Technical Specification

Transport and Main Roads Specifications MRTS08 Plant-Mixed Heavily Bound (Cemented) Pavements

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Queensland Government

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1 Introduction

This Technical Specification applies to the construction of road pavements using plant-mixed heavily bound (cemented) pavement layers.

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

This Technical Specification forms part of the Transport and Main Roads Specifications Manual.

This Technical Specification is applicable to both base and subbase layers which have historically been referred to as follows:

- Cement Treated Base (CTB)
- Cement Treated Sub-base (CTSB)

These terms continue to be used today although General Purpose (GP) cement is no longer specified for these materials (rather blended cements, cementitious blends, or other binders are now typically used).

The terms 'heavily bound' and 'cemented' are often used interchangeably when referring to these materials.

Either Category 1 or Category 2 material may be used in either base or subbase layers. Further guidance on the suitability of these materials is provided in the Transport and Main Roads *Pavement Design Supplement* (PDS).

2 Definition of terms

The terms used in this Technical Specification shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Specifications*. Further definitions are as defined in Table 2.

Table 2 – Definition of terms

Term	Definition
Actual content (of stabilising agent)	The content of stabilising agent in the production mix.
Allowable working time	The time within which compaction and trimming of each heavily bound pavement layer shall be completed, measured from the commencement of the incorporation of the stabilising agent (i.e. mixing of the stabilising agent into the material) to completion of compaction and trimming. The following activities are not required to be completed in the allowable working time: • hard-cut of the surface prior to placing another heavily bound pavement layer • static rolling to prepare the surface for sealing, and • proof rolling. At completion of the allowable working time, the layer must comply with the specified requirements for surface level (excluding hard cutting), deviation from a straight edge and surface evenness. That is, rolling (static or vibratory) or other construction processes are not permitted after the allowable working time to correct poor geometrics.

Term	Definition
APHA	American Public Health Association
Base course (base)	A course principally intended to directly support the traffic loads, constructed from a mixture of unbound granular pavement materials, cementitious stabilising agent and water.
Cement slurry	A semi-liquid mixture of stabilising agent (either a blended cement or cementitious blend) and water.
Course	A layer or multiple layers of a particular pavement material as reflected in the pavement design. For example, surfacing course, base course, sub-base course or improved layer.
Intelligent Construction (IC) Roller	A single (smooth) drum roller that incorporates equipment to measure the stiffness of compacted layers while simultaneously tracking the position and number of passes using a global positioning system (GPS). Stiffness, position and coverage results are displayed in real time to the plant operator and the data can be exported to provide a complete record of compaction and undertake further analysis with Veta.
Layer	A thickness of material placed in a single continuous pass. A single or multiple layers may make up a course.
Mixing plant variability	The Mixing Plant Variability (MPV) is an estimate of the likely variability in stabilising agent content during production from the actual mixing plant to be used in the Works. The MPV shall be expressed as a percentage, by dry mass, of unbound pavement material.
Mixture	The plant-mixed heavily bound pavement material after incorporation and mixing of the stabilising agent.
Production result	A tested or measured result obtained from previous operation of the mixing plant to produce cementitiously bound pavement materials. A specific test shall represent an individual result. Alternatively, individual results may be obtained from continuous data collection systems that measure the throughput mass of all constituent materials fed into the plant.
Quarry	A site from which construction materials are won by blasting, ripping or other excavation means for use in their natural state or after processing such as by crushing, screening or combining with other materials. The term quarry also includes pits and natural deposits such as sand sources. When used in relation to department's quarry registration system, a quarry may also include a material recycler.
Subbase course (subbase)	A structural pavement course immediately below the base course. A subbase course may be divided into upper and lower courses.
Target Content (of stabilising agent)	The content of stabilising agent nominated by the Contractor based on mix design testing and the historic MPV.
$UCS_{7\text{-lower}}$	The seven day UCS corresponding to the minimum 28 day UCS specified in Table 7.1.
$UCS_{7\text{-upper}}$	The seven day UCS corresponding to the maximum 28 day UCS specified in Table 7.1.

Term	Definition
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.
Work Shift	The time period during which work is undertaken. Work would typically be undertaken as either day or night shift with each being a separate work shift.

3 Referenced documents

The requirements of the referenced documents listed in Table 3 below apply to this Technical Specification. Where there are inconsistencies between this Technical Specification and the referenced documents, the requirements specified in this Technical Specification shall take precedence.

Table 3 – Referenced documents

Reference	Title
AS 1289.2.1.1	*Methods of testing soils for engineering purposes Soil moisture content tests – Determination of the moisture content of a soil – Oven drying method (standard method)*
AS 1289.2.1.4	*Methods of testing soils for engineering purposes Soil moisture content tests – Determination of the moisture content of a soil – Microwave-oven drying method (subsidiary method)*
AS 1289.2.1.6	*Methods of testing soils for engineering purposes Soil moisture content tests - Determination of the moisture content of a soil – Hotplate drying method*
AS 1289.2.3.1	*Methods of testing soils for engineering purposes – Soil moisture content tests - Establishment of correlation - Subsidiary method and the standard method*
AS 1289.4.2.1	*Methods of testing soils for engineering purposes Soil chemical tests— Determination of the sulfate content of a natural soil and the sulfate content of the groundwater – Normal method*
AS 1478.1	*Chemical admixtures for concrete, mortar and grout - Admixtures for concrete*
AS 3582.2	*Supplementary cementitious materials – Slag – Ground granulated blast-furnace*
AS 3972	*General purpose and blended cements*
AS/NZS 3582.1	*Supplementary cementitious materials – Flyash*
MRTS01	*Introduction to Technical Specifications*
MRTS05	*Unbound Pavements*
MRTS23	*Supply and Delivery of Quicklime and Hydrated Lime for Road Stabilisation*
MRTS50	*Specific Quality System Requirements*
MRTS56	*Construction Surveying*
-	*Pavement Design Supplement,* Transport and Main Roads

4 Standard test methods

The standard test methods specified in Table 4 will be used in this Technical Specification.

Further details of test numbers and test descriptions are specified in Clause 4 of MRTS01 *Introduction to Technical Specifications*.

Table 4 – Standard test methods

Property to be Tested	Method No.
Addition of stabilising agents	Q135A
Ball penetration	AG:PT/T251
Calculation of characteristic value of a lot	Q020
Conductivity (water)	APHA 2510-B
Curing of moulded specimens	Q135B
Deviation from a three metre straight edge	Q712
Moisture content	AS 1289.2.1.1, AS 1289.2.1.4, AS 1289.2.1.6
Moisture content test – Establishment of correlation for subsidiary methods (AS 1289.2.1.4 or AS 1289.2.1.6)	AS 1289.2.3.1
Particle size distribution (segregation)	Q103A
pH (water)	APHA 4500-H B
Proof rolling test	Q723
Relative compaction	Q140A
Road roughness (surface evenness)	Q708B, Q708C, Q708D
Sampling of soils, crushed rock and aggregates	Q060
Selection of sampling or test locations	Q050
Spot sampling of soils, crushed rock and aggregates	Q061
Stabilising agent content – heat of neutralisation	Q134
Sulfate content	AS 1289.4.2.1, other published or validated classical chemistry technique or instrumentation technique[#]
Unconfined compressive strength (UCS)	Q115
Working time of stabilised materials	Q136A

Note [#] Instrumentation techniques may include Ion Chromatography / Inductively Coupled Plasma / Discrete Analyser and so on. NATA endorsed test results are evidence of a validated technique.

4.1 Supplementary requirements for Test Method AS 1289.2.1.1, AS 1289.2.1.4 and AS 1289.2.1.6

Moisture Content determinations during production shall be undertaken in accordance with Test Method AS 1289.2.1.1, AS 1289.2.1.4 or AS 1289.2.1.6. If one of the subsidiary methods (AS 1289.2.1.4 or AS 1289.2.1.6) are used, a correlation using AS 1289.2.3.1 must be applied.

Testing to determine the moisture content of the material at the point of production shall be started as soon as possible, after the commencement of incorporation of stabilising agent into the unbound pavement material. The maximum time between incorporation of stabilising agent into the unbound pavement material and the commencement of weighting samples as required by these test methods shall be 30 minutes.

4.2 Supplementary requirements for Test Method Q115

The sample from which production UCS specimens are taken shall also be tested for stabilising agent content and moisture content and the results reported together.

With the exception of testing for mix design purposes (refer Clause 7.3) UCS testing shall be carried out at the sampled moisture content with the specimen compacted to 100% of maximum dry density (MDD).

To achieve compaction of UCS specimens to 100% MDD, the Contractor will need to determine the mass of material to add to the mould and compact the material using the standard compaction rammer (2.7 kg) in layers until the material fills the mould.

Where the material is not produced at Optimum Moisture Content (OMC), the Contractor may need to apply more blows with the standard rammer (that is more than 25 blows per layer) to achieve the required density (100% MDD).

To calculate the mass of material to be added to the mould the Contractor will need to determine the moisture content at which the material has been produced at – this may not be OMC.

