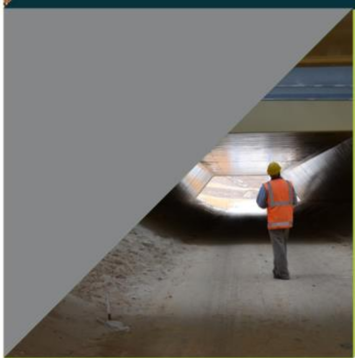
WARRIP

WESTERN AUSTRALIAN ROAD RESEARCH
AND INNOVATION PROGRAM

High Modulus Asphalt (EME2)

Tonkin Hwy - Kelvin Road Intersection



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AN INITIATIVE BY:

THE GOVERNMENT OF WESTERN AUSTRALIA

mainroads WESTERN AUSTRALIA

arrb AUSTRALIAN ROAD RESEARCH BOARD

High Modulus Asphalt (EME2)

Report 3 of 3

for Main Roads Western Australia

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SUMMARY

This report presents details of an EME2 (Enrobés á Module Élevé Class 2) asphalt production and placement pre-trial and trial that took place in April 2017 at the intersection of the Tonkin Highway and Kelvin Road in Perth, Western Australia. The purpose of the trial was to confirm that the design mix could be manufactured, placed and compacted to the expected standards using local materials and locally-available equipment. A key aspect was to include guidance on the construction process with input from expert EME2 practitioners brought over for the trial. The conduct of a successful trial would assist Main Roads and industry to successfully transfer the French EME2 technology to Western Australia. The trial was conducted as part of the Western Australia Road Research and Innovation Program (WARRIP).

Based on the results of laboratory testing conducted on cores, it can be concluded that EME2 can be successfully produced and placed using local aggregates and locally-available equipment. EME2 achieved the target thickness, very high density and low in situ air voids on both layers.

To achieve optimum quality control, it is essential that a thorough plan – in terms of production, placement and safety – be developed if EME2 asphalt is to be successfully implemented.

It is recommended that, during compaction, the rollers should not remain stationary on the newly-compacted asphalt or following the completion of the works until it cools as this could leave deep imprints on the asphalt surface. It is also recommended that the method of joint construction adopted for Lift 2 of the trial be adopted for future EME2 asphalt pavements to reduce air voids along the joint lines.

This report also summarises the knowledge transfer activities undertaken and the proposed changes to the current Main Roads EME2 specification and Engineering Road Note.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of Main Roads WA, the Queensland Department of Transport and Main Roads, Downer Group WA, SAMI Bitumen Technologies and Mr Pierrick Dupuy of COLAS in the conduct of this project and the preparation of this report.

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1 INTRODUCTION

EME2 is a high modulus asphalt where mixes are produced using a hard-paving grade bitumen which is applied at a higher binder content (approximately 6%) with low air voids content (typically 2–4%) compared with conventional asphalt with unmodified binders. High modulus asphalt is characterised by high stiffness, high durability, superior resistance to permanent deformation, good fatigue resistance and good workability. As a result, it potentially allows for a significant reduction in pavement thickness.

This report presents a record of an EME2 (Enrobés á Module Élevé Class 2) asphalt production and placement field trial as well as a pre-trial performed on 12 April 2017 at Downer Group's asphalt plant yard in Gosnells to adjust the EME2 construction processes (details are presented in Appendix B). The main trial took place on 26 and 27 April 2017 at the intersection of the Tonkin Highway and Kelvin Road in Orange Grove, WA. The purpose of the trial was to confirm that the design mix could be manufactured, placed and compacted to the expected standards using local aggregates and locally-available equipment. A key aspect was to include guidance on construction processes with input from expert EME2 practitioners brought over for the trial. The conduct of a successful trial would assist Main Roads Western Australia (Main Roads) and industry to successfully transfer the French EME2 technology to Western Australia. The trial was conducted as part of the Western Australia Road Research and Innovation Program (WARRIP).

The mix was produced at Downer Group's Gosnells plant. The total quantities of EME2 that were produced and placed for the pre-trial and main trial were 100 tonnes and 998 tonnes respectively.

1.1 Details of the Trial

The trial involved the following tasks:

- design of an EME2 asphalt mix in accordance with the Australian EME2 asphalt mix design process
- validate the EME2 asphalt mix in a French EME2 asphalt laboratory to confirm compliance with French methods
- identify the location of the trial and selection of a suitable test site
- develop a draft guideline for the structural design of pavements containing EME2
- design and construct a full-depth EME2 asphalt pavement overlaid with a standard asphalt wearing course
- manufacture the EME2 mix in line with Main Roads' *Draft Specification 514 High Modulus Asphalt (EME2)* (Main Roads 2016b)
- report the findings of the trial and use of this information to revise, if necessary, Main Roads *Specification 514* (Main Roads 2016b) and Main Roads *Engineering Road Note 13* (ERN13) (Main Roads 2016c).

In addition, there was a need to assess the feasibility of producing and constructing EME2 using asphalt plants and road construction equipment currently available in WA by:

- using asphalt production control data to assess the variability of EME2 during production
- analysing in situ air void contents and checking the level of compaction
- monitoring the rolling pattern and recording mix temperatures throughout production and paving

- monitoring level control and rideability of the EME2 asphalt pavement.

Working Group meetings involving all parties to the trial (Downer Group, Main Roads, Colas and ARRB) were conducted prior to the trial commencing. Arrangements were also made for a Colas representative (EME2 expert) to oversee the trial and conduct a knowledge transfer (Section 10).

2 THICKNESS DESIGN

2.1 Introduction

The potential application of EME2 asphalt is in thick asphalt structures which are increasingly being used for heavily trafficked roads in Perth. Accordingly, the trial pavement consisted of:

- a wearing course of dense-graded asphalt with a polymer modified binder
- an intermediate course of EME2 asphalt
- crushed limestone subbase
- sand subgrade.

The structural design was determined using two methods, both of which resulted in similar pavement structures:

- Austroads design method (Section 2.2)
- French design method (Section 2.3).

As described in Section 5, the trial was constructed in the right-hand turning lanes from the Tonkin Highway southbound into Kelvin Road, Orange Grove.

The design traffic for the southbound carriageway of the Tonkin Highway used for the pavement design is shown in Table 2.1. This data was provided by Main Roads and reflects the design traffic over 20 years on the through lanes. It is important to note that a 20-year design was adopted as the intersection had been flagged for a possible grade separation in 10–15 years, therefore, adopting a 40-year design would have been excessive. Late in the planning stages, the location of the trial was moved from the through lanes to the turning lanes and the design undertaken was not replicated for the lower traffic.

Table 2.1: Design traffic data: Tonkin Highway, southbound carriageway

Design traffic (ESAs)	SAR5/ESA	SAR7/ESA
3.8E+7	1.13	1.64

2.2 Austroads Design Method

2.2.1 Characterisation of Asphalt Wearing Course

Presumptive values design modulus for the size 14 mm, A15E intersection mix were adopted in accordance with Main Roads *Engineering Road Note 9* (ERN9) (Main Roads 2013c) and the Austroads *Guide to Pavement Technology* (AGPT) *Part 2: Pavement Structural Design* (Austroads 2012).

For size 14 mm asphalt with Class C320 binder, the indirect tensile test (ITT) modulus of a typical laboratory-manufactured sample under standard test conditions and 5% air voids is 5000 MPa (Table 6.13 of Austroads 2012). The ITT modulus of a size 14 mm asphalt with type A15E polymer modified binder was estimated by multiplying the modulus of the C320 by an adjustment factor of 0.75 (Table 6.12 of Austroads 2012).

ERN9 (Main Roads 2013c) specifies that the in situ air voids and binder volume for size 14 mm intersection mixes should be at least 8.8% and 10.3% respectively, as indicated in Table 2.2.

To determine the design modulus of the wearing course, the presumptive ITT modulus (3750 MPa), was adjusted:

- from the measurement temperature (25 °C) to the weighted mean annual pavement temperature (WMAPT) for Perth (29 °C)
- from the ITT rise time of 40 ms to the heavy vehicle design speed (10 km/h because the location of the trial was near a signalised intersection)
- from the 5% air voids to a design air voids of 8.8%.

As listed in Table 2.2, the design modulus was determined to be 1000 MPa, the minimum allowable modulus using the Austroads (2012) design method.

Table 2.2: Design modulus determination: 14 mm intersection mix A15E

Asphalt mix	Laboratory values					In situ design values						
	ITT (MPa)	PMB factor	Air voids (%)	Temp. (°C)	Rise time (ms)	Air void V_{air} (%)	Binder volume V_{bit} (%)	WMAPT (°C)	HV design speed (km/h)	Calculated modulus (MPa)	Design modulus (MPa)	Parameter k
14 mm intersection mix (A15E)	5000	0.75	5	25	40	8.8	10.3	29	10	914	1000	5695

2.2.2 Characterisation of Asphalt Intermediate and Basecourse Layers

As there is no published guidance for the modulus of asphalt mixes with EME2 in either the Main Roads or Austroads guides, the Queensland Department of Transport and Main Roads (TMR) *Technical Note TN142* (TMR 2015a) was used to determine a design modulus.

The design moduli for an EME2 base asphalt at the WMAPT for Brisbane (32°C) are listed in Table 2.3. The design moduli at the WMAPT for Perth (29°C) were then calculated using Equation 1.

$$\frac{Modulus\ at\ WMAPT}{Modulus\ at\ 32°C} = e^{-0.08(WMAPT-32)} \qquad 1$$

where

$Modulus\ at\ WMAPT$ = design modulus for Perth

$Modulus\ at\ 32\ °C$ = design modulus for Queensland as per TN142

$WMAPT$ = weighted mean annual pavement temperature (Perth = 29 °C)

Table 2.3: Presumptive values for elastic characterisation of EME2 at WMAPT 32 °C and 29 °C

Asphalt mix	Binder type	Volume of binder (%)	WMAPT (°C)	Asphalt modulus at heavy vehicle operating speed (MPa)			
				10 km/h	30 km/h	50 km/h	80 km/h
EME2 asphalt base	EME binder (15/25 pen)	13.5	32	2000	3000	3600	4200
			29	2500	3800	4500	5300

Design values for WMAPT 29 °C have been rounded down.

2.2.3 Thickness Design

To calculate the design thickness, the following design inputs were used:

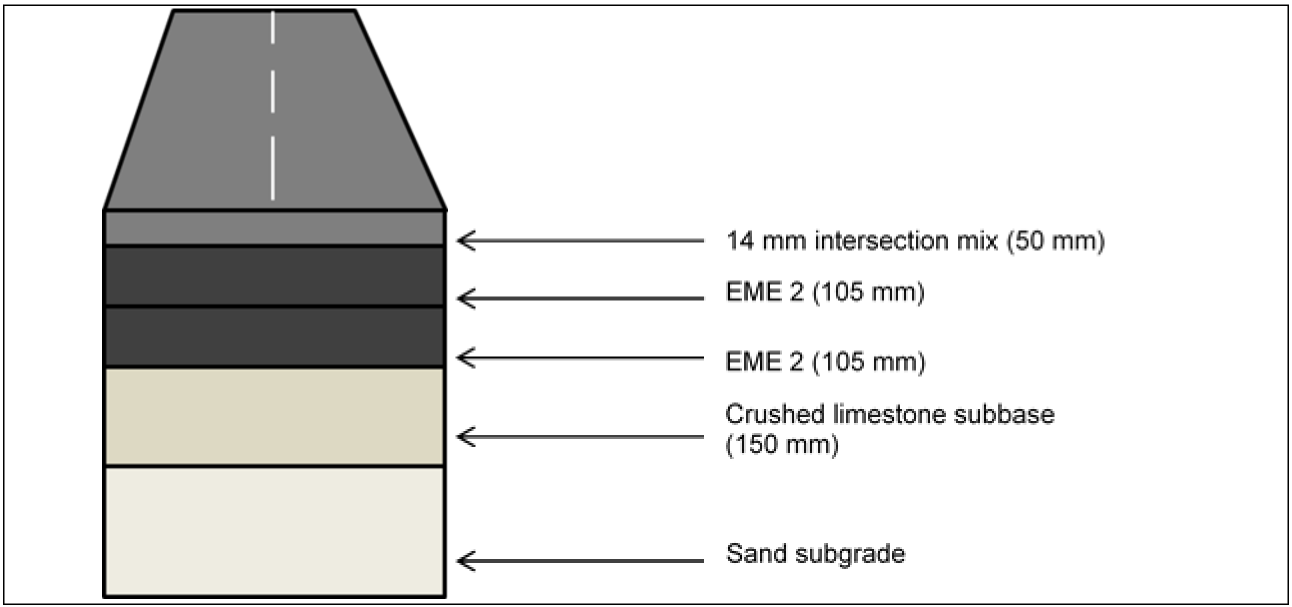
- characteristics of the asphalt mix (Table 2.2 and Table 2.3)
- modulus of the crushed limestone subbase and sand subgrade modulus in accordance with Main Roads (2013c)
- design traffic loading as described in Section 2.1.

For a subbase design modulus of 150 MPa and the design traffic, the cumulative damage factor (CDF) was determined using CIRCLY (Table 2.4). The final design pavement designed for through lanes in the EME2 trial was adopted for the turning lanes shown in Figure 2.1. It is important to note that the wearing course thickness was increased from 40 mm to 50 mm for levelling purposes as there was no 14 mm intermediate course for level control and to address the mix placement directly on top of the EME2 layers.

Table 2.4: Pavement design details: Tonkin Highway, southbound (10 km/h)

Material type	Modelled thickness (mm)	Design modulus (MPa)	Volume of binder (%)	Parameter k	CDF
Size 14 mm intersection mix (A15E)	50	1000	10.3	5695	
Size 14 mm EME2 mix	210	2500	13.5	5228	6.85E-01
Crushed limestone subbase	150	150	N/A	N/A	
Sand subgrade CBR 12%	Semi-infinite	120	N/A	N/A	1.67E-03
Asphalt thickness	260				

Figure 2.1: EME2 trial pavement thickness design

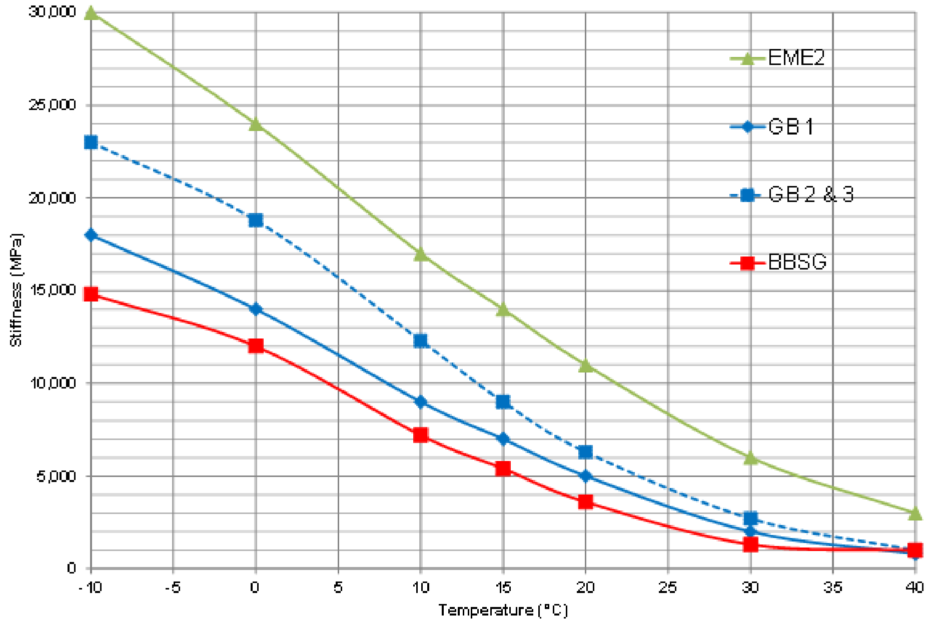


Source: ARRB.

2.3 French Pavement Design

The trial pavement structure was checked using the French mechanistic procedure in accordance with NF P 98-086 (AFNOR 2011). The pavement response was calculated using the software package ALIZÉ and the modulus values were selected based on the WMAPT for Perth (29 °C). The design modulus value for the EME2 mix was adopted from the presumptive modulus values presented in the Laboratoire Central des Ponts et Chaussées *French Design Manual for Pavement Structures* (LCPC 1997), which is in line with the material library of the software package ALIZÉ. The temperature dependency of the different asphalt types is presented in Figure 2.2.

Figure 2.2: Temperature dependency of different asphalt types (complex modulus at 10 Hz, 2-point bending)



Note: GB = 'grave-bitume' (road base asphalt), class 1 (3.5% bitumen, 0/20 grading), class 2 (4.2% bitumen, 0/14 grading), class 3 (4.5% bitumen, 0/14 grading) and BBSG = 'béton bitumineux semi-grenu' (semi-coarse asphalt), 0/14 grading

Source: Laboratoire Central des Ponts et Chaussées (1997).

The asphalt mix design parameters and assumptions made are shown in Table 2.5. The calculation of the allowable strains using the French pavement design method should consider the following:

- the design fatigue properties were calculated according to NF P 98-086 (AFNOR 2011)
- the minimum mix performance requirements were taken into account, i.e. 14 000 MPa modulus at 15 °C, 10 Hz and 130 με at 10 °C, 25 Hz.

Table 2.5: Design input for the Australian design procedure based upon French mechanistic procedure

Asphalt type	Design modulus (MPa)
BBSG (similar to 14 mm intersection mix)	1250(1)
EME2	6400(1)
Crushed limestone subbase	150
Sand subgrade CBR 10%	100

1. Refer to Figure 2.2

It should be noted that the Australian and French pavement design methods cannot be directly compared. Although they both utilise the mechanistic procedure, the amplitude of traffic loadings, shift factors, reliability factors and the fatigue properties are determined using separate methods. The major differences in the design procedures are shown in Table 2.6.

The pavement designs using the French method for a range of EME2 asphalt thicknesses are summarised in Table 2.7. It can be seen that the pavement consists of 230 mm of EME2 overlaid by 40 mm thick wearing course (excluding construction tolerances). This is similar to the thickness derived using the Australian procedure (220 mm + 10 mm tolerance = 230 mm).

Table 2.6: Comparison of the French and Australian pavement design input

Input	French method	Australian method
Number of vehicles	Similar	
Design traffic (NDT)	N/A	Required
Traffic load in equivalent standard axles $(NE)_{pavement}$	Required	N/A
Equivalent standard axles (ESA)	N/A	Required
Material parameters	Different	
Fatigue equations	Different	
Pavement design outcome	Very similar	

Source: ARRB.

Table 2.7: Tonkin Highway EME2 trial, pavement design according to French method NF P 98-086/ALIZE

Material type	Modulus (MPa)	Trial thickness 1		Trial thickness 2		Trial thickness 3		Allowable strain (micro strain)
		Thickness (mm)	Calculated strain (με)	Thickness (mm)	Calculated strain (με)	Thickness (mm)	Calculated strain (με)	
BBSG	1250	40	N/A	40	N/A	40	N/A	N/A
EME2	6400	210	72.6(1)	220	68.3(1)	230	64.3(2)	**67.4**
Crushed rock	150	150	N/A	150	N/A	150	N/A	N/A
Sand subgrade	100	N/A	194.4	N/A	182.2	N/A	171.2	**255.0**

1 Calculated strain is greater than allowable strain.
2 Calculated strain is lower than allowable strain.

Source: ARRB.

The allowable strains calculated according to the French pavement design method are summarised in Table 2.8.

Table 2.8: Pavement thickness design according to French method NF P98-086/ALIZE-EME2

Pavement structure	Property	EME2 allowable strain calculation input
Formation support	MPa	100
Traffic	Annual average daily traffic (AADT) (traffic class TS-)	1 690
	Design period - p (year)	40
	Annual growth rate (τ) (%)	2.6
	Cumulative growth factor over design period (C)	69
	Mean traffic aggressiveness $(CAM)_{pavement}$	0.8
	$NE_{pavement}$	33 933 920
	Number of heavy vehicles over design period (NPL)	42 417 400
Allowable subgrade vertical strain	Medium-heavy traffic	0.012
	CAM (subgrade)	0.8
	NE	33 933 920
	Exponent	–0.222
	$\varepsilon_{vertical}$	**255 E-06**
Allowable asphalt horizontal strain	$T_{equivalent}$	29
	E (10 °C, 10 Hz) (MPa)	17 000
	E (32 °C, 10 Hz) (MPa)	6 400
	ε_6 (10 °C, 25 Hz)	130E-6
	ε_6 (29 °C, 10 Hz)	105E-6
	Pavement thickness (cm)	26
	Formation support (MPa)	100
	Risk level associated with traffic class (%)	1
	Variable associated with risk (u)	–2.326
	Slope of the fatigue line (b)	–0.2
	Coefficient c	0.02
	Standard deviation of pavement thickness (S_h)	2.5
	Standard deviation of the fatigue test (S_N)	0.25
	Standard deviation at distribution of logN at failure (δ)	0.354
	Coefficient kr	0.685
	Coefficient kc	1.0
	Coefficient ks	0.94
	$\varepsilon_{t, allow}$	**67.4 E-06**

Source: ARRB.

3 EME2 MIX DESIGN

3.1 Mix Design Requirements

Main Roads required the EME2 mix to comply with the requirements of *Draft Specification 514 High Modulus Asphalt (EME2)* (Main Roads 2016b) and ERN13 (Main Roads 2016c). ERN13 states 'constituent materials nominated in the Australian mix design, developed and finalised in Australia are to be shipped overseas to France for validation and that the testing needs to be performed by a French laboratory accredited for testing by the Comité Français d'Accréditation'.

3.2 Downer Group Laboratory Test Results

The EME2 mix design was developed and tested by Downer Group, in accordance with TMR's *Pilot Specification PSTS107* (TMR 2015b), at their National Research and Development Laboratory in Somerton Victoria, using materials sourced from the Holcim Quarry at Gosnells and binder from SAMI Bitumen Technologies Brisbane. The submitted EME2 mix design and supplementary documentation were reviewed by Main Roads.

The EME2 mix design criteria and the Downer Group test results are presented in Table 3.1 to Table 3.3, whilst Figure 3.1 compares the measured and target particle size distribution (PSD) of the EME2 mix.

Table 3.1: Properties of EME2 binder

Property	Test standard	Units	Limits	Test result
Penetration at 25 °C	AS 2341.12	pu	≥ 15 ≤ 25	15
Softening point	AS 2341.18	°C	≥ 56 ≤ 72	68
Viscosity at 60 °C	AS/NZS 2341.2	Pa.s	≥ 900	10 700
Loss on heating	AS/NZS 2341.10 or AGPT/T103	%	≤ 0.5	0.0
Retained penetration	AS/NZS 2341.10 and AS 2341.12	%	≥ 55	67
Increase in softening point after rolling thin film oven (RTFO) treatment	AS/NZS 2341.10 and AS 2341.18	°C	≤ 8	9
Viscosity at 135 °C	AS/NZS 2341.2, AS 2341.3, AS/NZS 2341.4 or AGPT/T111	Pa.s	≥ 0.6	2.44
Matter insoluble in toluene	AS/NZS 2341.8	% mass	≤ 1.0	1.2
Viscosity at 60 °C after RTFO	AS/NZS 2341.10 and AS/NZS 2341.2	Pa s	Report	44 900
Percent increase in viscosity at 60 °C after RTFO test	AS/NZS 2341.10 and AS/NZS 2341.2	%	Report	420

Source: Based on laboratory data from Downer Group.

Table 3.2: Main Roads draft specification 514 EME2 mix design criteria and test results

Property	Test standard	Limit	Test result
Air voids in specimen compacted bygyratory compactor at 100 cycles	AS/NZS 2891.9.3 using a Servopac	≤ 6.0%	3.7%
Stripping potential of asphalt – tensile strength ratio	AGPT/232	≥ 80%	84%
Wheel tracking at 60 °C and 30 000 cycles (60 000 passes)	AGPT/231	≤ 4.0 mm	1.2 mm
Wheel tracking at 60 °C and 5 000 cycles (10 000 passes)	AGPT/231	≤ 2.0 mm	0.8 mm
Minimum flexural stiffness modulus at 50 ± 3 με, 15 °C and 10 Hz	AGPT/274	≥ 14 000 MPa	14 964 MPa
Fatigue resistance at 20 °C, 10 Hz and 1 million cycles	AGPT/274	≥ 150 με	163 με
Richness modulus	N/A	≥ 3.4	4.0

Source: Based on Downer Group data.

Based on these tables, it can be concluded that the EME2 mix design met all the Australian and Austroads specification limits, with the exception of:

- increase in softening point after rolling thin film oven (RTFO) – result of 9 °C, exceeding limit of 8 °C or less
- percentage by mass insoluble – result of 1.2%, exceeding a maximum of 1%.

Due to time constraints associated with the project and the reduced design life of the trial, these values were deemed acceptable for the purposes of the trial. However, complete compliance will be required on future EME2 work.

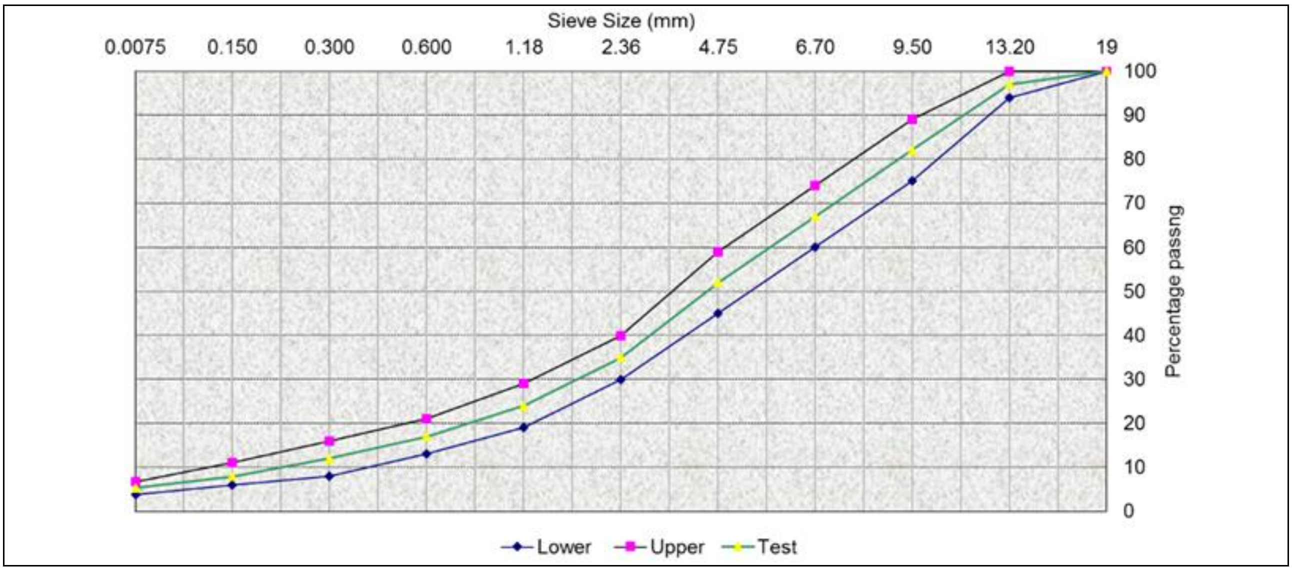
Binder results from production are discussed in Section 8.7.

Table 3.3: Design and target particle size distribution

Particle size distribution AS sieve size (mm)	Combined design grading EME2	Tolerances on percentage by mass passing EME2
19.00	100	100
13.2	97	94–100
9.50	82	75–89
6.70	67	60–74
4.75	52	45–59
2.36	35	30–40
1.18	24	19–29
0.600	17	13–21
0.300	12	8–16
0.150	8	6–11
0.075	5.3	3.8–6.8

Source: Based on laboratory data from Downer Group.

Figure 3.1: Design mix particle size distribution



Source: Based on laboratory data from Downer Group.

3.3 French Laboratory Test Results

Downer Group commissioned an independent laboratory, Colas Campus for Science and Techniques (CST) located in France to undertake the mix testing. It included determining the performance and characteristics of the EME2 mix design developed by Downer Group. Table 3.4 through Table 3.6 show binder properties, mix design criteria and PSD of EME2. Figure 3.2 shows the design target PSD graph.

Table 3.4: Properties of EME2 binder tested by European laboratory

Property	Test method	Limit	Design result
Penetration at 25 °C (1/10 mm)	EN 1426	15–25 pu	17 pu
Softening point ($T_{R\&B}$) ° C	EN 1427	55–71 °C	70.2 °C

Source: Based on Colas CST laboratory data.

Table 3.5: Specification properties of EME2 tested by European laboratory

Property	Test method	Note	Limit	Results
Air voids in specimens compacted by gyratory compactor at 100 gyratory cycles	EN 12697-31		Maximum 6%	3.8%
Water sensitivity	EN 12697-12		Minimum 70%	95%
Wheel tracking at 60 °C and 30 000 cycles (void content 4.8%)	EN 12697-22	Large size device, two slabs	Maximum 7.5%	1.9%
Minimum stiffness modulus at 15 °C & 10 Hz (void content 3.6%)	EN 12697-26 Method A	Two-point bending trapezoidal specimens	Minimum 14 000 MPa	14 632 MPa
Fatigue resistance at 10 °C, 25 Hz & 106 cycles (void Content 3.9%)	EN 12697-24 Method A	Two-point bending, trapezoidal specimens, three strain levels, six specimens for each strain level	Minimum 130 µε	145 µε

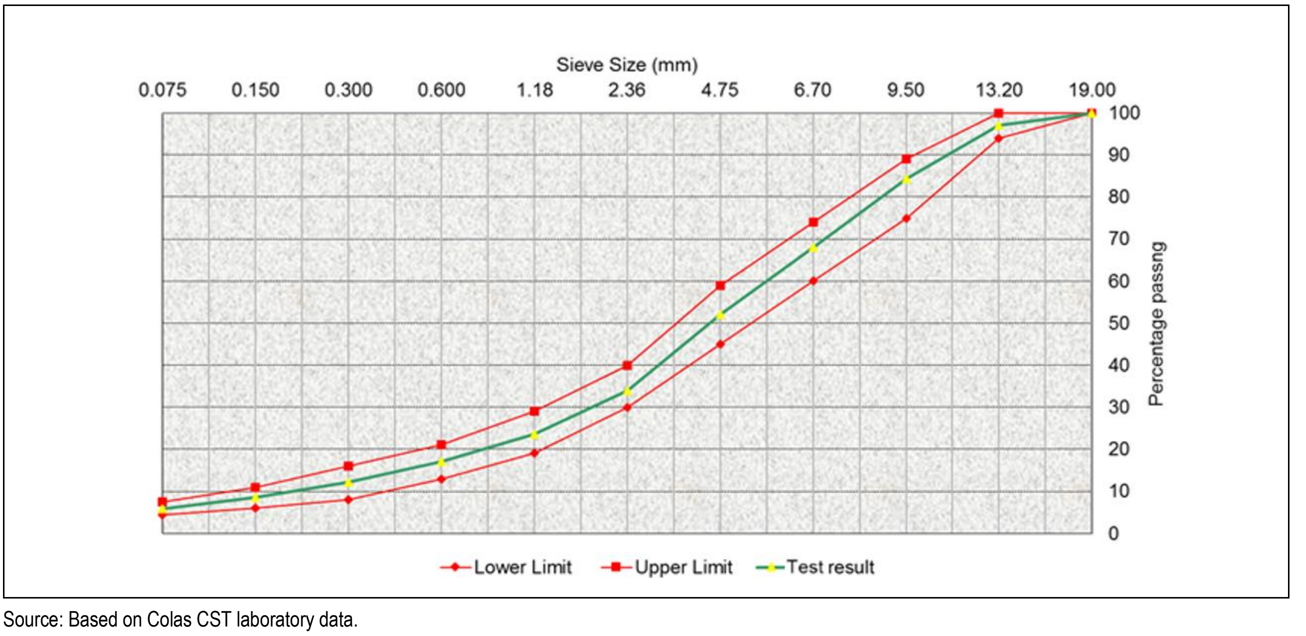
Source: Based on Colas CST laboratory data.

Table 3.6: Design mix particle size distribution: EN 12697-35 by European laboratory

Particle size distribution sieve size (mm)	Combined design grading EME2
20	100
16	100
12.5	97.0
9.5	84.4
8	–
6	–
4.75	52.0
2.36	34.0
1.18	23.6
0.6	17.0
0.3	12.2
0.15	8.6
0.075	5.9

Source: Based on Colas CST laboratory data.

Figure 3.2: PSD by European laboratory



Source: Based on Colas CST laboratory data.

The EME2 results obtained by the Colas CST laboratory in France validated the design values obtained by Downer Group and complied with Main Roads requirements stated in ERN13 (Main Roads 2016c).

3.4 Aggregate Requirements

The EME2 mix aggregates and fillers were required to conform with Main Roads *Draft Specification 514* (2016b) and *Specification 511: Materials for Bituminous Treatments* (Main Roads 2015b).

The specification and test results are shown in Table 3.7 and Table 3.8. Note that natural sand should not be used in the design or manufacture of EME2 asphalt mixes.

Table 3.7: Aggregates specifications

Test	Requirement	Test Method	Results
Los Angeles Abrasion value	35% maximum	WA 220.1	17.7%
Flakiness Index	25% maximum	WA 216.1	10 mm 16%; 14 mm 18%
Water absorption	2% maximum	AS 1141.6.1	0.4%
Wet strength	100 kN minimum	AS 1141.22	275 kN
Wet/dry strength variation	35% maximum	AS1141.22	4%
Degradation Factor	50% minimum	AS 1141.25.2	82%
Petrographic examination	Statement of suitability for use as an asphalt aggregate		Suitable

Source: Based on Downer Group laboratory data.

Table 3.8: Filler specifications

Test method	Unit	Property	Mineral filler		Results
			Min	Max	
AS/NZS 1141.17	%	Voids in dry compacted filler	28	45	40
EN 13179–1: 2000 and AS 2341.18	°C	Delta ring and ball	8	16	14.5

Source: Based on laboratory data from Downer Group (Appendix N).

4 DOWNER GROUP YARD PRE-TRIAL

On 12 April 2017, Downer Group placed approximately 100 tonnes of EME2 at the Holcim quarry stockpile area adjacent to Downer Group's asphalt plant yard in Gosnells as part of a production and placement pre-trial of EME2 asphalt mix for the Main Roads Tonkin Highway trial.

4.1 Pavement Composition of Pre-trial

The pavement structure for the pre-trial comprised a rock base with a single layer of EME2 asphalt placed directly on top. The target thickness for the EME2 layer was 105 mm, placed in one layer on top of the subbase, placed in two paving runs.

4.2 Production and Construction

The Downer Group plant maintained a production rate of 100 tonnes per hour (tph) for the EME2, with a target production temperature of 185–190 °C. There were no noted issues with the production of the EME2 for the pre-trial.

4.2.1 Paving

Asphalt paving commenced at approximately 8:00 pm on 12 April 2017 during a cool night, and took place in a northbound direction in one layer. Downer Group utilised one paver (CAT AP65D) for construction, conforming to requirements in Main Roads *Draft Specification 514* (Main Roads 2016b).

4.2.2 Compaction

The compaction of the EME2 mat in the pre-trial was performed using a 9 tonne vibrating steel-drum tandem roller, a 9.2 tonne pneumatic multi-tyred roller and a 7 tonne steel-drum roller. The rolling pattern may be described in the following manner:

1. two static and three vibratory passes of a 9 tonne steel-drum roller
2. six passes of a 9.2 tonne pneumatic multi-tyred roller
3. four static back rolling passes using a 7 tonne steel-drum roller.

It is important to note that the multi-tyred roller did not commence compaction of the mat until the 9 tonne steel-drum roller had completed its passes due to concerns regarding over-compaction. Additionally, temperature monitoring was conducted during paving showing that surface temperatures of the mix for each stage of the compaction were approximately as follows:

- directly behind the paver – 140–150 °C
- 9.0 tonne static smooth steel-drum roller – 110–130 °C (commencing directly behind paver for approximately 20 minutes)
- 9.2 tonne pneumatic multi-tyred roller – 100–120 °C (commencing directly behind vibratory steel-drum roller for approximately 10 minutes)
- 7 tonne static smooth steel-drum back roller – 90–110 °C (commencing directly behind the multi-tyred roller for approximately 10 minutes).

It was observed during the pre-trial that the EME2 asphalt held its temperature more than a conventional mix, with surface temperatures of up to 80 °C approximately one hour after the mix had left the paver.

4.3 Quality Control

Throughout the pre-trial, production testing included material sampling, in situ temperature monitoring and density measurements using the pavement quality indicator (PQI). Post-production testing was also conducted by Main Roads to evaluate the air voids, tensile strength ratio, modulus and rut performance (using the Hamburg wheel tracker). The sampling and testing plan is summarised in Appendix A.

Notably, of the tests conducted for the pre-trial the only non-conformances were related to the softening point of the binder. The pre-trial binder test results are discussed in Section 8.7, with the performance tests discussed in the relevant sections of Section 9. The reports for each of the tests conducted for the pre-trial are presented in Appendix B.

4.4 Findings and Recommendations

The purpose of the Downer Group yard pre-trial was to document the production and placement of EME2 asphalt mix using the plant and methods intended for use on the Tonkin Highway trial and implement any findings, to ensure best practice is conducted on the main trial. The findings show that the EME2 mix was produced, placed and compacted without any major issues.

Recommendations relative to the Tonkin Highway trial include:

- reducing the target production temperature from 185–190 °C to 175–185 °C to reduce the risk of overheating the mix
- ensuring the trial is continually monitored from commencement
- ensuring the production and construction crews are aware of the differences between EME2 and typical dense graded asphalt (DGA) intermediate course mixtures.

5 TONKIN HIGHWAY TRIAL DETAILS

5.1 Location

The EME2 mix was placed on the new southbound right-turn lanes from Tonkin Highway onto Kelvin Road accessing a major industrial area. The geographic coordinates of the trial section were: 32°01’46.4”S 116°00’22.1”E. An aerial view of the trial site is presented in Figure 5.1**Error! Reference source not found.**. The paving lane closest to the median was designated LR1 while the outer lane was designated LR2 in accordance with Main Roads practice.

Figure 5.1: Map of the trial

Source Google maps (2017), Western Australia, Map data, Google, WA, Australia.

5.2 Construction of Subbase

Construction of the subbase working platform took place during April 2017. Photos of the construction of the crushed limestone subbase are shown in Figure 5.2 through to Figure 5.5. The limestone complied with Main Roads *Specification 501: Pavements* (Main Roads 2017a). Additionally, there was no rain during or in the week leading up to the trial.

Figure 5.2: Construction of subbase

Figure 5.3: Vibrating smooth drum roller

Figure 5.4: Thickness of subbase

Figure 5.5: Multi-tyred roller

Source: ARRB.

The finished surface of the subbase was completed on 24 April 2017. The condition of the surface before the EME2 asphalt was placed, is shown in Figure 5.6 and Figure 5.7. Due to time constraints, a prime was not applied to the subbase because the minimum curing time could not be met before construction was due to commence.

Nuclear density testing by the contractor on both the subgrade and subbase confirmed compliance with Main Roads *Specification 501*. Dryback testing was also performed on the subbase and complied. The test results are provided in Appendix D and Appendix E.

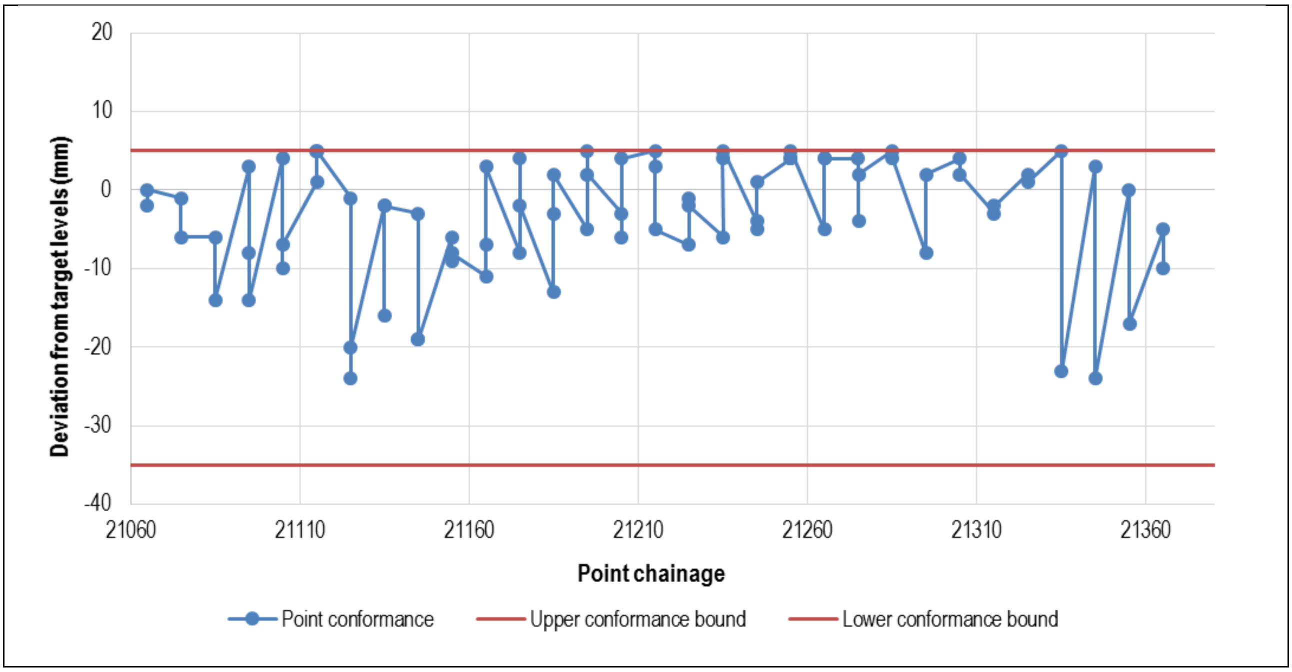
Figure 5.6: Visual inspection of subbase

Figure 5.7: Subbase ready for asphalt placement

Source: ARRB.

