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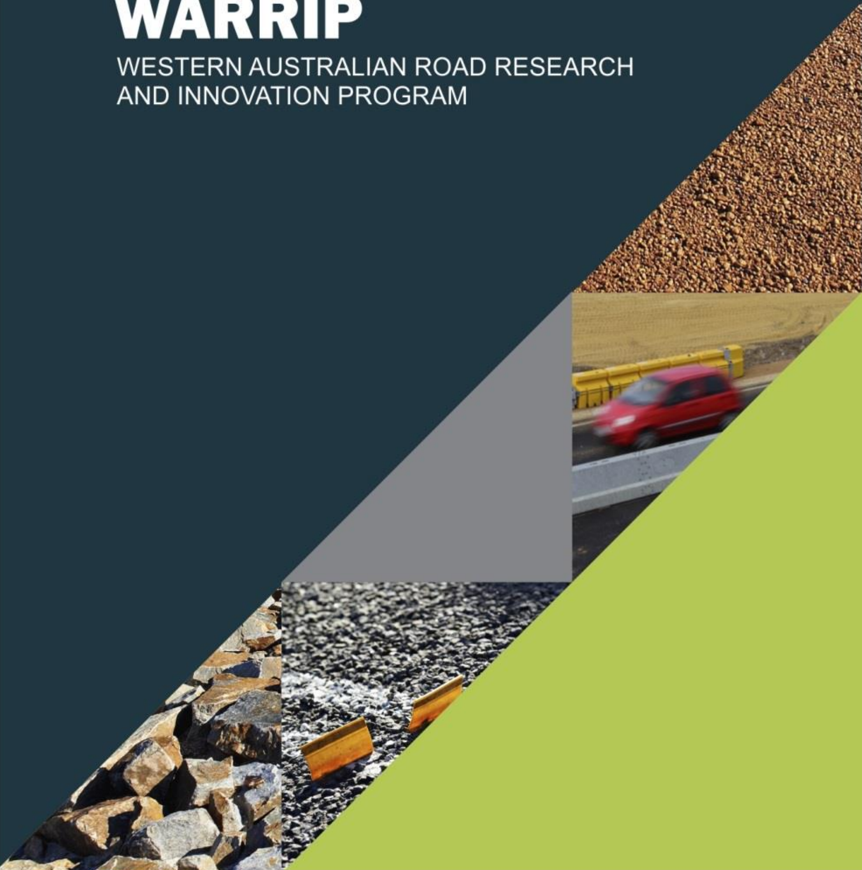
WESTERN AUSTRALIAN ROAD RESEARCH AND INNOVATION PROGRAM



EME2 Workshop

19 July 2017

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AGENDA

19/07/2017

Time	Topic	Presenter
9:00 – 9:05	Introduction	Les Marchant
9:05 – 9:10	WARRIP	Jon Griffin
9:10 – 9:35	Trial Planning and Mix Design	Willie Valenzuela
9:35 – 9:50	EME2 Pavement Design	Jon Griffin
9:50 – 10:00	Questions	All
10:00 – 10:15	Morning Tea Break	
10:15 – 11:00	Production and Construction	Chris Skantzos
11:00 – 11:25	Conformance and Research Testing	Steve Halligan
11:25 – 11:35	What's Next	Steve Halligan
11:35 – 11:50	Questions	All
11:50 – 12:00	Closing Remarks	Les Marchant

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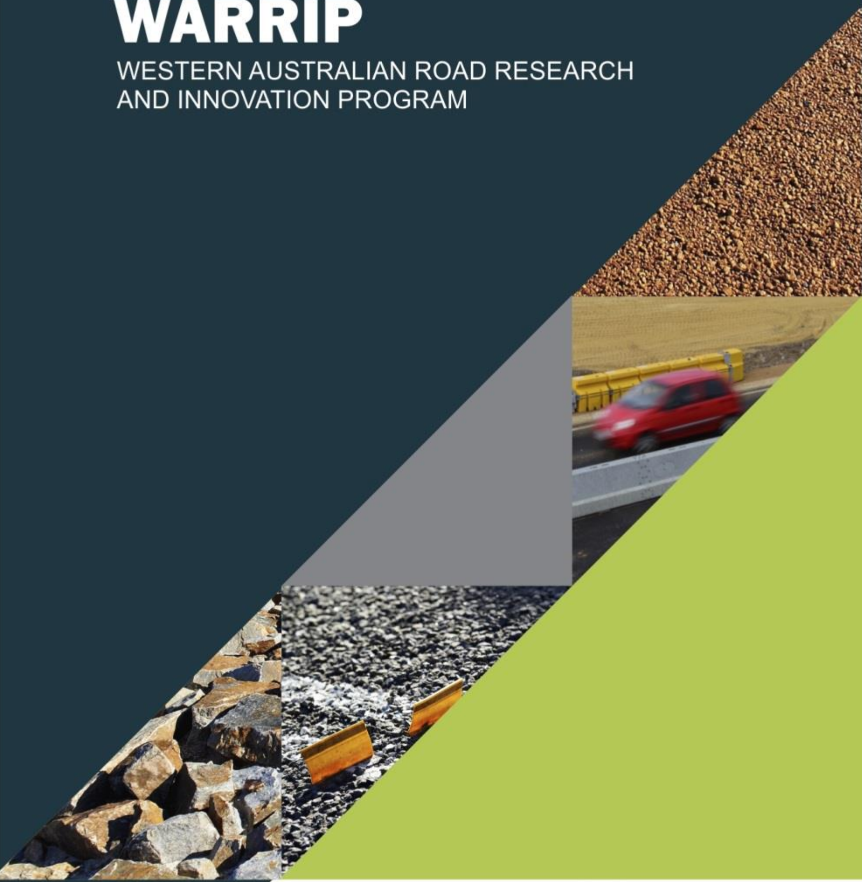