5 Quality system requirements

5.1 Hold Points, Witness Points and Milestones

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

The Hold Points, Witness Points and Milestones applicable to this 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 Procedure for heavily bound pavement works		
5.2.1			Submit Construction Procedure for heavily bound pavement construction (14 days).
6.1.1	2. Demonstration of unbound pavement material compliance prior to stabilisation		
7.1	3. Acceptance of mix design report		Submission of mix design report (14 days)

Clause	Hold Point	Witness Point	Milestone
8.1	4. Demonstration of ability to manufacture and construct conforming pavement	1. Construction of Trial Pavement	
9.4.10		2. Proof Rolling	
9.5.1	5. Covering a heavily bound pavement layer		
9.5.3	6. Nonconformance of compressive strength or stabilising agent requirements		

5.2 Construction procedures

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

No heavily bound pavement works shall commence until all relevant construction procedures have been accepted by the Administrator. **Hold Point 1**

5.2.1 Heavily bound (cemented) pavement construction procedure

For heavily bound pavement materials, the Contactor shall prepare a Construction Procedure, which details at least the following:

a) details of all plant associated with the works

b) procedures to demonstrate the accuracy of the mixing plant (including calibration procedures for load cells where applicable)

c) details for all aspects of the pavement works, including:

   i. location of and management processes for stockpiles

   ii. location of the mixing plant, and logistics for the operation of the plant in that location

   iii. the lengths and widths of each paving run

   iv. the location and type of joints required between each paving run

   v. procedures for the transport, placement, compaction and trimming of the pavement material

   vi. the proposed rolling pattern and number of passes needed to achieve the specified compaction standard for each layer thickness and support condition (to be validated during the placement trial)

   vii. procedures and equipment to prepare joints (refer Clause 8.2.10) prior to placing an adjacent layer of heavily bound material

   viii. procedures and equipment to hard-cut the surface (refer Clause 8.2.8.2) prior to placing an overlying layer of heavily bound material

   ix. slurrying procedures, including details of how the slurry will be mixed and spread evenly and safely to the cut-back joint edges and the hard-cut surfaces

x. details for working up to or against to structures, kerbs, road safety barriers, access chambers, drainage gullies and other fixed infrastructure within or adjacent to the pavement, including how the material will be placed and compacted to meet the minimum requirements of this Technical Specification

xi. procedure and equipment proposed for proof rolling pavement layers

xii. curing procedures, and

xiii. procedure and equipment to prepare the surface prior to sealing (refer Clause 8.2.8.1).

d) proposed upper and lower moisture content limits for heavily bound pavement construction (refer Clause 8.2.5)

e) proposed methodology for verifying the accuracy of the system used to dispense stabilising agent in the mixing plant (refer Clause 9.4.7)

f) process to provide traceability of unbound pavement materials from stockpiles through to material incorporated into the final pavement.

Where both Category 1 and Category 2 materials are to be incorporated into the works, or the same material is to be used in different courses or applications, the Contractor may prepare a single procedure provided that any differences in construction process are clearly noted.

The heavily bound pavement construction procedure shall be submitted to the Administrator at least 14 days prior to the commencement of heavily bound pavement works. **Milestone**

6 Materials

6.1 Unbound pavement material

6.1.1 General

Unbound pavement materials to be used for plant-mixed heavily bound pavements shall comply with the requirements of Clause 6.1.2.

The Contractor shall not incorporate unbound pavement material into the works unless it has been demonstrated that the unbound pavement material lot conforms fully to the requirements of this Technical Specification. **Hold Point 2** Such conformance results shall be no more than six months old.

The unbound pavement material to be stabilised shall be provided by a supplier registered and operated in accordance with the Transport and Main Roads Quarry Registration System requirements. The current Quarry Registration Certificate shall be submitted to the Administrator as part of the mix design report (refer Clause 7.4).

6.1.2 Unbound pavement material for heavily bound pavements

The Contractor shall nominate in their mix design the unbound pavement material to be incorporated into the heavily bound pavement material.

The material nominated shall be one of the permissible materials specified in Table 6.1.2.

Recycled materials may be used in the following applications:

Permanent Pavements:

- Base courses
    - when the average daily traffic in the design lane in year of opening is less than 500 Equivalent Standard Axles (ESAs), (the average daily traffic in the design lane in the year of opening is given in Clause 1 of Annexure MRTS08.1), and
    - an asphalt surfacing is provided over the base
- Sub-base courses
- Subgrade treatments

Temporary pavements (≤ two year design life):

- All layers

Table 6.1.2 – Unbound pavement materials for heavily bound pavement materials

Material	Specification	Permissible Material	Testing Frequencies
Category 1	MRTS05 *Unbound Pavements*	Subtype 2.1	Refer MRTS05
Category 2	MRTS05 *Unbound Pavements*	Subtype 2.1, Subtype 2.2	Refer MRTS05

In relatively dry environments, the use of Subtype 3.1 or 3.2 materials in Category 2 materials may be specified in Clause 4 of Annexure MRTS08.1. Further guidance on these applications is provided in the Transport and Main Roads *Pavement Design Supplement*.

6.2 Stabilising agent

The constituents incorporated into the stabilising agent (binder) to be used in the works shall comply with the requirements of Clauses 6.2.1 to 6.2.4. The stabilising agent type, the proportion of each constituent and the supplier to be used shall be nominated by the Contractor as part of their mix design (refer Clause 7.4).

All of the components of the stabilising agent shall be completely, homogeneously and accurately blended before they are incorporated into the unbound pavement material. At the time of mixing the stabilising agent with the unbound pavement material, each component of the stabilising agent shall:

a) not be more than three months old, measured from its date of manufacture to the time of blending, unless it has been retested for conformance within one month of use, and

b) comply with the requirements nominated in the Contractor's mix design (refer Clause 7.4).

6.2.1 Cement

All cement used shall comply with AS 3972. The type of cement used shall be Type GP or Type GB.

6.2.2 Fly Ash

Fly ash used shall comply with AS/NZS 3582.1 and be Special Grade or Grade 1.

6.2.3 Slag – ground granulated iron blast-furnace

Slag shall comply with AS 3582.2.

6.2.4 Hydrated Lime

Hydrated lime shall comply with MRTS23 *Supply and Delivery of Quicklime and Hydrated Lime for Road Stabilisation*.

6.3 Chemical admixtures

Chemical admixtures used in heavily bound pavements shall be nominated by the Contractor as part of their mix design (refer Clause 7.4). Admixtures shall comply with, and be used in accordance with AS 1478.1.

6.4 Cement slurry

Where required under Clause 8 of this Technical Specification a cement slurry shall be applied between plant-mixed heavily bound pavement layers. In these applications, the slurry shall be as follows:

- the slurry shall have a water / cement ratio of between 0.6 and 0.7, and
- the application rate shall be approximately equivalent to 2 kg/m² of cement (stabilising agent).

The heavily bound pavement material shall be placed onto the slurry immediately after it has been placed, but before the slurry has set. If the slurry sets before placement of the next heavily bound pavement layer, additional slurries shall be placed at the Contractor's expense, until the requirements of this clause are met.

The maximum time between mixing the slurry and covering the slurry with heavily bound material shall be:

- three hours, or
- the working time determined for the heavily bound material using Test Method Q136A without the use of a set retarder, where the same stabilised agent is used in the slurry as in the heavily bound material.

6.5 Water quality

Water used in heavily bound pavement manufacture and construction shall be free from oil, acids, organic matter and other matter which could be deleterious to the mixture. Unless otherwise accepted by the Administrator, the water shall satisfy the following requirements:

a) have a pH within the range of 6 to 10, when tested using Test Method APHA 4500-H B or equivalent

b) have an electrical conductivity not more than 3500 µS/cm when tested using Test method APHA 2510-B or equivalent, and

c) have a Sulfate Content of not more than 1.9 grams of sulfate (expressed as SO_4) per litre, when tested in accordance with AS 1289.4.2.1.

Unless otherwise accepted by the Administrator, water sources shall be tested at a maximum of 12 monthly intervals during the course of supply or when the nature of the water source has changed.

Water sources classified by the relevant water authority as 'potable water' shall be exempt from testing.

Electrical conductivity is an indirect measurement of the concentration of salts dissolved in the water.

pH measures the acidity or basicity of the water to assess its corrosiveness.

Where the Contractor can demonstrate a proven history or conformance from a specific water source, such as might be required for ongoing environmental monitoring purposes, the Administrator may waive the requirement for water quality testing of non-potable water sources.

7 Mix Design

7.1 General

The Contractor shall be responsible for undertaking all testing and design required to develop a mix design that consistently conforms with this Technical Specification.

The mix design must satisfy the following requirements:

1. comply with the UCS requirements specified in Table 7.1 when tested in accordance with Test Method Q115
2. for Category 1 materials - have a UCS gain of at least 1 MPa when measured at seven and 28 days (at the nominated target content of stabilising agent), and
3. for Category 1 materials - have a working time in excess of six hours when tested in accordance with Test Method Q136A (without the use of chemical admixtures).

Table 7.1 – UCS mix design requirements

Material	UCS (28 days) (Q115)		UCS Gain	Working Time (Q136A)
	Minimum	Maximum	Minimum	
Category 1	3.0 MPa	6.0 MPa	1.0 MPa	Min 6 hours *
Category 2	2.0 MPa	4.0 MPa	–	–

Notes:

* The requirements of Clause 8.2.3 shall apply for the determination of the allowable working time during construction.

Category 1 materials have a higher presumptive design modulus than Category 2 materials. To achieve this stiffness the minimum unconfined compressive strength (UCS) of Category 1 materials is higher than for Category 2 materials. This higher UCS is typically attained by increasing the stabilising agent content, however this can increase the risk of cracking of the heavily bound pavement during service.

The intent of this Technical Specification is that to make use of the higher stiffness of Category 1 materials, the increased risk of cracking is managed by the use of slow-setting binders. This is specified by the requirement for Category 1 materials to meet the minimum working time and UCS strength gain requirements.

Using Unconfined Compressive Strength test results and the Mixing Plant Variability, the Contractor shall nominate the Target Content of Stabilising Agent to be used in production.

At least 14 days before mixing operations commence **Milestone** the Contractor shall submit the mix design report to the Administrator. Construction of heavily bound pavement layers shall not proceed until a conforming mix design (refer Clause 7.4) has been submitted to and accepted by the Administrator. **Hold Point 3**

7.2 Mixing plant variability

The Mixing Plant Variability (MPV) is an estimate of the likely variability in stabilising agent content that can be expected during production for the actual mixing plant to be used in the Works.