The surface levels at any point were required to be within +5 mm and –35 mm of the target subbase level. The data in Figure 5.8 shows that the measured surface levels conformed to these requirements. Apart from one small area in LR1, the surface was homogenous and tightly bound.

Figure 5.8: Measured surface levels of subbase



Source: Data supplied by Main Roads.

6 PRODUCTION OF EME2

6.1 Asphalt Plant

Downer Group used a 140 tonne per hour continuous drum plant to produce the EME2. The location of the Downer Group plant is shown in Figure 6.1 and the Downer Group plant used for the trial is shown in Figure 6.2.

Figure 6.1: Location of Downer Group asphalt plant

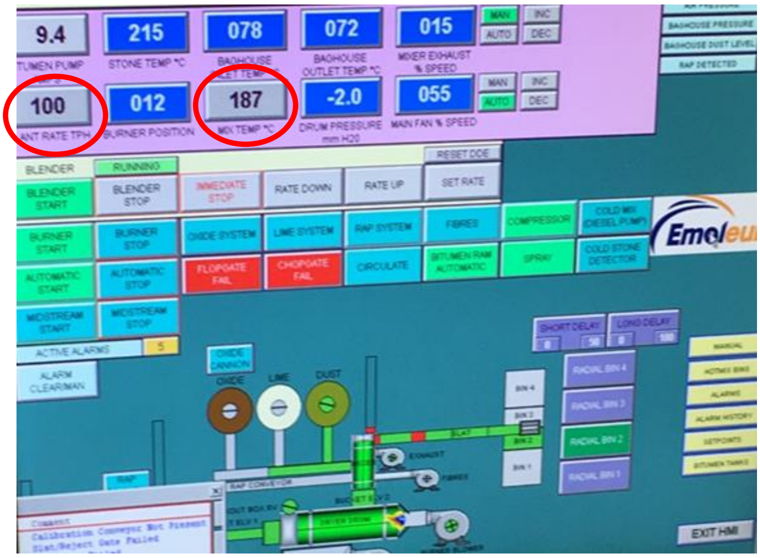
Source: Google maps (2017), Western Australia, Map data, Google, WA, Australia.

Figure 6.2: Downer Group plant used for the trial

Source: ARRB.

The plant was pre-heated and the binder flushed out before commencement of production to ensure a constant temperature. A total of 998 tonnes of the EME2 mix was produced, of which 507 tonnes were produced on 26 April 2017 and the subsequent 491 tonnes on 27 April 2017. The production rate was 100 tph with a target production temperature of between 175 °C and 185 °C. Figure 6.3 shows a typical computer screen showing production tonnes per hour and temperature.

Figure 6.3: Computer screen indicating production tonnes per hour and temperature



Source: ARRB.

6.2 Materials Management

6.2.1 Aggregate

Attention was placed on the quality of the aggregate, including stockpile grading checks. The mix had a high percentage of crusher dust. No natural sand or hydrated lime was used.

6.2.2 Binder

The EME2 binder was transported from Queensland to Downer Group Gosnells plant in road tankers (see Figure 6.4) where the EME2 binder was then pumped directly from the road tanker to the asphalt plant. Figure 6.5 shows the tanker bitumen line connected to the plant. There were no issues during the process – the only interruption was the delays during changeover of the tankers.

To maintain binder flow, the temperature of the tanker was maintained at 185 °C. Figure 6.6 shows the tanker temperature during production.

6.2.3 Additives

The adhesion agent Redicote BE was added to the binder at 0.3% of binder by mass in accordance with Main Roads *Specification 511* (Main Roads 2015b). The Redicote BE was added to the tanker and mixed prior to direct feed to the plant.

Figure 6.4: EME2 road tanker

Figure 6.5: EME2 being pumped to the plant

Figure 6.6: Monitoring of tank temperature

Source: ARRB.

6.3 Process Control

The items included in the process control were as follows:

Aggregates

- calibration of cold feed bins
- percentage of crusher dust
- baghouse fines quantities required checking
- blend sheets reviewed and checked
- plant trials to check grading/binder contents
- plant scales calibrated.

Bitumen

- tank selection
- circulation
- temperature during mixing
- in-line samples taken during production.

Samples were taken at the SAMI Bitumen Technologies Brisbane depot during transfer to the road tanker and at the Downer Group asphalt plant in supply line to plant (Figure 6.7 and Figure 6.8) respectively. The test results are presented in Section 8.7.

Figure 6.7: EME2 binder sampling

Figure 6.8: Line sampling heating

Source: ARRB.

7 ASPHALT CONSTRUCTION

7.1 Transportation of the EME2 Asphalt Mix

The haul distance from the plant to the trial site was less than 10 kilometres. However, there were still some significant construction delays. The time between haul loads on 26 April 2017 ranged between 7 minutes and 28 minutes for the paving of each lane, with an average of 14 minutes. The greater wait times were primarily due to the lack of delivery trucks. It is important to note that there was a 55-minute break between the paving of LR2 and LR1 on 26 April 2017.

On 27 April 2017 additional trucks were provisioned for delivery, however, issues on site and with the EME2 quantities led to an increase in the range of wait times between 8 minutes and 71 minutes. The 71-minute wait may be attributed to the paving of a small section of LR1 Lift 1 (as discussed in Section 7.2) before moving onto the paving of Lift 2. A malfunction of the paver at the commencement of Lift 2 then led to a 25 minute delay before the rest of the run was carried out relatively smoothly. The other significant delay was a 43 minute wait time, caused by a shortage of EME2 asphalt. There was also a 45 minute break between the paving of LR2 and LR1 on 27 April 2017.

A photo of the EME2 mix being delivered to the site is shown in Figure 7.1.

The delivery temperature ranged between 162 °C and 180 °C, resulting in high laying temperatures, due to minimal heat loss during transportation. The truck delivery times and mix temperatures for 26 April 2017 and 27 April 2017 are reported in Table 7.1 and Table 7.2 respectively.

Figure 7.1: EME2 asphalt being delivered

Source: ARRB.

Table 7.1: Truck delivery times and mix temperatures (26/4/17)

Docket number	Time of arrival at plant	Time mix unloaded into paver	Time between haul loads (minutes)	Mix temperature at plant (°C)	Mix temperature at site (°C)	Tonnes delivered	Weather conditions	Ambient temperature (°C)
080881	10:26 am	11:21 am		169	168	24.46	Clear	20

Docket number	Time of arrival at plant	Time mix unloaded into paver	Time between haul loads (minutes)	Mix temperature at plant (°C)	Mix temperature at site (°C)	Tonnes delivered	Weather conditions	Ambient temperature (°C)
080882	10:48 am	11:42 am	21	171	170	25.92	Clear	20
080883	10:58 am	11:49 am	7	174	172	24.81	Clear	21
0n0884	11:24 am	11:59 am	10	163	162	27.29	Clear	22
080885	11:45 am	12:15 pm	16	175	174	25.77	Clear	22
080886	12:11 am	12:43 pm	28	177	177	24.46	Clear	23
080887	12:24 pm	12:53 pm	10	171	170	26.14	Clear	24
080888	12:39 pm	1:13 pm	20	170	170	24.70	Clear	24
080889	1:40 pm	2:08 pm	55*	172	171	27.37	Clear	25
080890	2:00 pm	2:28 pm	20	182	180	24.00	Clear	25
080891	2:22 pm	2:45 pm	17	174	173	25.31	Clear	25
080892	2:38 pm	3:00 pm	15	171	170	24.57	Clear	24
080893	2:46 pm	3:07 pm	7	173	173	25.73	Clear	24
080894	2:55 pm	3:20 pm	13	175	174	24.81	Clear	24
080895	3:07 pm	3:30 pm	10	183	180	23.83	Clear	24
080896	3:22 pm	3:43 pm	13	175	173	27.33	Clear	23
080897	3:33 pm	4:00 pm	17	179	178	23.87	Clear	23
080898	3:51 pm	4:15 pm	13	174	170	25.92	Clear	23
080899	4:01 pm	4:27 pm	14	179	177	24.56	Clear	22
080900	4:14 pm	4:34 pm	7	177	176	25.80	Clear	22
		Total	**5.22 hrs**			**Total: 506.65 t**		

*Note: Transition from LR2 to LR1.

Source: Based on data from Downer Group, Main Roads and ARRB.

Table 7.2: Truck delivery times and mix temperatures (27/4/17)

Docket number	Time of arrival at plant	Time mix unloaded into paver	Time between haul loads (minutes)	Mix temperature at plant (°C)	Mix temperature at site (°C)	Tonnes Delivered	Weather conditions	Ambient temperature (°C)
080906	8:05 am	9:17 am		183	177	25.38	Clear	19
080908	8:21 am	10:35 am	71	173	173	26.21	Clear	19
	8:44 am	11:00 am	25			24.93	Clear	20
080910	9:23 am	11:08 am	8	179	177	24.10	Clear	22
080911	9:38 am	11:20 am	12	173	166	24.20	Clear	22
080912	10:12 am	11.29 am	9	170	170	25.10	Clear	23
080914	10:21 am	11:39 am	10	180	172	22.60	Clear	24
080916	10:30 am	11:47 am	8	180	175	25.35	Clear	24
080918	11:13 am	12:00 pm	13	170	169	25.15	Clear	24
080919	11:35 am	12:45 pm	45[1]	179	180	25.20	Clear	25
080920	11:50 pm	1:12 pm	27	176	177	24.86	Clear	25
080922	11:59 am	1:25 pm	13	173	174	24.29	Clear	25
080923	12:11 pm	1:36 pm	11	173	172	24.33	Clear	25

Docket number	Time of arrival at plant	Time mix unloaded into paver	Time between haul loads (minutes)	Mix temperature at plant (°C)	Mix temperature at site (°C)	Tonnes Delivered	Weather conditions	Ambient temperature (°C)
080924	12:21 pm	1:45 pm	9	173	165	22.76	Clear	25
	12:30 pm	1:53 pm	8			25.49	Clear	
080927	12:44 pm	14:02 pm	9	173	173	25.02	Clear	25
080928	??	14:13 pm	11	181	172	25.51	Clear	26
080929	2:40 pm	14:30 pm	17	173	166	19.17	Clear	26
080931	2:47 pm	15:13 pm	43[2]	178	173	26.32	Clear	25
080932	3:04 pm	15:24 pm	11	177	172	25.13	Clear	25
		Total	**6.00 hrs**			**Total: 491.10 t**		

1 Transition from LR2 to LR1.
2 Shortage of EME2 mix.
Source: Based on data from Downer Group, Main Roads and ARRB.

7.2 Asphalt Paving

Placement of the EME2 asphalt took place during fine and warm weather between Wednesday 26 and Thursday 27 April 2017. Paving run details were as follows:

1. two lanes – each 3.5 m wide (approximately) – see Figure 7.2 for road lanes
2. length – approximately 223 m
3. for each lane, two 105 mm thick layers of EME2 mix were placed to provide a total compacted thickness of 210 mm.
   - 105 mm thick EME2 paved in LR2 Lift 1 in southbound direction
   - 105 mm thick EME2 paved in LR1 Lift 1 in northbound direction
   - 105 mm thick EME2 paved in LR2 Lift 2 in southbound direction
   - 105 mm thick EME2 paved in LR1 Lift 2 in northbound direction.

Figure 7.2: Limestone subbase marked ready for EME2 mix placement

Source: ARRB.

Downer Group used one paver (CAT AP65D) for construction, which complied with Main Roads *Draft Specification 514* (Main Roads 2016b) Figure 7.3. It is important to note that there were variations in the truck delivery times, which resulted in the paver stopping and starting two to three times per layer. Figure 7.4 show the paver during the placement of EME2 mix.

Figure 7.3: Paver CAT AP65D

Figure 7.4: Paver operation

Source: ARRB.

Paving took place in a southbound direction on 26 April 2017. The first delivery truck arrived at 11:10 am and paving of LR2 Lift 1 commenced at approximately 11:20 am (see Figure 7.5). Compaction of LR2 Lift 1 was completed by 2:00 pm. Before starting LR1, the longitudinal edge of the previous laid mix was cut back. A cutter wheel mounted to the roller cut away completely the uncompacted edge (up to 75 mm width) and the excess asphalt was removed before paving (see Figure 7.6).

Figure 7.5: Paving operation southbound

Figure 7.6: Roller cutting edge

Source: ARRB.

Paving of LR1 Lift 1 commenced at approximately 2:20 pm (see Figure 7.7). Compaction stopped at approximately 5:30 pm with a 10 m long section left to be paved on the morning of 27 April 2017.

Figure 7.7: Paving of Layer 1 of LR1

Source: ARRB.

After the completion of the placement of LR1 Lift 1, a tack coat was applied to the surface of the EME2 in both lanes at the rate of 0.6 L/m^2. The purpose of the tack coat was to aid with the application and bond with the second EME2 layer in accordance with Main Roads *Draft Specification 514* (Main Roads 2016b). Lift 2 was not placed until the emulsion had broken and the water had substantially evaporated. Figure 7.8 shows the application of the tack to the surface.

Paving of LR2 Lift 2 commenced at 9:30 am and was completed by 12:00 pm, with compaction still to be completed. Paving of LR1 Lift 2 commenced at 1:00 pm and was completed by 3:45 pm. However, the shortage of EME2 asphalt led to a significant delay of 43 minutes between loads in the paver in the last run. Figure 7.9 shows the Lift 2 paving operation.

Due to a shortage of the EME2 asphalt, paving of the final 15 m (approximately) of LR1 Lift 1 was completed with size 20 mm C320 dense-graded asphalt.

Figure 7.8: Application of tack coat

Figure 7.9: Placement of second layer of EME2 asphalt

Source: ARRB.

7.3 Compaction

7.3.1 Plant

Initial rolling was performed immediately behind the asphalt paver with a vibrating smooth-drum tandem roller (9 tonnes, series HD / Series H 181). No tearing or cracking was observed (see Figure 7.10). A multi-tyred roller (GRW280) followed immediately behind the vibrating roller, ensuring the time gap between drum roller compaction and multi-tyred roller compaction was minimal (see Figure 7.11 and Figure 7.12). Static rolling using a tandem 7 tonne roller was adopted to finish the surface and remove multi-tyred roller marks (see Figure 7.13). Temperature monitoring was conducted during paving (Section 7.5), showing that the surface temperatures of the EME2 asphalt varied during construction in the range of 100 °C and 155 °C, as discussed in Section 7.5.1. Similarly, compaction times varied during paving and was generally carried out until the desired levels of compaction were achieved.

Figure 7.10: Vibrating smooth drum roller

Figure 7.11: Multi tyred roller behind the vibrating roller

Source: ARRB.

Figure 7.12: Multi-tyred roller behind the vibrating roller

Figure 7.13: Static rolling to finish

Source: ARRB.

7.3.2 Rolling Pattern

The following rolling pattern was adopted for the EME2 mix:

1. compaction commenced on the open edge with 300 mm overhang of the roller, starting with one pass static and followed by a vibratory second pass 150 mm from the edge
2. two static and three vibratory passes of a 9 tonne steel-drum roller
3. six passes of a 9.2 tonne pneumatic multi-tyred roller
4. four static back rolling passes using 7 tonne steel-drum roller.

It is important to note that the rolling pattern was used as a guideline and adjustments were made as appropriate on site to achieve the desired levels of compaction as it is difficult to follow a predefined number of passes on site. Compaction using the multi-tyred roller was typically conducted until small patches of bleeding were visible on the surface. Furthermore, the rate of production and the number of trucks allotted to the trial led to the paver stopping for periods of up to 20 minutes, thus altering the compaction train in the following ways:

- plant operators continued the compaction procedure until the paver resumed operation, which may lead to an excess in the required number of passes
- plant operators could not reach the asphalt closest to the paver, which may lead to areas containing high voids that may be difficult to reduce once the paver resumed operation.

7.4 Joint Construction

The Lift1 joints between LR1 and LR2 were constructed using standard Main Roads practice where the unconfined edge is cut back using a cutter wheel mounted on a roller to form a vertical face (up to 75 mm width), excess material removed (Figure 7.14) and the edge is then pressed (Figure 7.15). Typically, joint overlapping is completed by raking and flicking the unconfined edge and this was adopted for construction of the Lift 1 joint. However, following paving of Lift 1, nuclear gauge density results indicated that the percentage of air voids was relatively high in the joint (see Figure 8.15) and as a result, the joint overlapping methodology was altered for the construction of the Lift 2 joint.

The joint overlapping for Lift 2 was completed using three methodologies: typical practice (same as Lift 1), overlapping of the unconfined edge with large stones removed by hand raking and overlapping of the unconfined edge without the removal of large stones. The overlapping on the joint using the paver is displayed in Figure 7.16 with the finished joint presented in Figure 7.17.

Figure 7.14: Cut edge with excess material

Figure 7.15: Roller pressing pavement edge

Source: ARRB.

Figure 7.16: Joint overlapping from paver

Figure 7.17: Finished Layer 2 joint

Source: ARRB.

7.5 Temperature Monitoring of EME2 Mix

Due to the viscoelastic nature of bituminous materials, temperature has a significant influence on asphalt workability and long-term performance. Hence, temperature monitoring was performed throughout the trial to examine possible segregation during production, placement and compaction. It allowed for the location of cold areas and/or sections of lower temperatures to be identified, which could minimise premature pavement distresses such as ravelling and cracking resulting from irregular temperature distribution.

The temperature of the asphalt during compaction was all higher than 145 °C resulting in good workability and achievement of the desired density. The results of the compaction testing are discussed in Section 8.2.

The mix temperature was recorded at the commencement of production and was continually monitored throughout the entire construction process. Temperature monitoring was carried out using a digital thermometer with a probe, a Testo 830-T1 infrared thermometer and a Testo model 875i thermal imager (see Figure 7.18 through to Figure 7.21).

Figure 7.18: Mat temperature with thermal imager

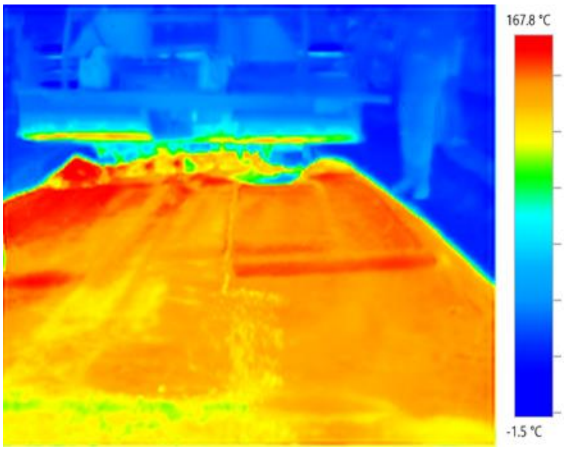


Figure 7.19: Mat compactor with digital thermometer

Source: ARRB.

Figure 7.20: EME2 on hopper between haul loads

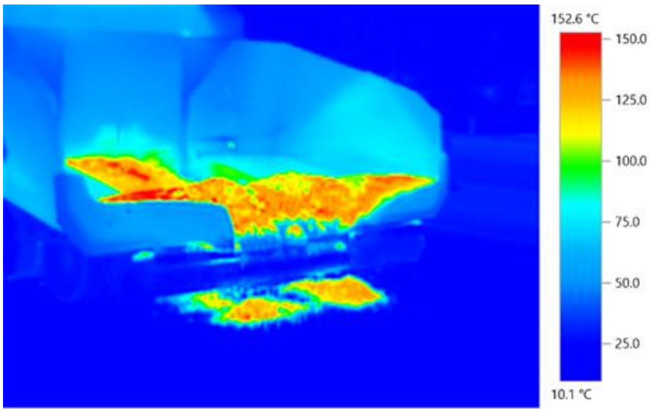


Figure 7.21: Surface temperature monitoring

Source: ARRB.

7.5.1 Temperatures Monitoring during Paving using Thermography

Delivery temperatures

The variations in temperature of the delivered mix are shown in Table 7.1 and Table 7.2. The thermal imager temperature of the EME2 mix in a delivery truck is displayed in Figure 7.22 whilst the temperature behind the paver is shown in Figure 7.23.

Paving temperatures

Temperatures between 160 °C and 170 °C were maintained when the mix was unloaded to the paver. Thermal images showed laydown temperatures of no less than 140 °C, resulting in a uniform surface temperature. No significant temperature variation was observed during construction (see Figure 7.24 and Figure 7.25).

Figure 7.22: Thermal image of the mix in the truck

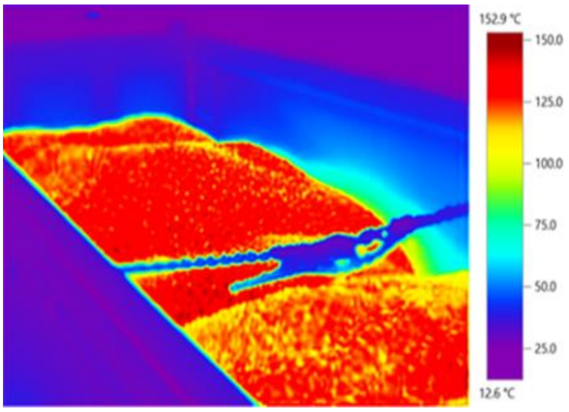
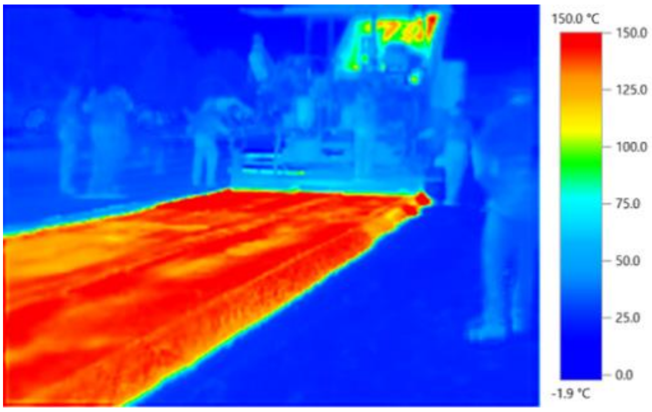


Figure 7.23: Thermal image behind the paver



Source: ARRB.

Figure 7.24: Temperature no less than 140 °C

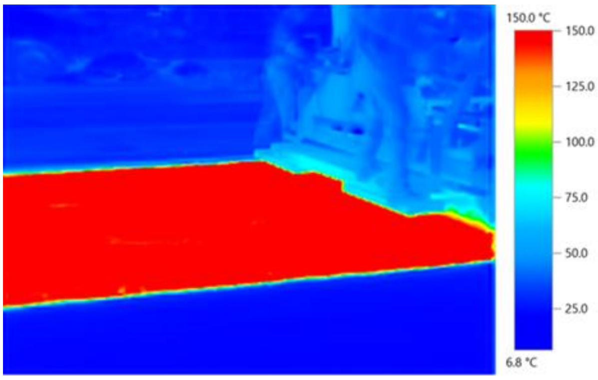
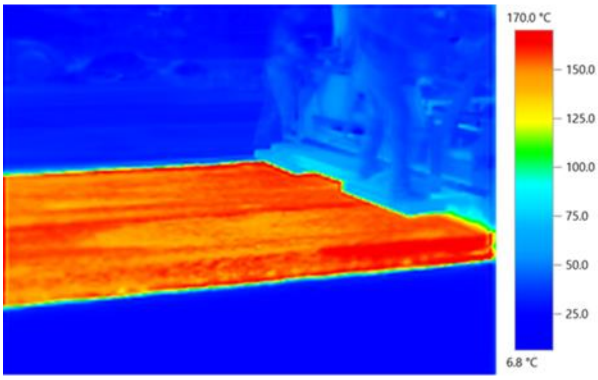


Figure 7.25: Temperature between 160 °C and 170 °C



Source: ARRB.

Compaction temperatures

Surface temperatures were between 100 °C and 155 °C during the entire compaction process. Surface temperatures nearing completion of the rolling pattern are shown in Figure 7.26 and Figure 7.27. Although surface temperatures of the mat varied during the compaction operation, the general surface temperatures of the mat when each item of plant was applied was observed to be approximately:

- directly behind the paver – 140–155 °C
- 9.0 tonne static smooth steel-drum roller – 120–135 °C (commencing directly behind paver for approximately 20 minutes)
- 9.2 tonne pneumatic multi-tyred roller – 110–130 °C (commencing directly behind vibratory steel-drum roller for approximately 10 minutes)
- 7 tonne static smooth steel-drum back roller – 100–120 °C (commencing directly behind the multi-tyred roller for approximately 15 minutes).

Figure 7.26: Monitoring mat temperature

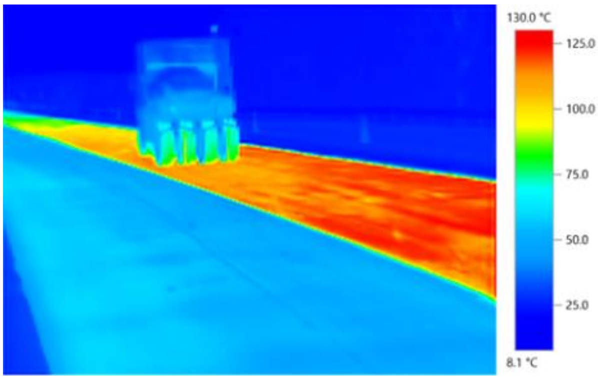
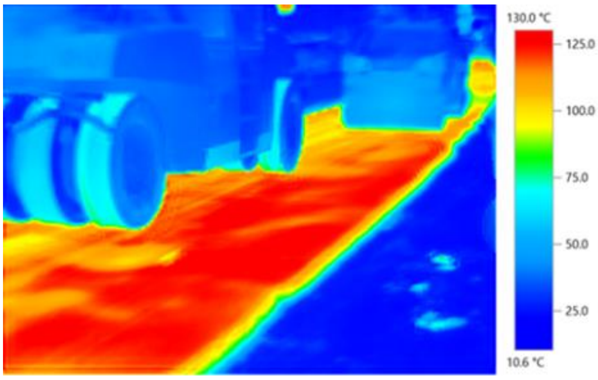


Figure 7.27: Mat temperature during roller operation



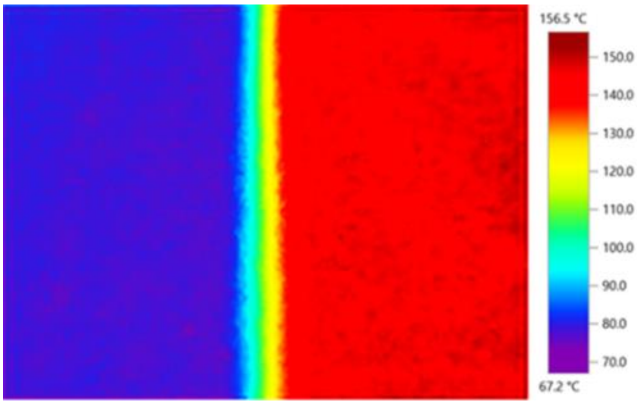
Source: ARRB.

Temperatures near construction joints

The temperature of the material forming the adjacent faces of a longitudinal construction joint has a significant impact on the adhesion and density and this influences the long-term performance of the asphalt. During the trial, nuclear gauge density results showed a high percentage of air voids in the vicinity of joints. Figure 7.28 through to Figure 7.31 clearly show examples of variation in surface temperatures near longitudinal joints. The temperature variation at the interface of the hot and warm longitudinal joint shows the influence the freshly paved asphalt layer has on the warm asphalt.

Figure 7.28: Paving line joint

Figure 7.29: Joint temperature



Source: ARRB.

Figure 7.30: Variation temperature

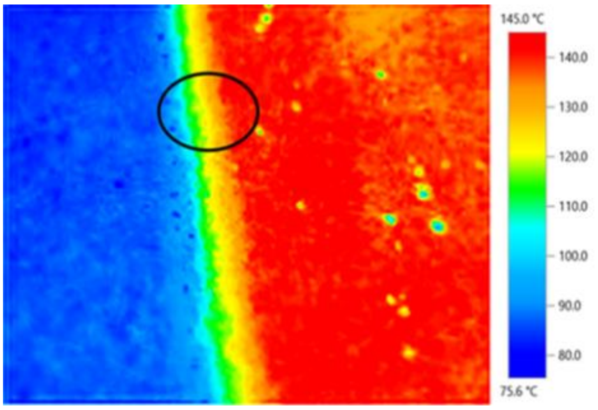
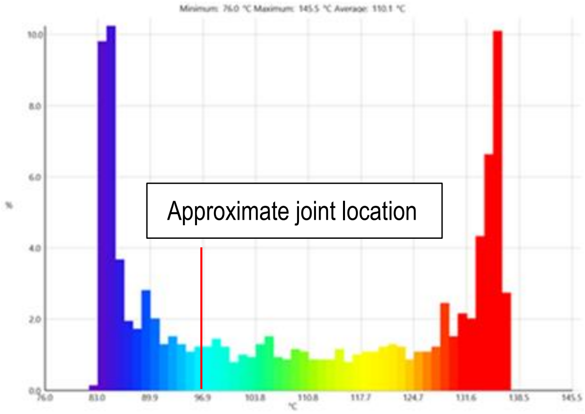


Figure 7.31: Details of variation temperature



Source: ARRB.

7.6 Surface Levels of the EME2 Mix

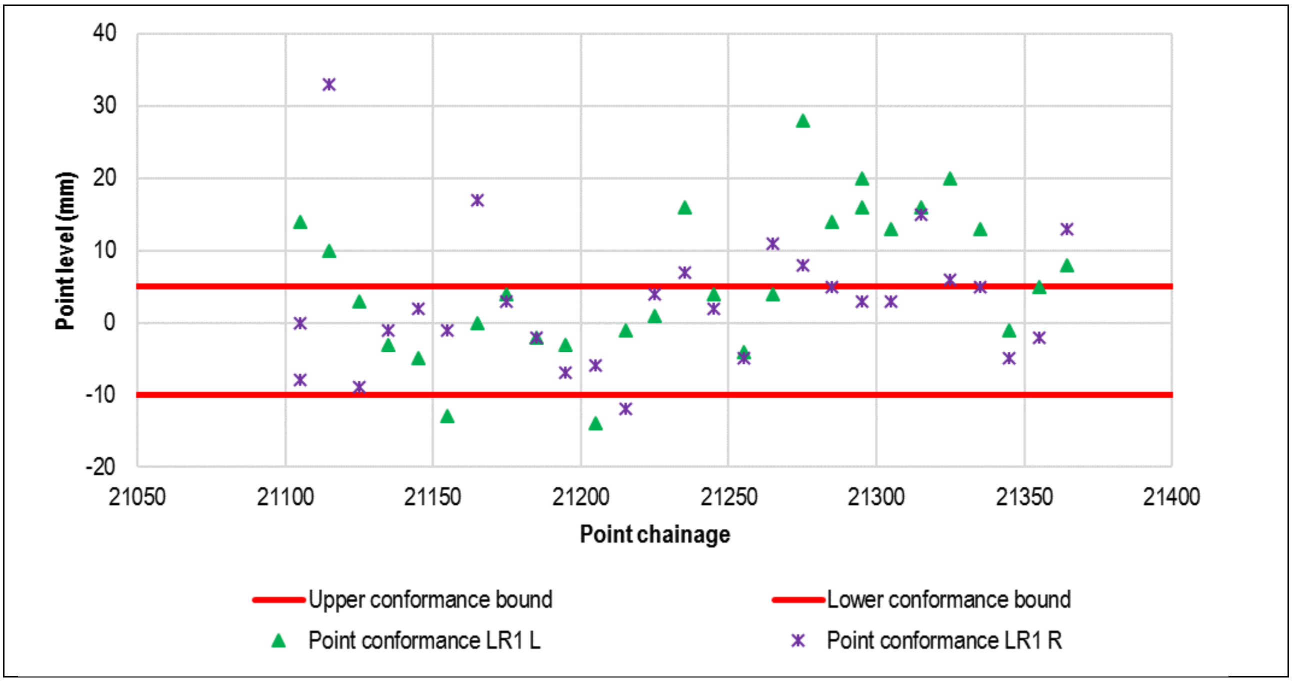
The surface levels of the EME2 base at any point were required to be within +5 mm and –10 mm of the specified level in accordance with *Draft Specification 514* (Main Roads 2016b). Figure 7.32 to Figure 7.35 show the levels measured on the top of Lift 1 and Lift 2 of the EME2 mix. Level control is difficult to achieve on the first layer above the subbase and as expected, a better level control was obtained on the top of Lift 2. Therefore, it is important to have 5 m surveys for all layers. There was no data available to allow a comparison with conventional dense-asphalt mixes.

The range of the measured levels shows that there is a significant variation for both lanes in Lift 1 and Lift 2, however, the non-conformances are generally higher in Lift 1 and on the left side of each lane. The difficulty achieving levels may be attributed to the degree of variance with the surface levels of the subbase (Figure 5.8) and/or the contractor's lack of experience regarding best practice for EME2 asphalt. It is important to note that the left side of each run (i.e. LR1 L and LR2 L) was paved next to the confined edge, and this may have impacted the height management. The results from the survey levels are summarised in Table 7.3.

Table 7.3: EME2 mix survey level summary

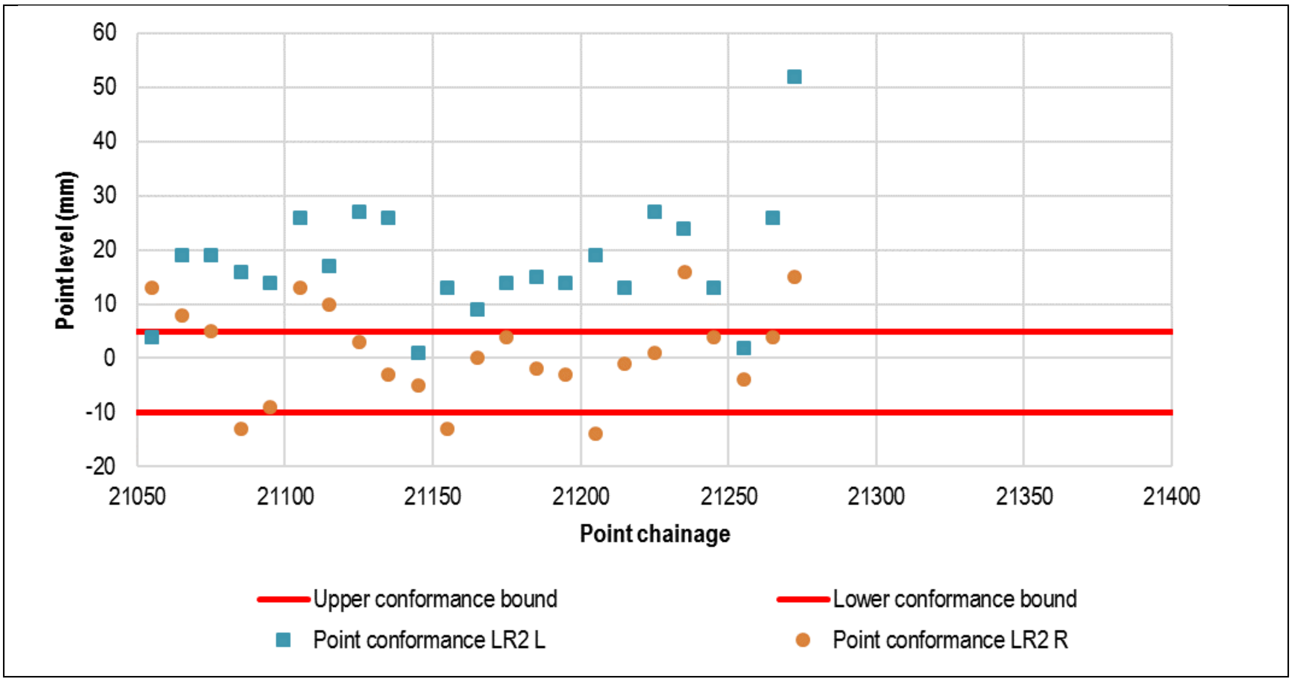
Lift	Lane designation	Range of survey levels (mm)	Non-conformances (%)	Mean (%)
1	LR1 L	–14 to +28	50	42
	LR1 R	–12 to +33	33	
	LR2 L	+1 to +52	87	63
	LR2 R	–14 to +16	39	
2	LR1 L	–14 to +17	46	30
	LR1 R	–13 to +23	14	
	LR2 L	–10 to +14	48	50
	LR2 R	–17 to +37	52	

Figure 7.32: Measured levels of EME2 Lift 1 LR1



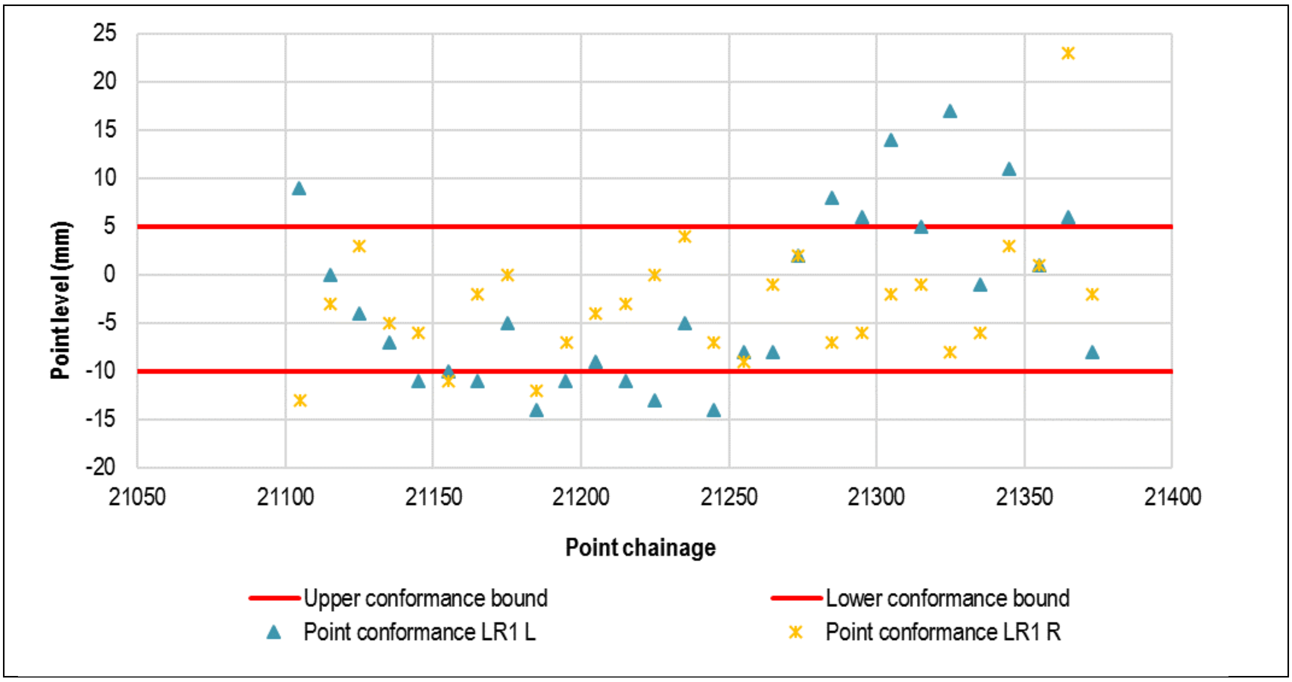
Source: Data supplied by Main Roads.

Figure 7.33: Measured levels of EME2 Lift 1 LR2



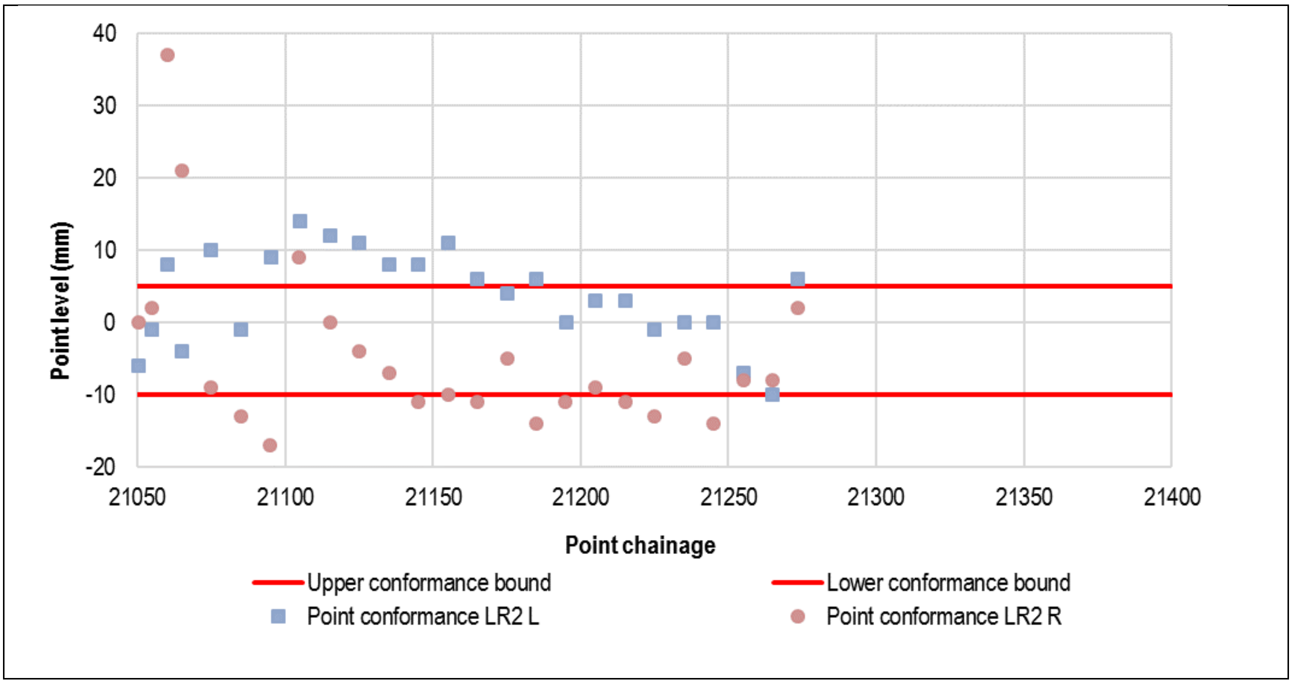
Source: Data supplied by Main Roads.