WARRIP Overview

Jonathon Griffin
Main Roads Western Australia / Materials Engineering Branch

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Program Objectives

- Conduct **leading research** of road pavements and surfacings, asset management and structures
- **Implementation** of innovative practices that reduce cost and increase rate of return
- Improve specialist **technical capability** in Western Australia
- Contribute to the body-of-knowledge and **collaboration** with other national research programs such as Austroads and NACoE

Current Program (1 of 2)

Pavement Design

- Best practice for major projects - underway
- Cost effective pavement design - underway
- Engineering Road Note 9 Update - underway
- Full-depth asphalt (FDA) temperature profiles - underway
- Asphalt fatigue at elevated temperatures - underway
- Dynamic heavy vehicle loading effects - scope development

Asset Management

- Preliminary trial of traffic speed deflectometer (TSD) - completed
- Australian National Risk Assessment Model (ANRAM) using TSD - underway
- Improved decision making using TSD data - scope development
- Best practice road asset management - scope development

Current Program (2 of 2)

Pavement Technology

- Review of future pavement technologies - completed
- **High modulus asphalt (EME2) - underway**
- Stone mastic asphalt (SMA) - underway
- Crumb-rubber modified open-graded asphalt (OGA) - underway
- Specifications & guidelines for warm-mix asphalt - underway
- Increased reclaimed asphalt pavement (RAP) utilisation - underway
- Review of Tonkin & Reid Hwy trial sections - underway
- Investigation of hydrated cement treated crushed rock base (HCTCRB) trial sections - underway
- Light-emitting lane demarcation - scope development
- Asphalt modification using Nano-technology - scope development

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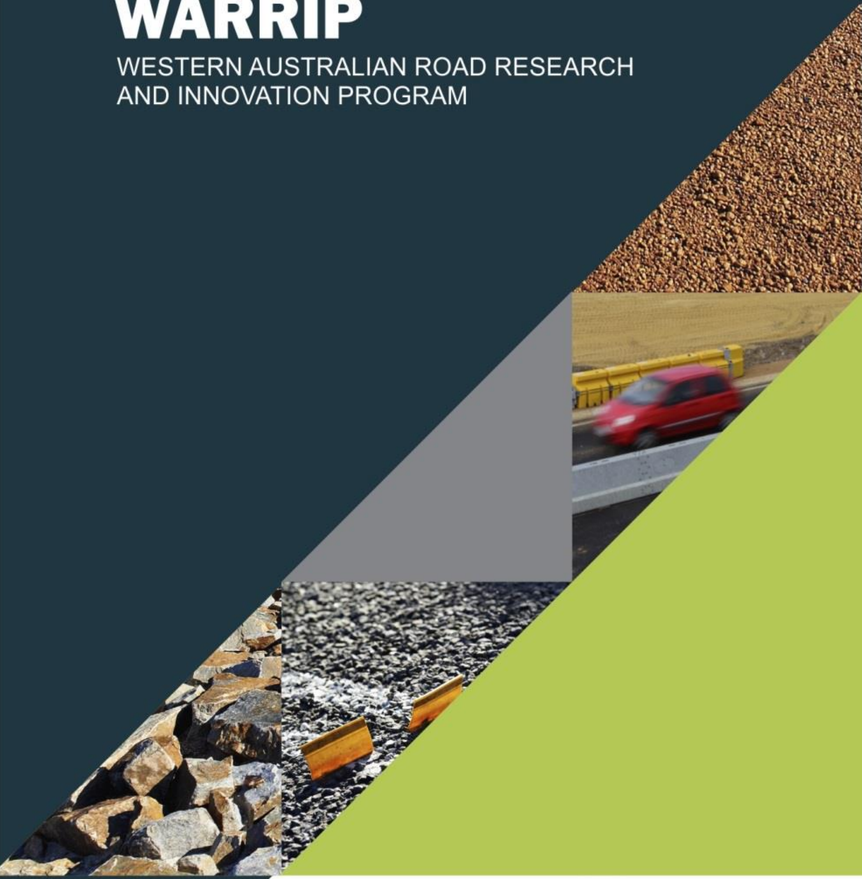