The Contractor shall nominate the MPV, expressed as a percentage (by dry mass) of the unbound pavement material rounded up to the nearest 0.1%.

Where a minimum of 30 consecutive historic production results are available, the nominated MPV shall be as follows:

$$MPV \geq z\sigma$$

where:

z = 1.28, representing an 80% confidence interval (for normally distributed data)

σ = the standard deviation of historic production results for the difference between the Target Content and the Actual Content of stabilising agent for the actual mixing plant to be used for the Works, expressed as a percentage (by dry mass) of unbound pavement material.

Where there are no historic production test results available for the mixing plant to be used in the Works, the Contractor shall nominate an interim MPV value. This interim value shall be a minimum of 0.5%. As soon as 30 production tests for additive content have been made, the Contractor shall review this interim value and nominate an MPV value in accordance with this clause. Where this value is higher than the interim value, the Contractor shall resubmit the mix design report in accordance with Clause 7.4.

The Mixing Plant Variability (MPV) to be used for each project will be nominated by the Contractor. The nominated value may be greater than the minimum value obtained by analysing the actual standard deviation of historic production results.

For example, if the standard deviation (σ) of historic production results is 0.18%, the MPV must be greater than or equal to 0.23% and rounded up to the nearest 0.1%. The Contractor may elect, for their processes, to adopt a MPV of any value greater than or equal to 0.3%.

When selecting the MPV, it is important that the Contractor considers both mix design and production compliance requirements:

- Selecting the minimum permitted MPV will increase the acceptable target content range, which will generally allow the Contractor to target a lower stabilising agent content.
- Selecting the minimum permitted MPV will also minimise the allowable tolerances on the actual stabilising agent content in production (refer Clause 8.3.2).
- Selecting a higher MPV will increase the allowable tolerances which will also reduce the acceptable target content range. This may result in the Contractor needing to use more stabilising agent to achieve the required UCS.

7.3 Mix Design testing

Using the proposed unbound pavement material and stabilising agent to be incorporated into the works, the Contractor shall undertake:

- testing which demonstrates the unbound pavement material used in the mix design tests conforms to MRTS05 *Unbound Pavements*
- a minimum of three UCS tests at three different stabilising agent contents such that the required stabilising agent content can be plotted across the full UCS range specified in Table 7.1 with at least one UCS test result falling between the Minimum and Maximum UCS values specified in Table 7.1, and
- working time testing.

For the purposes of undertaking the mix design process, all testing shall be undertaken on specimens taken from the same unbound material lot. UCS tests shall be compacted at (Standard) Optimum Moisture Content, and Maximum Dry Density.

All testing for mix design purposes shall be undertaken on laboratory prepared specimens.

UCS test results shall be used by the Contractor to determine the target content of stabilising agent.

Where a chemical admixture is proposed to be used in the Works, the same chemical admixture and dose rate shall be used in all UCS and working time testing.

> To undertake the mix design, it is the Contractors responsibility to undertake sufficient UCS testing from the same unbound material lot to fully identify the stabilising agent content required to achieve UCS results across the range specified. To achieve this, the Contractor may need to undertake more than three tests at different stabilising agent contents.

7.3.1 Acceptable range for target content of stabilising agent

The Contractor shall use the MPV nominated in accordance with Clause 7.2 and UCS test results to determine the acceptable range for the Target Content of Stabilising Agent in accordance with the following requirements:

- the UCS at the Maximum Target Content plus MPV shall be ≤ the maximum UCS value specified in Table 7.1, and
- the UCS at the Minimum Target Content minus MPV shall be ≥ the minimum UCS value specified in Table 7.1.

Interpolation between data points is permitted in checking compliance with the above limits. Unless otherwise accepted by the Administrator, extrapolation beyond the range of test results is not permitted, and further testing must be undertaken if the above range of UCS limits is not covered.

To assess compliance with these UCS requirements, testing shall be undertaken after each prepared specimen has been cured for 28 days. In addition, the Contractor shall prepare duplicate specimens from the same sample for UCS testing after seven days of curing (refer Clause 7.1 and 7.4).

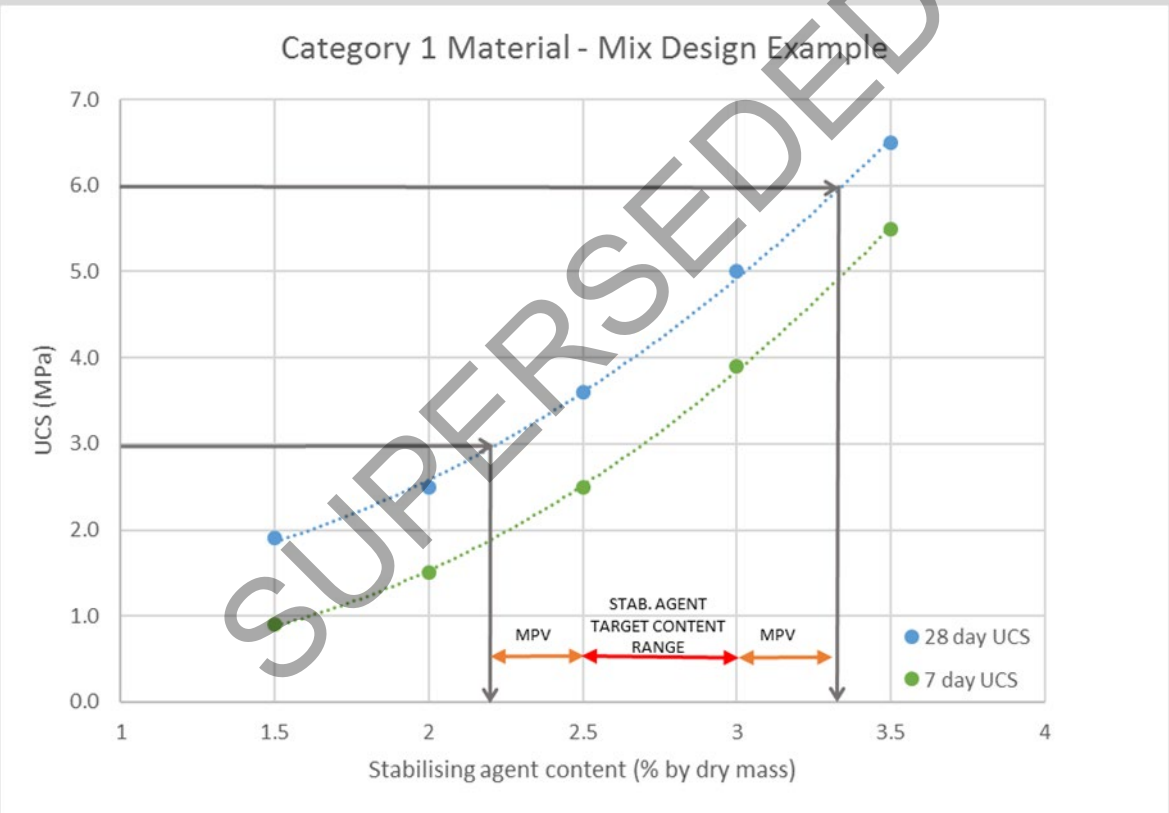
The equation used to interpolate between data points is not specified.

When preparing the mix design, the Contractor shall determine the most appropriate trendline to be used. The R^2 value of the trendline should be as close to 1 as possible.

Example determination of target stabilising agent content from UCS test results

Based on example UCS test results and a MPV of 0.3%, the acceptable stabilising agent target range is shown in Figure 7.3.1. In this example the range that a target content may be nominated between is 2.5% – 3.0%.

Figure 7.3.1 – Mix design example (Category 1 material)



7.3.2 Nominated target content of stabilising agent

Based on the acceptable target content range determined through UCS testing, the Contractor shall nominate a specific Target Content of Stabilising Agent to be adopted in the production of each heavily bound pavement material, expressed as a percentage (by dry mass) of unbound pavement material.

During construction, the Contractor may adjust the Target Content of Stabilising Agent within the acceptable target content range specified in Clause 7.3.1 without the need of resubmitting the mix design report. A written notification (including the revised Target Content of Stabilising Agent) shall be provided to the Administrator prior to producing heavily bound material with the revised Target Content of Stabilising Agent.

Where the Contractor nominates a target content of stabilising agent outside of the acceptable target content range agreed by the Administrator during the mix design approval, the mix design shall be resubmitted.

7.3.3 Working Time

Working time testing shall be carried out using Test Method Q136A, at a stabilising agent content within the acceptable target content range (refer Clause 7.3.1).

Where a chemical admixture is proposed to be used in the Works, the same chemical admixture and dose rate shall be used to determine the working time.