Figure 7.34: Measured levels of EME2 Lift 2 LR1



Source: Data supplied by Main Roads.

Figure 7.35: Measured levels of EME2 Lift 2 LR2



Source: Data supplied by Main Roads.

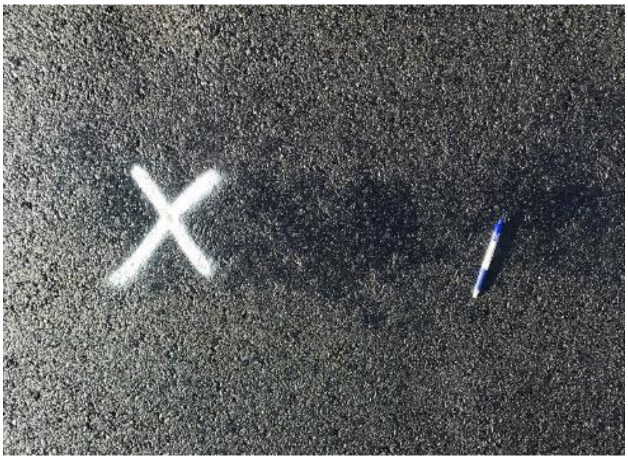
As shown in Figure 7.36 and Figure 7.37 the EME2 surface had a good visual appearance and showed a tight finish, with some sections showing flush patches on the surface, as presented in Figure 7.38.

Figure 7.36: Surface appearance after compaction

Source: ARRB.

Figure 7.37: Finished surface

Figure 7.38: Surface flush patches



Source: ARRB.

7.8 Wearing Course

The 50 mm thick, size 14 mm intersection mix wearing course was constructed one week after the EME2 was placed. Figure 7.39 shows the finished surface of the wearing course whilst the mix and compaction compliance results are reported in Appendix P.

Figure 7.39: Finished wearing course and line marking

Source: ARRB.

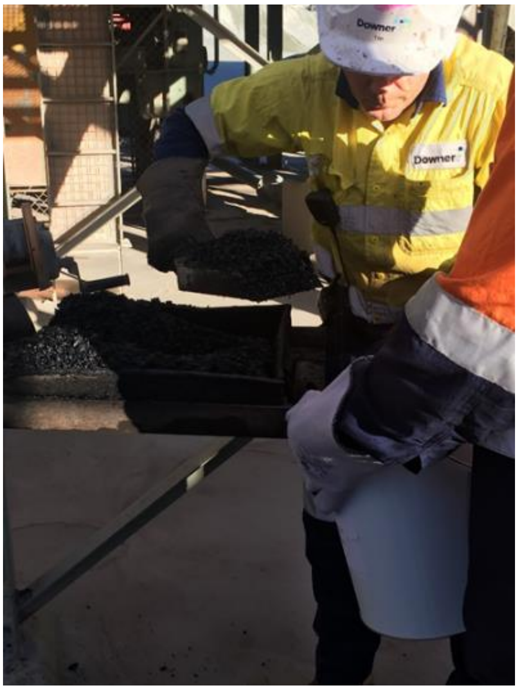
8 CONFORMANCE AND RESEARCH TESTING

8.1 Introduction

An intensive program of sampling and testing of the binder, filler and the mix was performed by staff from Boral, Main Roads, Downer Group, Queensland TMR and ARRB. Sampling from the plant and sample distribution are shown in Figure 8.1 and Figure 8.2 respectively. Appendix A presents Main Roads sampling and testing plan.

Figure 8.1: Sampling of EME2 from plant

Figure 8.2: Distribution of the samples



Source: ARRB.

Table 8.1 presents the record of the quality assurance testing results.

Table 8.1: Record of quality assurance testing results

Quality assurance testing	Record of testing
Sampling and testing plan	Appendix A
Pre-trial	Appendix B
In situ density, thickness and air voids of EME2	Appendix C
Subgrade and subbase	Appendix D
Dryback	Appendix E
Surface shape	Appendix F
Surface texture	Appendix G
Resilient modulus	Appendix L
Wearing course	Appendix P

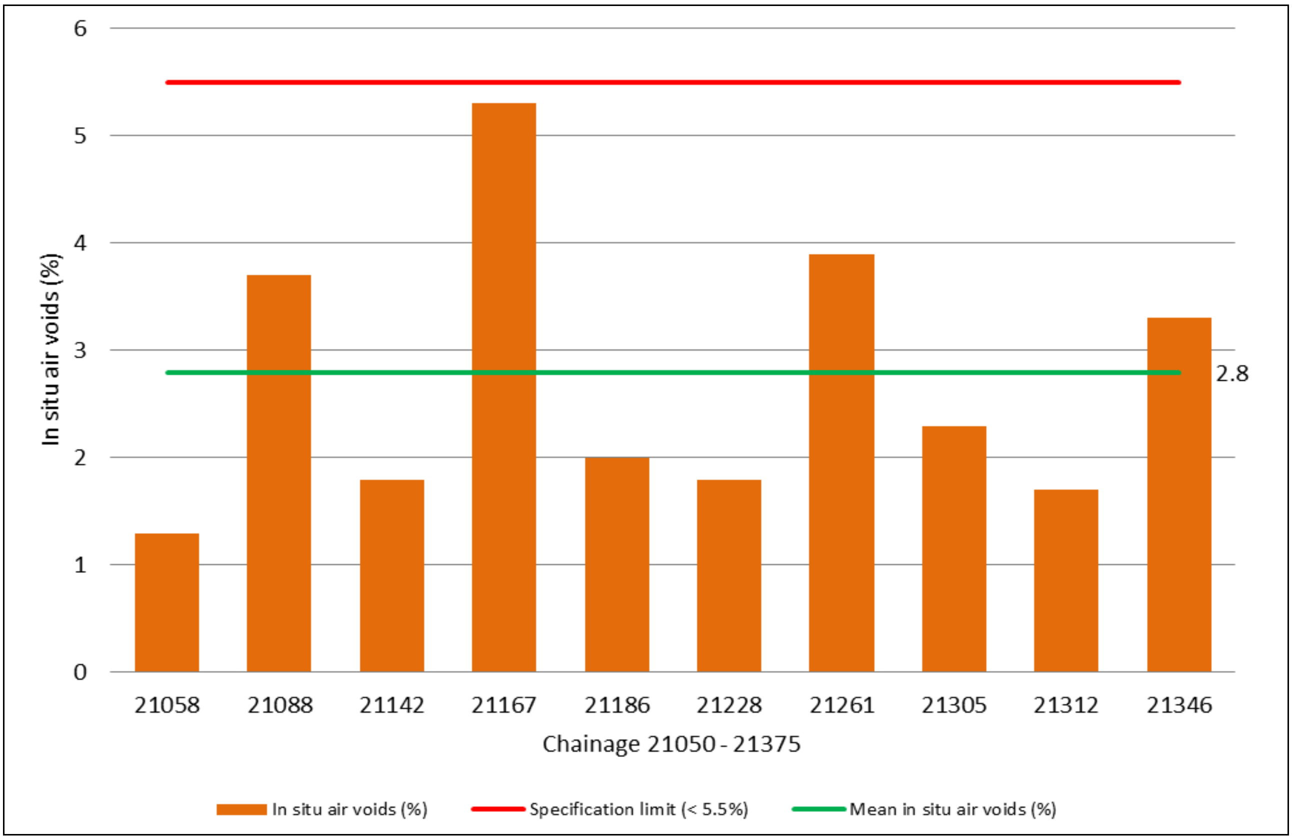
8.2 Compaction Results

8.2.1 Air Voids of Field Cores

Ten field cores of the completed asphalt layers, through Lift 1 and Lift 2 were taken at random locations sampled on 28/04/17 in accordance with WA 701.1. Bulk density determination was in accordance with AS/NZS 2891.9.2 and the in situ air voids in accordance with AS/NZS 2891.8. Figure 8.3 and Figure 8.4 show a summary of the measured air voids of the cores. The in situ density and thickness results are presented in Appendix C.

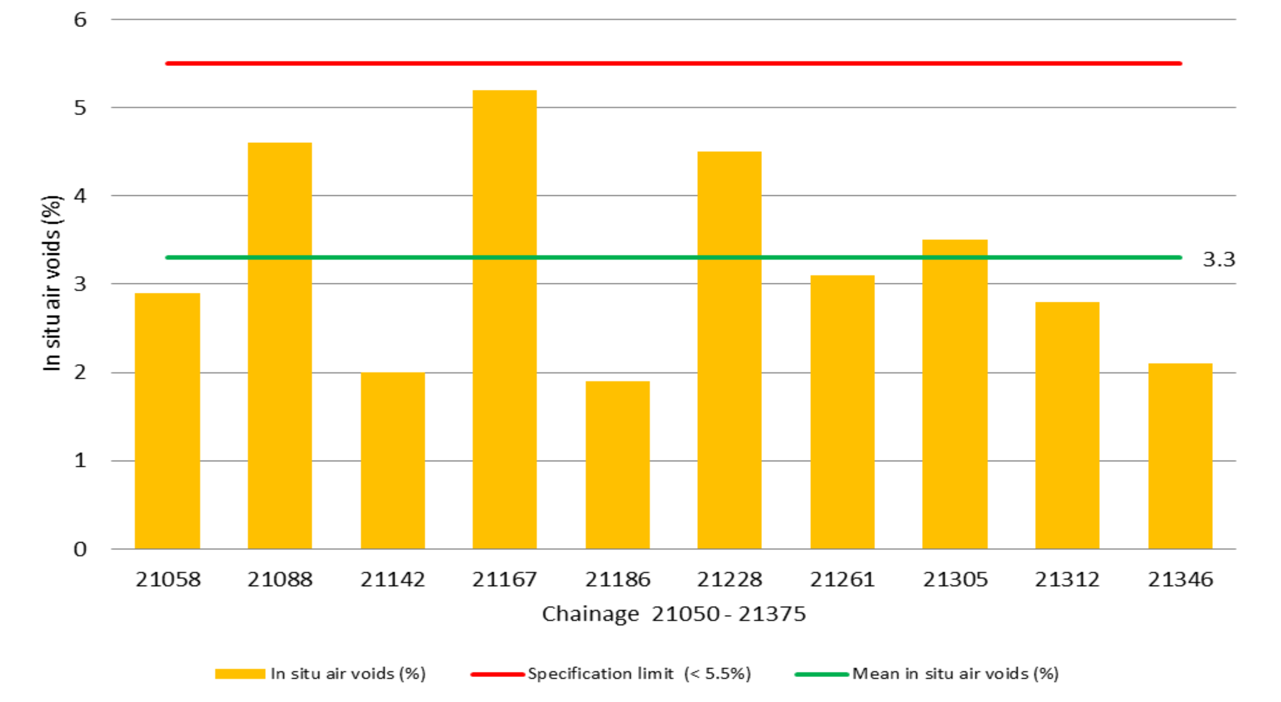
Main Roads *Draft Specification 514* requires a characteristic in situ air void value of no greater than 5.5% which was comfortably met. The mean air voids content was 2.7% and 3.3% for Lift 1 and Lift 2 respectively. The upper characteristic air voids for Lift 1 and Lift 2 were 3.7% and 4.1% respectively, while the lower characteristic air voids was 1.8% for Lift 1 and 2.4% for Lift 2.

Figure 8.3: Air voids Lift 1 (LR1 & LR2)



Source: Based on laboratory data from Main Roads.

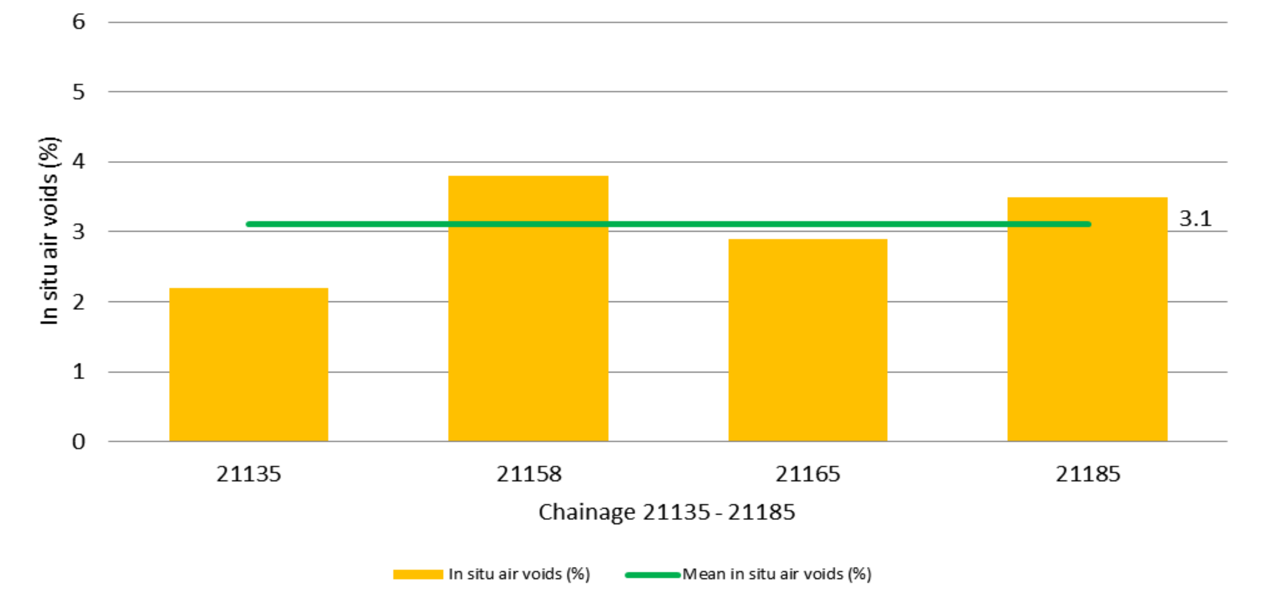
Figure 8.4: Air voids Lift 2 (LR1 & LR2)



Source: Based on laboratory data from Main Roads.

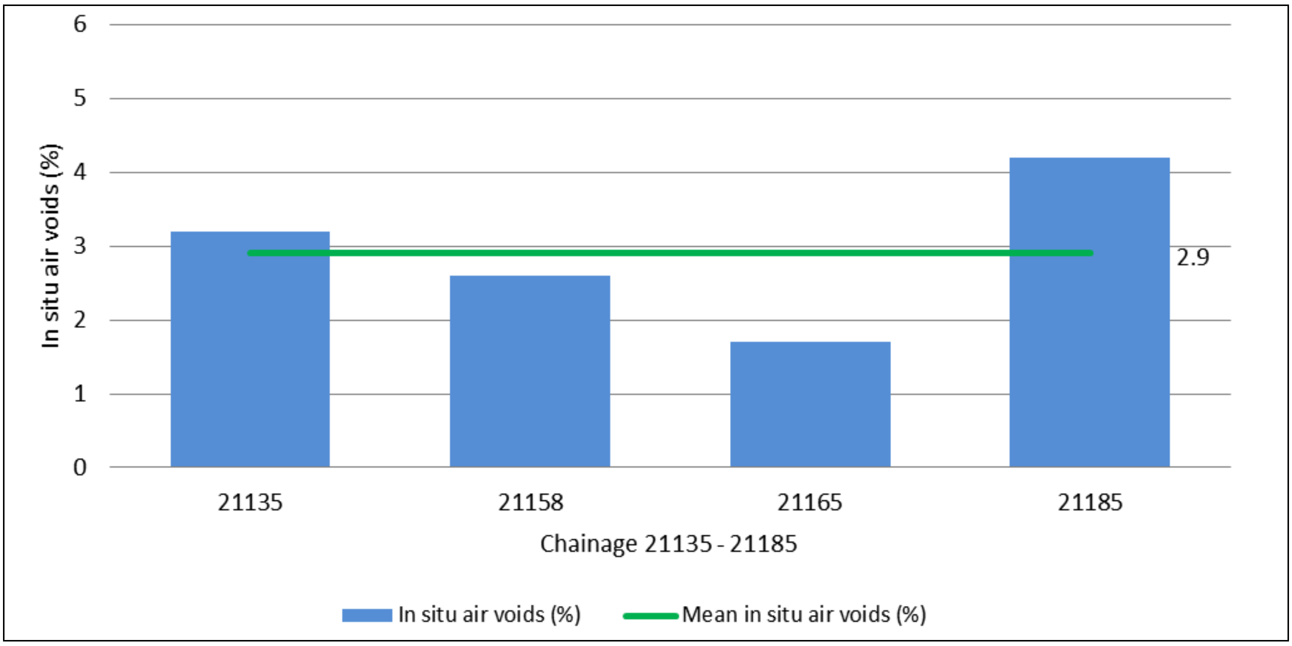
In addition, four cores and four nuclear density samples were taken from sections of Lift 2 that showed a bitumen rich surface. Testing was performed to determine the in situ air voids. The results, shown in Figure 8.5 and Figure 8.6, indicate that the air voids were typical of the values shown in Figure 8.4.

Figure 8.5: Core results bitumen rich surface, Lift 2 (LR1 & LR2)



Source: Based on laboratory data from Main Roads.

Figure 8.6: Nuclear gauge results bitumen rich surface, Lift 2 (LR1 & LR2)

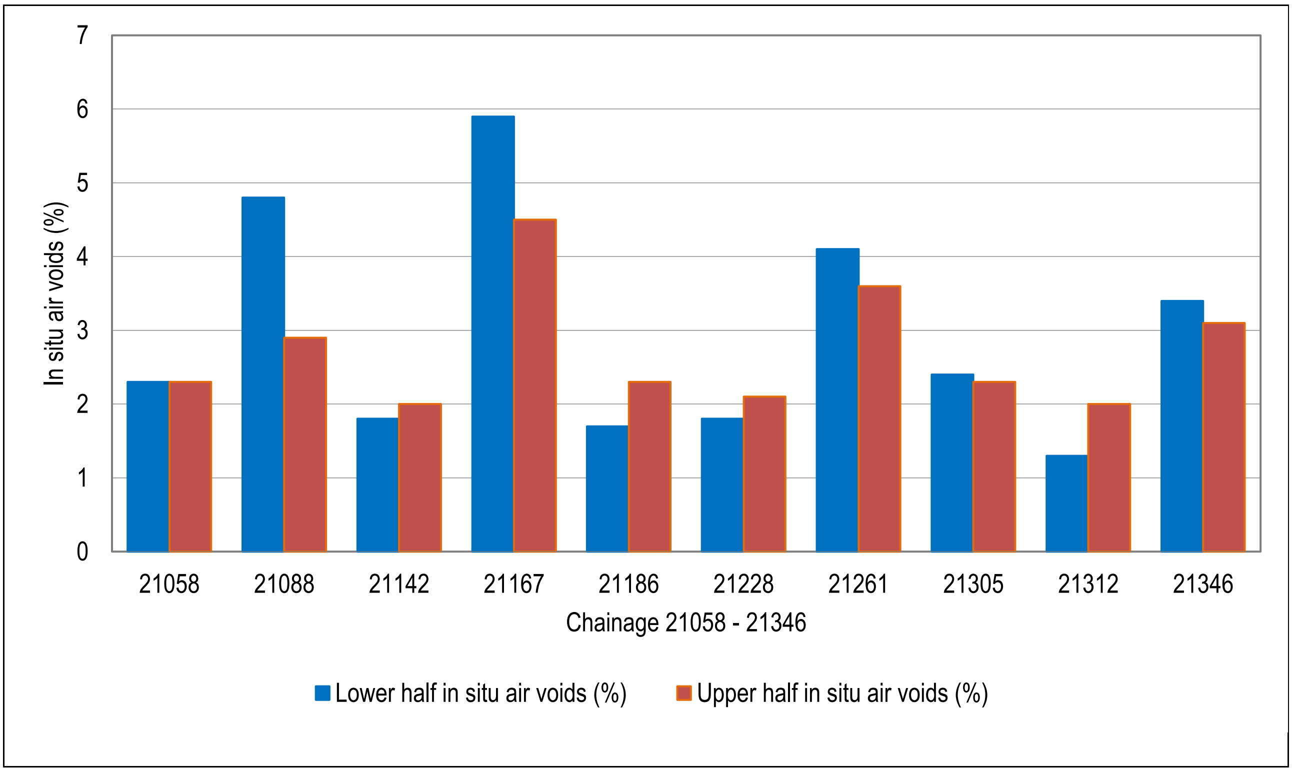


Source: Based on laboratory data from Main Roads.

8.2.2 Air Voids of Field Cores Upper and Lower Half

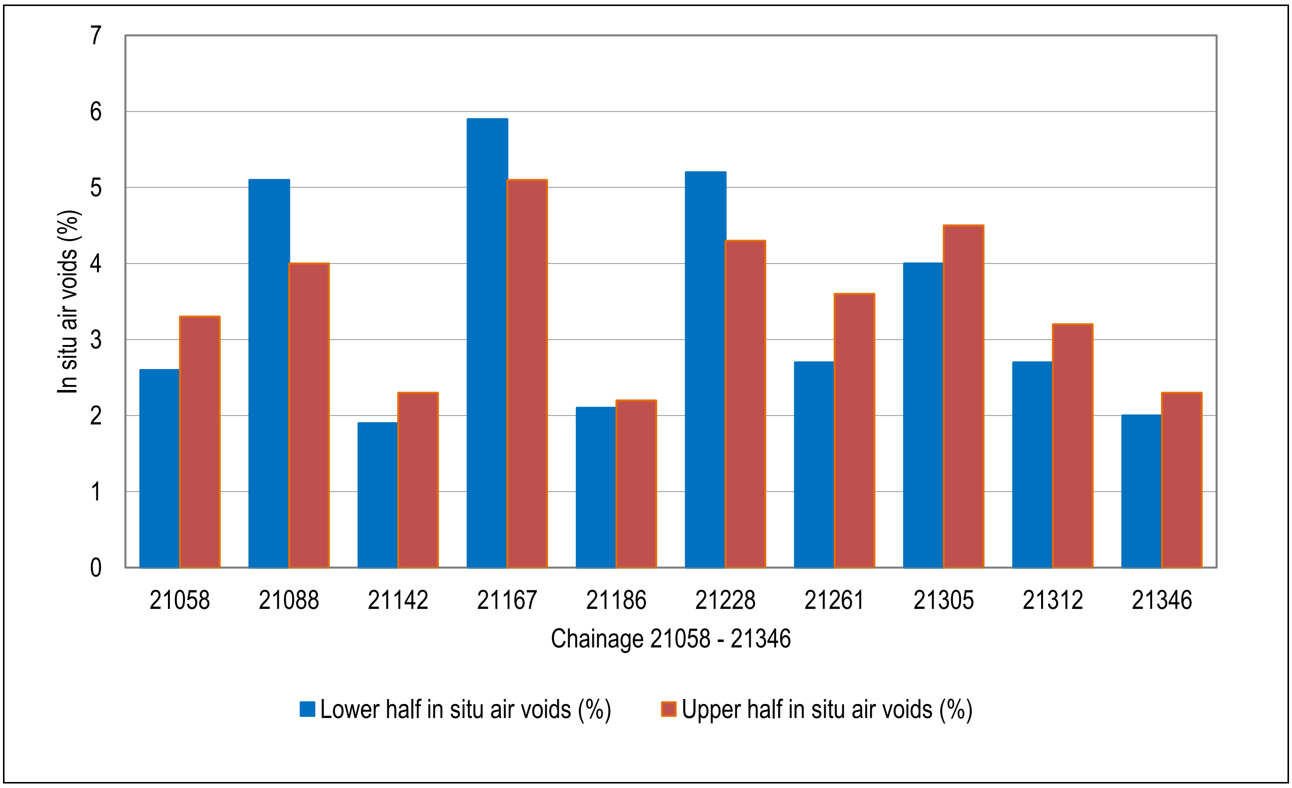
The cores from each lift were cut in half and the density of the top and bottom halves was tested in accordance with AS/NZS 2891.9.2 with the air voids content calculated in accordance with AS/NZS 2891.8. Figure 8.7 displays the air voids of the upper and lower half in Lift 1 and Figure 8.8 the upper and lower half air voids of Lift 2. Figure 8.9 indicates that for the lower and upper half of both Lift 1 and Lift 2, around the mean (approximately 3% air voids) there was little difference between the layers. However, above the mean higher air voids were observed in the lower half of both Lift 1 and Lift 2.

Figure 8.7: Air voids lower and upper layer of Lift 1 (LR1 and LR2)



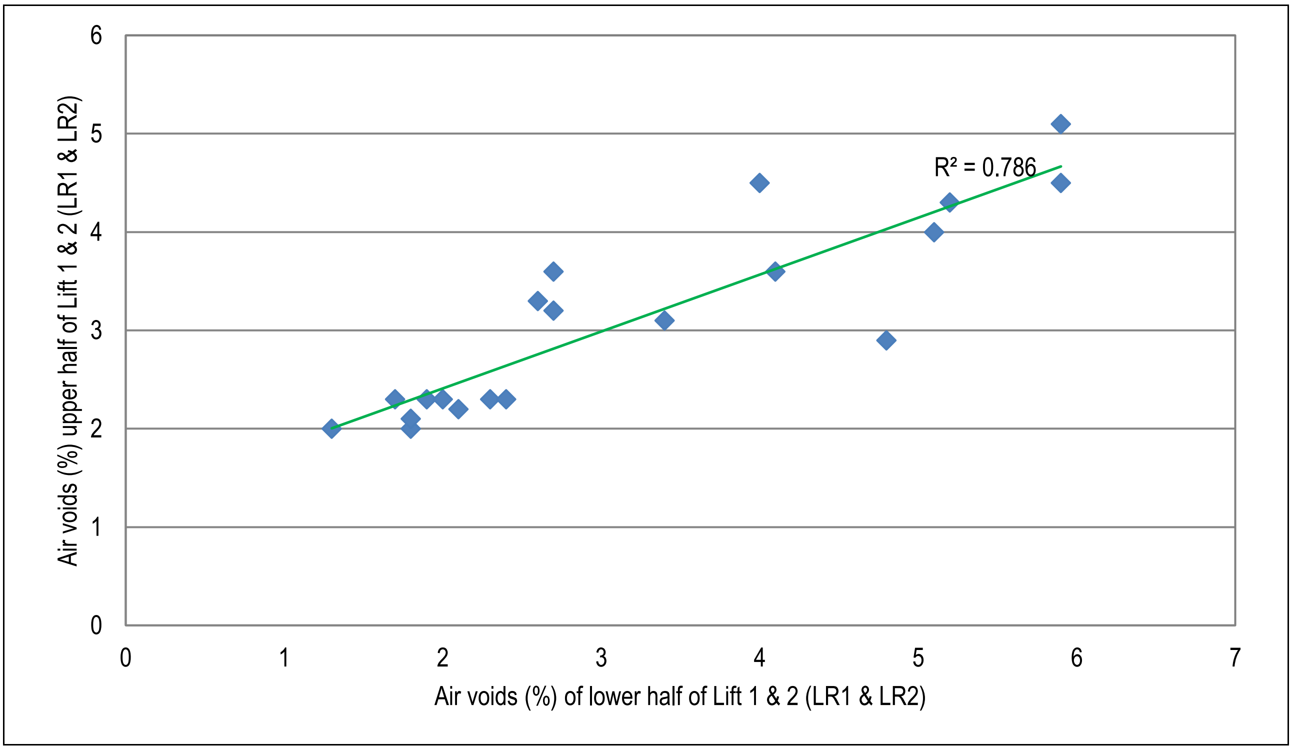
Source: Based on laboratory data from Main Roads.

Figure 8.8: Air voids lower and upper layer of Lift 2 (LR1 & LR2)



Source: Based on laboratory data from Main Roads.

Figure 8.9: Trend line of lower half air voids



Source: Based on laboratory data from Main Roads.

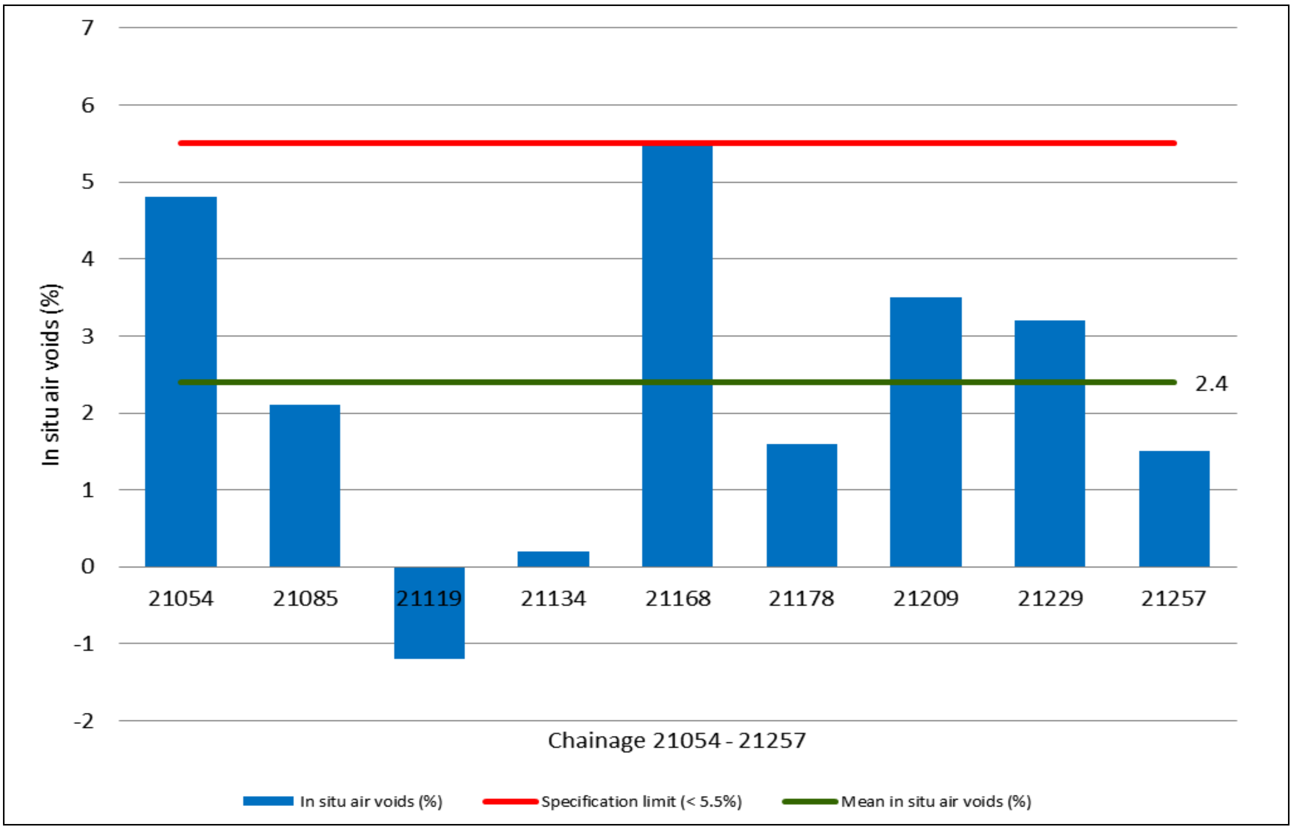
8.2.3 Air Voids from Thin Layer Gauge

Main Roads technicians carried out bulk density testing with a Troxler 3340 nuclear thin layer density gauge in accordance with AS/NZS 2891.14.2. Densities were recorded at 18 sites in Lift 1, coinciding with one lot per lane and 9 tests per lot. However, in Lift 2 densities were recorded at 10 sites, at the same locations the field cores were taken.

The in situ air voids measured by the thin layer gauge are shown in Figure 8.10 through to Figure 8.12. The nuclear density results for Lift 1 were measured separately in each lane and cannot be compared with the Lift 1 core results sampled across the whole lot. However, core and nuclear testing for Lift 2 were both conducted on a lot basis and were sampled at the same locations to provide a point of comparison, this is presented in Figure 8.13.

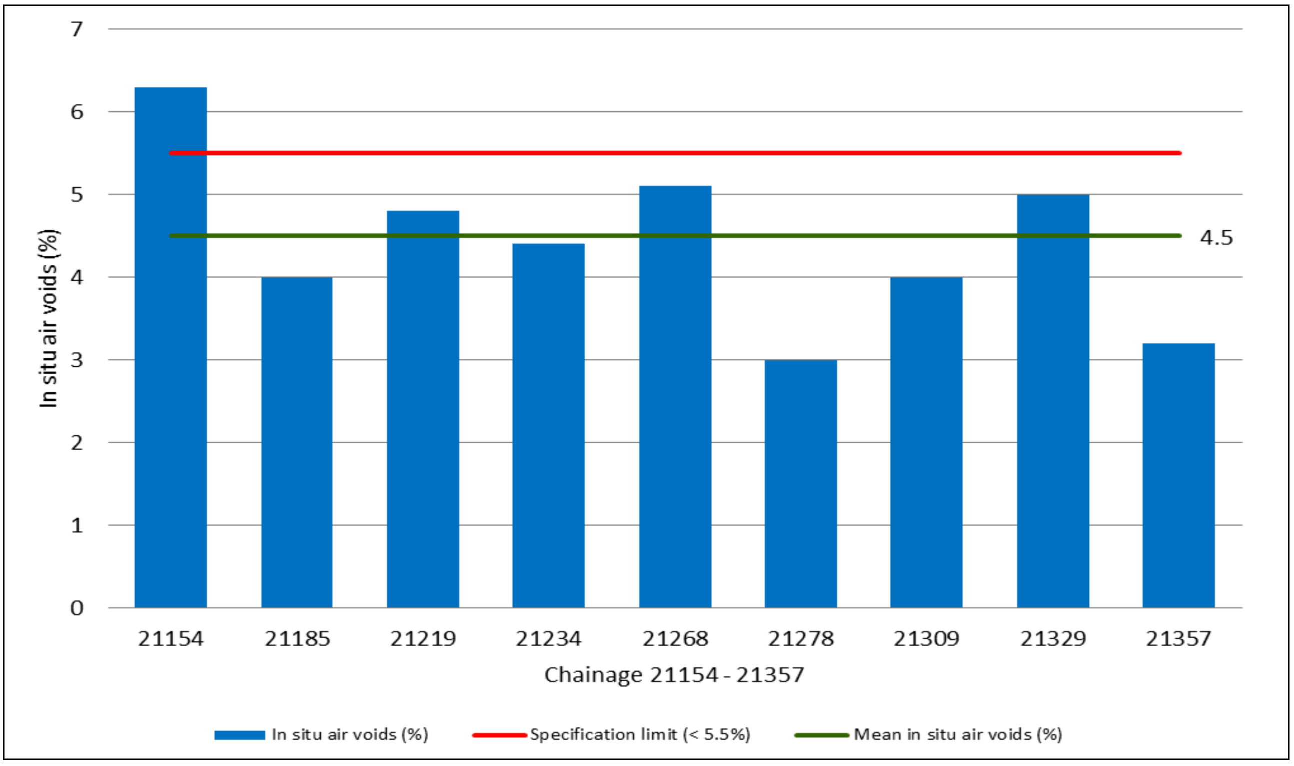
Air voids were calculated in accordance with WA 733.1 and the field bulk density was determined in accordance with AS/NZS 2891.14.2.

Figure 8.10: Nuclear gauge air voids results: Lift 1 (LR1)



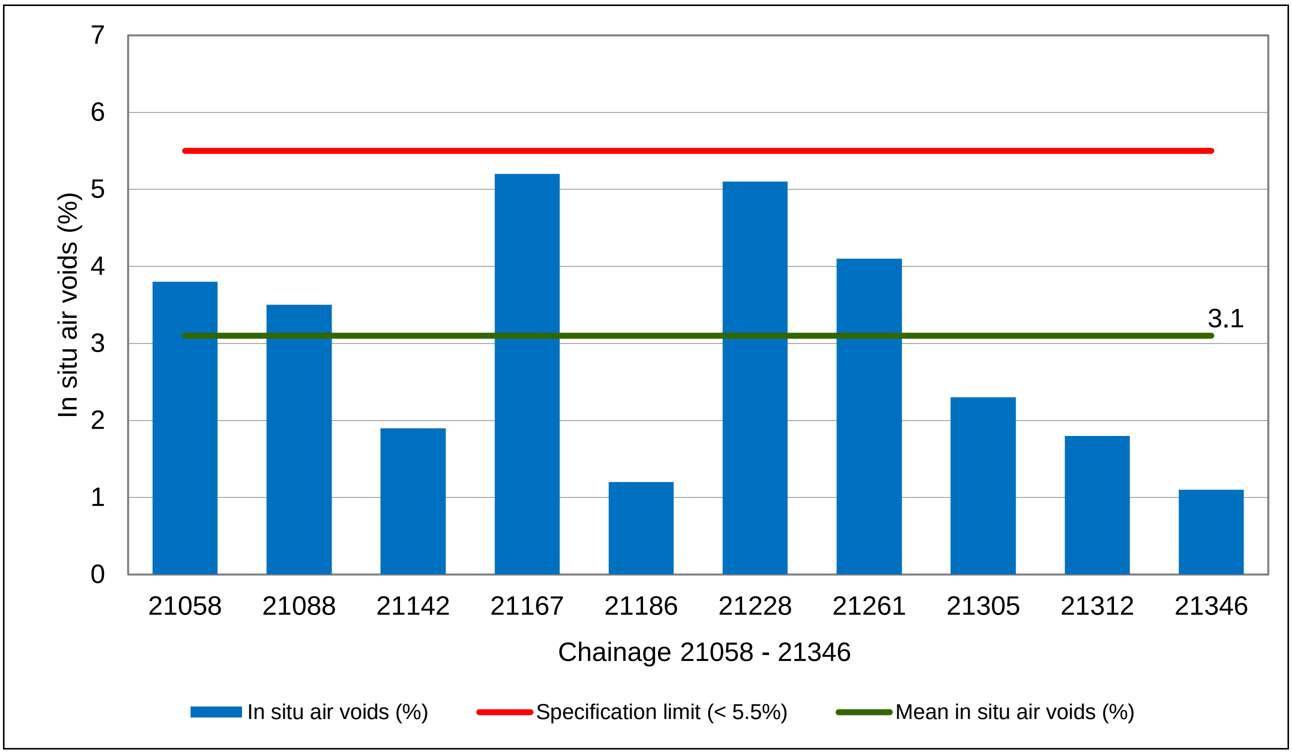
Source: Data supplied by Main Roads.

Figure 8.11: Nuclear gauge air voids results: Lift 1 (LR2)



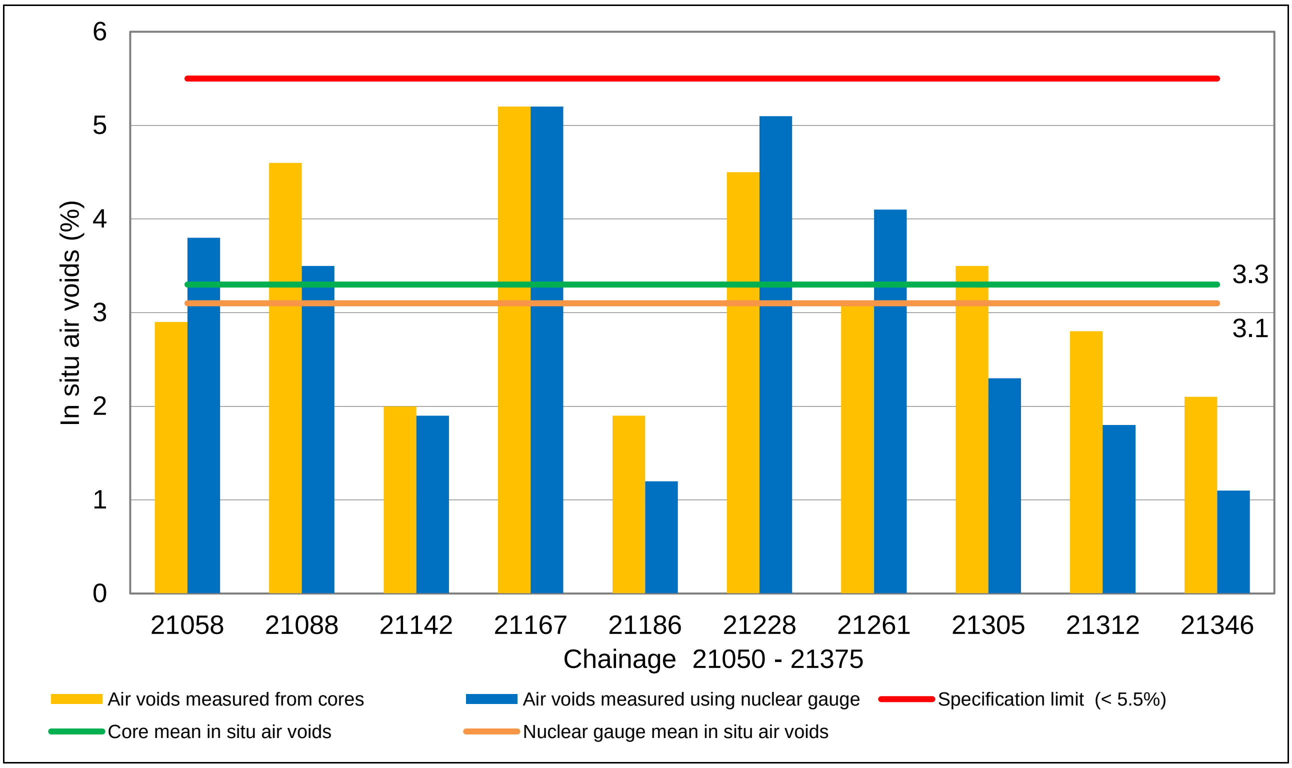
Source: Data supplied by Main Roads.