EME2 Workshop

Pre-trial Planning
- Mix Design
- Brisbane
- Site

Willie Valenzuela

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EME2
Enrobés á Module Élevé Class 2

- EME2 = high modulus asphalt.
- Mixes are produced using a hard-paving grade bitumen applied at a higher binder content in comparison to the conventional asphalt with unmodified binders.
- High modulus asphalt allows for a significant reduction in pavement thickness.

Properties

- Stiff
- Rut resistant
- Fatigue resistant
- Moisture resistant
- Workability

EME2

Characteristics

- Low air voids content (<6%)
- High binder content (approximately 6%)
- Hard binder: penetration 10-25 pu
- Performance based design

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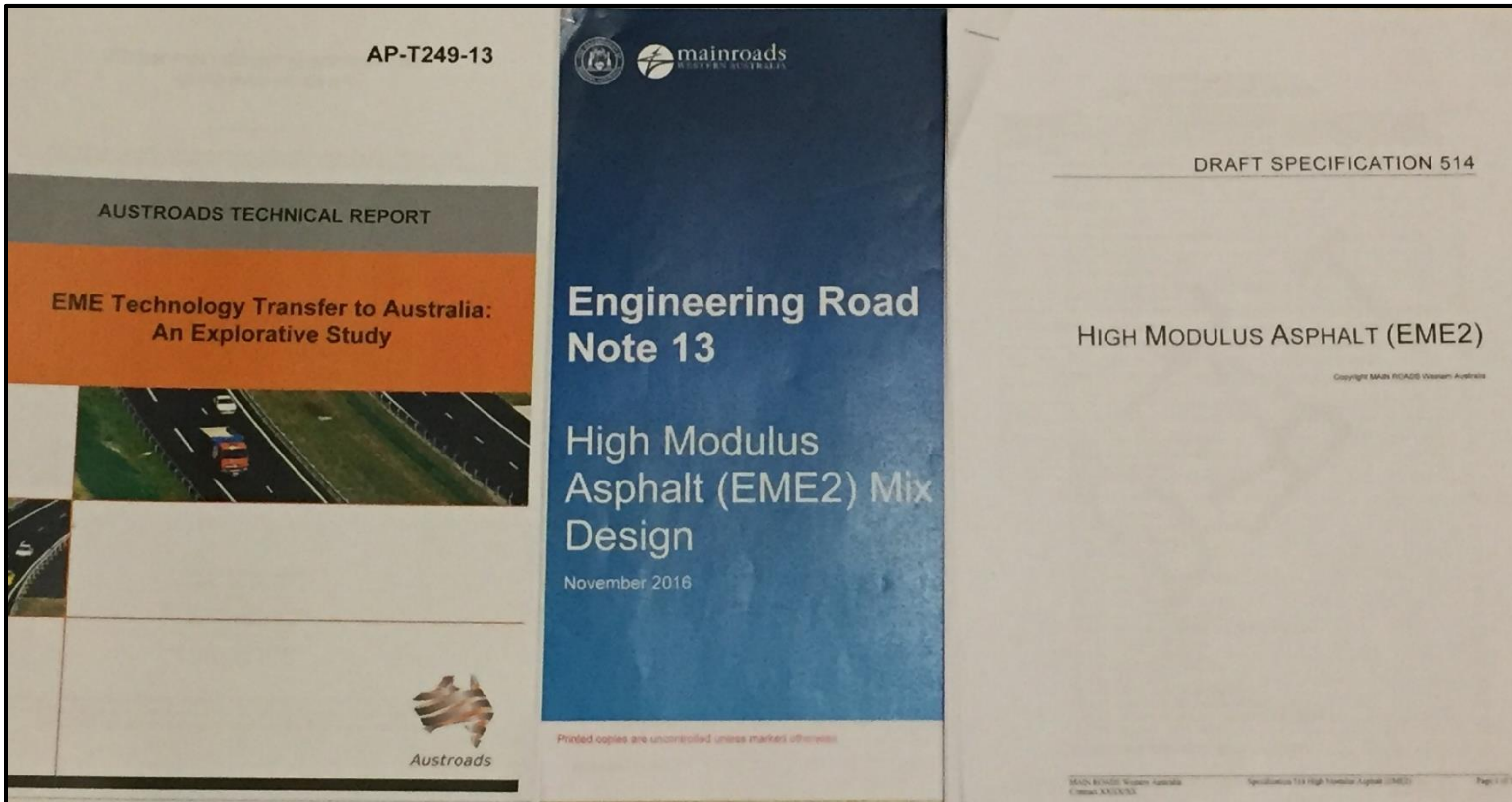
EME2 Mix Design