7.4 Mix design report

For each plant-mixed heavily bound pavement material to be used in the works, the Contractor shall submit a mix design report to the Administrator. The report shall include as a minimum:

a) A report on the unbound pavement material proposed to be used in the works including:
   i. the material type proposed to be used
   ii. details of the source of the material (refer Clause 6.1) – including the Transport and Main Roads Quarry Registration Certificate
   iii. test results for the unbound pavement material used in the UCS testing which demonstrates it complies in full with MRTS05 *Unbound Pavements* (refer Clause 6 and Clause 7.3).

b) Details of the stabilising agent to be used in the works including:
   i. The type of stabilising agent, with written certification from the stabilising agent supplier, supported by test results, confirming that the material proposed conforms to the requirements of this Technical Specification (refer Clause 6.2). The stabilising agent type and supplier proposed shall be the same as that used in the mix design testing.
   ii. The proportions of each constituent to be used in the stabilising agent (refer Clause 6.2).
   iii. The ATIC registration number (where available) of the stabilising agent used in the mix design (and proposed to be used in the Works).

c) Details of any chemical admixtures to be used, including the nominated dosage rate (refer Clause 6.3).

d) The MPV requirements (refer Clause 7.2), including:
   i. The Contractor's nominated MPV
   ii. Details of the proposed mixing equipment and controls to be adopted
   iii. Historic production test results summarised in a table with the following columns: Test ID, Test Date, Stabilising Agent Type, Actual Content of Stabilising Agent (Production Mix), Target Content of Stabilising Agent, Difference between Actual Content and Target Content

iv. All test certificates for the historic production test results

v. A statistical analysis of the difference between the Actual Content and Target Content for the historic production test results, and

vi. Any other relevant supporting information.

e) The acceptable target content range and the Contractor's nominated Target Content of stabilising agent (refer Clauses 7.3.1 and 7.3.2).

f) Seven and 28 day UCS test results (refer Clause 7.3).

g) Interpolated or tested seven and 28 day UCS results at the nominated Target Content of stabilising agent.

h) For Category 1 materials - demonstrated strength gain of at least 1 MPa between seven and 28 day UCS results at the nominated Target Content of stabilising agent (refer Clause 7.1).

i) The relationship (based on test results) between seven and 28 day UCS results to define $UCS_{7\text{-lower}}$ and $UCS_{7\text{-upper}}$ where:

i. $UCS_{7\text{-lower}}$ is the seven day UCS corresponding to the 28 day Minimum UCS specified in Table 7.1 and rounded to the nearest 0.1 MPa.

ii. $UCS_{7\text{-upper}}$ is the seven day UCS corresponding to the 28 day Maximum UCS specified in Table 7.1 and rounded to the nearest 0.1 MPa.

j) For Category 1 materials - working time results which demonstrate the mix design complies with the minimum working time requirements of Clause 7.1.

k) The allowable working time for the material, determined in accordance with Clause 7.3.3, with supporting test results.

All test results used in the mix design shall be less than 12 months old unless otherwise approved by the Administrator.

Where a mix design is otherwise conforming, but uses test results that are more than 12 months old, the mix design would normally be considered suitable if the following additional requirements have been satisfied within the last 12 months:

- there has been no substantial change to any of the constituent materials used in the mix design
- there has been no significant change to the mixing plant, and
- the Contractor can demonstrate consistent conformance with this Technical Specification.

Unless otherwise approved by the Administrator, where there are any changes to the constituent materials used in the production of the heavily bound pavement materials, including changes to the unbound pavement materials and stabilising agent, the Contractor shall resubmit the mix design report with test results based on the revised material.

8 Construction

8.1 Trial pavement

Unless otherwise agreed by the Administrator, a trial of the manufacturing and laying operations is required for each different plant-mixed heavily bound pavement material prior to commencement of the work involving that material. **Witness Point 1**

The trial shall not commence until the Administrator has accepted the heavily bound pavement construction procedure and released Hold Point 1 as specified in Clause 5.2.

Unless otherwise approved by the Administrator, the trial pavement must be more than 1000 m². Subject to the Administrator's approval, the trial may be incorporated into the permanent works.

The purpose of the trial is to determine:

a) the suitability of the Contractor's nominated upper and lower moisture content limits and the ability of the heavily bound pavement layer to comply with the requirements of Clause 8.2.5

b) based on the characteristics of the material, its ability to be handled, spread, and compacted to achieve the surface finish requirements of Clause 8.2.8.1

c) the adequacy of the joint and surface preparation procedures (including slurrying and the ability to hard-cut the surface as specified in Clause 8.2.8.2)

d) the rolling pattern and the number of passes of the rollers required to produce an acceptable compacted layer, and

e) the adequacy or otherwise of the manufacturing and construction plant proposed for the work.

The Contractor shall carry out material and construction compliance tests in accordance with Clause 9 to confirm the trial complies with the requirements of this Technical Specification. Prior to continuing works after completion of the trial, the Contractor shall submit to the Administrator, for their acceptance, records which demonstrate this compliance. **Hold Point 4** If the trial does not conform in full to the requirements of this Technical Specification, the Contractor shall review their construction procedure and mix design and a further trial shall be undertaken.

Where minor nonconformances occur in a trial, and the Administrator accepts to incorporate the lot into the permanent works (either at a reduced level of service or otherwise), the Administrator, at their sole discretion may elect to waive the requirement for a further trial to be undertaken.

However, where more significant nonconformances occur, and these or other nonconformances occur again after a further trial, the Contractor should substantially review their construction procedure and/or mix design prior to undertaking a subsequent trial.

8.2 Process requirements

8.2.1 Equipment

8.2.1.1 Equipment used to transport, transfer and store stabilising agent

The stabilising agent shall be transported, transferred and stored in a way that is both waterproof and watertight. These vessels and the associated apparatus shall be emptied and cleaned prior to the introduction of each type of material to be used in the Works to ensure no contamination occurs.

8.2.1.2 Mixing equipment

Mixing shall be carried out using a mechanically driven pugmill.

The mixing equipment shall:

1. have a control system with a metered and variable feed rate for each mix constituent
2. have displays that allow continuous monitoring of each mix constituent
3. produce plant-mixed heavily bound pavement materials complying with this Technical Specification
4. uniformly incorporate the stabilising agent and water into the unbound pavement materials
5. produce a consistent material that is free from segregation, and
6. be capable of continuously producing plant-mixed heavily bound pavement materials complying with this Technical Specification at a rate of 150 tonnes per hour or the Contractor's placing rate, whichever is the greater.

8.2.1.3 Delivery equipment

Vehicles used for the delivery of the mix shall be open-body trucks, or equivalent, equipped with adequate covers. These vehicles shall be capable of transporting and discharging the mixture without segregation. If discharging into the hopper of a self-propelled spreading machine, the vehicles shall be designed or equipped with the capacity to efficiently discharge into the hopper directly and without spillage.

Sufficient delivery vehicles shall be made available so that the mixture can be continuously delivered to ensure placement is essentially continuous throughout a construction lot.

8.2.1.4 Paving equipment

Irrespective of what equipment is used, the mix shall be placed and spread such that there is no segregation of the mixture.

Unless nominated otherwise in Clause 2.1 of Annexure MRTS08.1, plant-mixed heavily bound pavement shall be constructed using a self-propelled spreading machine purpose-built for this work (that is, a paver). Such machines have the capacity to either:

a) receive the material in a hopper and place and spread the mixture on the prepared surface to the required uncompacted layer thickness, width and shape in one pass, or

b) spread previously placed windrows of the mixture to the required uncompacted layer thickness, width and shape in one pass.

Where the heavily bound material is being placed adjacent to a fixed edge or the width of the layer varies, the paver shall be fitted with a variable width screed.

Where a paver is not required as per Clause 2.1 of Annexure MRTS08.1, the plant-mixed heavily bound pavement shall be constructed using a grader.

The Administrator may approve other methods of paving in areas where the use of the specified paving equipment is not practical.

In these instances the Contractor shall document the paving equipment to be used and the proposed construction methodology in their Heavily Bound Pavement Construction Procedure.

For example, the Administrator may approve:

- using a grader in areas where the pavement width is such that the use of a paver is not practical, and/or
- using a small plant at turnouts or other isolated areas where the use of paver or grader is not practical.

8.2.1.5 Equipment for water curing

The equipment used for water curing shall be able to discharge water in a fine and even mist over the layer being cured in a manner that avoids slurrying of the surface and does not result in pavement instability, erosion, or leeching of the stabilising agent.

8.2.1.6 Equipment for preparation of surfaces

The equipment used for the preparation of the surface prior to placing another layer of heavily bound pavement shall include:

- a machine capable of hard-cutting the surface of the layer (refer Clause 8.2.7.2)
- a machine capable of sweeping the surface, and
- equipment capable of evenly distributing the cement slurry (where required) at the specified rate on the layer's surface and edges (refer Clause 8.2.7.2).

The equipment used for the preparation of the surface prior to covering with a sprayed bituminous treatment shall include:

- a static three-point roller or pneumatic (multi-tyred) roller, and
- a machine capable of sweeping the surface.

The use of a drag broom in conjunction with the three-point or multi-tyred roller is recommended.

8.2.1.7 Intelligent Construction Rollers

Intelligent Construction (IC) rollers shall be used to compact heavily bound pavement material where specified in Clause 2.2 of Annexure MRTS08.1.

The IC rollers shall meet the following requirements:

a) IC rollers shall be self-propelled single smooth drum vibratory rollers equipped to measure the stiffness of the layer being compacted.

b) IC rollers shall be capable of recording and displaying

   i. real-time colour-coded maps of the roller position, coverage and stiffness of the compacted layer

   ii. number of roller passes

   iii. roller speeds, and

   iv. vibration frequency and amplitude of the roller drums.

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

To comply with this Clause, all single smooth drum rollers shall be IC rollers.

8.2.2 Stockpiling of heavily bound pavement material

Heavily bound pavement material shall not be stockpiled unless otherwise approved by the Administrator.

In general, heavily bound pavement material should not be stockpiled unless there are specific construction requirements. An example of this might be when the materials are required to be produced in the afternoon for use during night works (such as in an urban area when a pug mill is unable to operate at night). In this circumstance the Administrator may approve the material to be stockpiled provided the mix incorporated a set-retarder to provide a suitable increase in working time (refer Clause 8.2.3 for further information).

8.2.3 Allowable working time

The time between the commencement of mixing the stabilising agent into the unbound pavement material and the completion of compaction of a single layer shall be less than the allowable working time.

The following activities are not required to be completed in the allowable working time:

- hard-cut of the surface prior to placing another heavily bound layer
- static rolling to prepare the surface for sealing, and
- proof rolling.