Figure 8.12: Nuclear gauge air voids results: Lift 2 (LR1 & LR2)



Source: Data supplied by Main Roads.

Figure 8.13: Core vs. nuclear gauge air voids results: Lift 2 (LR1 & LR2)



Source: Data supplied by Main Roads.

Nuclear density tests were taken at various sites on the longitudinal construction joints (Figure 8.14). The air voids on the joint for Lift 1 and Lift 2 respectively are shown in Figure 8.15 and Figure 8.16. The results indicate variable and high air voids.

Figure 8.14: Nuclear gauge densities recorded in the joint lines

Source: ARRB.

Figure 8.15: Joint air voids: Layer 1 (LR1 & LR2)

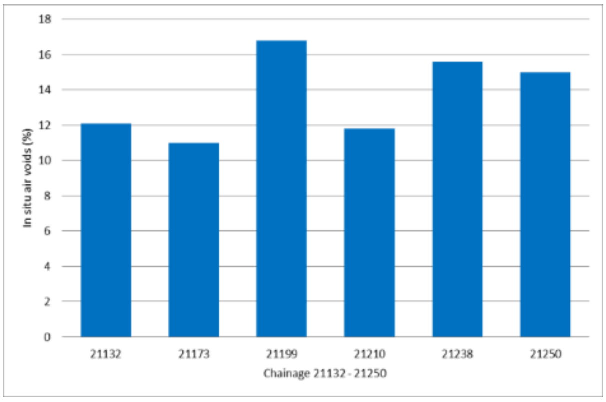
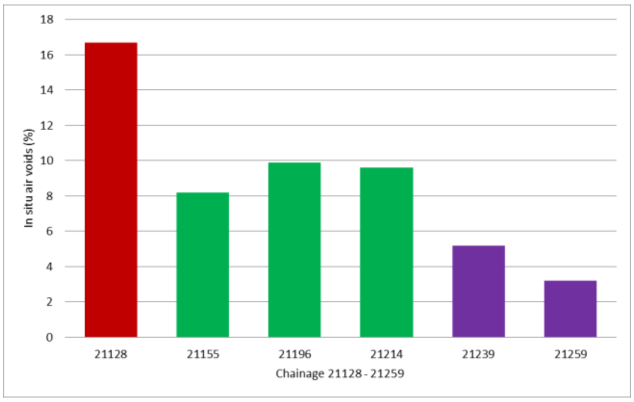


Figure 8.16: Joint air voids: Layer 2 (LR1 & LR2)



Source: Based on laboratory data from Main Roads.

The three joint overlapping methodologies discussed in Section 7.4 for Lift 2 are represented in Figure 8.16 where chainage 21128 was completed using typical practice from Lift 1, chainages 21155 to 21214 were constructed overlapping with large stone removal by hand raking and chainages 21239 and 21259 were taken at areas constructed with overlapping without the removal of large stones. The results indicate that overlapping the joint without the removal of large stones produced the lowest in situ air void content. Therefore, the solution is shown to be:

- compact the hot asphalt as described in Section 7.3.2, with a steel-drum roller overhanging the unsupported edge
- cut when warm (bevelled edge) at an angle of 45–60 ° using a cutting wheel attached to the roller, as per Main Roads *Specification 510*
- pave by overlapping of joint edge with 25–50 mm, in accordance with Main Roads *Specification 510* and/or Main Roads *Draft Specification 514*

- butting up, rolling and pressing of joints taking care not to remove the large stones while raking
- compact.

8.3 Compacted Thickness

The target thickness of 105 mm for both layers was achieved for the EME2 mix. The average thickness of Lift 1 and Lift 2 was 110 mm and 105 mm, respectively. Figure 8.17 shows a full-length core and Figure 8.18 shows a close-up of the cut surface.

Figure 8.17: Full depth cores

Figure 8.18: Cores of Layer 1 and Layer 2

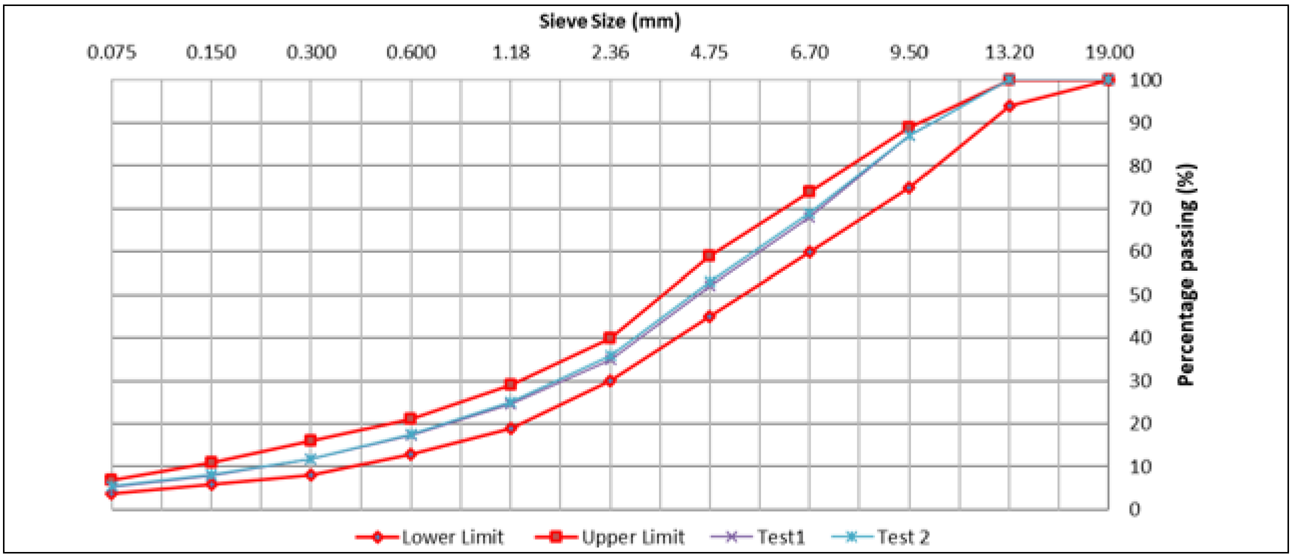
Source: ARRB.

8.4 Mix Conformance

8.4.1 Main Roads Results

The volumetric and PSD data was compiled from the results of the quality control tests performed by Main Roads on the mix sampled at the plant. PSD results are shown in Figure 8.19 and Figure 8.20, whilst the volumetric properties are presented in Table 8.2.

Figure 8.19: PSD results of EME2 mix (26/04/17)



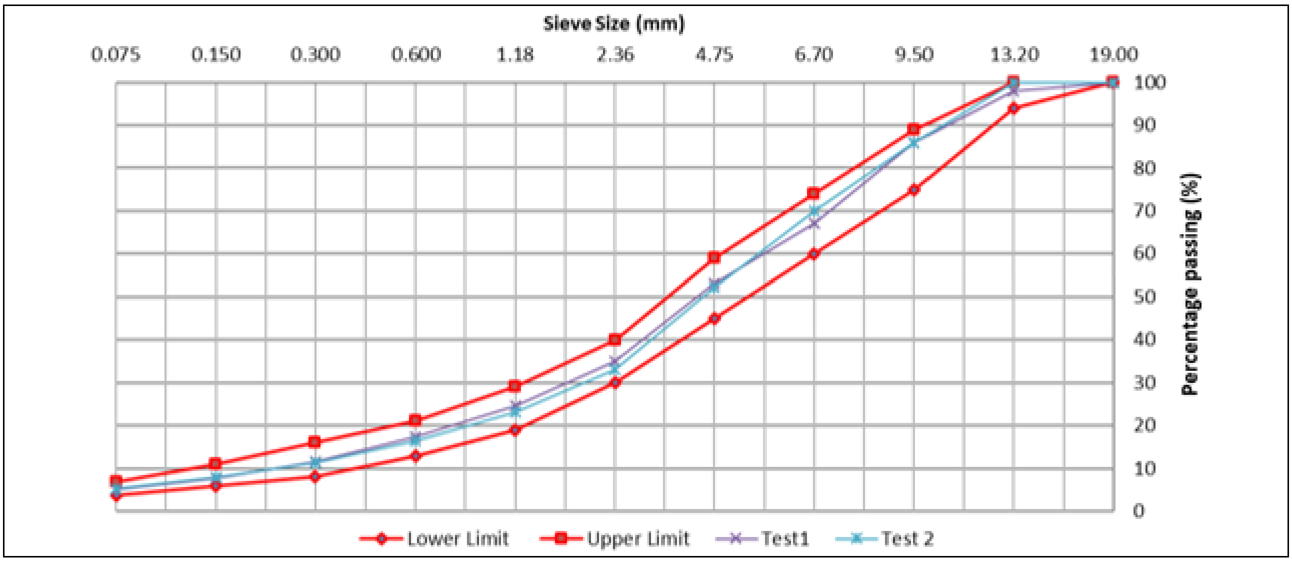
Source: Based on laboratory data from Main Roads.

Table 8.2: Volumetric properties Main Roads

Date & time sampled	Bitumen content (%)	Maximum density (t/m³)	Degree of particle coating (%)	Moisture content of asphalt (%)
26/4/17–10:24 am	5.9	2.492	100	0.1
26/4/17–2:53 pm	5.9	2.497		
27/4/17–7:53 am	5.9	2.483		
27/4/17–2:53 pm	6.0	2.496		

Source: Data supplied by Main Roads.

Figure 8.20: PSD results of EME2 mix (27/04/17)

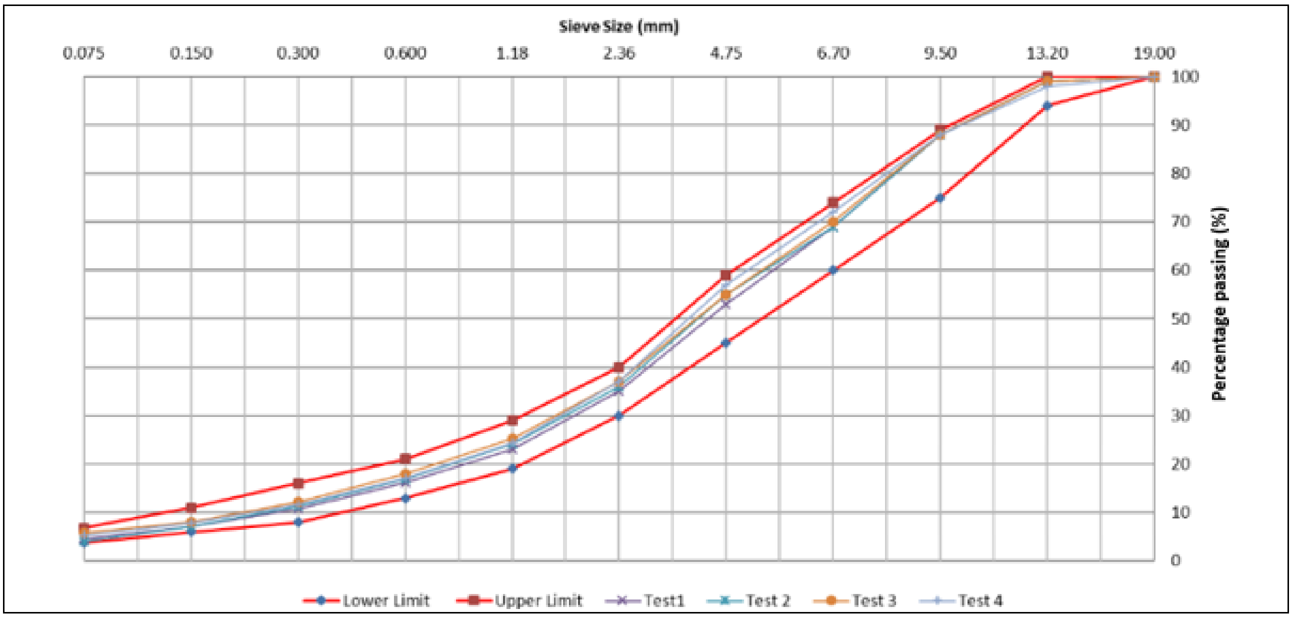


Source: Data supplied by Main Roads.

8.4.2 Downer Group Results

Downer Group performed gradation and volumetric property testing daily for the two days of production of the EME2 mix. Seven PSD results are shown in Figure 8.21 and Figure 8.22 while the volumetric properties are shown in Table 8.3. All the test results were within the specification tolerances.

Figure 8.21: PSD results of EME2 mix (26/04/17)



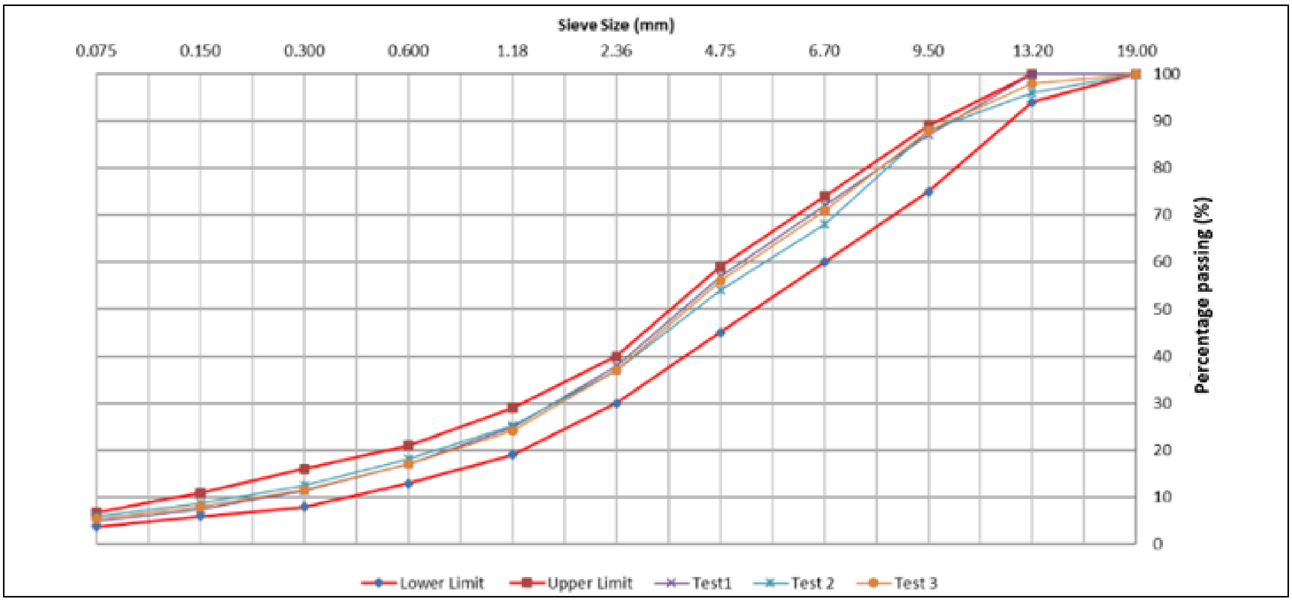
Source: Based on data supplied by Downer Group.

Table 8.3: Volumetric properties Downer Group

Date & time sampled	Bitumen content (%)	Maximum density (t/m³)	Degree of particle coating (%)	Moisture content of asphalt (%)
26/4/17–10:24 am	5.9	2.499	100	0
26/4/17–11:23 am	6	2.498		
26/4/17–2:08 pm	5.9	2.492		
26/4/17–2:21 pm	5.9	2.498		
27/4/17–7:54 am	6.1	2.485		
27/4/17–8:50 am	5.8	2.493		
27/4/17–9:32 am	6.0	2.488		

Source: Based on data supplied by Downer Group.

Figure 8.22: PSD results of EME2 mix (27/0417)



Source: Based on data supplied by Downer Group.

Therefore, the results indicate that there is a good alignment between the Main Roads and Downer Group laboratories, both showing results within specification tolerances. This indicates that a good process control was achieved for the EME2 target grading, with results generally well inside the envelope. However, it is important to note that the results obtained from Downer Group showed a finer mix. This may be attributed to the difference in the number of samples tested by each laboratory (4 by Main Roads, 7 by Downer Group) as well as the tendency for PSDs to be finer during production.

8.5 Shape of EME2

Main Roads *Specification 510 Asphalt Intermediate Course* states that the surface shape in the transverse direction on the top of the compacted intermediate layer shall not exceed 5 mm maximum deviation within any 3 m long section (Main Roads 2016d). The surface shape was determined using a 3 m straight edge in a transverse direction as shown in Figure 8.23. The deviations from the straight edge target levels ranged from 0–6 mm (showing one non-conformance) in LR2 Lift 2 and 0–3 mm in LR1 Lift 2. The results are detailed in Appendix F. Generally, the results from the straight edge indicate that a uniform and even surface was constructed, conforming with specifications.

Figure 8.23: Checking shape in a transverse direction using 3 m straight edge

Source: ARRB.

The ARRB Walking Profiler, in accordance with Main Roads Test Method WA 313.4 (Main Roads 2012e), was used to measure roughness.

The IRI values were converted to the traditionally used NAASRA counts using Equation 2 (Austroads 2007a).

$$NRM = -1.27 + 26.49 * Lane\ IRI_{qc} \tag{2}$$

where

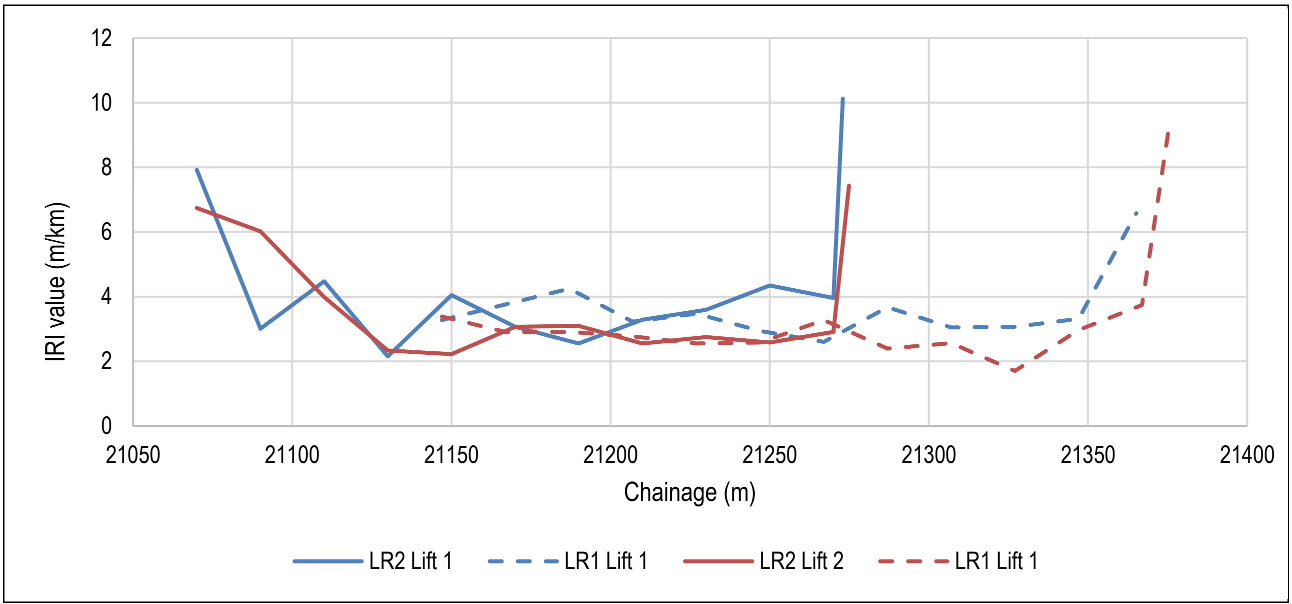
NRM = NAASRA roughness counts (counts/km)

$Lane\ IRI_{qc}$ = average International Roughness Index quarter-car of single outer and inner wheel path (m/km)

Figure 8.24 shows the International Roughness Index (IRI) of both lanes of Lift 1 and Lift 2. As expected, the results show that Lift 2 was generally smoother than Lift 1. The Austroads *Guide to Asset Management Part 5B: Roughness* approximate level of roughness for highways and main roads with a speed limit of 100 km/h is an IRI of 4.2 m/km (Austroads 2007a).

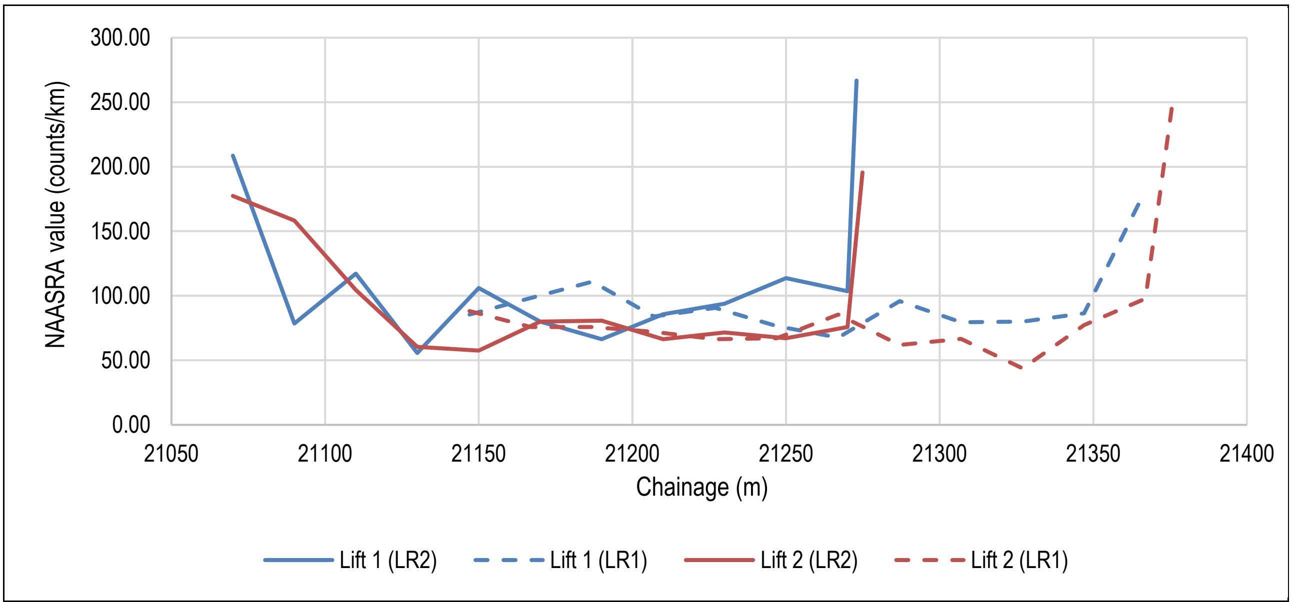
It is important to note the IRI_{qc} value measured using the ARRB Walking Profiler was assumed as the Lane IRI_{qc} as the measurement was taken between wheel paths on a new pavement and it is assumed roughness will be similar in a transverse direction across the surface. The traditionally used NAASRA counts are also presented in Figure 8.25.

Figure 8.24: Walking profiler results for IRI of EME2 Lift 1 & Lift 2



Source: Data supplied by Main Roads.

Figure 8.25: Walking profiler results for NAASRA counts of EME2 Lift 1 & Lift 2



Source: Adapted from IRI data supplied by Main Roads using Austroads relationship.

8.6 Surface Texture

Surface texture was measured using Main Roads Test Method 310.1 (Main Roads 2012d). Surface texture is not specified and was measured for report only. The texture depth results ranged from 0.5 to 0.7 mm, with a mean of 0.6 mm. The results are detailed in Appendix G.

8.8 Binder Results

Main Roads sampled the EME2 bitumen at three increments per day, targeted at 5000 L,10 000 L and 15 000 L in-line during asphalt production. The results of the SAMI Bitumen Technologies bitumen test results are presented in Table 8.4 and the binder results taken in-line for the pre-trial on 12 April 2017 are presented in Table 8.5 and Table 8.6. The results from the trial, carried out on 26 April 2017 and 27 April 2017 are presented in Table 8.7 through to Table 8.18.

Generally, the EME2 bitumen results complied with Main Roads *Draft Specification 514* (Main Roads 2016b). However, there were a number of notable non-conformances and variations. As two of the non-conformances were associated with the Downer Group yard pre-trial and the other two were marginal, these were deemed acceptable for the trial. The non-conformances and variations are summarised as follows:

- Softening point (AS 2341.18) non-conformance:
  - S6799 sampled at 40 tonnes of EME2 asphalt production for the pre-trial (12 April 2017) – result of 73 °C, exceeding limit of 56–72 °C.
  - S6800 sampled at 95 tonnes of EME2 asphalt production for the pre-trial (12 April 2017) – result of 72.5 °C, exceeding limit of 56–72 °C.
- Penetration at 25.0 °C (AS 2341.12) and softening point (AS 2341.18) variation:
  - S6897 sampled at 5 000 litres of EME2 asphalt production (27 April 2017) – result of 22 p.u and 67.5 °C softening point. This increase in penetration and decrease in softening point (from approximately 19 p.u and 71 °C) indicates that the sample may have been contaminated. This change was also observed in S6922 and S6923.
- Increase in softening point after RTFO treatment (AS/NZS 2341.10 and AS 2341.18) non-conformance:
  - S6922 sampled at 10 000 litres of EME2 asphalt production (27 April 2017) – result of 10 °C, exceeding limit of 8 °C.
  - S6923 sampled at 12 000 litres of EME2 asphalt production (27 April 2017) – result of 9 °C, exceeding limit of 8 °C.
- Viscosity at 60 °C (AS/NZS 2341.2) variation:
  - S6922 sampled at 10 000 litres of EME2 asphalt production (27 April 2017) – result of 5802 Pa.s, significant drop from S6921 (10 025 Pa.s)
  - S6923 sampled at 12 000 litres of EME2 asphalt production (27 April 2017) – result of 5805 Pa.s, significant drop from S6921 (10 025 Pa.s)

Notably, it may be seen that viscosity dropped from approximately 10 000 Pa.s to approximately 5800 Pa.s on 27 April 2017. The drop in viscosity between sample S6921 and S6922 and S6923 is also associated with an increase in mass change, softening point after RTFO and a marginal increase in softening point and penetration at 25.0 °C. Furthermore, the increase in mass change indicates that there was likely a contaminant in the bitumen tanker at point of loading. As sample S6897, S6922 and S6923 all show similar results, sampling error may be ruled out.

Table 8.4: Pre-trial binder properties (12/04/17)

Property	Test standard	Units	Limits	Test result
Penetration at 25 °C (100 g, 5 sec.)	AS 2341.12	pu	≥ 15 ≤ 25	16
Softening point	AS 2341.18	°C	≥ 56 ≤ 72	72.0
Viscosity at 60 °C	AS/NZS 2341.2	Pa.s	≥ 900	14 400
Loss on heating	AS/NZS 2341.10 or AGPT/T103	%	≤ 0.5	< 0.1
Retained penetration	AS/NZS 2341.10 and AS 2341.12	%	≥ 55	88
Increase in softening point after RTFO treatment	AS/NZS 2341.10 and AS 2341.18	°C	≤ 8	5.5
Viscosity at 135 °C	AS/NZS 2341.2, AS 2341.3, AS/NZS 2341.4 or AGPT/T111	Pa.s	≥ 0.6	3.29
Matter insoluble in toluene	AS/NZS 2341.8	% mass	≤ 1.0	< 0.1
Viscosity at 60 °C after RTFO	AS/NZS 2341.10 and AS/NZS 2341.2	Pa s	Report	41 300
Percent increase in viscosity at 60 °C after RTFO test	AS/NZS 2341.10 and AS/NZS 2341.2	%	Report	287

Source: Based on laboratory data from SAMI Bitumen Technologies.

Table 8.5: S6799 sampled at 40 tonnes of EME2 asphalt production (pre-trial 12/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Viscosity at 60 °C (Pa.s)	AS 2341.2	14781	900 Min	12/4/17 4:50pm
Viscosity at 135 °C (Pa.s)	AS 2341.4	2.69	0.6 Min	
Penetration at 25.0 °C (p.u)	AS 2341.12	18	15–25	
Penetration at 35.0 °C (p.u)	AS 2341.12	35		
Penetration Index 1.3		1.01		
Insoluble in toluene (%)	AS 2341.8	0.1	1.0 Max	
Softening point (°C)	AS 2341.18	73	56–72	
Mass change (%)	AS 2341.10	–0.04	0.5 Max	
AS2341.2 Dynamic viscosity at 60 °C	AS 2341.10	47924		
Ratio of viscosity before and after treatment at 60 °C (%)	AS 2341.10	324		
Softening point (°C)	AS 2341.10, AS 2341.18	78.5		
Increase in softening point after RTFO treatment (°C)	AS 2341.10, AS 2341.18	6	8 Max	
AS 2341.12 Penetration at 25 °C 100 g, 5 sec. (pu)	AS 2341.10	15		
Retained penetration (%)1,2	AS 2341.10, AS 2341.12	87	55 Min	

Source: Based on laboratory data from Main Roads.

Table 8.6: S6800 sampled at 95 tonnes of EME2 asphalt production (pre-trial 12/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Penetration at 25.0 °C (p.u)	AS 2341.12	18	15–25	12/4/17 5:10pm
Softening point (°C)	AS 2341.18	72.5	56–72	

Source: Based on laboratory data from Main Roads.

Table 8.7: S6892 sampled at 5 000 litres (trial 26/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Penetration at 25.0 °C (p.u)	AS 2341.12	22	15–25	26/4/17 10:38am
Softening point (°C)	AS 2341.18	71	56–72	

Source: Based on laboratory data from Main Roads.

Table 8.8: S6908 sampled at 10 000 litres (trial 26/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Viscosity at 60 °C (Pa.s)	AS 2341.2	11 019	900 Min	26/4/17 11:24am
Viscosity at 135 °C (Pa.s)	AS 2341.4	2.52	0.6 Min	
Penetration at 25.0 °C (p.u)	AS 2341.12	19	15–25	
Penetration at 35.0 °C (p.u)	AS 2341.12	37		
Penetration Index 1.3		0.85		
Insoluble in toluene (%)	AS 2341.8	0.1	1.0 Max	
Softening point (°C)	AS 2341.18	71	56–72	
Mass change (%)	AS 2341.10	–0.02	0.5 Max	
AS2341.2 Dynamic viscosity at 60 °C	AS 2341.10	40 549		
Ratio of viscosity before and after treatment at 60 °C (%)	AS 2341.10	368		
Softening point (°C)	AS 2341.10, AS 2341.18	77.5		
Increase in softening point after RTFO treatment (°C)	AS 2341.10, AS 2341.18	6	8 Max	
AS 2341.12 Penetration at 25 °C 100 g, 5 sec. (pu)	AS 2341.10	15		
Retained penetration (%)1,2	AS 2341.10, AS 2341.12	77	55 Min	

Source: Based on laboratory data from Main Roads.

Table 8.9: S6917 sampled at 12 500 litres (trial 26/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Viscosity at 60 °C (Pa.s)	AS 2341.2	10 623	900 Min	26/4/17 11:49am
Viscosity at 135 °C (Pa.s)	AS 2341.4	2.41	0.6 Min	
Penetration at 25.0 °C (p.u)	AS 2341.12	19	15–25	
Penetration at 35.0 °C (p.u)	AS 2341.12	38		
Penetration Index [1,3]		0.77		
Insoluble in toluene (%)	AS 2341.8	0.0	1.0 Max	
Softening point (°C)	AS 2341.18	70.5	56–72	
Mass change (%)	AS 2341.10	–0.03	0.5 Max	
AS2341.2 Dynamic viscosity at 60 °C	AS 2341.10	41 995		
Ratio of viscosity before and after treatment at 60 °C (%)	AS 2341.10	395		
Softening point (°C)	AS 2341.10 AS 2341.18	77.5		
Increase in softening point after RTFO treatment (°C)	AS 2341.10 AS 2341.18	7	8 Max	
AS 2341.12 Penetration at 25 °C 100 g, 5 sec. (pu)	AS 2341.10	16		
Retained penetration (%)[1,2]	AS 2341.10 AS 2341.12	86	55 Min	

Table 8.10: S6893 sampled at 5 000 litres (trial 26/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Penetration at 25.0 °C (p.u)	AS 2341.12	21	15–25	26/4/17 1:56pm
Softening point (°C)	AS 2341.18	71	56–72	

Source: Based on laboratory data from Main Roads.

Table 8.11: S6912 sampled at 10 000 litres (trial 26/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Viscosity at 60 °C (Pa.s)	AS 2341.2	10 477	900 Min	26/4/17 2:57pm
Viscosity at 135 °C (Pa.s)	AS 2341.4	2.45	0.6 Min	
Penetration at 25.0 °C (p.u)	AS 2341.12	20	15–25	
Penetration at 35.0 °C (p.u)	AS 2341.12	38		
Penetration Index 1.3		0.97		
Insoluble in toluene (%)	AS 2341.8	0.4	1.0 Max	
Softening point (°C)	AS 2341.18	71	56–72	
Mass change (%)	AS 2341.10	0.00	0.5 Max	
AS2341.2 Dynamic viscosity at 60 °C	AS 2341.10	44 074		
Ratio of viscosity before and after treatment at 60 °C (%)	AS 2341.10	421		
Softening point (°C)	AS 2341.10, AS 2341.18	78		
Increase in softening point after RTFO treatment (°C)	AS 2341.10, AS 2341.18	7	8 Max	
AS 2341.12 Penetration at 25 °C 100 g, 5 sec. (pu)	AS 2341.10	17		
Retained penetration (%)1,2	AS 2341.10, AS 2341.12	82	55 Min	

Source: Based on laboratory data from Main Roads.

Table 8.12: S6894 sampled at 15 000 litres (trial 26/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Penetration at 25.0 °C (p.u)	AS 2341.12	19	15–25	26/4/17 3:40pm
Softening point (°C)	AS 2341.18	71	56–72	

Source: Based on laboratory data from Main Roads.

Table 8.13: S6895 sampled at 5 000 litres (trial 27/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Penetration at 25.0 °C (p.u)	AS 2341.12	19	15–25	27/4/17 8:06am
Softening point (°C)	AS 2341.18	70.5	56–72	

Source: Based on laboratory data from Main Roads.

Table 8.14: S6921 sampled at 10 000 litres (trial 27/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Viscosity at 60 °C (Pa.s)	AS 2341.2	10 025	900 Min	27/4/17 8:54am
Viscosity at 135 °C (Pa.s)	AS 2341.4	2.31	0.6 Min	
Penetration at 25.0 °C (p.u)	AS 2341.12	19	15–25	
Penetration at 35.0 °C (p.u)	AS 2341.12	38		
Penetration Index [1,3]		0.77		
Insoluble in toluene (%)	AS 2341.8	0.1	1.0 Max	
Softening point (°C)	AS 2341.18	70.5	56–72	
Mass change (%)	AS 2341.10	–0.03	0.5 Max	
AS2341.2 Dynamic viscosity at 60 °C	AS 2341.10	34 444		
Ratio of viscosity before and after treatment at 60 °C (%)	AS 2341.10	344		
Softening point (°C)	AS 2341.10 AS 2341.18	76.5		
Increase in softening point after RTFO treatment (°C)	AS 2341.10 AS 2341.18	6	8 Max	
AS 2341.12 Penetration at 25 °C 100 g, 5 sec. (pu)	AS 2341.10	15		
Retained penetration (%)[1,2]	AS 2341.10 AS 2341.12	81	55 Min	

Source: Based on laboratory data from Main Roads.

Table 8.15: S6896 sampled at 15 000 litres (trial 27/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Penetration at 25.0 °C (p.u)	AS 2341.12	19	15–25	27/4/17 9:40am
Softening point (°C)	AS 2341.18	70.5	56–72	

Source: Based on laboratory data from Main Roads.

Table 8.16: S6897 sampled at 5 000 litres (trial 27/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Penetration at 25.0 °C (p.u)	AS 2341.12	22	15–25	27/4/17 11:32am
Softening point (°C)	AS 2341.18	67.5	56–72	

Source: Based on laboratory data from Main Roads.

Table 8.17: S6922 sampled at 10 000 litres (trial 27/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Viscosity at 60 °C (Pa.s)	AS 2341.2	5 802	900 Min	27/4/17 12:20pm
Viscosity at 135 °C (Pa.s)	AS 2341.4	1.87	0.6 Min	
Penetration at 25.0 °C (p.u)	AS 2341.12	22	15–25	
Penetration at 35.0 °C (p.u)	AS 2341.12	44		
Penetration Index [1,3]		0.55		
Insoluble in toluene (%)	AS 2341.8	0.1	1.0 Max	
Softening point (°C)	AS 2341.18	67.5	56–72	
Mass change (%)	AS 2341.10	0.17	0.5 Max	
AS2341.2 Dynamic viscosity at 60 °C	AS 2341.10	34 827		
Ratio of viscosity before and after treatment at 60 °C (%)	AS 2341.10	600		
Softening point (°C)	AS 2341.10, AS 2341.18	77		
Increase in softening point after RTFO treatment (°C)	AS 2341.10, AS 2341.18	**10**	8 Max	
AS 2341.12 Penetration at 25 °C 100 g, 5 sec. (pu)	AS 2341.10	16		
Retained penetration (%)[1,2]	AS 2341.10, AS 2341.12	75	55 Min	

Source: Based on laboratory data from Main Roads.

Table 8.18: S6923 sampled at 12 000 litres (trial 27/04/17)

Test type	Reference standard	Results	Specification limit	Date & time sampled
Viscosity at 60 °C (Pa.s)	AS 2341.2	5 805	900 Min	27/4/17 12:33pm
Viscosity at 135 °C (Pa.s)	AS 2341.4	1.87	0.6 Min	
Penetration at 25.0 °C (p.u)	AS 2341.12	22	15–25	
Penetration at 35.0 °C (p.u)	AS 2341.12	43		
Penetration Index [1,3]		0.60		
Insoluble in toluene (%)	AS 2341.8	0.1	1.0 Max	
Softening point (°C)	AS 2341.18	67.5	56–72	
Mass change (%)	AS 2341.10	0.18	0.5 Max	
AS2341.2 Dynamic viscosity at 60 °C	AS 2341.10	32 608		
Ratio of viscosity before and after treatment at 60 °C (%)	AS 2341.10	562		
Softening point (°C)	AS 2341.10 AS 2341.18	76		
Increase in softening point after RTFO treatment (°C)	AS 2341.10 AS 2341.18	9	8 Max	
AS 2341.12 Penetration at 25 °C 100 g, 5 sec. (pu)	AS 2341.10	16		
Retained penetration (%)[1,2]	AS 2341.10 AS 2341.12	73	55 Min	

Source: Based on laboratory data from Main Roads.

9 PERFORMANCE TESTING

9.1 Introduction

Laboratory testing of plant sampled mix obtained during the construction period was undertaken to characterise the engineering properties, validate the design mixture and investigate the performance of the EME2 mix. It is important to note that the samples used to test the resilient modulus, workability and moisture sensitivity were taken directly from the asphalt plant and were not laboratory prepared using reheated plant-sampled materials, as opposed to the other performance tests conducted. The laboratory testing was conducted during the period April 2017 to December 2017 by Main Roads, Queensland TMR, Downer Group, Boral and ARRB (as summarised in Appendix A). The samples were subjected to the laboratory tests presented in Table 9.1.

Table 9.1: Performance laboratory testing for EME2 specimens

Laboratory characterisation	Testing standard	Record of results
Air voids in specimens compacted by gyratory compactor at 100 cycles	AS/NZS 2891.8	Appendix H & Appendix L
Moisture sensitivity (tensile strength ratio)	AGPT/T232	Appendix H
Wheel tracking (rut resistance)	AGPT/T231	Appendix I
Flexural modulus	AGPT/T274	Appendix J
Fatigue resistance	AGPT/T274	Appendix K
Resilient modulus (ITT)	AS/NZS 2891.13.1	Appendix L
Richness modulus	N/A	Appendix M
Voids in dry compacted filler Delta ring and ball	AS/NZS 1141.17 EN 13179–1: 2000 and AS 2341.18	Appendix N
Hamburg wheel tracking	TMR Q325	Appendix O

9.2 Workability

The air void content of the mix after 100 gyrations of the gyratory compactor is used to provide an indication of the mix workability. It is important to note that the bulk density for the specimens was measured using two methods, the presaturation method (AS/NZS 2891.9.2) and the mensuration method (AS/NZS 2891.9.3). The air voids were also determined for two laboratory characterisations, the tensile strength ratio (TSR) test and the Indirect Tensile Test (ITT). The detailed results are presented in Appendix B for the pre-trial and Appendix H and Appendix L for the Tonkin Highway trial.

