positioning devices on the same project. Conversions of positioning system data need to be minimised to avoid errors introduced during the process.

All GPS devices for this project shall be set to the same consistent coordinate datum/system no matter whether GPS or Grid data are originally recorded. MGA is the preference and shall be set to zone no. (5x) for this project.

Use of MGA will facilitate GPS data checks onsite. If MGA coordinates are not available, contact the Transport and Main Roads local surveying representative to agree on an acceptable datum. Ad-hoc local coordinate systems are not allowed.

In addition, the positioning system shall be regularly maintained and calibrated in accordance with the manufacturer's / supplier's recommendations and to ensure the requirements of this Project Specific Technical Specification are met. The results of equipment calibration checks shall be recorded and reported to the Administrator as specified in Clause 8.1.1.

A.1.2 GPS requirements

Contractor shall provide the GPS system (including GPS receivers on IC rollers and hand-held GPS rovers) that makes use of the same coordinate reference system. The GPS system should be capable of achieving RTK-GPS accuracies. Examples of valid combinations are:

a) GPS receivers on IC rollers and hand-held GPS rovers referenced to the same ground-based GPS base station, or

b) GPS receiver on IC rollers and hand-held GPS rovers referenced to the same network RTK.

A.1.3 GPS data records and formats

The recorded GPS data, whether from the IC rollers or hand-held GPS rovers, shall be in the following formats:

a) Time: The time stamp shall be in military format, hhmmss.ss in either UTC or local time zone.0.01 second is required to differentiate sequence of IC data points during post process.

b) Geodetic coordinates of latitudes and longitude shall be in decimal degrees, dd.dddddddd (to at least eight decimal places which is approximately equivalent to 1 mm in Queensland). Latitudes are negative south of the equator and longitudes are positive when measuring eastward from the Prime Meridian.

c) GPS Grid coordinates shall be in meters with at least three digits of significance (0.001 m or 1 mm).

When importing IC-MV data into the data analysis management program, the GPS data and associated IC measurements shall be stored with minimum data conversions and minimum loss of precision. Users can then select unit of preference to allow real time unit conversion for the GUI display.

Post-process GPS check. Follow the vendor-specific instructions to export IC-MV data to Veta-compatible formats. The Contractor should import the IC roller data into Veta and enter GPS point measurements from the rover and visually inspect the IC map and point measurements on the Veta display screen for consistency.

A.1.4 Datum

The IC roller shall be able to output geodetic / grid coordinates using GDA94 / MGA94 respectively.

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