At the completion of the allowable working time, the layer must comply with the specified requirements for surface level (excluding hard cutting), deviation from a straight edge and surface evenness. That is, rolling (static or vibratory) or other construction processes are not permitted after the allowable working time to correct geometrics.

Unless otherwise approved by the Administrator, the allowable working time for each plant-mixed heavily bound pavement material shall be the lesser of:

a) the working time determined in accordance with Test Method Q136A (refer Clause 7.3.3), and

b) four hours.

Increasing the working time beyond four hours would not generally be approved unless significant constraints exist. Such examples might include:

- night works in urban areas requiring the mixing of materials at times when the pug mill is unable to operate (for example, due to noise restrictions), or
- where no suppliers are available locally, and extended travel times would significantly restrict the ability to construct the pavement within the working time.

In these circumstances, the Contractor should provide justification as to the reason for any proposed increase in allowable working time and provide results to the Administrator that demonstrate the working time in accordance with Test Method Q136A.

8.2.4 Weather conditions for construction

Heavily bound pavements shall not be manufactured (by blended the stabilising agent with the unbound pavement material) or constructed:

a) when the air temperature is less than 10ºC or greater than 40ºC, unless otherwise approved by the Administrator

b) during rain or when rain is likely to fall during placement, or

c) when the evaporation rate due to the combined effect of air temperature, wind and relative humidity may result in excessive drying of the heavily bound pavement layers surface.

The default temperature requirements specified represent the preferred conditions to place heavily bound materials. When assessing a proposal to place heavily bound materials outside of these requirements the Administrator should consider the following:

- When the air temperature is greater than 40ºC, the allowable working time may need to be reduced below the normal specification requirements.
- When the air temperature is less than 10ºC, the material may take significantly longer to set-up requiring an extended time prior to being trafficked.

8.2.5 Moisture content of the mixture

The Contractor shall nominate upper and lower moisture content limits as part of their construction procedures that will ensure:

a) there is adequate moisture to achieve the specified compaction standard

b) the constructed heavily bound pavement layer is trafficked in accordance with requirements of Clause 8.2.11, and

c) the heavily bound pavement material does not exceed the optimum moisture content (OMC), determined in accordance with Test Method Q142A.

Moisture must be uniformly distributed within each layer. At all times the moisture content of the material must be within the Contractor's nominated upper and lower moisture content limits.

During placement and compaction of the heavily bound pavement material, where permitted by the Administrator water may be added onsite as a fine mist (with no run off), to compensate for drying out of the surface of the layer. Water shall not be added onsite to re-moisture condition the material for compaction.

It is recommended that prior to the commencement of construction that the Contractor and Administrator agree the circumstances under which the Contractor would be allowed to add water onsite. Typically, this would be based on environmental factors such as temperate and wind drying the surface of the pavement.

Adding water onsite should not be used to compensate for inadequate moisture being added during production or poor handling and placement techniques delaying works onsite.

8.2.6 Paving

Heavily bound pavements shall be constructed such that each individual layer is laid in one pass that meets the requirements of this Technical Specification without the addition of extra material except as detailed below.

The material laid ready for compaction shall not have any visible areas of segregation. Any segregated areas are to be removed and replaced with fresh mix prior to the commencement of compaction of the lot. Material removed for this reason shall be disposed of in accordance with Clause 10 of MRTS01 *Introduction to Technical Specifications* and shall trigger a nonconformance, under which the Contractor must identify the cause of the segregation and propose preventative action to prevent reoccurrence **Nonconformance**

8.2.7 Layers

8.2.7.1 Layer thickness

Individual compacted layer thicknesses shall be chosen to suit the construction process and the requirements of the Contract. Unless otherwise approved by the Administrator, the completed layer thicknesses (after compaction and surface preparation) shall be in accordance with Table 8.2.7.

Table 8.2.7 – Layer thickness requirements

Material	Minimum Value	Maximum Value
Category 1, or Category 2	125 mm	250 mm

Except in batters, each layer shall be constructed in a uniform thickness unless otherwise approved by the Administrator.

Where multiple layers of the same heavily bound pavement material are placed together in a single course each layer shall be of equal thickness, unless otherwise approved by the Administrator.

Constructing multiple layers in a single course to the same thickness is intended to promote uniformity of each layer. However, there may be circumstances where this requirement is not able to be satisfied, such as where kerb and channel is being constructed. In such instances the Administrator may allow this requirement to be relaxed.

To achieve the minimum compaction standard specified, the Contractor may need to employ larger rollers than may normally be used. Particularly where layer thicknesses are towards the maximum allowable limit, not less than one 21 tonne (minimum weight) vibrating steel drum roller should be used to compact plant-mixed heavily bound pavements, unless the Contractor can demonstrate that the required standards can be achieved with a smaller roller.

Additional rollers, including pneumatic (multi-tyred) rollers, may also be used.

8.2.7.2 Preparation of a heavily bound layer prior to placing the next heavily bound layer

Where a heavily bound pavement layer is to be overlaid directly with another heavily bound pavement layer (within the same course or not), the finished surface shall be hard-cut:

- after the completion of compaction, and
- within the same work shift as the material was placed, unless otherwise approved by the Administrator.

Hard-cutting the surface shall uniformly roughen the surface across the full width of the layer. Scratching or marking the surface is not sufficient.

The Contractor will nominate in their Construction Procedure the proposed methodology to hard-cut the pavement. The hard-cut may be undertaken using a grader (with a straight blade, serrated blade or toothed blade), by heavy brooming or with other plant. The nominated hard-cut process should be assessed as part of the paving trial.

Where the construction process does not allow the heavily bound pavement layer to be hard-cut within the same work shift as the material was placed, the Administrator may approve the Contractor to delay the hard-cut process provided the Contractor can demonstrate that their nominated process will achieve an acceptable surface. The longer a heavily bound material is left prior to hard-cut, the more effort will be needed to hard-cut the surface and the more chance there is of damaging the pavement if inappropriate equipment is chosen (for example, using a grader with straight blade to hard-cut cured heavily bound pavement).

Figure 8.2.7.2 – Example of acceptable hard-cut surface

Unless the overlying layer is being constructed in the same work shift, a cement slurry (refer Clause 6.4) shall be applied to the hard-cut surface prior to placing the next heavily bound pavement layer.

The surface shall be thoroughly swept with a road broom immediately prior to placement of the slurry or overlying layer. All foreign and loose material, including lenses of pavement material, shall be removed from the surface.

Success has been achieved on many projects using basic and readily available equipment to pump and spray the slurry onto the surface. This method also allows slurry application rates to be achieved accurately and significantly reduces wastage and excess run-off.

All hard-cut material shall be disposed of in accordance with Clause 10 of MRTS01 *Introduction to Technical Specifications*.

8.2.7.3 Placing multiple layers

Multiple layers shall not be placed over one another within the same work shift unless otherwise approved by the Administrator.

Where the Administrator permits multiple layers to be placed in the same work shift, the requirements of Clause 8.2.7.2 shall apply – that is:

- The underlying layer shall be hard cut, and
- A cement slurry is not required between the layers.

This Clause is intended to be used in circumstances where there are significant benefits to the Principal from placing multiple layers in a single shift, and should not be applied to general construction. Accepting multiple layers to be placed in a single shift places increased risk on the Principal.

This provision would mainly be considered where road closures require accelerated construction and the Principal wishes to utilise heavily bound pavement material (as opposed to an alternative material such as asphalt).

For an Administrator to permit placing multiple layers in the same work shift, the Principal may need to relax the requirements of Hold Point 5 (refer Clause 9.5.1) with regards to proof rolling and time of compaction testing (not compaction conformance). Note that:

- As specified in Table A1 of Appendix A, a lot of heavily bound pavement material is a continuous single layer constructed in one days production, and
- As specified in Clause 9.5.1, each lot shall be conformed prior to being covered with the subsequent layer of pavement.

Where a Contractor wishes to utilise this provision, this should be specifically agreed during the tender process.

8.2.8 Surface finish

Notwithstanding the requirements for hard-cutting – from when the layer is presented to the Administrator for inspection (refer Hold Point 5), until immediately prior to covering, the finished surface of any heavily bound pavement layer shall:

- be hard and homogenous in appearance
- not be friable when subject to mechanical brooming
- not have transverse shrinkage cracks
- not have any loose, segregated or contaminated areas
- have the course particles slightly exposed
- not be affected by delamination
- not show signs of water pumping, and
- not visibly deflect under load when proof rolled in accordance with Clause 9.4.10.

For layers that are to be covered by a sprayed bituminous treatment, the surface shall have a maximum ball penetration value that complies with Clause 8.3.8.

Where a heavily bound pavement layer is required to be covered by a sprayed bituminous treatment, particular attention needs to be given to the surface finish of the heavily bound pavement layer in order to ensure good adhesion. This is particularly relevant when the treatment includes polymer modified bitumen.

The following factors are important to ensure the successful adhesion of a sprayed bituminous treatment:

- all dust must be removed from the pavement immediately before spraying
- compaction of heavily bound pavement materials may form a thin lens of dried slurry on the surface of the pavement. This can appear hard, however may be prone to ‘shattering’ or delamination and should be removed before spraying
- the surface ‘tightness’ of heavily bound pavement layers would typically warrant the specification of an AMC00 prime (or an equivalent emulsion prime accepted by the Administrator). However the effectiveness of any prime should be assessed in field trials.

Inadequate curing can lead to an excessively dusty surface, which may be difficult to prepare. To address this, curing should be undertaken to ensure the pavement remains continuously damp.

8.2.9 Curing and covering of constructed layers

Unless otherwise approved by the Administrator, each layer of heavily bound pavement material shall be covered with the next layer and/or a bituminous surfacing within seven days of placement.