The air void contents for each specimen, noting the laboratory characterisation and method of determining bulk density sampled on 12 April 2017, 26 April 2017 and 27 April 2017 are summarised in Table 9.2 and it can be seen that all samples complied with the 6.0% maximum limit, in accordance with Main Roads *Draft Specification 514*. Notably, the results indicate that the method of determining the bulk density affects the measured air voids. The air voids are approximately 2% higher when the bulk density was determined using the mensuration method as opposed to the presaturation method.

Table 9.2: Summary of air voids in specimens compacted by gyratory compactor (100 cycles)

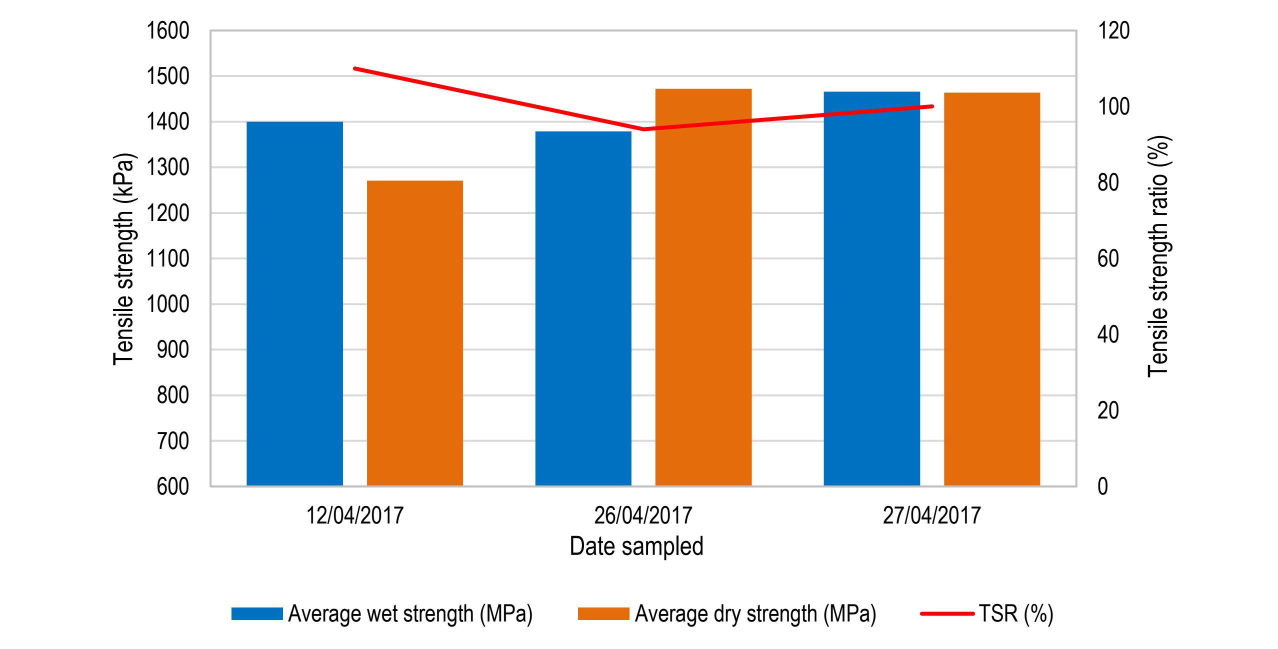
Date	Test report no.	AS/NZS 2891.9.2 – presaturation method (air voids %)			AS/NZS 2891.9.3 – mensuration method (air voids %)		
		Specimen 1	Specimen 2	Specimen 3	Specimen 1	Specimen 2	Specimen 3
12/04	S6850	2.9	2.9	3.1	4.9	5.1	4.8
12/04	S6851	3.1	3.2	2.6	5.7	5.1	4.6
26/04	S6848	2.6	2.6	2.5	4.3	4.9	4.4
26/04	S6852	2.7	3.1	3.2	4.6	4.5	5.4
27/04	S6849	2.9	2.9	3.0	4.8	4.8	4.8
27/04	S6853	3.1	3.5	3.1	5.0	4.7	5.3

Source: Based on laboratory data from Main Roads.

9.3 Moisture Sensitivity

Main Roads performed the stripping potential of asphalt, tensile strength ratio (TSR) testing for the pre-trial (12 April 2017) and both days of the trial in accordance with Austroads Test Method AGPT/T232 (Austroads 2007b). The results are summarised in Figure 9.1 and detailed in Appendix H. This shows compliance with Main Roads *Draft Specification 514* limit of a minimum TSR value of 80%.

Figure 9.1: TSR results of EME2 mix Lift 1 & Lift 2



Source: Based on laboratory data from Main Roads.

9.4 Rut Resistance (Wheel Tracking)

The deformation results from the wheel tracking test are summarised in Table 9.3 and presented in detail in Appendix I. The test results were below the maximum allowable deformations for both 5000 (2.0 mm) and 30 000 cycles (4.0 mm) in accordance with Main Roads *Draft Specification 514*.

Table 9.3: Summary of wheel tracking test results

Sample	Air voids (%)	Deformation (mm)	
		5 000 cycles (10 000 passes)	30 000 cycles (60 000 passes)
5203	4.1	1.3	1.5
5224	3.4	0.4	0.6
	Mean	0.9	1.1

Source: Based on laboratory data from ARRB.

9.5 Flexural Modulus

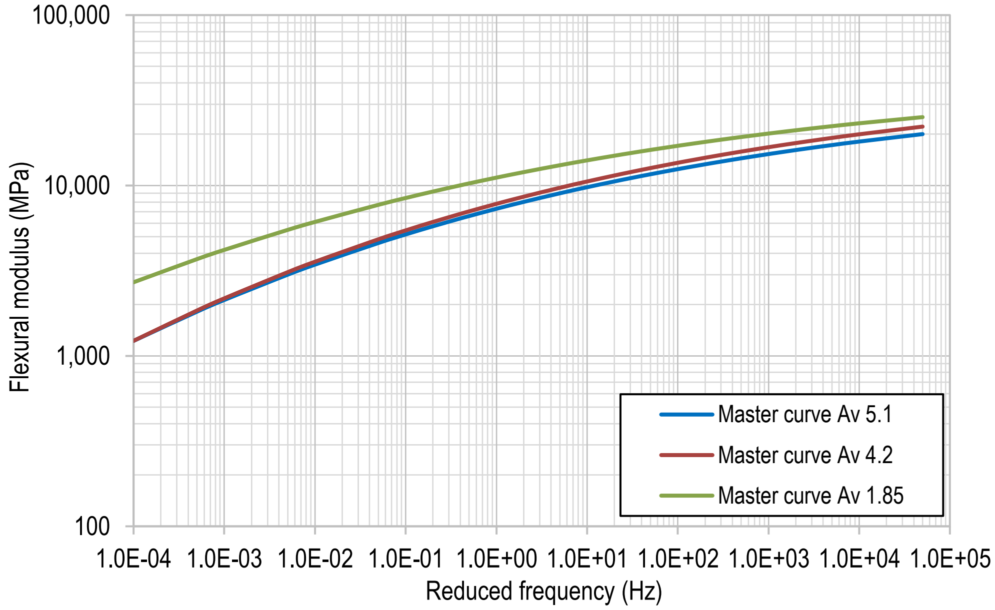
The asphalt flexural modulus was measured in accordance with Austroads Test Method AGPT/T274, *Characterisation of Flexural Stiffness and Fatigue Performance of Bituminous Mixes* (Austroads 2016). The test involves characterisation of the asphalt flexural modulus at different loading frequencies and temperatures, where the results are used to develop a flexural modulus master curve. The master curve is constructed by shifting the mean test results obtained at the different frequencies for each temperature to form a continuous function at a reference temperature, selected as 15 °C to allow comparisons to Main Roads *Draft Specification 514* (Main Roads 2016b).

The flexural modulus was tested using six beams containing differing air void contents, thus three master curves were constructed for the following air void (AV) contents (as detailed in Appendix J):

- air voids 5.10%: specimen at AV 5.1% (5202-1)
- air voids 4.20%: specimens at AV 4.0%, 4.2% and 4.5% (5202-2, 5202-3, 5202-4)
- air voids 1.85%: specimens at AV 1.8% and 1.8% (5231-1, 5231-4)

A comparison between the three master curves is presented in Figure 9.2, indicating that the master curve shape is similar for AV 4.2% and 5.1% while the AV 1.85% master curve shows a significantly increased modulus at low frequencies, converging with increased frequency. The moduli determined from the master curves at 15 °C and 10 Hz are presented in Table 9.4, showing that only the master curve created using an air voids content of 1.85% conformed to specification. This indicates that for compliance, the in situ air void content of the EME2 mix should be approximately 1.85%.

Figure 9.2: Master curve comparison for varying air voids



Source: Based on laboratory data from ARRB

Table 9.4: Flexural modulus results for master curves

Master curve	Flexural modulus at 15 °C and 10 Hz (MPa)
Air voids 5.1%	9 700
Air voids 4.2%	10 556
Air voids 1.85%	14 043

Source: Based on laboratory data from ARRB.

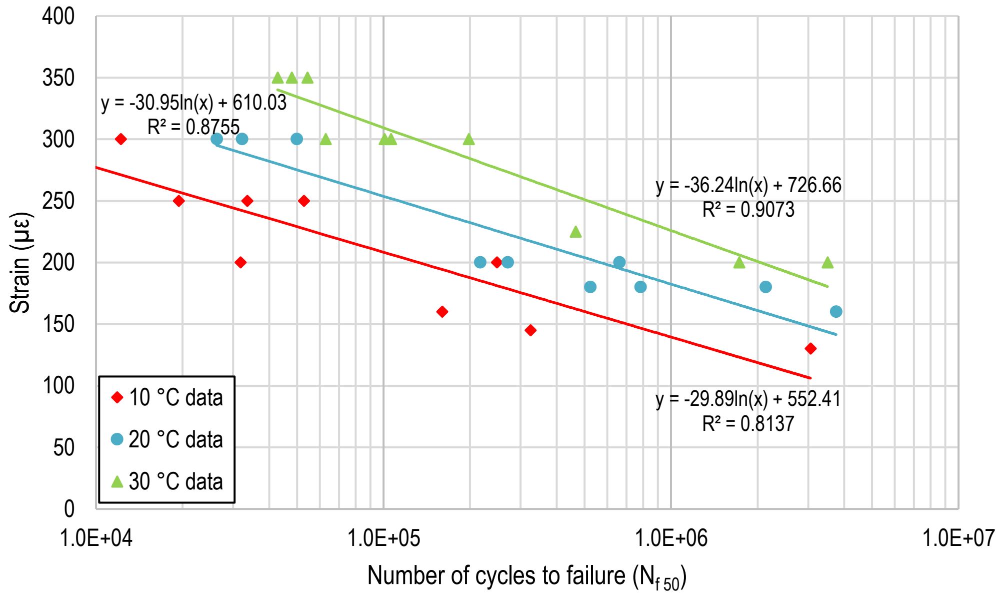
9.6 Fatigue Resistance

Asphalt fatigue testing was performed at a load frequency of 10 Hz, in accordance with the Austroads asphalt fatigue resistance test, AGPT/T274 (Austroads 2016). The tests were performed at a minimum of three strain levels (low, medium and high) and three temperatures (10 °C, 20 °C, 30 °C). However, Main Roads *Draft Specification 514* only includes requirements for the fatigue resistance at 20 °C, and as such, the tests conducted at 10 °C and 30 °C were only for research purposes.

Figure 9.3 presents a comparison of the fatigue results where $N_{f\,50}$ represents the number of cycles to failure, with failure defined as a 50% reduction in the asphalt modulus. Furthermore, the fatigue resistance at 1 million cycles for each of the testing temperatures is presented in Table 9.5. The results indicate that the fatigue characteristics of the EME2 mix improve with increase in temperature, with the fatigue resistance at 20 °C conforming to specifications. A summary of beam age, N_{f50} (number of repetitions to failure), strain level, beam air voids and initial modulus (at cycle 50) for each of the samples tested at 10 °C, 20 °C and 30 °C are detailed in Appendix K.

It is important to note that although AGPT/T274 recommends fatigue testing on a minimum of 18 beams tested at three different strain levels, a statistical analysis carried out as part of a NACoE project indicated it would be sufficient to test a minimum of 9 beams (Denneman & Bryant 2016, Denneman & Lam 2015, NACoE 2014).

Figure 9.3: Fatigue resistance results for EME2 mix



Source: Based on laboratory data from Boral.

Table 9.5: Fatigue resistance results

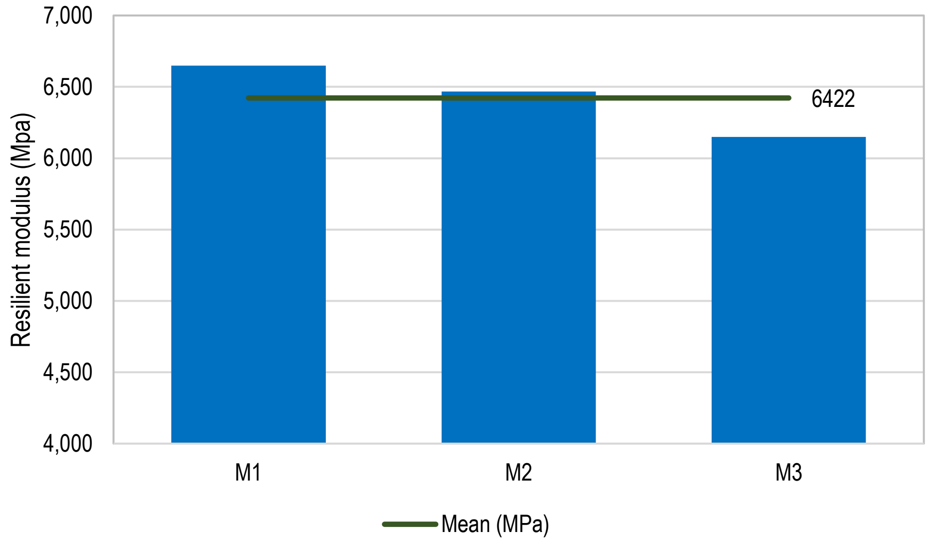
Temperature (°C)	Fatigue resistance at 10 Hz and 1 million cycles (με)
10	139.46
20	182.44
30	225.99

Source: Based on laboratory data from Boral.

9.7 Resilient Modulus

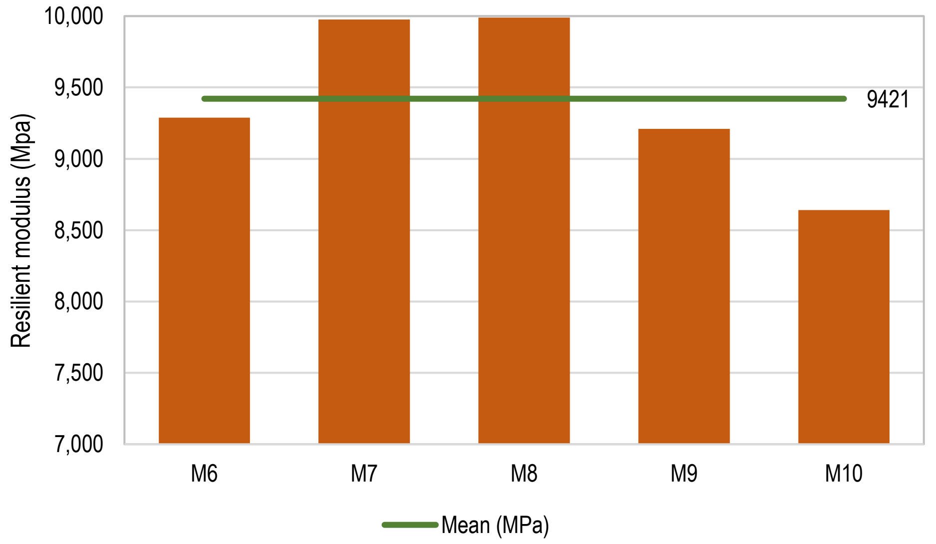
A summary of the indirect tensile testing results is presented in Figure 9.4, Figure 9.5 and Figure 9.6. The Downer Group yard pre-trial (sampled 12 April 2017) mean resilient modulus was 6422 MPa with an average bulk density of 2.39 t/m^3 and an average air void content of 4.5%. The mean resilient modulus for the Tonkin Highway trial was 9420 MPa and 6820 MPa for Lift 1 (sampled 26 April 2017) and Lift 2 (sampled 27 April 2017) respectively, with an average bulk density of 2.38 t/m^3 and an average air void content of 4.8%. The raw data from the indirect tensile test is presented in Appendix B and Appendix L for the pre-trial and main trial respectively. Indirect tensile testing is not included in the *Draft Specification 514* EME2 mix design criteria and was conducted for research purposes.

Figure 9.4: Resilient modulus of EME2 pre-trial, plant mixed (sampled 12/04/17)



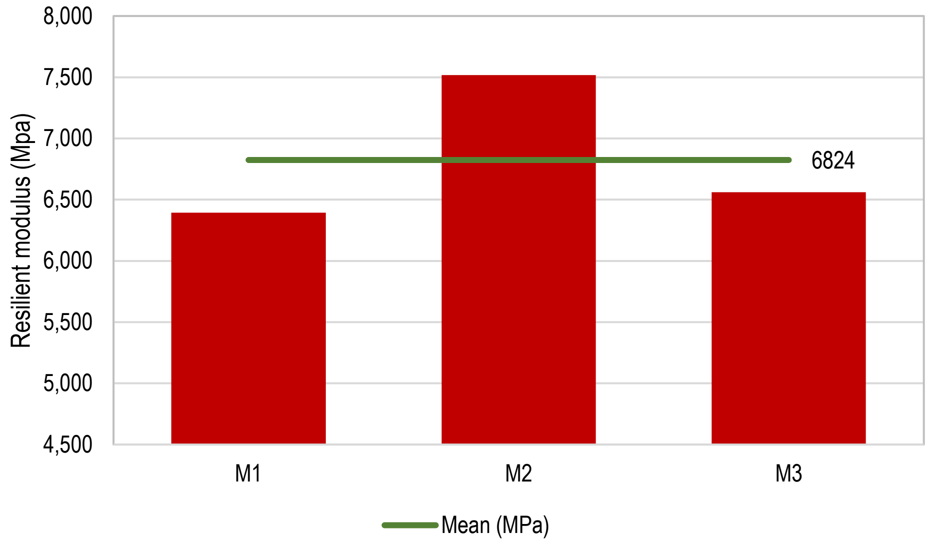
Source: Based on laboratory data from Main Roads

Figure 9.5: Resilient modulus of EME2 mix Layer 1, plant mixed (sampled 26/04/17)



Source: Based on laboratory data from Main Roads

Figure 9.6: Resilient modulus of EME2 mix Layer 2, plant mixed (sampled 27/04/17)



Source: Based on laboratory data from Main Roads

9.8 Richness Modulus

The minimum bitumen content by mass of the total mix must meet the minimum richness modulus in accordance with Main Roads *Draft Specification 514* requirements (Table 3.2). The richness modulus was calculated using the mix PSDs, binder content and maximum density according to Equation 3 (Main Roads 2016c).

$$K = \frac{\left(\frac{100B}{100-B}\right)}{\alpha \sqrt[5]{\Sigma}} \tag{3}$$

where

B	=	binder content (% by mass of total asphalt mix)
α	=	2.65 / ρ_a
ρ_a	=	particle density of combined mineral aggregates (t/m^3)
Σ	=	(0.25G + 2.3S + 12s + 150f) / 100
G	=	percentage of aggregate particles greater than 6.30 mm
S	=	percentage of aggregate particles between 6.30 mm and 0.250 mm
s	=	percentage of aggregate particles between 0.250 mm and 0.075 mm
f	=	percentage of aggregate particles less than 0.075 mm

Note: G, S and s may be interpolated using a linear relationship from the grading curve using Australian standard sieve sizes.

The richness modulus was determined for specimens sampled on both 26 April 2017 and 27 April 2017 with an average richness modulus of 3.9 and 3.8 respectively, exceeding the 3.4 minimum requirement in *Draft Specification 514* (Main Roads 2016b). The data used for calculation is presented in Appendix M.

9.9 Voids in Dry Compacted Filler – Delta Ring and Ball

The voids in dry compacted filler (Rigden voids) test and the delta ring and ball test are used to assess the stiffening effect fillers have on the bituminous binders, which can have a significant impact on the workability and performance of an asphalt mix. A summary of the results is presented in Table 9.6 and the test reports are contained in Appendix N.

The Main Roads delta ring and ball test resulted in a non-conforming result of 18 °C, exceeding the 8–16 °C limit. It is important to note that although the voids in dry compacted filler test (Figure N 1) and the delta ring and ball test (Figure N 2) were conducted by ARRB, the results may be classified as invalid and are included for information only. This was due to the use of EME2 bitumen in the delta ring and ball test where Austroads Class 170 should have been used.

Table 9.6: Voids and dry compacted filler test and delta ring and ball test results for EME2 mix

Method of test	Unit	Property	Mineral filler		Results		
			Min	Max	Main Roads	Downer Group	ARRB
AS 1141.17	%	Voids in dry compacted filler	28	45	38	40	33
EN 13179–1: 2000 and AS 2341.18	°C	Delta ring and ball	8	16	18	14.5	3.5

Source: Data supplied by Main Roads, Downer Group and ARRB.

9.10 Hamburg Wheel Tracking Device Testing

Although the Hamburg wheel tracking device (HWTD) testing is not a performance requirement for EME2 asphalt specified in *Draft Specification 514* (Main Roads 2016b), this testing was conducted to provide additional performance information to assist Main Roads and industry with future EME2 applications, in accordance with TMR *Test Method Q325* (TMR 2016). The device was designed to test an asphalt mix for susceptibility to moisture induced damage (including stripping) and resistance to rutting by tracking steel wheels over submerged samples at elevated temperatures (50–60 °C).

It is important to note that the Hamburg wheel tracking device testing was conducted using field cores and laboratory manufactured slabs from samples taken from Downer Group's asphalt plant during production. The testing was carried out by TMR and the results are summarised in Table 9.7, displayed in Figure 9.7 and Figure 9.8 for the slabs and cores respectively. The HWTD results are detailed in Appendix O.

The HWTD results for the EME2 mixes show a linear rutting trend, which indicates that stripping was not observed during testing. The rut depths observed for the Tonkin field cores are relatively low compared to the pre-trial cores, which may be due to differences in compaction methodology and as a result, air void contents between the pre-trial and main trial. Furthermore, the results indicate that the slabs exhibited lower final rut depths compared to the field cores. This may be attributed to the ability of the plant to meet field compaction that is achieved in the laboratory under controlled conditions.

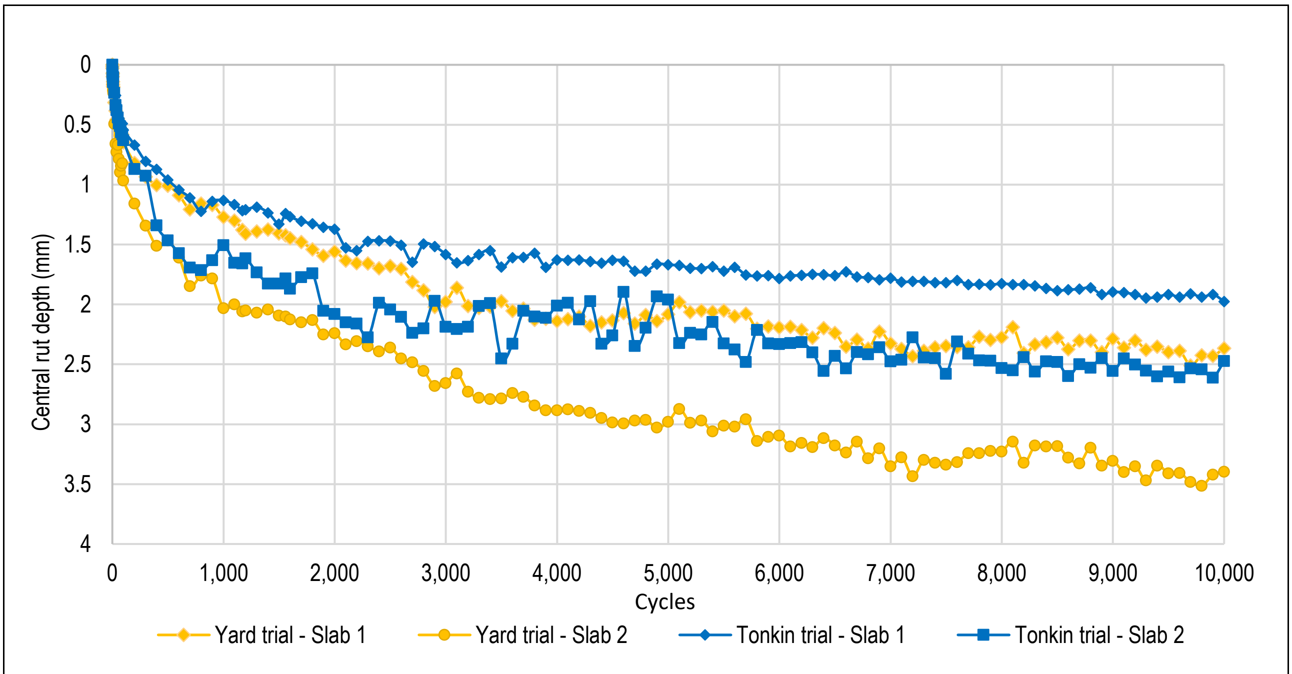
Although no dense graded mixes were tested as part of this project, ARRB, on behalf of Main Roads, had previously conducted a study on HWTD testing on mixes from the Gateway, WA trial section on Tonkin Highway. The rut depths observed in the 20 mm asphalt intermediate course containing C600 binder were in the range of 8.4–15.8 mm for slabs and 9.1–13.2 mm for cores, where some samples experienced stripping (Beecroft 2015). This indicates that the EME2 asphalt mix is less susceptible to moisture induced damage and rutting.

Table 9.7: Hamburg wheel track testing results for EME2 mix

Sample type	Sample number(s)	Description	Sample date	Air voids content (%)	Cycles	Final rut depth (mm)	Mean rut depth by sample type (mm)
Slab	BA17-176	Downer Group yard trial (slab 1)	12/04/17	4.6	10 000	2.33	2.87
Slab	BA17-176	Downer Group yard trial (slab 2)	12/04/17	4.7	10 000	3.40	
Core	BA17-178	Downer Group yard trial (cores 19A & 19B)	13/04/17	5.0	10 000	6.84	6.14
Core	BA17-178	Downer Group yard trial (cores 20A & 20B)	13/04/17	5.4	10 000	5.44	
Slab	BA17-177	Tonkin Hwy trial (slab 1)	26/04/17	5.3	10 000	1.95	2.26
Slab	BA17-177	Tonkin Hwy trial (slab 2)	26/04/17	4.7	10 000	2.57	
Core	BA17-179	Tonkin Hwy trial (cores 1 & 2)	27/04/17	3.3	10 000	3.45	4.18
Core	BA17-179	Tonkin Hwy trial (cores 3 & 4)	27/04/17	3.8	10 000	4.23	
Core	BA17-179	Tonkin Hwy trial (cores 5 & 6)	27/04/17	2.3	10 000	4.65	
Core	BA17-179	Tonkin Hwy trial (cores 7 & 8)	27/04/17	2.1	10 000	4.39	

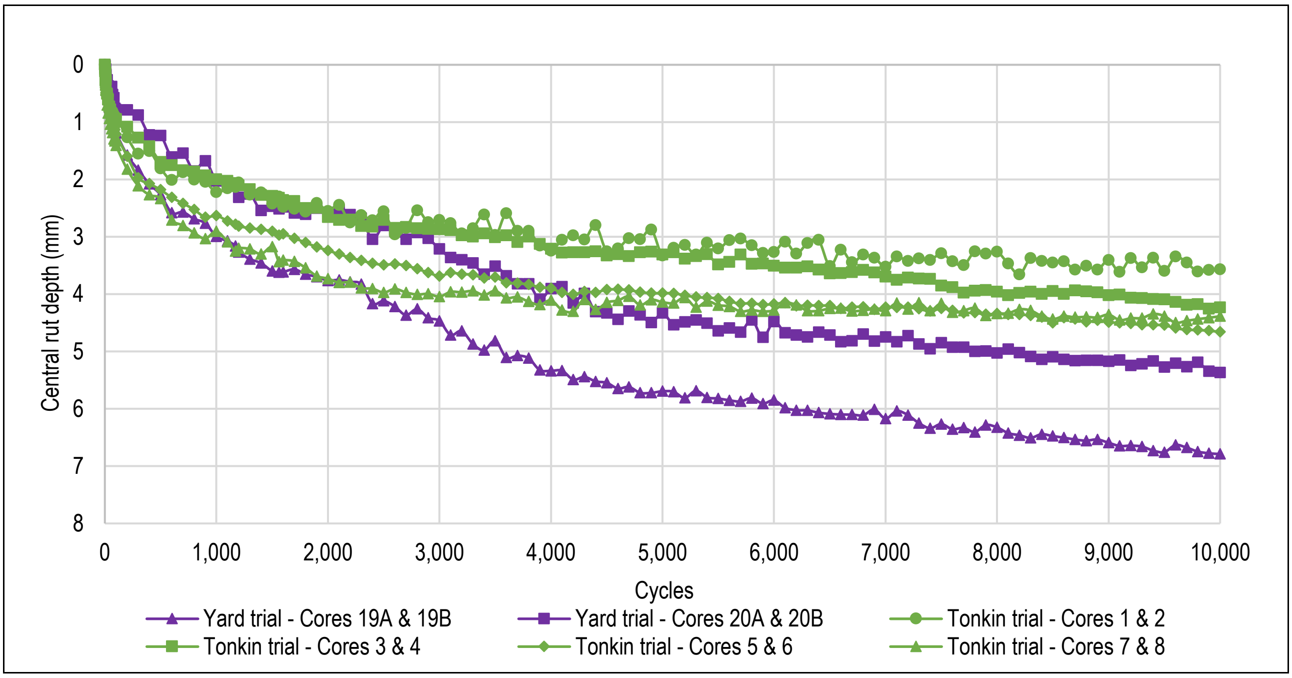
Note: Air void content of core test is the average air voids of the two cores.
Source: Data supplied by TMR.

Figure 9.7: Hamburg wheel track test results for all slabs



Source: Data supplied by TMR.

Figure 9.8: Hamburg wheel track test results for all cores



Source: Data supplied by TMR.

9.11 Performance Testing Summary

Laboratory testing was undertaken on samples from the Downer Group asphalt plant during construction of the trial section in an attempt to characterise the performance of the EME2 mix. The results of the performance tests conducted on the EME2 mix are summarised in Table 9.8. This shows that although the performance testing of the EME2 asphalt mix was generally in compliance with Main Roads *Draft Specification 514*, there were three non-conformances. The non-conformances were:

- Flexural stiffness at 50 ± 3 με, 15 °C and 10 Hz (AGPT/T274):
  - Master curve created using air voids 5.10% – result of 9700 MPa, below minimum 14 000 MPa.
  - Master curve created using air voids 4.20% – result of 10 556 MPa, below minimum 14 000 MPa.
- Delta ring and ball (EN 13179–1: 2000 and AS 2341.18):
  - Result of 18 °C, exceeding limit of 8–16 °C.

Although the flexural stiffness results show that two of the master curves created caused a non-conforming modulus at 50 ± 3 με, 15 °C and 10 Hz, one master curve did comply. This indicates that for the EME2 mix to conform to specifications, the in situ air void content should be approximately 1.85%. Additionally, the delta ring and ball test shows that the stiffening effect of the mineral filler may be excessive.

Table 9.8: Summary of performance testing of EME2 asphalt mix

Property	Unit	Min	Max	Results
Air voids in specimens compacted by gyratory compactor at 100 cycles	%	–	6.0	Presaturation bulk density TSR 12/4/17 3.0 TSR 26/4/17 2.6 TSR 27/4/17 2.9 ITT 12/4/17 3.0 ITT 26/4/17 3.0 ITT 27/4/17 3.2 Mensuration bulk density TSR 12/4/17 5.1 TSR 26/4/17 4.5 TSR 27/4/17 4.8 ITT 12/4/17 4.9 ITT 26/4/17 4.8 ITT 27/4/17 5.0
Stripping potential of asphalt – tensile strength ratio	%	80	–	12/4/17 110 26/4/17 94 27/4/17 100
Wheel tracking at 60 °C and 30 000 cycles (60 000 passes)	mm	–	4.0	1.1
Wheel tracking at 60 °C and 5 000 cycles (10 000 passes)	mm	–	2.0	0.9
Flexural stiffness at 50 ± 3 με, 15 °C and 10 Hz	MPa	14 000	–	AV 5.10% 9 700 AV 4.20% 10 556 AV 1.85% 14 043
Fatigue resistance at 20 °C, 10 Hz and 1 million cycles	με	150	–	10 °C* 139.5 20 °C 182.4 30 °C* 226.0
Resilient modulus (ITT)*	MPa	–	–	12/4/17 6 422 26/4/17 9 421 27/4/17 6 824

Property	Unit	Min	Max	Results
Richness modulus	%	3.4	–	26/4/17 3.9 27/4/17 3.8
Voids in dry compacted filler	%	28	45	38
Delta ring and ball	°C	8	16	18
Hamburg wheel tracking*	mm	–	–	DY Core 6.14 DY Slab 2.87 TH Core 4.18 TH Slab 2.26

Note: DY = Downer Group yard, TH = Tonkin Highway

*Note: Conducted for research purposes only, no specified design criteria.

10 KNOWLEDGE TRANSFER

10.1 Tonkin Highway Trial Workshop

One of the key aspects of the trial was to obtain guidance on the trial installation from a practitioner with extensive EME2 experience. Monsieur Pierrick Dupuy on behalf of Dupuy Conseils, Reunion Island, France attended the Tonkin Hwy trial to provide technical assistance and knowledge transfer for future EME2 projects. Pierrick Dupuy did not identify any significant issues with the construction processes conducted for the EME2 trial but did make a number of recommendations for improvements to future projects in a report and a workshop with Downer Group, Main Roads and ARRB personnel on 28 April 2017.

The workshop covered the risk management, materials and specifications, mix design of EME2, specification of EME2, mix design validation, the Tonkin Highway trial and proposed recommendations and improvements for future projects. The recommendations and proposed improvements may be summarised, as follows:

- Ensure a prime coat is applied to the subbase to increase the bond strength between the limestone and EME2 as a lack of bond strength may increase the strains at the interface and decrease the service life of the pavement.
- Use an abrasion resistant thermocouple to monitor the internal temperature of the asphalt behind the paver and ensure the temperature is at least 145 °C for workability.
- Ensure the rolling pattern of the compaction train does not have a high level of overlap (> 300 mm) as this may impact the density variation in the mat, recommendations regarding compaction movements are presented in Figure 10.1. However, it is important to note that French compaction procedures may begin with a multi-tyred roller rather than a steel-drum roller, which may impact the relevance of this recommendation to Main Roads.
- When there is a gap between asphalt supply trucks the operator should reduce the speed of the paver rather than stopping it to guarantee the regularity of the voids in the longitudinal profile. After 20 minutes of inactivity, compaction should be complete and the EME2 must not be over-compacted. Plant should be parked away from hot or warm asphalt to avoid rutting.
- Care should be taken to avoid excess compaction and bleeding of the EME2 asphalt, especially when compacting in multiple lifts.
- Tack coat applications are in accordance with NF P 98-150-1 (2010) (Table 10.1).
- Unless the longitudinal joint is constructed using echelon paving (two pavers less than 50 m of separation), the steel drum roller shall overhang the edge of the asphalt by approximately 100 mm.
- Overlap the joint by approximately 30–40 mm (Dupuy 2017) and push with a rake to ensure the finer asphalt particles remain close to the surface of the joint (notably, this differs from the practice identified in Section 8.2.3). Compaction of the joint should begin using a pinch pass of a steel drum roller with approximately 50–200 mm of overlap.

Figure 10.1: Recommended compaction operation

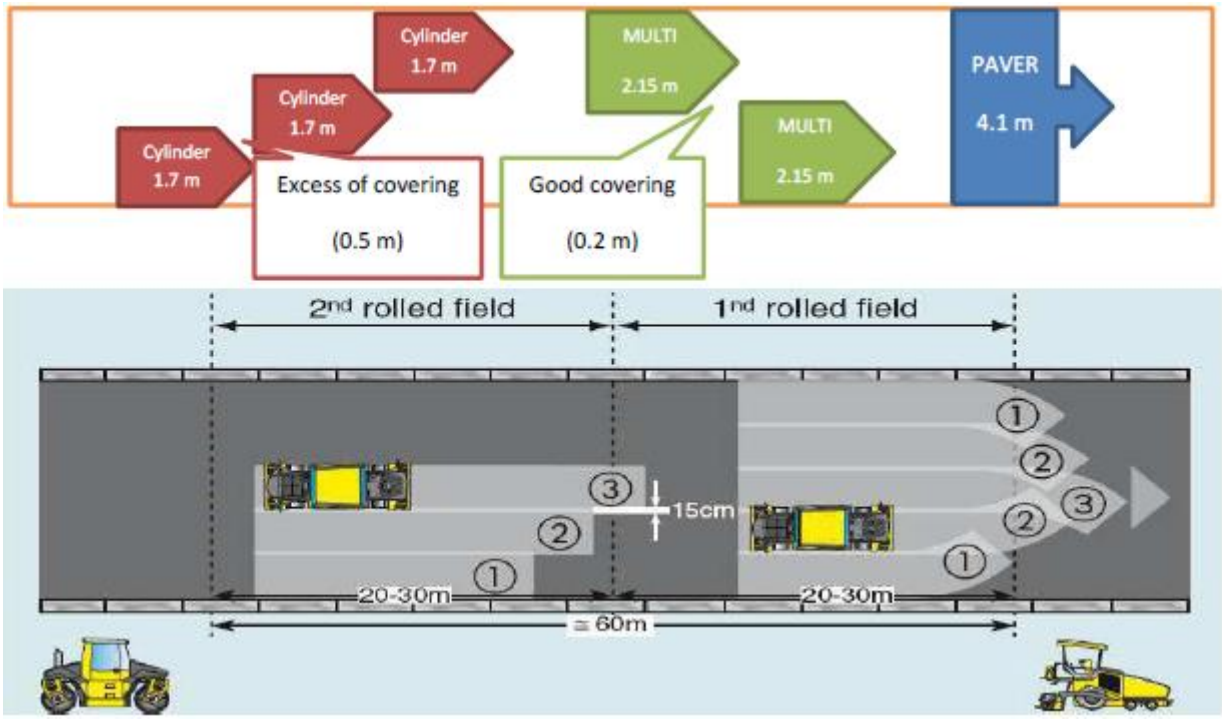


Table 10.1: Tack coat application rates

Asphalt interface	Tack coat	Bitumen rate	Emulsion
EME2/EME2	Emulsion 60% of 20/30 bitumen	250 g/m^2	420 g/m^2
EME2/EME2	Emulsion 60% of 35/50 bitumen	250 g/m^2	380 g/m^2

Source: NFP 98 150-1 (2010).

10.2 Asphalt Industry Workshop

On 19 July 2017 a workshop was held by Main Roads and ARRB to present the learnings from the Tonkin Highway trial to the asphalt industry. The workshop covered the following areas, with the key learnings described:

- Tonkin Highway trial planning and mix design:
  - For any project, additional emphasis should be placed on the importance of not exceeding the maximum production temperature of 190 °C.
  - EME2 is a mix with a high dust percentage (± 40%) therefore extreme care should be taken with the dust moisture content as this could affect achieving the desired production temperature. Good practice should be used in managing the dust, especially during winter.
- EME2 pavement design:
  - The design approach is compatible with the existing Austroads mechanistic design procedures.
  - The use of EME2 asphalt may save up 10% pavement thickness.
- production and construction:

  - EME2 may generally be constructed like normal DGA.
  - It is recommended that a vertical tank is used for the storage of EME2 binder.
  - Survey levelling should be taken in 5 m intervals.
  - The loose bulking factor shows an increase, compared to DGA.
  - The compaction rollers should stay as close as practicable to the paver, and there should be overlapping of all three rollers.
  - The roller tyres should be kept wet to prevent the lift-up of asphalt mix during compaction. However, the rollers should be taken off the mat if the mix is too hot and mobile. Rollers should not be kept stationary on mix paved on the same day.
  - Joints construction identified to produce low air voids, as described in Section 8.2.3.
  - Coring is to be undertaken the day following paving.
- conformance and research testing:
  - The results show that although the performance testing of the EME2 asphalt mix was generally compliant, there were non-conformances (it is important to note that when the workshop was undertaken performance testing was incomplete).
- future projects that may include EME2 pavements:
  - Kwinana Freeway widening
  - Roe Highway / Kalamunda Road.

11 CONCLUSIONS AND RECOMMENDATIONS

This report has presented details of an EME2 (Enrobés á Module Élevé Class 2) asphalt production and placement field trial that took place on 26 and 27 April 2017, as well as a pre-trial that was performed on 12 April 2017. The pre-trial was performed at Downer Group Gosnells asphalt plant yard whereas the main trial was carried out at the intersection of the Tonkin Highway and Kelvin Road in Perth, Western Australia. The purpose of the trial was to assess whether the design mix could be manufactured, placed and compacted to the expected standards using local materials and locally-available equipment. The conduct of a successful trial would assist Main Roads and industry to successfully transfer the French EME2 technology to Western Australia. The trial was conducted as part of the Western Australia Road Research and Innovation Program (WARRIP).

Laboratory testing was conducted by Main Roads, Boral, SAMI Bitumen Technologies, TMR Queensland and ARRB. Based on core results it can be concluded that EME2 can be successfully produced and placed using local aggregates and locally-available equipment. EME2 achieved the target thickness and low in situ air voids on both layers.