Unless otherwise approved by the Administrator, heavily bound pavement layers must not be covered with a sprayed seal (including a prime) within 48 hours of placement or rainfall.

The Administrator may approve a heavily bound pavement layer to be covered with a sprayed seal (including a prime) within 48 hours of placement or rainfall where the pavement is a temporary pavement (≤ two year design life) and the Contractor is responsible for the pavement condition for the duration of the Contract.

At the completion of its construction, the surface of any layer shall be water cured until placement of the next layer of heavily bound pavement or the first layer of a bituminous surfacing is applied.

Unless otherwise approved by the Administrator, water curing shall be completed in accordance with Clause 8.2.1.5.

The number of applications of water shall be such that the surface remains continuously damp.

8.2.10 Construction joints between adjacent paving runs

To the extent practical, the Contractor shall spread the heavily bound pavement material in a manner that minimises the number of joints.

Joints shall be constructed such that the material at the joints complies in all ways with the requirements of this Technical Specification.

Longitudinal joints must comply with the following requirements unless otherwise approved by the Administrator:

a) joints shall be offset by a minimum of 150 mm from joints in the underlying layers, except where required otherwise to achieve the design shape (for example to construct a crowned pavement)

b) joints shall be located away from trafficked wheel paths, and

c) joints in the final (uppermost) layer of heavily bound base courses shall coincide with the final traffic lane markings and/or line of change in crossfall (for example, crown of the pavement).

Transverse joints must be offset by a minimum of 2.0 m from a joint in any underlying layer, unless otherwise approved by the Administrator.

The Administrator may approve longitudinal joints in the final (uppermost) layer of the base course to be constructed away from lane markings where this represents the best outcome to achieve the pavement design intent. For example, when paving a single lane ramp with wide shoulders, the Administrator may allow the Contractor to form a single longitudinal joint along the centre of the ramp rather than paving the ramp lane between the edge line markings and the subsequently paving shoulders on either side.

8.2.10.1 Fresh joints

A construction joint shall be deemed ‘fresh’ when the material on each side of the joint has been stabilised, placed and compacted within the allowable working time (refer Clause 8.2.2) of the material that was laid first.

To construct a fresh joint between adjoining or adjacent runs, the outside 300 mm of material from the first run shall be left uncompacted until the adjacent material is ready for compaction.

When compacting the fresh mix against the face of the existing layer, the roller shall be partly supported on the previously compacted portion of the layer that was laid first.

8.2.10.2 Other joints

Joints that are not fresh shall have the edge of the existing layer cut back to form a neat, clean, vertical face. The cut back distance shall be the greater of:

a) The distance required to cut back into the area of existing material that is compacted to the standard specified in Clause 8.3.4, or

b) 150 mm.

Unless otherwise approved by the Administrator, immediately before placing an adjoining or adjacent layer, the cut back edge of the existing layer shall have a cement slurry applied (refer Clause 6.4).

All cut back material shall be disposed of in accordance with Clause 10 of MRTS01 *Introduction to Technical Specifications*.

8.2.11 Trafficking during construction

Unless otherwise specified in Clause 3 of Annexure MRTS08.1 or approved otherwise by the Administrator, the following requirements shall apply:

a) Heavily bound pavement layers shall not be opened to either construction traffic (other than needed to construct the lot) or general traffic until the lot has been tested for, and passes proof rolling in accordance with Clause 9.4.10.

b) Pavements containing heavily bound pavement layers shall not be opened to general traffic within seven days of the completion of construction of the heavily bound pavement layers.

The Administrator may permit a pavement containing heavily bound pavement layers to be trafficked by general traffic within seven days of the completion of construction of the heavily bound pavement layers where it is not practical to otherwise restrict doing so. For example, on a two-lane two-way road where side-tracking is not practical and the works are required to be built 'under traffic.'

In such circumstances, it would be expected the Contractor seeks clarification at the time of tender if this requirement can be varied.

The Administrator may also permit a pavement containing heavily bound pavement layers to be trafficked within seven days of the completion of construction of the heavily bound pavement layer where the pavement is a temporary pavement (≤ two year design life) and the Contractor is responsible for the pavement condition for the duration of the contract.

Where a heavily bound layer is permitted to be trafficked, the requirements for curing as per this Technical Specification must still be complied with.

The presumptive design modulus values provided in the Transport and Main Roads *Pavement Design Supplement* are based on the assumption that the heavily bound pavement is not trafficked for seven days after the completion of construction. These values may need to be reduced where the pavement is permitted to be trafficked earlier. The pavement thickness may therefore need to be reviewed and advice should be sought from the pavement designer.

8.2.12 Contractor's responsibilities

The Contractor shall maintain each layer such that it complies with all aspects of this Technical Specification until it has been overlaid with another pavement layer or surfaced with the final wearing surface, and then until the end of the defect liability period or as otherwise required under the Contract.

8.3 Product standards

8.3.1 Segregation

Segregation is the uneven distribution of particle sizes. The construction process shall control segregation so that the particle size distribution of the heavily bound pavement material complies with the particle size distribution requirements of the specified unbound pavement material prior to the commencement of compaction.

Where there are visible signs of segregation in any lot prior to the commencement of compaction, the Administrator may direct the area to be tested for conformance with the above requirements.

As the addition of stabilising agents is intended to bind unbound pavement materials, care needs to be taken in determining if a mix has in fact segregated. Typically if segregation testing is undertaken for heavily bound pavement materials, the proportion of the grading passing the 2.36 mm sieve would be disregarded.

8.3.2 Actual content of stabilising agent

The actual content of stabilising agent during production (determined using Test Method Q134) shall comply with the requirements specified in Table 8.3.2.

The target content of stabilising agent shall be as per Clause 7.3.2.

Table 8.3.2 – Stabilising agent content requirements

Property	Minimum Value	Maximum Value
Actual stabilising agent content	target content minus MPV	target content plus MPV

8.3.3 Unconfined compressive strength

UCS results for the production of heavily bound pavement materials must comply with the requirements specified in Table 8.3.3.

Table 8.3.3 – UCS requirements

Material	UCS (7day)	
	Minimum Value	Maximum Value
Category 1 or Category 2	$UCS_{7\text{-lower}}$*	$UCS_{7\text{-upper}}$*

Notes:

* Refer Clause 7.4.

28 day UCS testing has been specified for undertaking mix designs for heavily bound pavement materials as longer curing times are more suitable for a wider range of stabilising agents, including slower setting binders that may continue to increase in strength significantly beyond seven days. This is particularly important for heavily bound pavements where any cracking due to over-stiffening may significantly impact on pavement performance. However, for production conformance, it is recognised that 28 day testing is impractical, and as such the relationship between seven and 28 day UCS testing must be determined.

8.3.4 Compaction standard

The characteristic value of relative compaction must comply with the requirements specified in Table 8.3.4(a).

Table 8.3.4(a) – Compaction requirements

Material	Location	Minimum Value
Category 1 or Category 2	Upper most layer of base course	102% (Standard Compaction)
	All other cases	100% (Standard Compaction)

Where the use of IC Rollers is specified in Clause 2.2 of Annexure MRTS08.1, the lot coverage must comply with the requirements specified in Table 8.3.4(b).

Coverage shall be calculated as:

1. The area of the lot (that is to be incorporated into the Works) which has achieved the minimum number of roller passes nominated in the Heavily Bound Pavement Construction Procedure, divided by
2. the total area of the lot that is to be incorporated into the Works.

Table 8.3.4(b) – IC Roller Coverage

Property	Minimum Value
IC Roller coverage	90%

8.3.5 Geometrics

8.3.5.1 General

The pavement shall be constructed so as not to depart from the widths, length, height and shape specified in the design documentation by more than the tolerances stated in this clause.

The widths and heights of the surface of layers other than the final layer shall be calculated by the Contractor using the widths, heights and shapes for the completed pavement, and the depth to the surface of the particular layer within the pavement as described in the design documentation.

The location of longitudinal joints in paving runs must also comply with the requirements of Clause 8.2.10.

8.3.5.2 Geometrics, horizontal tolerances

The horizontal location of any point on the pavement shall not differ from the corresponding point shown in the design documentation, or the point calculated as described in Clause 8.3.5.1, by more than ± 50 mm except for the following situations:

a) for pavement edges not adjacent to any other part of the pavement and not adjacent to any fixed infrastructure or adjoining road, the transverse tolerance shall be – 50 mm, + 250 mm (where the + tolerance is in the direction which increases the width of the pavement), and

b) where alignment of the pavement with an existing pavement or piece of fixed infrastructure is necessary, the new work shall be joined neatly to the existing work in a smooth manner as shown on the drawings, or if this is not shown, in a manner approved by the Administrator.

8.3.5.3 Geometrics, vertical tolerances

The vertical tolerances as specified in Table 8.3.5.3 shall apply for:

- the surface level (height) measured at any point on the surface of any layer, and
- the average total thickness of the heavily bound pavement constructed under the Contract in accordance with this Technical Specification. Assessed as either:
  - where the pavement contains only a single heavily bound pavement layer – the average thickness of that individual layer, or
  - where the pavement contains multiple heavily bound pavement layers constructed immediately over one another in accordance with this Technical Specification – the average total thickness of the overall heavily bound pavement material.

Table 8.3.5.3 – Primary geometric tolerances

Surface Level / Height (Individual)		**Total Thickness (Average)**
When Covered with Asphalt Surfacing ≤ 50 mm Thick	**All Other Cases**	
± 10 mm	± 15 mm	- 20 mm + unspecified

Where the pavement is required to be hard-cut as specified in Clause 8.2.7.2, these tolerances shall apply after the pavement has been hard-cut and prepared ready for construction of the overlying layer.

At all times the Contractor shall target construction at the mid-point of the surface level tolerances.

8.3.5.4 Crossfall

For the final (uppermost) layer of base course constructed under the Contract from heavily bound pavement materials, the crossfall shall not depart from the design crossfall by more than 0.5% absolute.

The crossfall shall be measured:

a) between any two points more than two metres apart (excluding where the overall width of a single crossfall is less than two metres wide). For crossfalls less than two metres wide, the measurement shall be made between the extreme edges of the crossfall as shown in the design documentation

b) transverse to the centre line, and

c) within the boundaries of a cross-section element which has a constant crossfall as shown in the design documentation.

8.3.6 Deviation from a straight-edge

The deviation from a three metre long straight-edge placed anywhere on the surface of the final (uppermost) layer of a base course to be constructed under the Contract, shall be in accordance with the requirements of Table 8.3.6 with due allowance being made for design shape, where relevant.

Table 8.3.6 – Requirements for deviation from a straight-edge

Tolerance Alternative	Maximum Value
Alternative C	5 mm
Alternative D	8 mm

8.3.7 Road roughness (surface evenness)

Unless otherwise specified in Clause 2.4 of Annexure MRTS08.1, for base courses constructed from heavily bound pavement materials, the road roughness of the final (uppermost) layer to be constructed under the Contract, shall be in accordance with the requirements of Table 8.3.7.

Table 8.3.7 – Road roughness requirements for heavily bound bases

Property	Maximum Value
Road roughness (Rs) (m/km)	2.31

The Administrator may waive the requirement for roughness testing of the heavily bound base when the heavily bound base will be overlaid with asphalt or another pavement material within the same contract, and there is a roughness requirement specified elsewhere in the contract for the overlying layer.

Calculation of road roughness should accurately represent the ride quality of the complete pavement. It is generally accepted that the inclusion of other road features within the pavement are likely to reduce ride quality.

In accordance with the test method adopted, these features are required to be noted during roughness testing. The following features are typically allowed to be excluded from the ride quality assessment:

- roundabouts
- railway lines
- bridge joints, and
- inspection pit covers (for example, drainage manholes).

The Contractor should nominate a methodology and provide calculations on ride quality for the Administrators acceptance, showing how each feature has been excluded from the assessment and the subsequent lot structure.

Under no circumstances should pavement features (including joints) or signalised / unsignalised intersections (other than roundabouts) be excluded from the ride quality assessment without the express agreement of the Administrator.

8.3.8 Ball Penetration

For heavily bound pavement layers that are to be covered be a sprayed bituminous treatment, the surface shall have a maximum ball penetration value that complies with the requirements specified in Table 8.3.8.

Table 8.3.8 – Ball penetration requirements for heavily bound pavements

Property	Maximum Value
Ball Penetration	3 mm

9 Compliance testing

9.1 General

Compliance testing of plant-mixed heavily bound pavements shall be undertaken on a lot basis in accordance with MRTS01 *Introduction to Technical Specifications*.

For each lot, the Contractor is responsible for performing sufficient tests to ensure that the pavement complies in all regards with the requirements of this Technical Specification. As a minimum the Contractor's testing program shall not be less than that specified in this clause.

The Contractor shall ensure that sufficient, clearly documented construction compliance records are provided to the Administrator to ensure that traceability of unbound pavement materials is provided from their source (for example, quarry face) to the constructed pavement.

Maximum lot sizes, minimum test frequencies and the minimum number of tests required are specified in Appendix A.

Where testing frequencies are specified as a number of tests per a quantity, the tests should be representative of the quantity of materials nominated, or part thereof.

For example, if a frequency of 1 test per 1000 m² is nominated, and a lot includes 2500 m² of that material a minimum of three tests would be required.

9.2 Test locations

Locations for compliance testing shall be selected by random stratified sampling as specified in Test Method Q050. Representative sampling shall be undertaken as detailed in Test Method Q060. Spot sampling shall be undertaken as detailed in Test Method Q061.

9.3 Maximum lot sizes

The maximum lot sizes for plant-mixed heavily bound pavement works shall be as specified in Table A1 of Appendix A.

9.4 Compliance testing requirements

9.4.1 Segregation

Minimum testing frequencies for segregation shall be as specified in Table A3 of Appendix A.

The Administrator may direct additional testing of any areas which show visible signs of segregation during construction.

9.4.2 Compaction

Minimum testing frequencies for compaction shall be as specified in Table A3 of Appendix A.

The compaction standard for each lot shall be represented by the minimum characteristic value of relative compaction. The characteristic value shall be calculated in accordance with Test Method Q020 using the individual relative compaction results reported for each lot.

For each lot where IC is used, the Contractor shall use Veta to analyse the IC data for coverage.

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 has been be output directly from Veta). The Veta report shall include the locations and values of all individual compaction compliance test results.

All data and files must be clearly linked to the construction lot which they relate to.

> The Veta software is freely available on the website https://www.intelligentconstruction.com/

9.4.3 Unbound pavement material

Minimum testing frequencies for unbound pavement materials shall be as specified in MRTS05 *Unbound Pavements*.

For each heavily bound pavement lot, the Contractor shall provide the unbound pavement material source and product test results to confirm that the unbound material conforms to the requirements of MRTS05 *Unbound Pavements*.

9.4.4 Stabilising agent and chemical admixture certification

For each heavily bound pavement lot, the Contractor shall provide written certification from the stabilising agent and chemical admixture supplier, with supporting test results, confirming that the material delivered conforms to the requirements of Clause 6.2 and Clause 6.3.

Where the stabilising agent is a blend, the Contractor shall also certify for each pavement lot that the proportions of the blend comply with that nominated in the mix design report (refer Clause 7.4)

9.4.5 Cement slurry

For each lot where a cement slurry is incorporated into the works, the Contractor shall report the average spread rate of the slurry by reconciling the amount of slurry spread (measured my mass) over the area treated.

9.4.6 Stabilising agent content

Minimum testing frequencies for stabilising agent content shall be as specified in Table A2 of Appendix A.

The actual content of stabilising agent determined using Test Method Q134 for each lot shall be represented by both the:

a) minimum characteristic value of the actual content of stabilising agent, and

b) maximum characteristic value of the actual content of stabilising agent.

9.4.7 Mixing plant variability

Minimum testing frequencies for mixing plant variability shall be as specified in Table A2 of Appendix A.

For each lot, the accuracy of the system used to dispense stabilising agent shall be verified by reconciliation between:

a) *The stabilising agent used*

The actual (measured) amount of stabilising agent added to the pug mill (refer Clause 8.2.1.2) to produce the lot, and

b) *The amount of unbound pavement material used*

The amount of unbound pavement material used in the heavily bound pavement material shall be established based on the wet mass of mixture, as shown on weighbridge records, adjusted to a dry mass (using the average measured moisture content of the mixture for the Lot), minus the mass of stabilising agent used.

The average stabilising agent content can then be calculated as a percentage by dry mass of the unbound pavement material.

Alternatively, for assessment of the accuracy of the system, the Contractor may propose an alternative compliance method, such as one that includes a continuous (real time) data collection system of the throughput mass of all constituent materials. Any proposed alternative must be approved by the Administrator prior to use.

Example of approach to calculate average stabilising agent content:

The stabilising agent used

- production records shown 6 tonnes of stabilising agent was added to the pug-mill to produce a lot

The amount of heavily bound pavement material produced

- weight bridge records show a total of 200 tonnes of heavily bound pavement materials was produced in the same lot
- moisture content testing for the lot returned an average result of 7.5%
- the equivalent dry tonnage of the mixture would therefore be calculated as 186 tonnes
- the equivalent dry tonnage of unbound pavement material used would be 180 tonnes
- the average stabilising agent content is therefore 3.33%

Testing for mixing plant variability is not intended to assess the plant performance during production against the MPV nominated in the mix design process.

While there is no specific specification limit for this property, excessive variation in the actual mixing plant variability during production should be investigated by the Contractor, and consideration given to reviewing process controls accordingly.

9.4.8 Moisture content

Minimum testing frequencies for moisture content testing shall be as specified in Table A2 and Table A3 of Appendix A.

The moisture content of each lot shall be represented by the individual moisture content results.

9.4.9 Unconfined compressive strength

Minimum testing frequencies for unconfined compressive strength (UCS) testing shall be as specified in Table A2 of Appendix A.

When UCS tests are being undertaken, the sample being used must also be tested for stabilising agent content and moisture content.

Conformance testing for UCS and stabilising agent content must be undertaken in accordance with the time requirements given in the respective Test Methods. Under normal circumstances, these tests would all be undertaken on samples taken from material being discharged directly from the pug mill. These results would therefore represent material properties at the point of production.

Material properties at the point of placement are controlled by ensuring materials are placed within the allowable working time, which allows a reduction in both the UCS and maximum dry density of the material as detailed in Test Method Q136A. However, there is no specific requirements that the material is tested for conformance in this regard.

9.4.10 Proof rolling

Each heavily bound pavement layer shall be tested for perceptible surface deformation by ‘proof rolling’ the pavement, in the presence of the Administrator. **Witness Point 2** All areas of heavily bound pavements shall be ‘proof rolled’, including all trafficked lanes, shoulders and other areas.

Testing shall be undertaken in accordance with Test Method Q723. Testing for perceptible surface deformation is exempt from the requirement for NATA accreditation or Construction Material Testing (CMT) registration.

In areas where perceptible surface deformation is observed, the Contractor shall remove and replace the affected section, or take other corrective action to the satisfaction of the Administrator. In doing so, the Administrator may require the Contractor to carry out additional compliance testing to ensure that the affected section of pavement complies with Clause 8.2.5 and 8.3.4. No additional payment will be made by the Principal for any such additional testing.