To achieve optimum quality control, it is essential that a thorough plan – in terms of production, placement and safety – be developed if EME2 asphalt is to be successfully implemented.

This plan should be continually monitored from commencement, to ensure the production and construction crews are aware of the differences between EME2 and typical DGA intermediate course mixtures.

It is recommended that, during compaction, the rollers should not remain stationary whether on the newly-compacted EME2 or following the completion of the works until the mix has cooled, as this could leave deep imprints on the EME2 surface. Furthermore, care should be taken to avoid excessive compaction and bleeding of the EME2 asphalt, especially when compacting in multiple lifts. It is also recommended that the method of joint construction adopted for Lift 2 of the trial be adopted for future EME2 asphalt pavements to reduce air voids along the joint lines.

Recommendations relative to the current Main Roads EME2 documentation are provided in Section 12.

12 MAIN ROAD DOCUMENTATION RECOMMENDATIONS

Findings from the Tonkin Highway trial indicate that best practice for the production and construction of EME2 asphalt is generally in accordance with *Draft Specification 514* (Main Roads 2016b). Recommendations based upon the findings from the trial, as well as the report of experienced EME2 practitioner Monsieur Pierrick Dupuy (available on the WARRIP website (www.warrip.com.au)) for Main Roads to consider relative to the revision of *Draft Specification 514* include:

- Reducing the target production temperature from 185–190 °C to 175–185 °C to reduce the risk of overheating the mix (514.32).
- The temperature of the mixed asphalt shall be measured and recorded at the discharge point of the pugmill or mixing drum. The temperature of the asphalt shall be between 170 °C and 180 °C for EME2 unless otherwise directed by the Superintendent (514.32.6).
- Include a note regarding the placement of EME2 as follows:
  - While EME2 asphalt is similar in many ways to conventional DGA, the Contractor's placement methodology for EME2 asphalt should recognise EME2 specific construction practices or conditions may need to be adopted for construction. For example, experience has shown that EME2 asphalt may be more 'lively' during compaction in periods of hot weather and contractors may need to adjust their construction processes to manage this.
- Asphalt shall be delivered to the work site at temperatures between 160 °C and 180 °C. The internal temperature of the asphalt behind the paver must be no less than 145 °C (514.41.3).
- If a delay is forecast to occur between successive truck deliveries of more than 20 minutes to the paver, the speed of paving should be slowed rather than halted (514.41.4).
- The longitudinal joint unconfined edges of a paving run shall be compacted using a steel drum roller with approximately 100 mm drum overhang. Compaction of the uncompacted asphalt adjacent to the longitudinal joint shall begin using a pinch pass of a steel drum roller (514.48.2).
- When the adjacent paver run is placed the uncompacted asphalt shall be placed to overlap the compacted asphalt of the previous run by approximately 25 and 75 mm in width of loose asphalt. The loose asphalt shall be pushed back using a lute to form a ridge along the edge of the joint. Hand raking should not remove large stones (514.48.3).
- The rolling pattern of the compaction train should target 150 mm of overlap (514.52.2).
- Compaction plant shall be kept in continuous operation as much as practicable and in such a manner that all parts of the pavement receive substantially equal compaction. In the event of a delay in laying operation, rolling is to be carried out as close as practicable to the paving machine. After 20 minutes of inactivity compaction operation is to be halted to avoid over-compaction, plant shall not be parked on work carried out on the same day (514.52.4).

Furthermore, it is recommended that Main Roads incorporate a requirement regarding a placement trial before an EME2 mix is approved for use on further works into ERN13 and/or *Draft Specification 514*, as follows:

- Each nominated mix must be subjected to a placement trial. A trial section shall be constructed using the same construction plant, processes and methodology that is proposed to be used for the remainder of the works represented by the trial section.

- A trial section shall be at least 200 m long and 3 m wide, this is suggested so that a longitudinal joint is included in the section. The Contractor must design the trial to implement all operations and testing required by this Specification. The Contractor shall submit a copy of the completed inspection and test plan and all relevant test results and records from the placement trial. Prior to further placement of the Contractor's nominated mix in the works, the Administrator shall review the outcomes of the placement trial. No further works shall be undertaken until Main Roads has given approval to proceed (Hold Point).
- In the event of a non-conformance in the placement trial, or when Main Roads determines that a previous trial is not representative of the materials, asphalt mix proportions, temperature, plant, rate of output and/or method of placement, a new trial must be undertaken and the Hold Point re-released, prior to full-scale placement resuming.

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APPENDIX A SAMPLING AND TESTING PLAN

Table A 1: Sampling and testing plan from Downer Group asphalt plant

Sample No.	Date of sampling	Tests	Tested	Laboratory
Pre Trial				
6797	12/04/2017	PSD & binder content (AS/NZS 2891.3.1 or AG:PT/T234 or WA 730.1)	✓	Main Roads WA
6797	12/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6797	12/04/2017	Moisture content (AS/NZS 2891.10 or T660)	✓	Main Roads WA
6797	12/04/2017	Uniform coating of binder (AS/NZS 2891.11)	✓	Main Roads WA
6898	12/04/2017	PSD & binder content (AS/NZS 2891.3.1 or AG:PT/T234 or WA 730.1)	✓	Main Roads WA
6798	12/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6850	12/04/2017	ITT (AS/NZS 2891.13.1)	✓	Main Roads WA
6850	12/04/2017	Voids and volumetric properties (AS/NZS 2891.8)	✓	Main Roads WA
6850	12/04/2017	Bulk density – presaturation method (AS/NZS 2891.9.2)	✓	Main Roads WA
6850	12/04/2017	Bulk density – mensuration method (AS/NZS 2891.9.3)	✓	Main Roads WA
6851	12/04/2017	TSR (AG:PT/ T232)	✓	Main Roads WA
6851	12/04/2017	Voids and volumetric properties (AS/NZS 2891.8)	✓	Main Roads WA
6851	12/04/2017	Bulk density – presaturation method (AS/NZS 2891.9.2)	✓	Main Roads WA
6851	12/04/2017	Bulk density – mensuration method (AS/NZS 2891.9.3)	✓	Main Roads WA
6804	12/04/2017	Hamburg wheel tracking (Q325)	✓	TMR Queensland
Trial				
6821	26/04/2017	PSD & binder content (AS/NZS 2891.3.1 or AG:PT/T234 or WA 730.1)	✓	Main Roads WA
6821	26/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6821	26/04/2017	Moisture content (AS/NZS 2891.10 or T660)	✓	Main Roads WA
6821	26/04/2017	Uniform coating of binder (AS/NZS 2891.11)	✓	Main Roads WA
6822	26/04/2017	PSD & binder content (AS/NZS 2891.3.1 or AG:PT/T234 or WA 730.1)	✓	Main Roads WA
6822	26/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6848	26/04/2017	TSR (AG:PT/ T232)	✓	Main Roads WA
6848	26/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6848	26/04/2017	Voids and volumetric properties (AS/NZS 2891.8)	✓	Main Roads WA
6848	26/04/2017	Bulk density – presaturation method (AS/NZS 2891.9.2)	✓	Main Roads WA
6848	26/04/2017	Bulk density – mensuration method (AS/NZS 2891.9.3)	✓	Main Roads WA
6852	26/04/2017	ITT (AS 2891.13.1)	✓	Main Roads WA
6852	26/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6852	26/04/2017	Voids and volumetric properties (AS/NZS 2891.8)	✓	Main Roads WA
6852	26/04/2017	Bulk density – presaturation method (AS/NZS 2891.9.2)	✓	Main Roads WA
6852	26/04/2017	Bulk density – mensuration method (AS/NZS 2891.9.3)	✓	Main Roads WA

6857	26/04/2017	Wheel tracking at 60 °C and 30,000 cycles (60,000 passes)	✓	ARRB
6857	26/04/2017	Wheel tracking at 60 °C and 5,000 cycles (10,000 passes)	✓	ARRB
6857	26/04/2017	Fatigue resistance at 20 °C, 10 Hz and 1 million cycles	✓	Boral
6857	26/04/2017	Flexural stiffness (AG:PT/T274)	✓	ARRB
6855	26/04/2017	Hamburg wheel tracking (Q325)	✓	TMR Queensland
6933	26/04/2017	Voids in dry compacted filler, softening point, delta ring and ball (AS/NZS 1141.17, EN 13179-1 and AS 2341.18)	✓	ARRB, Main Roads
Trial				
6823	27/04/2017	PSD & binder content (AS/NZS 2891.3.1 or AG:PT/T234 or WA 730.1)	✓	Main Roads WA
6823	27/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6823	27/04/2017	Moisture content (AS/NZS 2891.10 or T660)	✓	Main Roads WA
6823	27/04/2017	Uniform coating of binder (AS/NZS 2891.11)	✓	Main Roads WA
6824	27/04/2017	PSD & binder content (AS/NZS 2891.3.1 or AG:PT/T234 or WA 730.1)	✓	Main Roads WA
6824	27/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6849	27/04/2017	TSR (AG:PT/ T232)	✓	Main Roads WA
6849	27/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6849	27/04/2017	Voids and volumetric properties (AS/NZS 2891.8)	✓	Main Roads WA
6849	27/04/2017	Bulk density – presaturation method (AS/NZS 2891.9.2)	✓	Main Roads WA
6849	27/04/2017	Bulk density – mensuration method (AS/NZS 2891.9.3)	✓	Main Roads WA
6853	27/04/2017	ITT (AS 2891.13.1)	✓	Main Roads WA
6853	27/04/2017	Maximum density of asphalt (AS/NZS 2891.7.1)	✓	Main Roads WA
6853	27/04/2017	Voids and volumetric properties (AS/NZS 2891.8)	✓	Main Roads WA
6853	27/04/2017	Bulk density – presaturation method (AS/NZS 2891.9.2)	✓	Main Roads WA
6853	27/04/2017	Bulk density – mensuration method (AS/NZS 2891.9.3)	✓	Main Roads WA
6858	27/04/2017	Wheel tracking at 60 °C and 30,000 cycles (60,000 passes)	✓	ARRB
6858	27/04/2017	Wheel tracking at 60 °C and 5,000 cycles (10,000 passes)	✓	ARRB
6858	27/04/2017	Fatigue resistance at 20 °C, 10 Hz and 1 million cycles	✓	Boral
6858	27/04/2017	Flexural stiffness (AG:PT/T274)	✓	Main Roads WA
6858	27/04/2017	Hamburg wheel tracking (Q325)	✓	TMR Queensland
6858	27/04/2017	Voids in dry compacted filler, softening point, delta ring and ball (AS 1141.17, EN 13179-1 and AS 2341.18)	✓	ARRB, Main Roads

APPENDIX B PRE-TRIAL TEST RESULTS

Table B 1: EME2 bitumen test report RQ170093 (SAMI)

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Accreditation Number 5598

SAMI BITUMEN TECHNOLOGIES
SAMI Bitumen Technologies

1 Bulk Terminals Drive
Port of Brisbane
Queensland 4178

Laboratory @samibitumen.com.au

Ph: 07 3895 2183
Fax: 07 3895 2189

PRODUCT TEST REPORT

Test Report No.: RQ170093
Product: SAMIFALT EME
Batch: PB17260
SAMI Sample No.: S170696
Date of Sampling: 28-03-2017
Sample Source: Tank 10 ex SBT POB
Details: High Modulus Asphalt Binder
Date Tested: 28-03-2017
Specification: QTMR PSTS107

Method	Property	Result	Specification
AS 2341.12	Penetration at 25°C, 100g, 5s, 0.1mm	16	15 - 25
AS 2341.18	Softening Point, °C	72.0	56 - 72
AS 2341.2	Viscosity at 60°C, Pas	14400	900 min.
SAMI-IT09B41	Penetration Index	0.7	Report
AS 2341.4	Viscosity at 135°C, Pas	3.29	0.6 min.
AS 2341.12/.10	Penetration at 25°C RTFO, 100g, 0.1mm	14	Report
AS 2341.18/.10	Softening Point RTFO, °C	77.5	Report
AS 2341.2/.10	Viscosity at 60°C RTFO, Pas	41300	Report
Calculation	Viscosity at 60°C RTFO as % of original	287	Report
Calculation	Increase in Softening Point, °C	5.5	≤ 8
Calculation	Pen Retain %	88	55 min.
Frequency tests	Batch PB17219 was tested in the SAMI Sydney laboratory		
AGPT/T103	Loss on heating, % mass	<0.1	0.5 max.
AS 2341.8	Matter insoluble in toluene, % mass	<0.1	1.0 max.

Certificate Issued Date: 29-03-2017
Sampling Method: AS 2008 (1997) B5.2
Testing Operator Name: G. R. & A. S.

Authorised Officer of the Company
J. Hoffman, Technical Support Manager, QLD

Doc: SAMI-IT09M29KBIT
Issue A Revision 0
11/10/2006
Page 1 of 1

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Table B 2: EME2 bitumen test report R17-0360 (Downer Group)

Downer

National Research and Development Laboratory
125-129 Somerton Road
Somerton VIC 3062
Ph: (03) 9930 4844

BITUMEN TEST REPORT

PSTS107 – High Modulus Asphalt (EME2) Table 10.2.5

Report No:	R17-0360	**Client Ref:**	EME2 Trial 12-04-2017
Sample Description:	EME	**Client Address:**	Downer, WA Quarry Road Gosnells WA 6110
Sample Source:	WA		

Test Type	Reference Standard	Results	Spec Limit
Penetration at 25.0ºC (p.u)	AS 2341.12	16	**15 - 25**
Softening point	AS2341.18	73	**56 - 72**
Viscosity at 60ºC (Pa.s)	AS2341.2	19032	**Min 900**
Loss on heating (%)	AGPT/T103	0.0	**Max 0.5**
Retained penetration (%)[1,2]	AS 2341.10, AS 2341.12	87	**Min 55**
Increase in softening point after RTFO[1]	AS 2341.10, AS 2341.18	8	**Max 8**
Viscosity @ 135.0ºC (Pa.s)	AS2341.4*	2.92	**Min 0.6**
Insolubles in Toluene (%)	AS 2341.8	0.67	**Max 1.0**
Penetration Index [1,3]	-	0.83	-
Viscosity at 60°C after RTFO	AS 2341.10 AS 2341.2	113988	-
Percent increase in viscosity at 60°C after RTFO	AS 2341.10	599	-

AS2341.2 Viscosity @ 60ºC Test Conditions	
Shear Rate (1/s)	0.027
Viscosity @ 60ºC Post RTFO Test Conditions	
Shear Rate (1/s)	0.022

AS2341.4 Viscosity Test Conditions	
Brookfield Viscometer Model	DVII + Pro, LV
Temperature (ºC)	135.0
Spindle Model Number	SC4-34
Rotational Speed (rpm)	10

Comments:
Sample Tested as Received.
1. Not in scope of accreditation
2. Calculated according to PSTS107 Table 10.2.5
3. Calculated according to PSTS107 10.2.5.1

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NATA ACCREDITED LABORATORY NUMBER: 15351

APPROVED SIGNATORY: B. Van den Eynde

DATE: 31/05/2017

CHECKED: Petar Davcev

Table B 3: EME2 bitumen test report S6800 (Main Roads 20/06/17)

mainroads WESTERN AUSTRALIA
ABN: 50 860 676 021

BITUMEN TEST REPORT

Page 1 of 1

Report No	17 S6800 / 1	Classification	15/25 Grade EME2 Binder
Customer :	Main Roads Western Australia	Customer Identification	S6800
Contract No. / Name :		EME2 Trial	
Location		Downer Quarry - Martin	
Supplier	Downer	Date/s Tested	20/06/2017
Sampling Details		Sampled at 95 tonnes	

Sampling Method	Supplied by Others, Tested as Received		SPECIFICATION
Sample Number	S6800		
Client Reference Number	Not Applicable		
Date Sampled	12/04/2017		MRWA Specification 514
Time Sampled	5:10 PM		
Batch Number	Not Supplied		
Tank Number	Not Supplied		

Test Method	Dynamic Viscosity - AS 2341.2		Specification*
Dynamic Viscosity at 60°C (Pa.s)			900 Min.
Dynamic Viscosity at 135°C (Pa.s)			0.6 Min.

Test Method		Penetration - AS 2341.12		Specification*
Penetration at 25°C (pu)	100g, 5 sec.	18		15 - 25
Penetration at 35°C (pu)				
*Penetration Index		0.97		

Test Method	Matter Insoluble in Toluene - AS 2341.8		Specification*
Matter Insoluble in Toluene (% mass)			1.0 Max.

Test Method	Softening Point - AS 2341.18		Specification*
Softening Point (°C)	72.5		56 - 72

Test Method	Rolling Thin Film Oven Test - AS 2341.10		Specification*
Mass Change (%)			0.5 Max.
AS 2341.2 - Dynamic Viscosity at 60°C (Pa.s)			
Ratio of Viscosities Before and After Treatment at 60°C (%)			
AS 2341.18 - Softening Point (°C)			
*Increase in Softening Point After RTFO Treatment (°C)			8 Max.
AS 2341.12 - Penetration at 25°C 100g, 5 sec. (pu)			
*Retained Penetration (pu)			55 Min.

* Denotes tests or calculations that are not covered by our NATA Scope of Accreditation

Comments / Distribution
Reports
TRIM 16/4441

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 22/06/2017

Document:71/05/2341.2 Issue:22/03/2017 TRIM:D14#629288

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Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
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Table B 4: EME2 bitumen test report S6799 (Main Roads 22/06/17)

mainroads WESTERN AUSTRALIA
ABN: 50 860 676 021

BITUMEN TEST REPORT Page 1 of 1

Report No	17 S6799 / 1	Classification	15/25 Grade EME2 Binder
Customer :	Main Roads Western Australia	Customer Identification	S6799
Contract No. / Name :	EME2 Trial		
Location	Downer Quarry - Martin		
Supplier	Downer	Date/s Tested	21-22/06/2017
Sampling Details	Sampled at 40 tonnes		

Sampling Method	Supplied by Others, Tested as Received		SPECIFICATION
Sample Number	S6799		
Client Reference Number	Not Applicable		
Date Sampled	12/04/2017		MRWA Specification 514
Time Sampled	4:50 PM		
Batch Number	Not Supplied		
Tank Number	Not Supplied		

Test Method	Dynamic Viscosity - AS 2341.2		Specification*
Dynamic Viscosity at 60°C (Pa.s)	14781		900 Min.
Dynamic Viscosity at 135°C (Pa.s)	2.69		0.6 Min.

Test Method		Penetration - AS 2341.12		Specification*
Penetration at 25°C (pu)	100g, 5 sec.	18		15 - 25
Penetration at 35°C (pu)		35		
*Penetration Index		1.01		

Test Method	Matter Insoluble in Toluene - AS 2341.8		Specification*
Matter Insoluble in Toluene (% mass)	0.1		1.0 Max.

Test Method	Softening Point - AS 2341.18		Specification*
Softening Point (°C)	73.0		56 - 72

Test Method	Rolling Thin Film Oven Test - AS 2341.10		Specification*
Mass Change (%)	-0.04		0.5 Max.
AS 2341.2 - Dynamic Viscosity at 60°C (Pa.s)	47924		
Ratio of Viscosities Before and After Treatment at 60°C (%)	324		
AS 2341.18 - Softening Point (°C)	78.5		
*Increase in Softening Point After RTFO Treatment (°C)	6		8 Max.
AS 2341.12 - Penetration at 25°C 100g, 5 sec. (pu)	15		
*Retained Penetration (pu)	87		55 Min.

* Denotes tests or calculations that are not covered by our NATA Scope of Accreditation

Comments / Distribution
Reports
TRIM 16/4441

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 22/06/2017

Document:71/05/2341.2 Issue:22/03/2017 TRIM:D14#629288

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Table B 5: EME2 mix design test report S6797 (page 1)

mainroads WESTERN AUSTRALIA
ABN: 50 860 676 021

DENSE GRADED ASPHALT TEST REPORT Page 1 of 3

Report:	17 S6797 / 1	Contract No:	EME2 Trial	Field No:	Not Applicable
Date Sampled:	12/04/2017	Date Tested:	12/04/2017	Customer:	Main Roads Western Australia
Road:	Not Applicable	Sample Source:	Downer - Martin		
Mix Type:	DG14 EME2	Lot Number:	Not Applicable		
Sample Location:	Sampled by Downer at 35.29 Tonnes				
Sampling Details:	Time Sampled 04:34 PM I Temperature 181.7°C				
Sampling Method:	SAMPLING PROCEDURES FOR ASPHALT WA 701.1				
Preparation Method:	PREPARATION OF ASPHALT FOR TESTING WA 705.1				

Sample No.	S6797				
Reference No.	Not Applicable				
BITUMEN CONTENT AND PARTICLE SIZE DISTRIBUTION OF ASPHALT:CENTRIFUGE METHOD WA 730.1					
Seive Size mm	**% Passing**				**SPECIFICATION ***
26.50mm	100				100
19.00mm	100				100
13.20mm	100				94 - 100
9.50mm	82				75 - 89
6.70mm	61				60 - 74
4.75mm	49				45 - 59
2.36mm	32				30 - 40
1.18mm	21.9				19 - 29
0.600mm	15.3				13 - 21
0.300mm	10.3				8 - 16
0.150mm	6.9				6 - 11
0.075mm	4.6				3.8 - 6.8
Bitumen Content %	6.0				
MAXIMUM DENSITY : RICE DENSITY WA 732.2					
Maximum Density t/m³					
BULK DENSITY AND VOID CONTENT WA 733.1					
Bulk Density t/m³					
% Air Voids					
% VMA					
% VFB					
STABILITY AND FLOW : MARSHALL METHOD WA 731.1					
TEMPERATURE @ COMPACTION °C					
NUMBER OF BLOWS					
Stability kN					
Flow mm					

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APPROVED SIGNATORY:
Mark Hopgood (Project Officer)
DATE: 21/04/2017

Document:71/05/730.1 Issue:08/03/2017 TRIM:D14#628103

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Table B 6: EME2 mix design test report S6797 (page 2)

TEST REPORT

mainroads WESTERN AUSTRALIA

ABN: 50 860 676 021

Page 2 of 3

Report No:	**17 S6797 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date/s Tested :	**12/04/2017**
Mix Identification:	**DG14 EME2**		
Road Name/LGA:	**Downer - Martin**		
Project/Contract No :	**EME2 Trial**	Customer:	**Main Roads Western Australia**

Test Methods	**Determination of maximum density of asphalt - Water displacement method AS 2891.7.1**

Results

Average Maximim Density t/m³	**2.501**

NOTES:

COMMENTS/DISTRIBUTION:

Reports

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Approved Signatory

Name: Mark Hopgood

Function: **Project Officer**

Date: 21/04/2017

Document:71/05/2891.7.1 Issue:08/03/2017 TRIM:D14#630740

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Table B 7: EME2 mix design test report S6797 (page 3)

mainroads WESTERN AUSTRALIA

Asphalt Test Report

Page 3 of 3

Report No: **17 S6797 /1** Project: **EME2 Trial**

Lot No: **Not Applicable** Date Sampled: **12/04/2017** DateTested: **12/04/2017**

Mix Details: **DG14 EME2** Supplied By: **Downer**

Location: **Downer - Martin**

Sampling Details: **Sampled by Downer at 35.29 Tonnes**
Time Sampled: 04:34 PM I Temperature: 181.7°C

Sampled in Accordance with: **WA 701.1 Sampling and Storage of Asphalt**

Tested in Accordance with: **AS 2891.11 Degree of Particle Coating**

Degree of Particle Coating (%)	**100**

Sampled in Accordance with: **WA 701.1 Sampling and Storage of Asphalt**

Tested in Accordance with: **AS 2891.10 Moisture Content of Asphalt**

Moisture Content (%)	**0.0**

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Approved Signatory:
Mark Hopgood (Project Officer)
Date 21/04/2017

Document:71/05/2891.11 Issue:08/03/2017 TRIM:D15#225134

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Table B 8: EME2 mix design test report S6798 (page 1)

mainroads WESTERN AUSTRALIA
ABN: 50 860 676 021

DENSE GRADED ASPHALT TEST REPORT Page 1 of 2

Report:	**17 S6798 / 1**	Contract No:	**EME2 Trial**	Field No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date Tested:	**12/04/2017**	Customer:	**Main Roads Western Australia**
Road:	**Not Applicable**	Sample Source:	**Downer - Martin**		
Mix Type:	**DG14 EME2**	Lot Number:	**Not Applicable**		
Sample Location:	**Sampled by Downer at 73.86 Tonnes**				
Sampling Details:	**Time Sampled 04:57 PM I Temperature 177.9°C**				
Sampling Method:	**SAMPLING PROCEDURES FOR ASPHALT WA 701.1**				
Preparation Method:	**PREPARATION OF ASPHALT FOR TESTING WA 705.1**				

Sample No.	S6798				
Reference No.	Not Applicable				
BITUMEN CONTENT AND PARTICLE SIZE DISTRIBUTION OF ASPHALT:CENTRIFUGE METHOD WA 730.1					
Seive Size mm	**% Passing**				**SPECIFICATION ***
26.50mm	100				100
19.00mm	100				100
13.20mm	98				94 - 100
9.50mm	81				75 - 89
6.70mm	64				60 - 74
4.75mm	51				45 - 59
2.36mm	33				30 - 40
1.18mm	22.5				19 - 29
0.600mm	16.1				13 - 21
0.300mm	11.1				8 - 16
0.150mm	7.8				6 - 11
0.075mm	5.4				3.8 - 6.8
Bitumen Content %	6.0				
MAXIMUM DENSITY : RICE DENSITY WA 732.2					
Maximum Density t/m^3					
BULK DENSITY AND VOID CONTENT WA 733.1					
Bulk Density t/m^3					
% Air Voids					
% VMA					
% VFB					
STABILITY AND FLOW : MARSHALL METHOD WA 731.1					
TEMPERATURE @ COMPACTION °C					
NUMBER OF BLOWS					
Stability kN					
Flow mm					

COMMENTS/DISTRIBUTION:
REPORTS
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APPROVED SIGNATORY:
Mark Hopgood (Project Officer)
DATE: **21/04/2017**

Document:71/05/730.1 Issue:08/03/2017 TRIM:D14#628103

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Table B 9: EME2 mix design test report S6798 (page 2)

mainroads WESTERN AUSTRALIA

ABN: 50 860 676 021

TEST REPORT

Page 2 of 2

Report No:	**17 S6798 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date/s Tested :	**12/04/2017**
Mix Identification:	**DG14 EME2**		
Road Name/LGA:	**Downer - Martin**		
Project/Contract No :	**EME2 Trial**	Customer:	**Main Roads Western Australia**

Test Methods	Determination of maximum density of asphalt - Water displacement method AS 2891.7.1

Results

Average Maximim Density t/m³	**2.498**

NOTES:

COMMENTS/DISTRIBUTION:

Reports

Trim File 16/4441

Approved Signatory

Name: Mark Hopgood

Function: **Project Officer**

Date: 21/04/2017

Document:71/05/2891.7.1 Issue:08/03/2017 TRIM:D14#630740

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Materials Engineering
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5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
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Table B 10: Core test report S6801 (Main Roads)

mainroads WESTERN AUSTRALIA

ASPHALT CORE TEST REPORT

Report No: 17 S6801 /1 Contract No / Name: **EME2 Trial**

Lot No: **Not Applicable** Date Laid: **12/04/2017** Date Cored: **13/04/2017**

Asphalt Type: **DG14 EME2** Supplied / Laid By: **Downer**

Location: **Downer Quarry - Martin**

Sampled in accordance with WA 701.1 Sampling and storage of asphalt
Tested in accordance with WA 705.1 Preparation of asphalt for testing
Tested in accordance with AS 2891.9.2 Determination of Bulk Density of Compacted Asphalt - Presaturation Method
Tested in accordance with AS 2891.8 Voids and Volumetric Properties of compacted asphalt mixes

Core No.	Chainage	Transverse *	Thickness (mm) (WA 705.1)	Bulk Density (t/m^3) (AS 2891.9.2)	Water Absorbtion (%) (AS 2891.9.2)	Air Voids (%) (AS 2891.8)
1	5	5.1	104	2.403	0.2	4.2
2	14	6.2	100	2.415	0.2	3.7
3	20	6.1	98	2.392	0.2	4.6
4	30	4.9	102	2.421	0.2	3.4
5	40	7.1	98	2.387	0.2	4.8
6	48	4.7	87	2.366	0.4	5.6
7	6	3.2	91	2.411	0.2	3.8
8	14	2.4	94	2.415	0.2	3.7
9	17	1.0	93	2.370	0.3	5.5
10	23	2.0	84	2.396	0.2	4.4
11	28	0.8	92	2.378	0.3	5.1
12	31	2.1	78	2.314	1.5	7.7
		Mean	95	Mean (%)	0.3	4.7

Standard Deviation	1.188
Acceptance Constance (k factor)	0.59
Upper Characteristic In-situ Air Voids (%)	5.4
Lower Characteristic In-situ Air Voids (%)	4.0
MRWA Specification 514	5.5% Maximum

* metres right of left edge

Maximum Theroetical Density (t/m^3) 2.507 from Report/s MRWA S6797 / 98 & Downer NA25128 / 29

Comments
Trim File 16/4441

Approved Signatory:

Mark Hopgood (Project Officer)

Note:
k factor derived from Engineering Road Note 8 - Other Roads

Date 21/04/2017

Document:71/05/733.1C Issue:08/03/2017 TRIM:D17#181690

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Table B 11: Resilient modulus and bulk density test report S6850 (page 1)

mainroads WESTERN AUSTRALIA

ABN: 50 860 676 021

TEST REPORT

Sheet 1 of 4

Report No:	17 S6850 / 1	Reference No:	Not Applicable
Date Sampled:	12/04/2017	Date/s Tested :	12-21/04/2017
Local Govt Authority:	Not Applicable		
Road Name:	Not Applicable		
Project/Contract No :	WARRIP EME2 Trial	Customer:	Main Roads WA
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6.0 % Type EME2	Binder Details reference sample N°:	S6798
Sampling Method / Preparation:	SAMPLING PROCEDURES FOR ASPHALT AS 2981.1		

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	2.498
Maximum Density reference Sample Number	S6798

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
M1	2.378	0.5	4.8
M2	2.391	0.8	4.3
M3	2.382	0.9	4.6
M4	2.385	0.8	4.5
M5	2.390	0.6	4.3
Mean	**2.385**	**0.7**	**4.5**

Comments / Distribution	Approved Signatory
16/4441	
REPORTS	Name: Mark Hopgood
	Function: Project Officer
	Date: 4/05/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Table B 12: Resilient modulus and bulk density test report S6850 (page 2)

mainroads WESTERN AUSTRALIA

ABN 50 860 676 021

TEST REPORT Sheet 2 of 4

Report No:	**17 S6850 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date/s Tested :	**12-21/04/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	**14mm Dense Grade Asphalt**		

Grading Type: Dense Nominal Mix Size: 14 mm

Binder Content: 6.0 % Type EME2 Binder Details reference sample N°: **S6798**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**

Determination of the Resilient Modulus of Asphalt - Indirect Tensile Method AS/NZS 2891.13.1

Test conditions: Standard reference test conditions used

Other properties of the asphalt that may have influenced the results

Asphalt mixing temperature (°C)	177.9
Temperature at compaction (°C)	180.1
Number of Gyratory Cycles	Various
Pressure in Modulus Machine Accuator (kPa)	850
Start of Conditioning time	9:05:00
Date and Time of test	21/04/2017 12:52:00
Conditioning Time (hours)	1028307.78
Temp after conditioning (°C)	25.8
Date of specimen manufacture	12/04/2017

Specimen Number	Core Temperature of Specimen (°C)	Mean Diameter (mm)	Mean Height (mm)	Resilient Modulus of Specimen (MPa)	Coefficient of Variation of Modulus (%)
M1	26.0	99.5	49.6	6649	1.07
M3	26.0	99.5	50.0	6467	0.96
M4	26.0	99.5	49.7	6150	1.01
	Mean	99.5	49.8	6,420	1.0

AS 2891.2.2

Gyratory Angle (°) 2 Number of Cycles Various

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name Mark Hopgood
Function Project Officer
Date 4/05/2017

Document 71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Table B 13: Resilient modulus and bulk density test report S6850 (page 3)

mainroads WESTERN AUSTRALIA

ABN. 50 860 676 021

TEST REPORT

Sheet 3 of 4

Report No:	**17 S6850 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date/s Tested :	**1/05/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt EME2		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6 % Type EME2	Binder Details reference sample N°:	**S6798**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.9.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.498**
Maximum Density reference Sample Number	**S6798**

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Gyratory Cycles	**5022**
Temperature at Compaction	**Not Recorded**

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
1	2.426	0.4	2.9
2	2.427	0.3	2.9
3	2.420	0.3	3.1
Mean	**2.424**	**0.3**	**3.0**

Comments / Distribution	Approved Signatory
TRIM 16/4441	Name: Mark Hopgood
REPORTS	Function: Project Officer
	Date: 4/05/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Table B 14: Resilient modulus and bulk density test report S6850 (page 4)

mainroads WESTERN AUSTRALIA

ABN: 50 860 676 021

TEST REPORT

Sheet 4 of 4

Report No:	**17 S6850 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date/s Tested :	**1/05/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6.0 % Type EME2	Binder Details reference sample N°:	**S6798**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.498**
Maximum Density reference Sample Number	**S6798**

Bulk Density AS 2891.9.3 / Air Voids AS 2891.8

Gyratory Cycles	**100**
Temperature at Compaction (°C)	**Not Recorded**

Specimen Number	Bulk Density (t/m³)	Air Voids (%)
1	2.376	4.9
2	2.370	5.1
3	2.378	4.8
Mean	**2.375**	**4.9**

Comments / Distribution	Approved Signatory
TRIM 16/4441 **REPORTS**	Name: Mark Hopgood Function: Project Officer Date: 5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Table B 15: TSR and bulk density test report S6851 (page 1)

mainroads WESTERN AUSTRALIA

ABN: 50 860 676 021

TEST REPORT

Sheet 1 of 3

Report No:	17 S6851 / 1	Reference No:	Not Applicable
Date Sampled:	12/04/2017	Date/s Tested :	12/4-3/5/2017
Sample Number:	S6797		
Local Govt Authority:	Not Applicable	Road Name:	Not Applicable
Project/Contract No :	WARRIP EME2 Trial	Customer:	Main Roads Western Australia
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6.0 % Type EME2	Binder Details reference sample N°:	S6797
Sampling Method / Preparation:	SAMPLING PROCEDURES FOR ASPHALT AS 2891.1.1		

AG:PT/T232 STRIPPING POTENTIAL OF ASPHALT - TENSILE STRENGTH RATIO

Test conditions: Standard reference test conditions used

Specimen Number	% Air Voids (AS 2891.8)	Degree of Saturation (%)	Swell (%)	Tensile Strength (kPa)
Wet				
T5	7.8	70.6	4.4	1457
T6	7.8	65.8	4.8	1366
T7	7.8	79.1	4.5	1378
Mean	**7.8**	**71.8**	**4.6**	**1400**
Dry				
T1	7.8			1219
T3	7.8			1303
T4	8.0			1292
Mean	**7.9**			**1271**
			Tensile Strength Ratio (%)	**110**

Visual Assessment on Degree of Stripping

(One Wet Sample and One Dry Sample Only)

Type of Aggregate		Nil	Minimal	Moderate	Severe	Comments
Wet	Coarse	x				Several cracked, appears mastic
	Fine	x				Several cracked, appears mastic
Dry	Coarse		x			Few cracked, appears mastic
	Fine		x			Several cracked, appears mastic

Observations

AS 2891.2.2

Gyratory Angle (°) 2.0 Number of Cycles Various

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name: Mark Hopgood
Function: Project Officer
Date: 4/05/2017

Document:71/05/T232 Issue:08/03/2017 TRIM:D14#630776

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Table B 16: TSR and bulk density test report S6851 (page 2)

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ABN: 50 860 676 021

TEST REPORT

Sheet 2 of 3

Report No:	**17 S6851 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date/s Tested :	**28/4 - 1/5/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6.0 % Type EME2	Binder Details reference sample N°:	**S6797**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.501**
Maximum Density reference Sample Number	**S6797**

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Gyratory Cycles	**100**
Temperature at Compaction (°C)	**177**

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
1	2.422	0.3	3.1
2	2.420	0.3	3.2
3	2.435	0.4	2.6
Mean	**2.426**	**0.3**	**3.0**

Comments / Distribution	Approved Signatory
TRIM 16/4441	
REPORTS	Name: Mark Hopgood
	Function: Project Officer
	Date: 4/05/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Table B 17: TSR and bulk density test report S6851 (page 3)

mainroads WESTERN AUSTRALIA

ABN: 50 860 676 021

TEST REPORT

Sheet 3 of 3

Report No:	**17 S6851 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**12/04/2017**	Date/s Tested :	**28/04/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6.0 % Type EME2	Binder Details reference sample N°:	**S6797**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.501**
Maximum Density reference Sample Number	**S6797**

Bulk Density AS 2891.9.3 / Air Voids AS 2891.8

Gyratory Cycles	**100**
Temperature at Compaction (°C)	**177**

Specimen Number	Bulk Density (t/m³)	Air Voids (%)
1	2.358	5.7
2	2.372	5.1
3	2.387	4.6
Mean	**2.372**	**5.1**

Comments / Distribution	Approved Signatory
TRIM 16/4441	
REPORTS	Name: Mark Hopgood
	Function: Project Officer
	Date: 5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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APPENDIX C IN SITU DENSITY, THICKNESS AND AIR VOIDS RESULTS OF ASPHALT

Table C 1: Report S6825 core density Lift 1 Chainage 21050 – 21375 (sampled 28/04/17)

Core no.	Chainage	Transverse metres right of left edge	Thickness (mm)	Bulk density (t/m³)	Water absorption (%)	Air voids (%)
1	21 058	0.9	107	2.462	0.2	1.3
2	21 088	1.0	106	2.404	0.2	3.7
3	21 142	0.6	118	2.449	0.1	1.8
4	21 167	5.4	103	2.364	0.3	5.3
5	21 186	3.3	118	2.446	0.1	2.0
6	21 228	5.2	99	2.449	0.1	1.8
7	21 261	3.8	134	2.397	0.2	3.9
8	21 305	2.7	112	2.436	0.1	2.3
9	21 312	4.1	120	2.454	0.1	1.7
10	21 346	1.1	99	2.413	0.2	3.3
		Mean	**111**	**2.427**	**0.2**	**2.7**
					Standard deviation	1.266
					Acceptance Constance (k factor)	0.75
					Upper characteristic in situ air void (%)	3.7
					Lower characteristic in situ air void (%)	1.8
					Main Roads Specification 514 (Draft)	**Maximum 5.5**

Source: Based on laboratory data from Main Roads

Table C 2: Core density LR1 and LR2 Lift 1 lower and upper half Chainage 21050 – 21375

Report no.	S6845 (lower half)		S6844 (upper half)	
Core no.	Bulk density (t/m³)	Air voids (%)	Bulk density (t/m³)	Air voids (%)
1	2.437	2.3	2.437	2.3
2	2.375	4.8	2.422	2.9
3	2.449	1.8	2.445	2.0
4	2.348	5.9	2.382	4.5
5	2.452	1.7	2.438	2.3
6	2.451	1.8	2.444	2.1
7	2.394	4.1	2.405	3.6
8	2.435	2.4	2.438	2.3
9	2.463	1.3	2.444	2.0
10	2.411	3.4	2.417	3.1
Mean	**2.422**	**2.9**	**2.427**	**2.7**
	Standard deviation	1.530		0.832

Note: Results are the product of cutting the cores from Report S6825 into lower and upper halves.

Source: Based on laboratory data from Main Roads.

Table C 3: Report S6826 core density Lift 2 Chainage 21050 – 21375 (sampled 28/04/2017)

Core no.	Chainage	Transverse metres right of left edge	Thickness (mm)	Bulk density (t/m^3)	Water absorption (%)	Air voids (%)
1	21 058	0.9	157	2.417	0.1	2.9
2	21 088	1.0	100	2.376	0.2	4.6
3	21 142	0.6	100	2.439	0.1	2.0
4	21 167	5.4	108	2.360	0.2	5.2
5	21 186	3.3	101	2.440	0.1	1.9
6	21 228	5.2	94	2.377	0.2	4.5
7	21 261	3.8	92	2.411	0.2	3.1
8	21 305	2.7	89	2.401	0.2	3.5
9	21 312	4.1	94	2.419	0.2	2.8
10	21 346	1.1	110	2.436	0.1	2.1
		Mean	**104**	**2.404**	**0.2**	**3.3**
					Standard deviation	1.154
					Acceptance Constance (k factor)	0.75
					Upper characteristic in situ air void (%)	4.1
					Lower characteristic in situ air void (%)	2.4
					Main Roads Specification 514 (Draft)	**Maximum 5.5**

Source: Based on laboratory data from Main Roads.

Table C 4: Core density LR1 and LR2 Lift 2 lower and upper half Chainage 21050 – 21375

Report no.	S6847 (lower half)		S6846 (upper half)	
Core no.	Bulk density (t/m^3)	Air voids (%)	Bulk density (t/m^3)	Air voids (%)
1	2.424	2.6	2.408	3.3
2	2.361	5.1	2.389	4.0
3	2.442	1.9	2.432	2.3
4	2.343	5.9	2.361	5.1
5	2.438	2.1	2.433	2.2
6	2.359	5.2	2.382	4.3
7	2.421	2.7	2.400	3.6
8	2.390	4.0	2.377	4.5
9	2.421	2.7	2.408	3.2
10	2.438	2.0	2.432	2.3
Mean	**2.404**	**3.4**	**2.402**	**3.5**
	Standard deviation	1.499		1.008

Note: Results are the product of cutting the cores from Report S6826 into lower and upper halves.

Source: Based on laboratory data from Main Roads.

Table C 5: Report S6827 core density Lift 1 Chainage 21050 – 21375 (selected sites) (sampled 28/4/17)

Core no.	Chainage	Transverse metres right of left edge	Thickness (mm)	Bulk density (t/m³)	Water absorption (%)	Air voids (%)
1	21 135	2.0	120	2.462	0.1	1.2
2	21 158	2.0	112	2.404	0.1	2.1
3	21 165	2.0	116	2.449	0.1	1.8
4	21 185	5.5	91	2.364	0.1	1.9
		Mean	**110**	**2.420**	**0.1**	**1.8**

Source: Based on laboratory data from Main Roads.

Table C 6: Report S6828 core density Lift 2 Chainage 21050 – 21375 (selected sites) (sampled 28/4/17)

Core no.	Chainage	Transverse metres right of left edge	Thickness (mm)	Bulk density (t/m³)	Water absorption (%)	Air voids (%)
1	21 135	2.0	105	2.435	0.1	2.2
2	21 158	2.0	112	2.394	0.1	3.8
3	21 165	2.0	103	2.417	0.1	2.9
4	21 185	5.5	106	2.402	0.12	3.5
		Mean	**106**	**2.412**	**0.1**	**3.1**

Source: Based on laboratory data from Main Roads.

Table C 7: Report 17M175 nuclear density LR1 (lane side) Lift 1 Chainage 21050 – 21275 (tested 27/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Field density (t/m³)	Air voids (%)
1	21 054	2.8	90	2.374	4.8
2	21 085	1.8	90	2.443	2.1
3	21 119	1.1	90	2.525	–1.2
4	21 134	2.4	90	2.490	0.2
5	21 168	1.4	90	2.359	5.5
6	21 178	0.4	90	2.454	1.6
7	21 209	3.0	90	2.408	3.5
8	21 229	2.1	90	2.414	3.2
9	21 257	1.1	90	2.457	1.5
				Mean	**2.4**
				Standard deviation	2.135
				Acceptance Constance (k factor)	0.75
				Upper characteristic in situ air void (%)	4.0
				Lower characteristic in situ air void (%)	0.8
				Main Roads Specification 514 (Draft)	**Maximum 5.5**

Source: Based on laboratory data from Main Roads.

Table C 8: Report 17M176 nuclear density LR1 (median side) Lift 1 Chainage 21153 – 21365 (tested 27/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Field density (t/m³)	Air voids (%)
1	21 154	7.3	90	2.338	6.3
2	21 185	7.8	90	2.396	4.0
3	21 219	7.6	90	2.375	4.8
4	21 234	7.9	90	2.385	4.4
5	21 268	4.9	90	2.369	5.1
6	21 278	0.4	90	2.420	3.0
7	21 309	4.0	90	2.394	4.0
8	21 329	2.1	90	2.370	5.0
9	21 357	1.1	90	2.415	3.2
				Mean	**4.4**
				Standard deviation	1.014
				Acceptance Constance (k factor)	0.75
				Upper characteristic in situ air void (%)	5.2
				Lower characteristic in situ air void (%)	3.7
				Main Roads Specification 514 (Draft)	**Maximum 5.5**

Source: Based on laboratory data from Main Roads.

Table C 9: Report 17M177 nuclear density joint LR1 and LR2 Lift 1 Chainage 21125 – 21275 (tested 27/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Field density (t/m³)	Air voids (%)
1	21 132	3.5	90	2.193	12.1
2	21 173	3.5	90	2.221	11.0
3	21 199	3.5	90	2.077	16.8
4	21 210	3.5	90	2.201	11.8
5	21 238	3.5	90	2.107	15.6
6	21 250	3.5	90	2.121	15.0

Source: Based on laboratory data from Main Roads.

Table C 10: Report 17M178 nuclear density LR1 and LR2 Lift 2 Chainage 21050 – 21375 (tested 28/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Field density (t/m³)	Air voids (%)
1	21 058	0.9	90	2.394	3.8
2	21 088	1.0	90	2.401	3.5
3	21 142	0.6	90	2.442	1.9
4	21 167	5.4	90	2.360	5.2
5	21 186	3.3	90	2.458	1.2
6	21 228	5.2	90	2.361	5.1
7	21 261	3.8	90	2.386	4.1
8	21 305	2.7	90	2.432	2.3
9	21 312	4.1	90	2.444	1.8
10	21 346	1.1	90	2.462	1.1
				Mean	**3.0**
				Standard deviation	1.546
				Acceptance Constance (k factor)	0.75
				Upper characteristic in situ air void (%)	4.2
				Lower characteristic in situ air void (%)	1.9
				Main Roads Specification 514 (Draft)	**Maximum 5.5**

Source: Based on laboratory data from Main Roads

Table C 11: Report 17M179 nuclear density LR1 and LR2 Layer 2 Chainage 21135 – 21186 (selected site) (tested 28/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Field density (t/m³)	Air voids (%)
1	21 135	2.0	90	2.410	3.2
2	21 158	2.0	90	2.425	2.6
3	21 165	2.0	90	2.446	1.7
4	21 185	5.5	90	2.384	4.2

Source: Based on laboratory data from Main Roads

Table C 12: Report 17M180 nuclear density joint LR1 and LR2 Layer 2 Chainage 21125 – 21275 (tested 28/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Field density (t/m³)	Air voids (%)
1	21 128	3.5	90	2.074	16.7
2	21 155	3.5	90	2.285	8.2
3	21 196	3.5	90	2.243	9.9
4	21 214	3.5	90	2.251	9.6
5	21 239	3.5	90	2.360	5.2
6	21 259	3.5	90	2.409	3.2

Source: Based on laboratory data from Main Roads

APPENDIX D IN SITU DENSITY RESULTS: SUBGRADE AND SUBBASE

Table D 1: Report N34704 subgrade compaction results (tested 21/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Moisture content (%)	Wet density (t/m³)	Dry density (t/m³)	Compaction (%)
1	21 078	1.5	150	13	1.992	1.763	96.1
2	21 130	4.5	150	12.6	2.000	1.776	96.8
3	21 165	6.0	150	12.8	1.992	1.765	96.2
4	21 182	4.0	150	12.5	1.997	1.775	96.7
5	21 209	1.0	150	10.6	1.969	1.780	97.0
6	21 245	5.0	150	11.0	1.973	1.777	96.9
7	21 284	4.0	150	10.9	1.959	1.767	96.9
8	21 325	2.0	150	12.4	1.974	1.756	96.3
9	21 357	3.5	150	11.4	1.957	1.757	96.4
						Mean	96.5
						Standard deviation	0.334
						(k factor)	50.0
						Characteristic moisture (%)	**94.8**
						Characteristic density (%)	**96.4**
						Main Roads Specification 302 characteristic dry density ratio (%)	**Minimum 96**

Source: Based on laboratory data from Kanga & Associates (supplied by Main Roads).

Table D 2: Report N34710 subbase compaction results (tested 23/4/17)

Site no.	Chainage	Transverse metres right of left edge	Test depth (mm)	Moisture content (%)	Wet density (t/m³)	Dry density (t/m³)	Compaction (%)
1	21 070	7.0	100	11.3	2.028	1.822	95.3
2	21 101	2.5	100	12.1	2.055	1.832	95.8
3	21 128	4.0	100	11.4	2.033	1.825	95.5
4	21 160	2.5	100	11.0	2.021	1.821	95.2
5	21 186	2.5	100	11.1	2.030	1.827	95.5
6	21 227	0.5	100	10.9	2.017	1.818	95.4
7	21 273	3.5	100	10.7	2.012	1.817	95.0
8	21 303	5.0	100	10.9	2.023	1.824	95.4
9	21 355	2.5	100	12.2	2.071	1.845	96.5
						Mean	95.5
						Standard deviation	0.448
						(k factor)	0.59
						Characteristic moisture (%)	**98.3**
						Characteristic density (%)	**95.2**
						Main Roads Specification 302 characteristic dry density ratio (%)	**Minimum 94**

Source: Based on laboratory data from Kanga & Associates (supplied by Main Roads).

APPENDIX E DRYBACK

Table E 1: Report N34714 dryback sub-base test results (tested 24/4/17)

Site no.	Chainage	Transverse metres right of left edge	Moisture ratio (%)
1	21 065	1.0	80.8
2	21 103	3.5	82.3
3	21 136	4.5	84.3
4	21 165	3.0	73.4
5	21 185	6.0	74.8
6	21 232	0.5	83.6
7	21 258	6.0	84.2
8	21 285	2.0	80.3
9	21 340	4.5	74.3
	Mean	79.8	
	Standard deviation	4.310	
	(k factor)	0.59	
	Characteristic moisture (%)	**82.3**	
	Main Roads Specification 501 characteristic dryback moisture content (%)	**maximum 85**	

Source: Based on laboratory data from Kanga & Associates (supplied by Main Roads).

APPENDIX F SURFACE SHAPE RESULTS

Figure F 1: Surface shape using straightedge results Lift 2 LR2 Chainage 21 075 – 21 275 LWP

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ABN: 50 860 676 021

Surface Shape Using a Straightedge Report **W.A. 313.2** Page 1 of 1

Customer: Main Roads Western Australia

Sample No.: S6834 Date/s of Test: 28/04/2017

Local Govt Authority: City Of Gosnells

Road: Tonkin Highway Kelvin Road Intersection

Carriageway: Tonkin Highway Southbound Lane: LR2

Sampling Method: WA 110.1

Wheelpaths: **LWP** = Left wheel path **BWP** = Between wheel path **RWP** = Right wheel path

Location: Distance from Start (m)	Location: Start Chainage (m) / Chainage (m)	Presence of Shoving (Yes ✓ / No ×)	Rut Depth (mm), Size of Straightedge: 3.00m – LWP	BWP	RWP	Maximum Deviation from Straightedge 3.00 m (mm)	Crossfall 3.00 m Average (%)
20	21075	×	0			3m	
40	21095	×	4			3m	
60	21115	×	2			3m	
80	21135	×	1			3m	
100	21155	×	1			3m	
120	21175	×		0		3m	
140	21195	×			1	3m	
160	21215	×		1		3m	
180	21235	×		0		3m	
200	21255	×	2			3m	
220	21275	×			4	3m	

Comments / Distribution
TRIM 16/4441

Approved Signatory
Name: Mark Hopgood
Function: Project Officer
Date: 3/05/2017

Document:71/05/313.2 Issue:21/03/2017 TRIM:D14#628231 MAIN ROADS Western Australia

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Figure F 2: Surface shape using straightedge results Lift 2 LR1 Chainage 21 075 – 21 275 BWP

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Surface Shape Using a Straightedge Report **W.A. 313.2** Page 1 of 1

Customer: Main Roads Western Australia
Sample No.: S6835 Date/s of Test: 28/04/2017
Local Govt Authority: City Of Gosnells
Road: Tonkin Highway Kelvin Road Intersection
Carriageway: Tonkin Highway Southbound Lane: LR1

Sampling Method: WA 110.1

Wheelpaths: **LWP** = Left wheel path **BWP** = Between wheel path **RWP** = Right wheel path

Location		Presence of Shoving	Rut Depth			Maximum Deviation from Straightedge	Crossfall
Distance from Start	Start Chainage (m)		Size of Straightedge: 3.00m			3.00 m	3.00 m
(m)	Chainage (m)	Yes ✓ No ×	LWP	(mm) BWP	RWP	(mm)	Average (%)
20	21075	×	1			3m	
40	21095	×				3m	
60	21115	×		0		3m	
80	21135	×		3		3m	
100	21155	×	2			3m	
120	21175	×		0		3m	
140	21195	×		0		3m	
160	21215	×		0		3m	
180	21235	×		1		3m	
200	21255	×		0		3m	
220	21275	×		2		3m	

Comments / Distribution
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Approved Signatory
Name: Mark Hopgood
Function: Project Officer
Date: 3/05/2017

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Figure F 3: Surface shape using straightedge results Lift 2 LR2 Chainage 21 075 – 21 275

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Surface Shape Using a Straightedge Report W.A. 313.2

Page 1 of 1

Customer: Main Roads Western Australia

Sample No.: S6836 — Date/s of Test: 28/04/2017

Local Govt Authority: City Of Gosnells

Road: Tonkin Highway Kelvin Road Intersection

Carriageway: Tonkin Highway Southbound — Lane: LR2

Sampling Method: WA 110.1

Wheelpaths: **LWP** = Left wheel path **BWP** = Between wheel path **RWP** = Right wheel path

Location		Presence of Shoving	Rut Depth			Maximum Deviation from Straightedge	Crossfall
Distance from Start	Start Chainage (m)		Size of Straightedge: 3.00m			3.00 m	3.00 m
		Yes ✓	(mm)				Average
(m)	Chainage (m)	No ×	-1m	0m	+1m	(mm)	(%)
20	21075	×			1	3m	
40	21095	×		0		3m	
60	21115	×		1		3m	
80	21135	×		1		3m	
100	21155	×			3	3m	
120	21175	×		0		3m	
140	21195	×			3	3m	
160	21215	×			6	3m	
180	21235	×		0		3m	
200	21255	×			4	3m	
220	21275	×		2		3m	

Comments / Distribution
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Name: Mark Hopgood
Function: Project Officer
Date: 3/05/2017

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Figure F 4: Surface shape using straightedge results Lift 2 LR2 Chainage 21 075 – 21 275 BWP

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Surface Shape Using a Straightedge Report **W.A. 313.2** Page 1 of 1

Customer	Main Roads Western Australia
Sample No.	S6837
Date/s of Test	28/04/2017
Local Govt Authority	City Of Gosnells
Road	Tonkin Highway Kelvin Road Intersection
Carriageway	Tonkin Highway Southbound
Lane	LR2

Sampling Method WA 110.1

Wheelpaths: **LWP** = Left wheel path **BWP** = Between wheel path **RWP** = Right wheel path

Location		Presence of Shoving	Rut Depth			Maximum Deviation from Straightedge	Crossfall
Distance from Start	Start Chainage (m)		Size of Straightedge: 3.00m			3.00 m	3.00 m
		Yes ✓	(mm)				Average
(m)	Chainage (m)	No ×	-1m	0m	+1m	(mm)	(%)
20	21075	×		0		3m	
40	21095	×		0		3m	
60	21115	×		4		3m	
80	21135	×		1		3m	
100	21155	×	3			3m	
120	21175	×		0		3m	
140	21195	×		0		3m	
160	21215	×		2		3m	
180	21235	×		1		3m	
200	21255	×			6	3m	
220	21275	×		0		3m	

Comments / Distribution	Approved Signatory
TRIM 16/4441	Name: Mark Hopgood Function: Project Officer Date: 3/05/2017

Document:71/05/313.2 Issue:21/03/2017 TRIM:D14#628231 MAIN ROADS Western Australia

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APPENDIX G SURFACE TEXTURE RESULTS

Figure G 1: Skid resistance and surface texture results Layer 2 (LR1 & LR2) Chainage 21 050 – 21 275

TEST REPORT

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Page 1 of 1

PAVEMENT SKID RESISTANCE WA 310.1 AND SURFACE TEXTURE WA 311.1

Sample/ Report No.	17 S6843/1	Project/Contract No.	EME2 Trials		
Date Tested.	28/04/2017	Date Received.	28/04/2017	Surface Age.	Not Supplied
Road.	Tonkin Highway / Kelvin Road Intersection			Aggregate Type	Not Supplied
Location.	21050-21275			Aggregate Size	Not Supplied

Lane	SLK	Offset / Wheelpath	Surface Type	Texture Depth (mm)
BWP	21185	LR2	14mm Dense Grade Asphalt EME2 Trial Mix	0.5
		Join		0.7
		LR1		0.6
BWP	21225	LR2		0.6
		Join		0.7
		LR1		0.6
			Mean	0.6

Comments / Distribution
TRIM 16/4441

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 3/05/2017

Document:71/05/2341.2 Issue:18/02/2016 TRIM:D14#629288

APPENDIX H TENSILE STRENGTH RATIO

Figure H 1: Tensile strength ratio test results S6848 (sampled 26/04/17) (page 1)

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TEST REPORT

Sheet 1 of 3

Report No:	17 S6848 / 1	Reference No:	Not Applicable
Date Sampled:	26/04/2017	Date/s Tested:	27/4-3/5/2017
Sample Number:	S6821		
Local Govt Authority:	City of Gosnells	Road Name:	Tonkin Highway
Project/Contract No:	WARRIP EME2 Trial	Customer:	Main Roads Western Australia
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	S6821
Sampling Method / Preparation:	SAMPLING PROCEDURES FOR ASPHALT AS 2891.1.1		

AG:PT/T232 STRIPPING POTENTIAL OF ASPHALT - TENSILE STRENGTH RATIO

Test conditions: Standard reference test conditions used

Specimen Number	% Air Voids (AS 2891.8)	Degree of Saturation (%)	Swell (%)	Tensile Strength (kPa)
Wet				
T4	7.6	66.6	4.2	1238
T6	7.8	66.8	4.5	1423
T9	7.7	66.4	4.5	1475
Mean	**7.7**	**66.6**	**4.4**	**1379**
Dry				
T1	7.2			1468
T3	7.5			1488
T7	7.3			1459
Mean	**7.3**			**1472**
			Tensile Strength Ratio (%)	**94**

Visual Assessment on Degree of Stripping
(One Wet Sample and One Dry Sample Only)

Type of Aggregate		Nil	Minimal	Moderate	Severe	Comments
Wet	Coarse		x			Few cracked, appears mastic
	Fine		x			Several cracked, appears mastic
Dry	Coarse		x			Several cracked, appears mastic
	Fine		x			Moderate cracking, appears mastic

Observations

AS 2891.2.2

Gyratory Angle (°) 2.0 Number of Cycles Various

Comments / Distribution
TRIM 16/4441
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Approved Signatory

Name Mark Hopgood
Function Project Officer
Date 5/04/2017

Document:71/05/T232 Issue:08/03/2017 TRIM:D14#630776

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Figure H 2: Tensile strength ratio test results S6848 (sampled 26/04/17) (page 2)

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TEST REPORT

Sheet 2 of 3

Report No:	**17 S6848 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**26/04/2017**	Date/s Tested :	**26/04/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	**S6821**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.492**
Maximum Density reference Sample Number	**S6821**

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Gyratory Cycles	**100**
Temperature at Compaction (°C)	**177**

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
1	2.428	0.2	2.6
2	2.428	0.3	2.6
3	2.430	0.3	2.5
Mean	**2.429**	**0.3**	**2.6**

Comments / Distribution	Approved Signatory
TRIM 16/4441	Name: Mark Hopgood
REPORTS	Function: Project Officer
	Date: 5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure H 3: Tensile strength ratio test results S6848 (sampled 26/04/17) (page 3)

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TEST REPORT

Sheet 3 of 3

Report No:	**17 S6848 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**26/04/2017**	Date/s Tested :	**28/04/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	**S6821**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.492**
Maximum Density reference Sample Number	**S6821**

Bulk Density AS 2891.9.3 / Air Voids AS 2891.8

Gyratory Cycles	**100**
Temperature at Compaction (°C)	**177**

Specimen Number	Bulk Density (t/m³)	Air Voids (%)
1	2.384	4.3
2	2.369	4.9
3	2.383	4.4
Mean	**2.379**	**4.5**

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name Mark Hopgood
Function Project Officer
Date 5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure H 4: Tensile strength ratio test results S6849 (sampled 27/04/17) (page 1)

ABN. 50 860 676 021

TEST REPORT

Sheet 1 of 3

Report No:	**17 S6849 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**27/04/2017**	Date/s Tested :	**27/4 - 3/5/2017**
Sample Number:	**S6823**		
Local Govt Authority:	**City of Gosnells**	Road Name:	**Tonkin Highway**
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Mainroads WA**
Asphalt mixture details:	**14mm Dense Grade Asphalt**		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	**S6823**
Sampling Method / Preparation:	**SAMPLING PROCEDURES FOR ASPHALT AS 2891.1.1**		

AG:PT/T232 STRIPPING POTENTIAL OF ASPHALT - TENSILE STRENGTH RATIO

Test conditions: Standard reference test conditions used

Specimen Number	% Air Voids (AS 2891.8)	Degree of Saturation (%)	Swell (%)	Tensile Strength (kPa)
Wet				
T2	8.3	64.6	4.1	1451
T6	7.9	64.7	4.5	1473
T8	7.8	66.2	4.9	1473
Mean	**8.0**	**65.2**	**4.5**	**1466**
Dry				
T3	7.4			1448
T4	7.2			1577
T5	8.0			1365
Mean	**7.5**			**1464**
			Tensile Strength Ratio (%)	**100**

Visual Assessment on Degree of Stripping

(One Wet Sample and One Dry Sample Only)

Type of Aggregate		Nil	Minimal	Moderate	Severe	Comments
Wet	Coarse		x			**Several cracked, appears mastic**
	Fine		x			**Several cracked, appears mastic**
Dry	Coarse		x			**Several cracked, appears mastic**
	Fine		x			**Several cracked, appears mastic**

Observations

AS 2891.2.2

Gyratory Angle (°) 2.0 Number of Cycles Various

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name: Mark Hopgood
Function: Project Officer
Date: 5/04/2017

Document:71/05/T232 Issue:08/03/2017 TRIM:D14#630776

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Figure H 5: Tensile strength ratio test results S6849 (sampled 27/04/17) (page 2)

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TEST REPORT

Sheet 2 of 3

Report No:	17 S6849 / 1	Reference No:	Not Applicable
Date Sampled:	27/04/2017	Date/s Tested :	2/05/2017
Local Govt Authority:	Not Applicable		
Road Name:	Not Applicable		
Project/Contract No :	WARRIP EME2 Trial	Customer:	Main Roads Western Australia
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	S6823

Sampling Method / Preparation: SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	2.483
Maximum Density reference Sample Number	S6823

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Gyratory Cycles	100
Temperature at Compaction (°C)	177

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
1	2.410	0.2	2.9
2	2.411	0.2	2.9
3	2.409	0.2	3.0
Mean	2.410	0.2	2.9

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name: Mark Hopgood
Function: Project Officer
Date: 5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure H 6: Tensile strength ratio test results S6849 (sampled 27/04/17) (page 3)

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ABN: 50 860 676 021

TEST REPORT

Sheet 3 of 3

Report No:	17 S6849 / 1	Reference No:	Not Applicable
Date Sampled:	27/04/2017	Date/s Tested :	2/05/2017
Local Govt Authority:	Not Applicable		
Road Name:	Not Applicable		
Project/Contract No :	WARRIP EME2 Trial	Customer:	Main Roads Western Australia
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	S6823
Sampling Method / Preparation:	SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1 COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2		

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	2.486
Maximum Density reference Sample Number	S6823

Bulk Density AS 2891.9.3 / Air Voids AS 2891.8

Gyratory Cycles	100
Temperature at Compaction (°C)	177

Specimen Number	Bulk Density (t/m³)	Air Voids (%)
1	2.367	4.8
2	2.368	4.8
3	2.366	4.8
Mean	2.367	4.8

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name	Mark Hopgood
Function	Project Officer
Date	5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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APPENDIX I WHEEL TRACKING TEST RESULTS

Figure I 1: Wheel tracking test report ARRB 16-8-4, 60 000 passes (30 000 cycles)

Wheel Tracking Test Report

Test Method Austroads AGPT/T231

Report No: 16-8-4

Client: MRWA

Mix Details: EME2 Tonkin Hwy, Plant Downer, Martin, 10x 10L asphalt samples (tins: 8, 13, 16, 18, 19, 26 and 4 tins with no identification)

ARRB Lab No.	5203	5224
Client Sample No.	N/A	N/A
Date Manufactured	22/06/17	03/07/17
Testing date	27/06/17	07/07/17
Age of specimen	5 days	4 days
Maximum number of loading passes	60,000	60,000
Bulk Density (t/m^3)	2.395	2.411
Air Voids of Slab (%)	4.1	3.4
Temperature Start / Finish (°C)	60 / 61	60 / 60
Maximum Tracking Depth (mm)	1.5	0.6
Average Max Tracking Depth (mm)	1.1	

Notes:

- All specimens 50 mm thick
- Applied load for all tests was 708 N
- This report relates specifically to the sample tested as supplied
- Specimen manufactured in the laboratory by reheating plant mix
- Air voids calulated from supplied maximum density of 2.495 t/m^3
- Speciemens tested to 60,000 passes

Approved Signatory: (Shannon Malone) Date: 11/08/17

NATA Accredited for compliance with ISO/IEC 17025 - Testing. The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

NATA Accredited Laboratory Number: 5594

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Issue H
Authorised by Shannon Malone
RR-422-1-0-105

Page 1 of 1

Figure I 2: Wheel tracking test report ARRB 16-8-5, 10 000 passes (5 000 cycles)

Wheel Tracking Test Report

Test Method Austroads AGPT/T231

Report No: 16-8-5

Client: MRWA

Mix Details: EME2 Tonkin Hwy, Plant Downer, Martin, 10x 10L asphalt samples (tins: 8, 13, 16, 18, 19, 26 and 4 tins with no identification)

ARRB Lab No.	5203	5224
Client Sample No.	N/A	N/A
Date Manufactured	22/06/17	03/07/17
Testing date	27/06/17	07/07/17
Age of specimen	5 days	4 days
Maximum number of loading passes	10,000	10,000
Bulk Density (t/m³)	2.395	2.411
Air Voids of Slab (%)	4.1	3.4
Temperature Start / Finish (°C)	60 / 61	60 / 60
Maximum Tracking Depth (mm)	1.3	0.4
Average Max Tracking Depth (mm)	**0.9**	

Notes:

- All specimens 50 mm thick
- Applied load for all tests was 708 N
- This report relates specifically to the sample tested as supplied
- Specimen manufactured in the laboratory by reheating plant mix
- Air voids calulated from supplied maximum density of 2.495 t/m³

Approved Signatory: ______________________ Date: 11/08/17
(Shannon Malone)

NATA Accredited Laboratory Number: 9584

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

AUSTRALIAN ROAD RESEARCH BOARD

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Authorised by Shannon Malone
RR-422-1-0-105

Page 1 of 1

APPENDIX J FLEXURAL MODULUS RESULTS

Table J 1: Flexural modulus results for EME2

Temperature (ºC)	Frequency (Hz)	Flexural modulus for replicate specimens (MPa)						Statistics		
		5202-1 (AV 5.1)	5202-2 (AV 4.2)	5202-3 (AV 4.0)	5202-4 (AV 4.5)	5231-1 (AV 1.9)	5231-4 (AV 1.8)	Mean (MPa)	STDEV (MPa)	CoV (%)
5	0.1	10 383	11 015	10 777	9 860	14 813	13 998	11 808	2 066	17.5
	0.5	11 942	12 726	13 011	11 818	16 255	16 159	13 652	2 031	14.9
	1	12 576	13 537	13 810	12 538	17 017	16 873	14 392	2 042	14.2
	3	13 806	14 801	15 181	13 942	18 555	18 371	15 776	2 145	13.6
	5	14 241	15 552	15 934	14 686	19 306	19 021	16 457	2 183	13.3
	10	15 045	16 352	16 920	15 739	20 536	19 963	17 426	2 282	13.1
	15	15 259	16 841	17 160	16 041	20 254	20 248	17 634	2 132	12.1
	20	15 410	16 952	17 233	16 081	20 380	20 310	17 728	2 128	12.0
10	0.1	7 557	8 365	8 768	8 351	11 877	11 030	9 325	1 716	18.4
	0.5	9 578	10 046	10 413	10 217	13 952	12 994	11 200	1 808	16.1
	1	10 283	10 888	11 274	10 996	14 763	13 831	12 006	1 828	15.2
	3	11 395	12 150	12 752	12 332	16 096	15 188	13 319	1 875	14.1
	5	12 129	12 911	13 321	12 970	16 780	15 944	14 009	1 882	13.4
	10	12 922	13 880	14 369	13 832	17 620	16 799	14 904	1 864	12.5
	15	13 464	14 541	14 809	14 264	18 120	17 324	15 420	1 856	12.0
	20	13 614	14 711	14 964	14 354	18 032	17 653	15 555	1 834	11.8
20	0.1	4 553	4 759	4 763	4 594	7 673	7 348	5 615	1 474	26.3
	0.5	5 348	5 991	6 024	5 758	9 108	8 889	6 853	1 681	24.5
	1	5 951	6 692	6 610	6 434	9 698	9 591	7 496	1 684	22.5
	3	7 161	7 714	8 016	7 585	11 043	10 975	8 749	1 772	20.3
	5	7 724	8 415	8 521	8 216	11 603	11 426	9 318	1 725	18.5
	10	8 459	9 329	9 446	9 118	12 624	12 447	10 237	1 814	17.7
	15	9 027	9 988	9 973	9 683	13 210	13 030	10 819	1 817	16.8
	20	9 298	10 271	10 240	9 832	13 465	13 372	11 080	1 846	16.7
30	0.1	2 027	2 139	1 998	2 153	4 334	3 793	2 741	1 041	38.0
	0.5	2 611	2 798	2 743	2 828	5 061	4 690	3 455	1 109	32.1
	1	3 079	3 279	3 208	3 343	5 675	5 324	3 985	1 182	29.7
	3	3 795	4 180	4 081	4 177	6 789	6 350	4 895	1 312	26.8
	5	4 255	4 635	4 562	4 640	7 411	6 988	5 415	1 396	25.8
	10	4 847	5 243	5 251	5 297	8 145	8 215	6 166	1 568	25.4
	15	5 183	5 639	5 575	5 736	8 588	8 554	6 546	1 580	24.1
	20	5 395	5 892	5 801	5 912	8 906	9 303	6 868	1 747	25.4
40	0.1	754	827	895	896	1 826	1 732	1 155	487	42.2
	0.5	1 105	1 189	1 222	1 234	2 453	2 359	1 594	632	39.6
	1	1 305	1 410	1 487	1 456	2 907	2 782	1 891	742	39.2
	3	1 806	1 964	2 054	2 008	3 587	3 489	2 485	821	33.0

Temperature (°C)	Frequency (Hz)	Flexural modulus for replicate specimens (MPa)						Statistics		
		5202-1 (AV 5.1)	5202-2 (AV 4.2)	5202-3 (AV 4.0)	5202-4 (AV 4.5)	5231-1 (AV 1.9)	5231-4 (AV 1.8)	Mean (MPa)	STDEV (MPa)	CoV (%)
	5	2 068	2 284	2 411	2 314	4 048	3 883	2 835	885	31.2
	10	2 506	2 721	2 892	2 779	4 653	4 486	3 340	962	28.8
	15	2 694	2 957	3 163	3 042	4 964	4 793	3 602	1 002	27.8
	20	2 829	3 174	3 282	3 199	5 180	4 999	3 777	1 030	27.3

Figure J 1: Master curve for air voids 5.1% (reference temperature 15 °C)

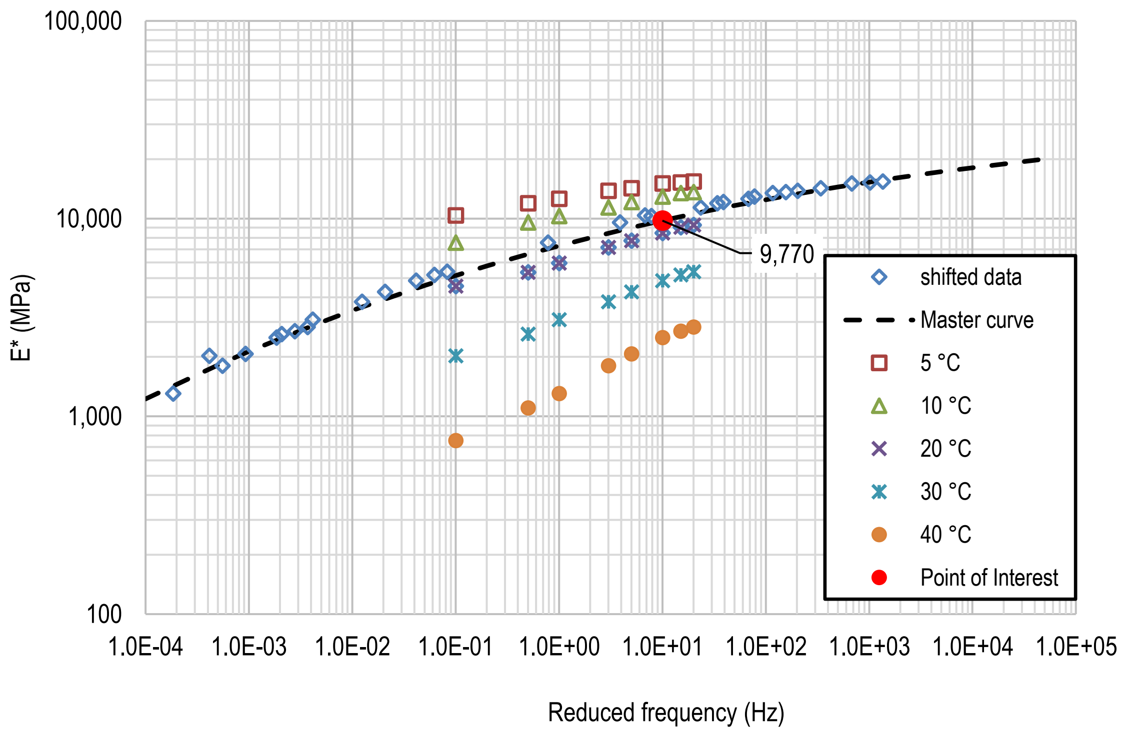


Figure J 2: Master curve for air voids 4.2% (reference temperature 15 °C)

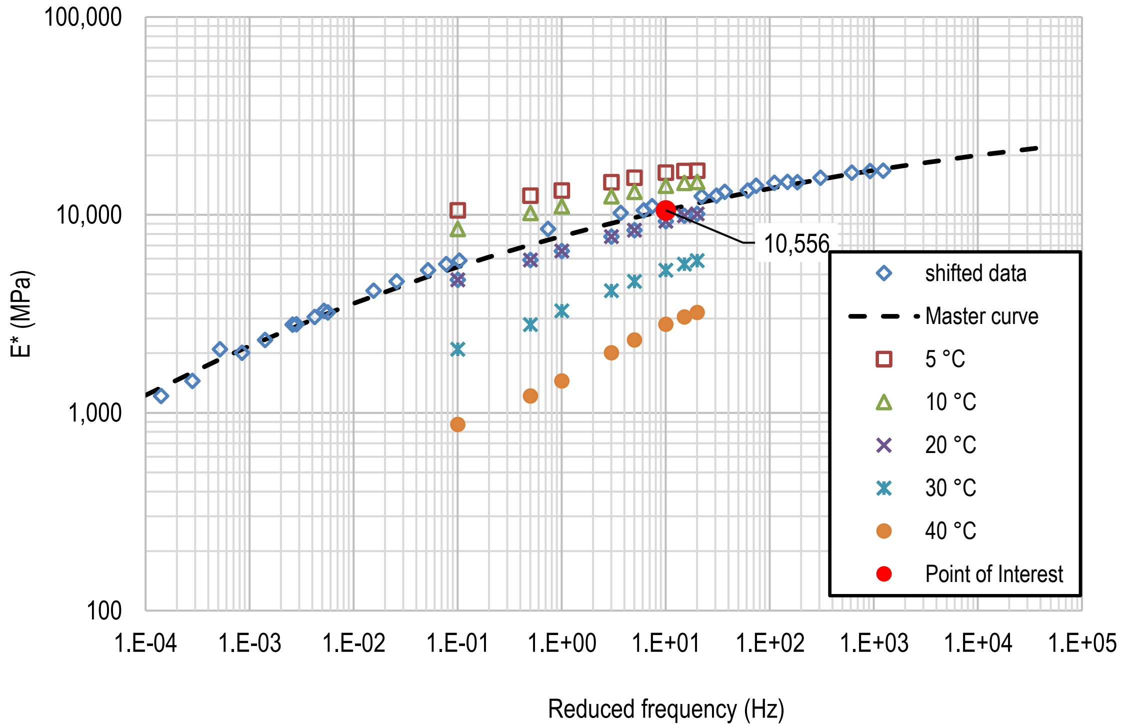
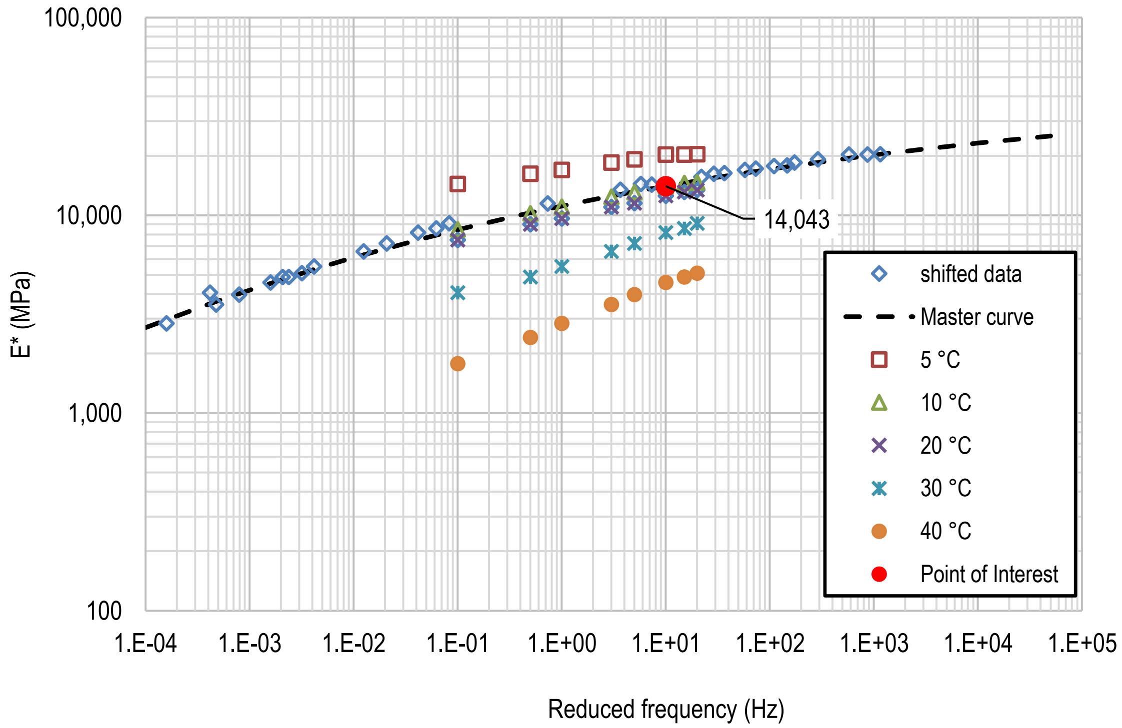


Figure J 3: Master curve for air voids 1.85% (reference temperature 15 °C)



APPENDIX K FATIGUE RESISTANCE RESULTS

Table K 1: Fatigue results

Temperature (°C)	Sample #	Strain level (με)	$N_{f\,50}$	Air void (%)	Age (days)	Initial modulus (MPa)
10	4-197541	160[1]	159 952	3.4	56	14 856
	6-197541	130[1]	3 053 782	3.1	84	16 316
	7-197541	145[1]	324 684	3.5	83	16 084
	29	200[2]	247 581	3.0	116	14 545
	1-197541	200[2]	31 788	3.2	5	15 247
	23	250[3]	19 401	2.9	97	16 239
	26	250[3]	33 530	2.9	102	16 213
	27	250[3]	52 874	3.0	110	14 878
	19	300[3]	12 197	2.9	85	15 937
	21	300[3]	6 326	2.9	90	14 847
20	16	160[1]	3 749 683	2.9	69	10 591
	8	180[1]	524 454	2.7	44	9 929
	12	180[1]	2 136 444	2.7	48	9 534
	10	180[1]	782 686	2.8	45	10 144
	3	200[2]	660 889	2.6	41	9 204
	11	200[2]	270 661	2.9	43	9 600
	9	200[2]	216 787	2.6	43	10 237
	13	300[3]	26 288	3.1	51	9 119
	14	300[3]	49 965	2.9	68	9 230
	15	300[3]	32 200	3.0	68	8 642
30	8-197540	200[1]	3 501 255	3.5	24	6 859
	5-197541	200[1]	1 726 130	3.4	57	6 675
	3-197541	225[1]	465 747	3.3	45	7 048
	20	300[2]	197 823	2.9	86	5 295
	22	300[2]	62 960	2.8	91	5 575
	24	300[2]	100 840	2.7	98	5 812
	2-197541	300[2]	105 953	2.7	7	5 910
	25	350[3]	42 815	3.1	101	5 681
	28	350[3]	54 379	2.8	101	5 412
	30	350[3]	47 889	2.8	118	5 412

1 Low strain.
2 Medium strain.
3 High strain.

APPENDIX L INDIRECT TENSILE TEST RESULTS

Figure L 1: Resilient modulus (ITT) results 17 S6852 (page 1) (26/04/17)

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TEST REPORT

ABN: 50 860 676 021
Sheet 1 of 4

Report No:	**17 S6852 / 2**	Reference No:	**Not Applicable**
Date Sampled:	**26/04/2017**	Date/s Tested :	**1-3/5/2017**
Local Govt Authority:	**City of Gosnells**		
Road Name:	**Tonkin Highway**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	**14mm Dense Grade Asphalt**		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	**S6822**
Sampling Method / Preparation:	**SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**		

Determination of the Resilient Modulus of Asphalt - Indirect Tensile Method AS/NZS 2891.13.1

Test conditions: Standard reference test conditions used

Other properties of the asphalt that may have influenced the results

Asphalt mixing temperature (°C)	Not Supplied
Temperature at compaction (°C)	177
Number of Gyratory Cycles	Various
Pressure in Modulus Machine Accuator (kPa)	850
Start of Conditioning time	7:50:00
Date and Time of test	3/05/2017 12:47:00
Conditioning Time (hours)	4.95
Temp after conditioning (°C)	24.8
Date of specimen manufacture	26/04/2017

Specimen Number	Core Temperature of Specimen (°C)	Mean Diameter (mm)	Mean Height (mm)	Resilient Modulus of Specimen (MPa)	Coefficient of Variation of Modulus (%)
M6	25.0	99.3	49.9	9288	0.90
M7	25.0	99.4	49.8	9975	0.77
M8	25.0	99.5	49.9	9990	0.83
M9	25.0	99.6	49.9	9209	0.69
M10	25.0	99.5	49.8	8641	0.39
	Mean	99.5	49.9	9,420	0.7

AS 2891.2.2

Gyratory Angle (°) 2 Number of Cycles Various

Comments / Distribution
TRIM 16/4441
REPORTS

This report replaces 17 S6852/1. Rectified error in manufacture date of the resilient modulus specimens.