The proof rolling result reported for any lot shall be representative of the condition of the lot immediately prior to it being covered by another pavement layer. If the pavement lot has been subjected to rainfall or moisture ingress in any way since proof rolling was undertaken, the Administrator may direct the Contractor to retest the lot to prove conformance. If the retested results do not comply with the requirements of this Technical Specification, the Contractor shall dry back and/or reprepare the pavement such that it complies with the requirements of this Technical Specification. No additional payment will be made by the Principal for any such additional efforts.

Test Method Q723 provides a method for using either a 7,000 L single rear axle or 10,000 L tandem rear axle loaded water tanker for proof rolling.

9.4.11 Ball penetration

For heavily bound pavement layers that are to be covered by a sprayed bituminous treatment, the Contractor shall undertake ball penetration testing in accordance with Test Method AG:PT/T251 on the completed layer prior to undertaking the sprayed bituminous treatment.

Minimum testing frequencies for ball penetration testing shall be as specified in Table A3 of Appendix A.

In accordance with Test Method AG:PT/T251, ball penetration results shall be reported as both individual and average values.

For the average value to be adopted for lot conformance and seal design purposes, the results must be representative of a homogeneous section of pavement. Any areas represented by excessively low or high individual values should be considered for sub-lotting, and may require additional construction or testing actions before they can be incorporated into the final works. Any such works shall be undertaken by the Contractor at no cost to the Principal.

The ball penetration result reported for any lot shall be representative of the condition of the lot immediately prior to it being covered. If the pavement lot has been subjected to rainfall or moisture ingress in any way since ball penetration testing was undertaken, the Administrator may direct the Contractor to retest the lot to prove conformance. If the retested results do not comply with the requirements of this Technical Specification, the Contractor shall dry back and/or reprepare the pavement such that it complies with the requirements of this Technical Specification. No additional payment will be made by the Principal for any such additional efforts.

9.4.12 Geometrics and deviation from a straight edge

Minimum testing frequencies for geometric tolerances and deviation from a straight edge shall be as specified in Table A4 of Appendix A.

Horizontal position, vertical levels, crossfall and layer thickness shall be determined by survey unless otherwise agreed by the Administrator.

9.4.13 Road roughness (surface evenness)

The road roughness of the final (uppermost) layer of all heavily bound bases shall be measured by Test Methods Q708B, Q708C or Q708D.

For road roughness testing, a lot shall not be less than 100 m or greater than 500 m in length, unless otherwise approved by the Administrator. Areas of pavement affected by roundabouts, railway lines, bridge joints and inspection pit covers may be excluded from ride quality assessment.

Road roughness testing is not required to be undertaken on subbase layers.

9.5 Compliance testing results

9.5.1 Acceptance of lots

Unless otherwise approved by the Administrator, no layer of heavily bound pavement shall be covered by a subsequent layer of pavement or by a surfacing until **Hold Point 5**:

a) all testing has been completed (other than UCS testing)

b) the surface finish of the layer complies with the requirements of Clause 8.2.8

c) all test results (other than UCS testing) comply with the requirements of this Technical Specification, or any non-conformances have been submitted, with corrective actions proposed by the Contractor, and accepted by the Administrator

d) all (production) UCS test results for preceding heavily bound pavement lots constructed more than 10 working days prior comply with the requirements of this Technical Specification, or any non-conformances have been submitted, with corrective actions proposed by the Contractor, and accepted by the Administrator

e) the layer has been presented to the Administrator for inspection, and

f) the As-Constructed Survey requirements of the lot have been met as specified in MRTS56 *Construction Surveying* and notice of such works has been provided to the Administrator.

9.5.2 Recurring nonconformances

A nonconformance is considered recurring when more than 5 out of the most recent 20 test results for the following properties are nonconforming:

a) unbound pavement material properties

b) unconfined compressive strength, or

c) actual stabilising agent content.

Where a recurring nonconformance occurs, the Contractor shall cease using the mix, retest the plant-mixed heavily bound pavement material and resubmit the mix design report in accordance with Clause 7.4.

9.5.3 Nonconformances with compressive strength or stabilising agent requirements

Where the UCS or Actual Content of Stabilising Agent test results for any lot do not comply with the requirements of this Technical Specification, the Contractor shall cease using the mix, review the mix design, and propose to the Administrator how the mix design will be adjusted to ensure compliance with this Technical Specification **Nonconformance**

Works shall not continue until the proposed actions outlined in the NCR are accepted by the Administrator. **Hold Point 6**

Unless a recurring nonconformance has been triggered, the mix is not required to be retested or the mix design resubmitted.

Where UCS results are nonconforming the lot must be assessed for its suitability to be incorporated into the permanent works. This should be done by the RPEQ Pavement Designer responsible for the project.

10 Supplementary requirements

The requirements of this Technical Specification are varied by the supplementary requirements specified in Clause 4 of Annexure MRTS08.1.

Appendix A: Maximum lot sizes and minimum testing frequencies

Table A1 – Maximum lot size requirements

Construction Activity	Maximum Lot Size
Supply of unbound pavement materials	Refer MRTS05 *Unbound Pavements*
Construction of heavily bound pavements	A continuous single layer constructed in 1 day's production
Road roughness testing	500 m

Table A2 – Heavily bound pavement materials – source and product testing

Property	Test Method	Lot Size	Normal Testing Level		Reduced Testing Level	
			Minimum Testing Frequency	Minimum No. of Tests	Minimum Testing Frequency	Minimum No. of Tests
Unbound pavement material (source and product)	Refer MRTS05 *Unbound Pavements*					
pH (water)	APHA 4500-H B	–	Before use and then at 12 month intervals			
Conductivity (water)	APHA 2510-B					
Sulfate content (water)	AS 1289.4.2.1#					
Stabilising agent content (heat of neutralisation)	Q134	≤ 100 t	–	1 per lot	–	1 per lot
		> 100 t	1 per 300 t	2 per lot	1 per 500 t	2 per lot
Stabilising agent content (mixing plant variability)	Refer Clause 9.4.7	Any	–	1 per lot	–	1 per lot
Moisture content (sampled at plant)	AS 1289.2.1.1 AS 1289.2.1.4 or AS 1289.2.1.6	≤ 100 t	–	1 per lot	–	1 per lot
		> 100 t	1 per 300 t	2 per lot	1 per 500 t	2 per lot
	AS 1289.2.3.1	–	1 per material type if subsidiary methods used			
Unconfined compressive strength (7 day)	Q115	≤ 200 t	–	–	–	–
		> 200 t	1 per 1000 t*	1 per lot	1 per 1000 t*	1 per lot

Notes:

* 1 test is the average of 3 individual UCS specimens.

Or other published or validated classical chemistry technique or instrumentation technique.

Table A3 – Construction standard testing

Property	Test Method	Normal Testing Level		Reduced Testing Level	
		Minimum Testing Frequency	**Minimum No. of Tests**	**Minimum Testing Frequency**	**Minimum No. of Tests**
Segregation	Q103A	1 per lot (Additional testing as directed by the Administrator)			
Moisture Content (sampled in field prior to compaction)	AS 1289.2.1.1, AS 1289.2.1.4 or AS 1289.2.1.6	1 per 500 m²	4 per lot	1 per 1000 m²	4 per lot
	AS 1289.2.3.1	1 per material type if subsidiary methods used			
Compaction	Q140A	1 per 500 m²	4 per lot	1 per 1000 m²	4 per lot
Proof rolling	T198	Refer Clause 9.4.10			
Ball penetration testing	AG:PT/T251	**For heavily bound pavement layers where the final surfacing (to be trafficked) is a sprayed bituminous treatment:** • 5 test chainages per lot • Test chainages (longitudinal coordinates) determined in accordance with Test Method Q050 – random stratified • At each test chainage an individual test must be undertaken in both the inner and outer wheel path for each traffic lane in the lot at that chainage. **For heavily bound pavement layers where the final surfacing (to be trafficked) is not a sprayed bituminous treatment (ie. the sprayed bituminous treatment will be covered by asphalt):** • 5 test chainages per lot • Test chainages (longitudinal coordinates) determined in accordance with Test Method Q050 – random stratified • At each test chainage one individual test must be undertaken at the offset (lateral coordinate) determined in accordance with Test Method Q050 – random stratified.			

Table A4 – Geometrics testing

Property	Test Method	Normal Testing Level	Reduced Testing Level
Layer thickness	Survey	1 per 20 linear m	1 per 50 linear m
Horizontal position & vertical levels	Survey	Each 20 linear metres^ - measured at all shoulder edges, lane lines and other changes in grade across the pavement	
Deviation from a straight edge	Q712	a) **within lane**: 1 per 20 linear metres^ along each paving run, unless otherwise approved by the Administrator. Measurements shall be taken in both the transverse and longitudinal directions. b) **longitudinal joint**: 1 per 20 linear metres^ along each joint, unless otherwise approved by the Administrator. c) **transverse joint**: 1 measurement per joint in each wheel path in each lane. For the measurement of joints, place the straightedge on the completed layer, perpendicular to the joint. With the end of the straightedge directly over the joint, gradually move the straightedge across the joint for its full length and identify the point on the layer that produces the largest deviation under the straightedge (between two points of contact). Record the deviation at this point. For all joints that tie the new works to existing pavement (not constructed under the Contract), place the straightedge on the road surface perpendicular to the joint. With the end of the straightedge directly over the joint and the other end located within the works, record the largest deviation under the straightedge (between two points of contact).	
Crossfall	Survey	1 per 20 linear metres^ – measured for all crossfalls shown in the design documentation at the point of testing	
Road roughness	Q708B, Q708C or Q708D	Refer Clause 9.4.13	

Notes:

^ The Administrator may approved the adoption of a reduced testing frequency of 1 per 50 m in ‘mid-block’ applications (that is, areas of pavement not located in the vicinity of intersections, roundabouts, steep grades and/or sharp curves).