Approved Signatory
Name Mark Hopgood
Function Project Officer
Date 28/06/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure L 2: Resilient modulus (ITT) results 17 S6852 (page 2) (26/04/17)

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ABN: 50 860 676 021

TEST REPORT Sheet 2 of 4

Report No:	**17 S6852 / 2**	Reference No:	**Not Applicable**
Date Sampled:	**26/04/2017**	Date/s Tested :	**1-3/5/2017**
Local Govt Authority:	**City of Gosnells**		
Road Name:	**Tonkin Highway**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	**S6822**
Sampling Method / Preparation:	**SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**		

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.497**
Maximum Density reference Sample Number	**S6822**

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
M6	2.377	0.8	4.8
M7	2.379	0.6	4.7
M8	2.374	0.6	4.9
M9	2.373	0.6	5.0
M10	2.378	0.6	4.7
Mean	**2.376**	**0.6**	**4.8**

Comments / Distribution	Approved Signatory
TRIM 16/4441	
REPORTS	Name Mark Hopgood
This report replaces 17 S6852/1. Rectified error in	Function Project Officer
manufacture date of the resilient modulus specimens.	Date 28/06/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure L 3: Resilient modulus (ITT) results 17 S6852 (page 3) (26/04/17)

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ABN 50 860 676 021

TEST REPORT

Sheet 3 of 4

Report No: 17 S6852 / 1 Reference No: Not Applicable

Date Sampled: 26/04/2017 Date/s Tested: 2/05/2017

Local Govt Authority: City of Gosnells

Road Name: Tonkin Highway

Project/Contract No: WARRIP EME2 Trial Customer: Mainroads WA

Asphalt mixture details: 14 Dense Grade Asphalt

Grading Type: Dense Nominal Mix Size: 14 mm

Binder Content: 5.9 % Type EME2 Binder Details reference sample N°: S6822

Sampling Method / Preparation: SAMPLING PROCEDURES FOR ASPHALT AS 2981.1
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	2.497
Maximum Density reference Sample Number	S6822

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Gyratory Cycles	100
Temperature at Compaction (°C)	177

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
1	2.429	0.3	2.7
2	2.420	0.3	3.1
3	2.416	0.3	3.2
Mean	2.422	0.3	3.0

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory
Name: Mark Hopgood
Function: Project Officer
Date: 4/05/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure L 4: Resilient modulus (ITT) results 17 S6852 (page 4) (26/04/17)

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ABN: 50 860 676 021

TEST REPORT

Sheet 4 of 4

Report No:	**17 S6852 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**26/04/2017**	Date/s Tested :	**1/05/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	5.9 % Type EME2	Binder Details reference sample N°:	**S6822**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	2.497
Maximum Density reference Sample Number	S6822

Bulk Density AS 2891.9.3 / Air Voids AS 2891.8

Gyratory Cycles	100
Temperature at Compaction (°C)	177

Specimen Number	Bulk Density (t/m³)	Air Voids (%)
1	2.382	4.6
2	2.385	4.5
3	2.363	5.4
Mean	**2.377**	**4.8**

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name: Mark Hopgood
Function: Project Officer
Date: 5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure L 5: Resilient modulus (ITT) results 17 S6853 (page 1) (27/04/17)

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ABN 50 860 676 021

TEST REPORT Sheet 1 of 4

Report No:	**17 S6853 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**27/04/2017**	Date/s Tested :	**28/4 - 1/5/2017**
Local Govt Authority:	**City of Gosnells**		
Road Name:	**Tonkin Highway**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	**14mm Dense Grade Asphalt**		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6 % Type EME2	Binder Details reference sample N°:	**S6824**
Sampling Method / Preparation:	**SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**		

Determination of the Resilient Modulus of Asphalt - Indirect Tensile Method AS/NZS 2891.13.1

Test conditions: Standard reference test conditions used

Other properties of the asphalt that may have influenced the results

Asphalt mixing temperature (°C)	176.8
Temperature at compaction (°C)	177
Number of Gyratory Cycles	Various
Pressure in Modulus Machine Accuator (kPa)	850
Start of Conditioning time	7:50:00
Date and Time of test	1/05/2017 11:28:00
Conditioning Time (hours)	3.63
Temp after conditioning (°C)	25.1
Date of specimen manufacture	27/04/2017

Specimen Number	Core Temperature of Specimen (°C)	Mean Diameter (mm)	Mean Height (mm)	Resilient Modulus of Specimen (MPa)	Coefficient of Variation of Modulus (%)
M1	25.0	99.6	49.5	6394	1.24
M2	25.0	99.5	49.8	7517	0.99
M5	25.0	99.6	49.5	6562	0.88
	Mean	99.6	49.6	6,820	1.0

AS 2891.2.2

Gyratory Angle (°) 2 Number of Cycles Various

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory
Name Mark Hopgood
Function Project Officer
Date 4/05/2017

Document 71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure L 6: Resilient modulus (ITT) results 17 S6853 (page 2) (27/04/17)

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TEST REPORT

Sheet 2 of 2

Report No:	**17 S6853 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**27/04/2017**	Date/s Tested :	**28/4 - 1/5/2017**
Local Govt Authority:	**City of Gosnells**		
Road Name:	**Tonkin Highway**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6 % Type EME2	Binder Details reference sample N°:	**S6824**
Sampling Method / Preparation:	**SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**		

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	2.495
Maximum Density reference Sample Number	S6824

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
M1	2.371	0.6	5.0
M2	2.379	0.7	4.7
M5	2.376	0.6	4.8
Mean	**2.375**	**0.6**	**4.8**

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory

Name Mark Hopgood
Function Project Officer
Date 4/05/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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Figure L 7: Resilient modulus (ITT) results 17 S6853 (page 3) (27/04/17)

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ABN. 50 860 676 021

TEST REPORT

Sheet 3 of 4

Report No: **17 S6853 / 1** Reference No: **Not Applicable**

Date Sampled: **27/04/2017** Date/s Tested : **28/04/2017**

Local Govt Authority: **City of Gosnells**

Road Name: **Tonkin Highway**

Project/Contract No : **WARRIP EME2 Trial** Customer: **Main Roads Western Australia**

Asphalt mixture details: 14mm Dense Grade Asphalt

Grading Type: Dense Nominal Mix Size: 14 mm

Binder Content 6.0 % Type EME2 Binder Details reference sample N°: **S6824**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.496**
Maximum Density reference Sample Number	**S6824**

Bulk Density AS 2891.9.2 / Air Voids AS 2891.8

Gyratory Cycles	**100**
Temperature at Compaction (°C)	**177**

Specimen Number	Bulk Density (t/m³)	Water Absorbtion (%)	Air Voids (%)
1	2.417	0.2	3.1
2	2.409	0.3	3.5
3	2.419	0.3	3.1
Mean	**2.415**	**0.3**	**3.2**

Comments / Distribution
TRIM 16/4441
REPORTS

Approved Signatory
Name Mark Hopgood
Function Project Officer
Date 4/05/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

NATA
Accredited for compliance with ISO/IEC 17025 - Testing
ACCREDITATION No. 1989 SITE No. 1982

Main Roads Western Australia
Materials Engineering
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
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Figure L 8: Resilient modulus (ITT) results 17 S6853 (page 4) (27/04/17)

mainroads WESTERN AUSTRALIA

ABN. 50 860 676 021

TEST REPORT

Sheet 4 of 4

Report No:	**17 S6853 / 1**	Reference No:	**Not Applicable**
Date Sampled:	**27/04/2017**	Date/s Tested :	**28/04/2017**
Local Govt Authority:	**Not Applicable**		
Road Name:	**Not Applicable**		
Project/Contract No :	**WARRIP EME2 Trial**	Customer:	**Main Roads Western Australia**
Asphalt mixture details:	14mm Dense Grade Asphalt		
Grading Type:	Dense	Nominal Mix Size:	14 mm
Binder Content:	6.0 % Type EME2	Binder Details reference sample N°:	**S6824**

Sampling Method / Preparation: **SAMPLING PROCEDURES FOR ASPHALT - AS 2981.1**
COMPACTION OF ASPHALT USING A GYRATORY COMPACTOR - AS 2891.2.2

Determination of the Maximum Density of Asphalt - Water Displacement Method AS 2891.7.1

Maximum Density t/m³	**2.496**
Maximum Density reference Sample Number	**S6824**

Bulk Density AS 2891.9.3 / Air Voids AS 2891.8

Gyratory Cycles	**100**
Temperature at Compaction (°C)	**177**

Specimen Number	Bulk Density (t/m³)	Air Voids (%)
1	2.371	5.0
2	2.378	4.7
3	2.365	5.3
Mean	**2.371**	**5.0**

Comments / Distribution	Approved Signatory
TRIM 16/4441	
REPORTS	Name: Mark Hopgood
	Function: Project Officer
	Date: 5/04/2017

Document:71/05/2891.13.1 Issue:08/03/2017 TRIM:D14#630733

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APPENDIX M RICHNESS MODULUS

Table M 1: Mix constituents and properties (26/04/17)

AS sieve size (mm)	Percent passing for Downer Group specimens (%)				Density for Downer Group specimens (t/m³)			
	A56278	A56280	A56282	A56287	A52678	A52680	A52682	A52687
26.5	100	100	100	100	2.499	2.498	2.492	2.498
19	100	100	100	100				
13.2	99	99	99	98				
9.5	88	88	88	88				
6.7	69	69	70	72				
4.75	53	55	55	57				
2.36	35	36	37	37				
1.18	23.1	24.2	25.2	24.3				
0.6	16.1	16.9	17.9	17.1				
0.3	10.7	11.2	12.1	11.6				
0.15	7.1	7.1	8.1	7.9				
0.075	4.5	4.1	5.2	5.3				
Bitumen content (% by mass of total mix)	6.0	6.0	5.9	5.9				

Source: Based on laboratory data from Downer Group.

Table M 2: Richness modulus calculations (26/04/17)

Richness modulus variables	Result for Downer Group specimens*			
	A56278 / A52678	A56280 / A52680	A56282 / A52682	A56287 / A52687
α	1.06	1.06	1.06	1.06
G (%)	34.28	33.87	33.08	31.08
S (%)	24.78	24.04	22.31	20.71
s (%)	5.00	5.73	5.57	5.07
f (%)	4.50	4.10	5.20	5.30
Σ	8.01	7.48	9.06	9.11
Richness modulus (K)	3.97	4.02	3.79	3.80

* Density measurements were assumed to align to the asphalt report numbers in the format, asphalt test report no. / max density test report no.

Table M 3: Mix constituents and properties (27/04/17)

AS sieve size (mm)	Percent passing for Downer Group specimens (%)			Density for Downer Group specimens (t/m³)		
	A56291	A56289	A56293	A52691	A52689	A52693
26.5	100	100	100	2.493	2.485	2.488
19	100	100	100			

AS sieve size (mm)	Percent passing for Downer Group specimens (%)			Density for Downer Group specimens (t/m³)		
	A56291	A56289	A56293	A52691	A52689	A52693
13.2	96	100	98			
9.5	88	87	88			
6.7	68	72	71			
4.75	54	57	56			
2.36	37	38	37			
1.18	25.3	24.8	24.1			
0.6	18.1	17.1	17			
0.3	12.6	11.4	11.7			
0.15	8.7	7.5	8.1			
0.075	6	4.9	5.5			
Bitumen content (% by mass of total mix)	5.8	6.1	6.0			

Source: Based on laboratory data from Downer Group.

Table M 4: Richness modulus calculations (27/04/17)

Richness modulus variables	Result for Downer Group specimens*		
	A56278 / A52678	A56280 / A52680	A56282 / A52682
α	1.06	1.07	1.07
G (%)	34.87	31.08	32.08
S (%)	23.57	20.98	21.58
s (%)	5.30	5.20	5.00
f (%)	6.00	4.90	5.50
Σ	10.27	8.53	9.43
Richness modulus (K)	3.64	3.97	3.83

* Density measurements were assumed to align to the asphalt report numbers in the format, asphalt test report no. / max density test report no.

APPENDIX N VOIDS IN COMPACTED DRY FILLER AND DELTA RING AND BALL TEST RESULTS

Figure N 1: ARRB voids in dry compacted filler test report (16-8-3)

TEST REPORT

Report No: 16-8-3

Client: MRWA

Sample Description: EME2 Filler

Apparent Particle Density of Filler
AS/NZS 1141.7

ARRB Sample No:	Mean Particle Density (t/m^3)
5198	2.770

Voids in Dry Compacted Filler
AS/NZS 1141.17

ARRB Sample No:	Mean Voids (%)
5198	33

Dilatometeric liquid used: Kerosene

This report relates specifically to the sample tested as supplied

Approved Signatory: ______________ Date: 11/08/17

(Hossein Jafari)

NATA

NATA Accredited Laboratory Number: 9594

Accredited for compliance with ISO/IEC 17025 - Testing.

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

ARRB Group Ltd
ACN 004 620 651
ABN 68 004 620 651
500 Burwood Highway
Vermont South VIC 3133
Australia
Tel: 03 9881 1555
Fax: 03 9887 8104

Issue E

Authorised by Shannon Malone
RR-422-1-0-141

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Figure N 2: ARRB delta ring and ball test report (16-8-6)

TEST REPORT

Delta ring and ball test

EN 13179-1 & AS 2341.18

ARRB Report #:	**16-8-6**	**Client:**	MRWA
Bitumen Sample #:	5199	**Supplied by:**	Client
Bitumen Class and Date Sampled:	26/04/17	**Quantity:**	2L
Identifying #, Batch # and place sampled:	Plant Downer, EME2 Tonkin Hwy, 10:38am, 173.5 °C, 1 tonne, tin 2/2, 5,000 L, Lab 3230		

ARRB Sample No.	Client Sample No.	Softening Point (°C)
5199	N/A	72.5

Sample #:	5198	**Client:**	MRWA
Supplied by:	Client	**Description:**	EME2 filler

ARRB Sample No.	Client Sample No.	Softening Point (°C)
5199 & 5198	N/A	76.0

$\Delta_{R\&B}$	3.5 °C

Notes:

- This report relates specifically to the samples tested as supplied
- Mastic blend created as required by EN 13179-1
- Softening point tests conducted in accordance with AS 2341.18
- Water method used for determination of softening point

Approved Signatory: ______________ (Shannon Malone) **Date:** 11/08/17

arrb AUSTRALIAN ROAD RESEARCH BOARD	ARRB Group Ltd ACN 004 620 651 ABN 68 004 620 651 500 Burwood Highway Vermont South VIC 3133 Australia Tel: 03 9881 1555 Fax: 03 9887 8104	Issue A Authorised by Shannon Malone RR-422-1-0-276 Page 1 of 1

Figure N 3: Downer Group voids in dry compacted filler test report (RD 14/05 WEME DCV)

Downer

National Research and Development Laboratory
125-129 Somerton Road
Somerton Vic 3062
Ph: (03) 9930 4844

VOIDS IN COMPACTED DRY FILLER
AS1141.7, AS1141.17

Report No:	RD14/05 WEME DCV	Client Ref:	-
Sample Description:	Filler fraction of Gosnells dust	Client Name and Address:	Warren Carter Rhondda Road Teralba NSW 2284
Sample Source:	Downer, WA		*Sample Tested as Received*

Apparent Particle density of filler (t/m^3) AS1141.7	2.848		
Percentage voids in dry compacted filler (%) AS1141.17	40.3	40.1	40.4
Mean Voids in dry compacted filler (%)	40		

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025
NATA Accredited Laboratory Number: 15351

APPROVED SIGNATORY: Henry Beh
Henry Beh
DATE: 03/08/2017
CHECKED:
Ben Van den Eynde

NRDL- RP-VOIDFILL-014 Page 1 of 1 Rev 2.0 Sep 16

Figure N 4: Downer Group delta ring and ball test report (RD 14/05 WEMEΔ)

Downer

National Research and Development Laboratory
125-129 Somerton Road
Somerton VIC 3062
Ph: (03) 9930 4844

BINDER TEST REPORT

Report No:	RD14/05 WEMEΔ	Client Ref:	-
Sample Source:	-	Client Address:	Warren Carter Rhondda Road Teralba NSW 2284

Test Type	Reference Standard	Sample	Results
Softening Point	AG:PT/T131	C170	47.5°C
		C170 with filler fraction of Gosnells dust*^	62.0°C

$\Delta_{R\&B}$ (EN13179-1)^	Spec**
14.5 °C	8°C - 16°C

Comments:
^EN13179-1 not in NATA scope of accreditation.
* Sample prepared as per EN13179-1
**Specification according to TMR PSTS107
$\Delta_{R\&B}$ = Difference between softening point of bitumen and softening point of bitumen with added mastic.

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

ACCREDITED FOR COMPLIANCE WITH ISO/IEC 17025

NATA ACCREDITED LABORATORY NUMBER: 15351

APPROVED SIGNATORY: Ben Van Den Eynde

DATE: 04/08/2017

CHECKED: Petar Davcev

NRDL- RP-BITDEN-026 Page 1 of 1 Rev 1.1 Aug 16

Figure N 5: Main Roads voids in dry compacted filler and delta ring and ball test report (S8933)

mainroads WESTERN AUSTRALIA

ABN: 50 860 676 021

MINERAL FILLER TEST REPORT

Page 1 of 1

Report No : 17 S8933 / 1 Customer : Main Roads Western Australia

Project / Contract : EME2 Trial

Other Details / Information : Not Applicable

Asphalt Filler Properties

Filler Supplier : Downer - Martin Date/s Filler Tested : 19/06/2017

Name / Type of Filler : Baghouse Dust Date Filler Sampled : Not Supplied

Filler Sampling Method : Supplied by Others, Tested as Received

Other Filler Details / Information : Received 07/04/2017

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	2.759

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	37.7

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : BP - Kwinana Date/s Binder Tested : 28/07/2017

Name / Type of Binder : S6100 / Class 170 Bitumen Date Binder Sampled : 26/04/2016

Binder Sampling Method : Supplied by Others, Tested as Received

Other Binder Details / Information : Not Applicable

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	49.5
Softening Point of Binder / Filler Blend (°C)	67.5
Stiffening Effect of the Filler Aggregate (°C) Calculated in accordance with EN 13179-1	18.0

Comments / Distribution
Reports
TRIM 16/4441

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 9/08/2017

Document 71/05/2341.2 Issue 22/03/2017 TRIM D14#529205

Main Roads Western Australia
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APPENDIX O HAMBURG WHEEL TRACK RESULTS

Table O 1: Hamburg wheel track testing results by cycle

Cycles	DY S1	DY S2	TH S1	TH S2	DY C19A & 19B	DY C20A & 20B	TH C1 & 2	TH C3 & 4	TH C5 & 6	TH C7 & 8
	Central rut depth (mm)									
1	0	0	0	0	0	0	0	0	0	0
2	0.01	0.06	0.02	–0.02	0.05	0.03	0.01	0.05	0.05	0.09
3	0.03	0.09	0.14	0.07	0.12	0.05	0.09	0.08	0.08	0.16
4	0.07	0.14	0.05	0.06	0.11	0.04	0.08	0.12	0.13	0.27
5	0.10	0.12	0.11	0.09	0.18	0.08	0.11	0.13	0.19	0.36
6	0.07	0.16	0.09	0.08	0.15	0.07	0.21	0.15	0.22	0.31
7	0.16	0.18	0.15	0.14	0.24	0.15	0.26	0.28	0.25	0.34
8	0.14	0.16	0.10	0.13	0.32	0.16	0.21	0.24	0.28	0.40
9	0.18	0.21	0.12	0.14	0.28	0.16	0.25	0.26	0.33	0.43
10	0.19	0.23	0.16	0.10	0.35	0.18	0.29	0.31	0.33	0.45
20	0.31	0.49	0.24	0.23	0.47	0.26	0.46	0.51	0.54	0.70
30	0.38	0.66	0.26	0.34	0.61	0.37	0.54	0.61	0.69	0.84
40	0.45	0.73	0.35	0.38	0.74	0.45	0.75	0.73	0.80	0.94
50	0.45	0.67	0.45	0.44	0.83	0.39	0.86	0.78	0.88	1.04
60	0.51	0.78	0.49	0.49	0.93	0.38	0.84	0.87	0.95	1.12
70	0.59	0.90	0.47	0.51	1.00	0.52	0.82	0.91	1.02	1.19
80	0.60	0.84	0.53	0.56	1.08	0.57	0.86	0.95	1.09	1.30
90	0.58	0.82	0.49	0.58	1.14	0.76	1.06	0.96	1.14	1.33
100	0.65	0.97	0.54	0.63	1.19	0.78	0.92	0.95	1.21	1.41
200	0.82	1.16	0.67	0.87	1.58	0.79	1.27	1.08	1.60	1.82
300	0.93	1.34	0.81	0.92	1.84	0.88	1.56	1.27	1.97	2.11
400	1.00	1.51	0.87	1.34	2.08	1.22	1.51	1.43	2.08	2.27
500	1.01	1.47	0.96	1.47	2.27	1.23	1.81	1.70	2.18	2.34
600	1.09	1.61	1.04	1.57	2.58	1.61	2.01	1.76	2.31	2.71
700	1.21	1.85	1.11	1.69	2.57	1.54	1.88	1.85	2.42	2.80
800	1.16	1.76	1.22	1.71	2.69	1.85	2.00	1.86	2.52	2.93
900	1.17	1.78	1.14	1.63	2.76	1.68	2.05	1.93	2.66	3.03
1000	1.27	2.03	1.13	1.51	3.00	2.03	2.22	2.00	2.63	2.91
1100	1.30	2.00	1.17	1.65	3.07	2.08	2.16	2.03	2.72	3.09
1171	1.38	2.06	1.22	1.66	3.16	2.09	2.14	2.07	2.78	3.25
1200	1.41	2.05	1.21	1.61	3.27	2.31	2.06	2.11	2.81	3.20
1300	1.39	2.07	1.19	1.73	3.39	2.25	2.27	2.17	2.85	3.21
1400	1.37	2.04	1.23	1.83	3.46	2.54	2.23	2.27	2.87	3.30
1500	1.41	2.09	1.33	1.83	3.60	2.47	2.42	2.29	2.90	3.17
1561	1.42	2.10	1.24	1.78	3.62	2.52	2.30	2.33	2.97	3.44

Cycles	DY S1	DY S2	TH S1	TH S2	DY C19A & 19B	DY C20A & 20B	TH C1 & 2	TH C3 & 4	TH C5 & 6	TH C7 & 8
	Central rut depth (mm)									
1600	1.45	2.12	1.27	1.87	3.61	2.48	2.48	2.36	2.95	3.41
1700	1.48	2.15	1.31	1.77	3.57	2.59	2.51	2.38	3.03	3.43
1800	1.54	2.13	1.33	1.74	3.66	2.61	2.56	2.50	3.10	3.54
1900	1.59	2.25	1.35	2.05	3.70	2.50	2.42	2.50	3.18	3.69
2000	1.56	2.24	1.37	2.08	3.76	2.58	2.55	2.66	3.24	3.73
2100	1.63	2.33	1.53	2.15	3.75	2.54	2.45	2.71	3.30	3.80
2200	1.66	2.31	1.55	2.16	3.79	2.61	2.75	2.71	3.36	3.79
2300	1.66	2.35	1.47	2.27	3.83	2.67	2.63	2.82	3.41	3.89
2400	1.70	2.39	1.47	1.99	4.17	3.04	2.71	2.82	3.46	3.90
2500	1.68	2.36	1.47	2.04	4.12	2.81	2.56	2.71	3.49	3.97
2600	1.70	2.45	1.50	2.10	4.22	2.91	2.96	2.85	3.47	3.91
2700	1.81	2.48	1.65	2.24	4.37	3.04	2.85	2.83	3.50	3.97
2800	1.88	2.55	1.50	2.20	4.26	2.93	2.54	2.85	3.56	4.01
2900	2.02	2.68	1.52	1.97	4.41	3.03	2.75	2.86	3.62	3.99
3000	1.98	2.66	1.58	2.19	4.47	3.21	2.71	2.87	3.69	4.04
3100	1.86	2.58	1.65	2.20	4.71	3.36	2.76	2.89	3.63	3.96
3200	2.01	2.73	1.63	2.19	4.64	3.40	2.94	2.97	3.65	3.97
3300	2.03	2.78	1.58	2.01	4.87	3.46	2.85	3.00	3.66	3.95
3400	2.02	2.79	1.55	1.99	4.98	3.66	2.61	2.95	3.72	4.02
3500	1.97	2.79	1.69	2.45	4.81	3.52	2.97	3.01	3.71	3.94
3600	2.05	2.74	1.61	2.33	5.11	3.68	2.59	2.97	3.80	4.07
3700	2.03	2.77	1.61	2.05	5.07	3.82	2.90	3.09	3.81	4.05
3800	2.13	2.84	1.57	2.10	5.12	3.82	2.90	3.00	3.83	4.13
3900	2.12	2.88	1.69	2.11	5.32	4.09	3.15	3.13	3.88	4.19
4000	2.14	2.88	1.63	2.01	5.34	3.91	3.24	3.21	3.90	4.11
4100	2.12	2.88	1.63	1.99	5.34	3.87	3.06	3.28	3.97	4.28
4200	2.10	2.89	1.63	2.12	5.49	4.16	2.98	3.28	4.01	4.30
4300	2.18	2.90	1.64	1.97	5.44	3.99	3.05	3.28	3.96	4.09
4400	2.15	2.95	1.66	2.33	5.52	4.31	2.80	3.26	3.97	4.27
4500	2.13	2.98	1.63	2.26	5.55	4.33	3.26	3.33	3.92	4.15
4600	2.07	2.99	1.64	1.90	5.65	4.44	3.21	3.31	3.92	4.11
4700	2.16	2.97	1.72	2.35	5.62	4.30	3.03	3.34	3.93	4.04
4800	2.09	2.96	1.72	2.19	5.72	4.36	3.05	3.28	3.97	4.19
4900	2.14	3.03	1.66	1.93	5.72	4.50	2.88	3.26	3.98	4.10
5000	2.08	2.98	1.67	1.96	5.69	4.33	3.33	3.31	3.98	4.14
5100	1.98	2.87	1.67	2.32	5.70	4.54	3.20	3.28	3.99	4.16
5200	2.06	2.99	1.70	2.24	5.81	4.48	3.15	3.38	4.02	4.06
5300	2.05	2.97	1.70	2.25	5.68	4.45	3.32	3.34	4.05	4.23

Cycles	DY S1	DY S2	TH S1	TH S2	DY C19A & 19B	DY C20A & 20B	TH C1 & 2	TH C3 & 4	TH C5 & 6	TH C7 & 8
	Central rut depth (mm)									
5400	2.06	3.06	1.68	2.15	5.80	4.51	3.11	3.31	4.06	4.12
5500	2.05	3.01	1.72	2.32	5.82	4.64	3.21	3.49	4.08	4.19
5600	2.10	3.02	1.69	2.38	5.85	4.59	3.06	3.44	4.13	4.22
5700	2.08	2.96	1.75	2.48	5.87	4.66	3.03	3.31	4.16	4.30
5800	2.20	3.14	1.76	2.21	5.81	4.45	3.15	3.47	4.16	4.28
5900	2.18	3.11	1.76	2.32	5.91	4.76	3.28	3.47	4.18	4.30
6000	2.19	3.09	1.78	2.33	5.85	4.48	3.27	3.51	4.17	4.28
6100	2.19	3.19	1.76	2.32	5.98	4.68	3.09	3.54	4.15	4.15
6200	2.21	3.16	1.76	2.31	6.02	4.71	3.30	3.54	4.21	4.19
6300	2.28	3.19	1.75	2.40	6.03	4.75	3.11	3.52	4.19	4.29
6400	2.20	3.12	1.75	2.56	6.07	4.67	3.06	3.58	4.20	4.29
6500	2.24	3.18	1.76	2.43	6.09	4.72	3.51	3.64	4.20	4.25
6600	2.35	3.24	1.73	2.53	6.10	4.83	3.23	3.64	4.25	4.25
6700	2.29	3.14	1.77	2.40	6.10	4.81	3.45	3.62	4.23	4.30
6800	2.37	3.28	1.78	2.42	6.11	4.70	3.31	3.58	4.22	4.28
6900	2.23	3.20	1.79	2.36	6.01	4.82	3.37	3.63	4.27	4.26
7000	2.32	3.35	1.78	2.47	6.17	4.75	3.52	3.70	4.23	4.29
7100	2.37	3.28	1.81	2.46	6.04	4.83	3.34	3.75	4.23	4.16
7200	2.43	3.43	1.81	2.28	6.11	4.73	3.43	3.71	4.23	4.26
7300	2.39	3.30	1.81	2.44	6.25	4.87	3.38	3.73	4.26	4.15
7400	2.36	3.32	1.82	2.45	6.34	4.96	3.41	3.74	4.30	4.29
7500	2.35	3.34	1.82	2.58	6.27	4.85	3.29	3.85	4.25	4.16
7600	2.35	3.32	1.80	2.31	6.36	4.93	3.43	3.88	4.28	4.32
7700	2.36	3.24	1.83	2.41	6.33	4.93	3.50	3.98	4.33	4.29
7800	2.27	3.24	1.83	2.47	6.40	5.00	3.26	3.94	4.33	4.24
7900	2.29	3.22	1.84	2.47	6.28	4.99	3.30	3.93	4.35	4.37
8000	2.27	3.23	1.83	2.53	6.32	5.03	3.26	3.96	4.34	4.34
8100	2.19	3.15	1.83	2.55	6.43	4.96	3.47	4.02	4.36	4.33
8200	2.41	3.32	1.83	2.44	6.46	5.02	3.66	3.98	4.36	4.27
8300	2.33	3.18	1.85	2.56	6.51	5.09	3.38	3.96	4.37	4.28
8400	2.31	3.18	1.87	2.48	6.44	5.14	3.43	4.00	4.40	4.38
8500	2.28	3.18	1.88	2.48	6.48	5.10	3.45	3.95	4.50	4.44
8600	2.37	3.28	1.88	2.60	6.50	5.14	3.43	4.00	4.41	4.39
8700	2.30	3.33	1.87	2.50	6.54	5.16	3.58	3.94	4.43	4.40
8800	2.30	3.20	1.86	2.53	6.56	5.16	3.51	3.96	4.49	4.40
8900	2.40	3.35	1.92	2.45	6.54	5.16	3.57	3.97	4.46	4.41
9000	2.29	3.31	1.90	2.56	6.59	5.17	3.41	4.02	4.49	4.36
9100	2.36	3.40	1.90	2.45	6.65	5.15	3.62	4.01	4.50	4.45

Cycles	DY S1	DY S2	TH S1	TH S2	DY C19A & 19B	DY C20A & 20B	TH C1 & 2	TH C3 & 4	TH C5 & 6	TH C7 & 8
	Central rut depth (mm)									
9200	2.30	3.35	1.92	2.50	6.64	5.24	3.38	4.07	4.52	4.42
9300	2.38	3.47	1.95	2.55	6.66	5.22	3.53	4.07	4.54	4.42
9400	2.35	3.35	1.94	2.60	6.73	5.17	3.37	4.09	4.54	4.35
9500	2.40	3.41	1.92	2.56	6.76	5.27	3.60	4.10	4.54	4.38
9600	2.39	3.41	1.94	2.61	6.63	5.21	3.35	4.14	4.59	4.50
9700	2.51	3.48	1.91	2.53	6.68	5.27	3.45	4.19	4.62	4.47
9800	2.43	3.51	1.94	2.54	6.75	5.19	3.61	4.18	4.63	4.44
9900	2.43	3.42	1.92	2.61	6.78	5.35	3.58	4.26	4.64	4.41
10000	2.37	3.40	1.97	2.47	6.79	5.37	3.57	4.23	4.66	4.39

Note: DY = Downer Group yard, TH = Tonkin Hwy, S = slab, C = core

APPENDIX P WEARING COURSE RESULTS

Figure P 1: Asphalt placement worksheet (KEE Group)

KEE Asphalt Contracting — Asphalt Placement Sheet

Lot Number: KELVIN – 27 | **Job Number : ASP 0104** | **Date:** 3/5/17

Material: DG14 A15E | **Customer: WBHO**

Location: Tonkin Hway & Kelvin Rd

Time	8:53	Air Temp (°C)	18°C	Road Temp (°C)		Wind Speed		Chill Factor		~~Day~~/ Night
Time		Air Temp (°C)		Road Temp (°C)		Wind Speed		Chill Factor		Day/ Night

Docket Number	Tonnes	Progressive Tonnes	Time	Temp (°C)	CH. Start	CH. Finish	Length	Width	Area	Depth Ave. (mm)	Lane/ Run	Comments
081037	25.06	25.06	8:53	170	21110	21129	19	2.2	41.8	50.3	1	
"	"	"	"	"	21129	21175	46	3.6	165.6	50.3	1	
081038	24.80	49.86	9:14	172	21175	21228	53	3.6	190.8	54.1	1	
081039	24.45	74.31	9:30	173	21228	21283	55	3.6	198	51.4	1	
081044	24.42	98.73	10:16	169	21283	21337	54	3.6	194.4	52.3	1	
081045	24.71	123.44	10:47	170	21337	21345	8	3.6	28.8	48.8	1	
"	"	"	11:32	162	21085	21110	25	2.8	70	48.8	2	
"	"	"	"	"	21110	21142	32	3.5	112	48.8	2	
081046	26.00	149.44	12.03	170	21142	21206	64	3.5	224	48.3	2	
081047	26.05	175.49	12.22	173	21206	21266	60	3.5	210	51.6	2	1435.4 m²

Delivery Mix Temperatures	
Wearing Course:	DG A15E: 160°C - 185°C; OG: 155°C - 170°C; DG C320/ C170: 140°C - 170°C; Sasobit: 135°C - 155°C
Intermediate Course :	DG A15E: 160°C - 185°C; DG C600: 150°C - 175°C; DG C320/ C170: 140°C - 170°C; Warm mix with Sasobit: 125°C - 155°C

Figure P 2: Asphalt test report NA 25234 (Downer Group)

Downer
Relationships creating success

Laboratory
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Fax: (08) 9391 3098

Administration
PO Box 145
Maddington WA 6989
Phone: (08) 9365 9999
Fax: (08) 9365 9900

ASPHALT TEST REPORT

Report No: **NA 25234** Issue Date **03/05/2017**
Project: Job No: **62160070XB**
Client: **Kee Asphalt**
Job Site: **Tonkin Hwy & Kelvin Rd, Maddington**

Product: **14mm Granite MRWA Intersection Mix - A15E 75Blow (JM13-DEW-14IM)**

Sample ID	A56352	A56353	Specification
Date Sampled	03/05/2017	03/05/2017	JM 13 - DEW - 14IM
Date Tested	03/05/2017	03/05/2017	Specification Limits
Percent Passing Seives			
26.5	100	100	100
19.0	100	100	100
13.2	97	97	91-100
9.50	85	83	76-90
6.70	71	69	61-75
4.75	59	57	48-62
2.36	40	39	32-42
1.18	26.0	25.6	21-31
0.600	17.8	17.7	15-23
0.300	11.7	11.8	8-16
0.150	7.6	7.8	5-10
0.075	5.0	5.1	3.0-5.5
Binder Content (%)	5.0	5.0	4.4-5.0
Maximum Density(T/m3)	2.502	2.498	-
Bulk Density (T/m3)	2.397	2.398	-
Air Voids (%)	4.2	4.0	4.0-7.0
VMA (%)	16.0	15.8	14.0 Min
VFB (%)	73.6	74.6	-
Stability (kN)	14.9	15.3	8.0 Min
Flow (mm)	3.9	3.9	2-4
Compaction (Blows)	75.0	75.0	
Compaction Temp (°C)	161.1	159.8	

Sample Method: **MRD WA: 701.1 - Ex Plant**
Test Method: **MRD WA 210.1, 730.1, 731.1, 732.2, 733.1.**
Comments:

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Approved Signatory: ____________________
Tim Giles

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Figure P 3: Asphalt test report NA 25237 (Downer Group)

Downer
Relationships creating success

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ASPHALT TEST REPORT

Report No: **NA 25237** Issue Date **03/05/2017**

Project: Job No: **62160070XB**

Client: **Kee Asphalt**

Job Site: **Tonkin Hwy & Kelvin Rd, Maddington**

Product: **14mm Granite MRWA Intersection Mix - A15E 75Blow (JM13-DEW-14IM)**

Sample ID	A56357	Specification
Date Sampled	03/05/2017	JM 13 - DEW - 14IM
Date Tested	03/05/2017	Specification Limits

Percent Passing Seives

26.5	100	100
19.0	100	100
13.2	99	91-100
9.50	90	76-90
6.70	74	61-75
4.75	58	48-62
2.36	37	32-42
1.18	24.6	21-31
0.600	17.2	15-23
0.300	11.7	8-16
0.150	7.9	5-10
0.075	5.2	3.0-5.5

Binder Content (%)	4.4	4.4-5.0
Maximum Density(T/m3)	2.510	-
Bulk Density (T/m3)	2.372	-
Air Voids (%)	5.5	4.0-7.0
VMA (%)	15.6	14.0 Min
VFB (%)	65.0	-
Stability (kN)	12.4	8.0 Min
Flow (mm)	3.9	2-4
Compaction (Blows)	75.0	
Compaction Temp (°C)	160.8	

Sample Method: **MRD WA: 701.1 - Ex Plant**
Test Method: **MRD WA 210.1, 730.1, 731.1, 732.2, 733.1.**
Comments:

NATA ACCREDITED FOR TECHNICAL COMPETENCE

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Figure P 4: Compaction report NA 25352 (Downer Group)

Downer
Relationships creating success

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PAVEMENT CORE TEST REPORT

Report No: **NA 25352**
Project:
Client: **Kee Asphalt**
Job Site: **Tonkin Hwy & Kelvin Rd, Maddington**

Issue Date: **05/05/2017**
Job No: **62160070XB**

Product: **14mm Granite MRWA Intersection Mix – A15E 75 Blow (JM-13-DEW-141M)**

Sample ID	Core ID	Date Laid	Chainage	Offset RHS (m)	Mix Bulk Density (t/m3)	Mix Maximum Density (t/m3)	Core Density (t/m3)	Insitu Air Voids %	Density Ratio %	Core Height (mm)
A56383	1	03/05/2017	30	2.9	2.389	2.503	2.372	5.2	99.3	53
A56383	2	03/05/2017	48	1.9	2.389	2.503	2.388	4.6	100.0	49
A56383	3	03/05/2017	63	4.9	2.389	2.503	2.240	10.5	93.8	53
A56383	4	03/05/2017	87	1.5	2.389	2.503	2.389	4.6	100.0	52
A56383	5	03/05/2017	113	5.5	2.389	2.503	2.342	6.4	98.0	51
A56383	6	03/05/2017	131	2.3	2.389	2.503	2.406	3.9	100.7	57
A56383	7	03/05/2017	153	4.0	2.389	2.503	2.368	5.4	99.1	50
A56383	8	03/05/2017	174	2.4	2.389	2.503	2.372	5.2	99.3	50
A56383	9	03/05/2017	198	1.0	2.389	2.503	2.387	4.6	99.9	55
A56383	10	03/05/2017	232	1.4	2.389	2.503	2.411	3.7	100.9	55

Statistical Data	Average	STDEV	Multiplier	Characteristic Value	Spec 504
Density Ratio (%)	99.1	2.0	0.75	97.6	Min 93.0%
Insitu Air Voids (%)	5.4	2.0	0.75		
Core Thickness (mm)	52.5				

Please refer to the attached site drawing for approximate core lactions

Comments: **Reference Mix Sample IDs A56352 A56353 A56357**

Asphalt laid on the 03/05/2017

Date Sampled: **04/05/2017**
Date Tested: **05/05/2017**
Sample Method: **Sampled by Client, tested as received**
Test Methods: **MRD WA 705.1, 732.2 &733.1 (Wax Coating)**

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Figure P 5: Core locations for KEE Group

CORE LOCATIONS for KEEGROUP

Sample# A56383

Report# NA 25352

Customer: WBHO

Site: Kelvin Rd - Tonkin Hwy

Date Laid: 03/05/2017

Mix Type: DG14 Wearing Course

CORE #	CHAINAGE from 0		OFFSET	
	Meters	Start From Beginning of Matt		
1	30	North	2.9	R/Hand
2	48	North	1.9	R/Hand
3	63	North	4.9	R/Hand
4	87	North	1.5	R/Hand
5	113	North	5.5	R/Hand
6	131	North	2.3	R/Hand
7	153	North	4	R/Hand
8	174	North	2.4	R/Hand
9	198	North	1	R/Hand
10	232	North	1.4	R/Hand

Coring Date: 04/05/2017

Cored By: Udo Belser