Specifications Guidelines



Properties of EME2 Binder

Method of test	Unit	Property	EME2 binder	
			Min	Max
AS 2341.12	pu (Note 1)	Penetration at 25°C (100g, 5s)	15	25
AS 2341.18	°C	Softening point	56	72
AS/NZS 2341.2	Pa.s	Viscosity at 60°C (Note 2)	900	-
AS/NZS 2341.10	%	Mass change	-	0.5
AS/NZS 2341.10 and AS 2341.12	%	Retained penetration (Note 3)	55	-
AS/NZS 2341.10 and AS 2341.18	°C	Increase in softening point after RTFO treatment (Note 4)	-	8
AS/NZS 2341.2, AS 2341.3, AS/NZS 2341.4 or AGPT/T111	Pa.s	Viscosity at 135°C	0.6	-
AS 2341.8	% mass	Matter insoluble in toluene	-	1.0
N/A	N/A	Penetration index	Report	
AS/NZS 2341.10 and AS/NZS 2341.2	Pa.s	Viscosity at 60°C after RTFO (Note 2)	Report	
AS/NZ 2341.10 and AS/NZS 2341.2	%	Viscosity at 60°C, percentage of original after RTFO treatment	Report	

Aggregate Properties

Test	Requirement	Test Method
Los Angeles Abrasion value	35% maximum	WA220.1
Flakiness Index	25% maximum	WA 216.1
Water Absorption	2% maximum	AS 1141.6.1
Wet strength	100 kN minimum	AS 1141.22
Wet/dry strength variation	35% maximum	AS1141.22
Degradation Factor	50% minimum	AS 1141.25.2
Petrographic examination	Statement of suitability for use as an asphalt aggregate	

Requirements of the combined filler

Method of test	Unit	Property	Mineral filler	
			Min	Max
AS 1141.17	%	Voids in dry compacted filler	28	45
EN 13179–1: 2000 (Note2) and AS 2341.18	°C	Delta ring and ball (Note 1)	8	16

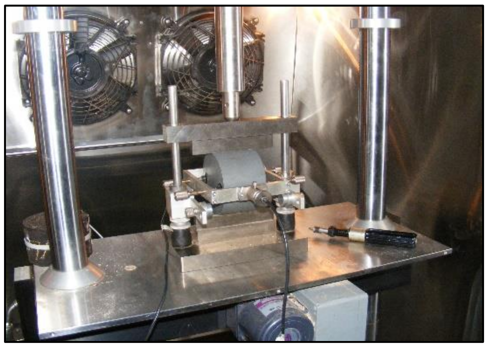
Mix design criteria of EME2

Property	Min	Max
Air voids in specimens compacted by gyratory compactor at 100 cycles	–	6.0%
Stripping potential of asphalt – tensile strength ratio	80%	–
Wheel tracking at 60°C and 30,000 cycles (60,000 passes)	–	4.0mm
Wheel tracking at 60°C and 5,000 cycles (10,000 passes)	-	2.0mm
Flexural stiffness at 50 ± 3 με, 15°C and 10 Hz	14,000MPa	–
Fatigue resistance at 20°C, 10 Hz and 1 million cycles	150 με	–
Richness modulus	3.4	–

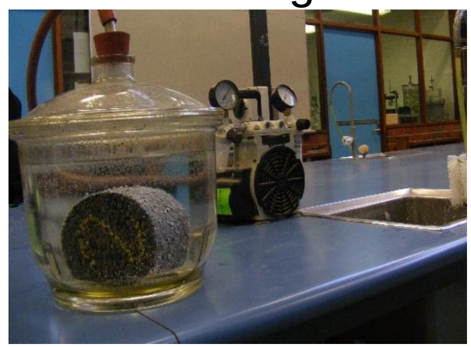
Specimens shall be compacted to an air void content of 1.5 – 4.5% (SDD)

EME2 Mix Design Process

Resilient Modulus



Tensile Strength Ratio



Flexural Stiffness

Fatigue Resistance

Wheel tracking

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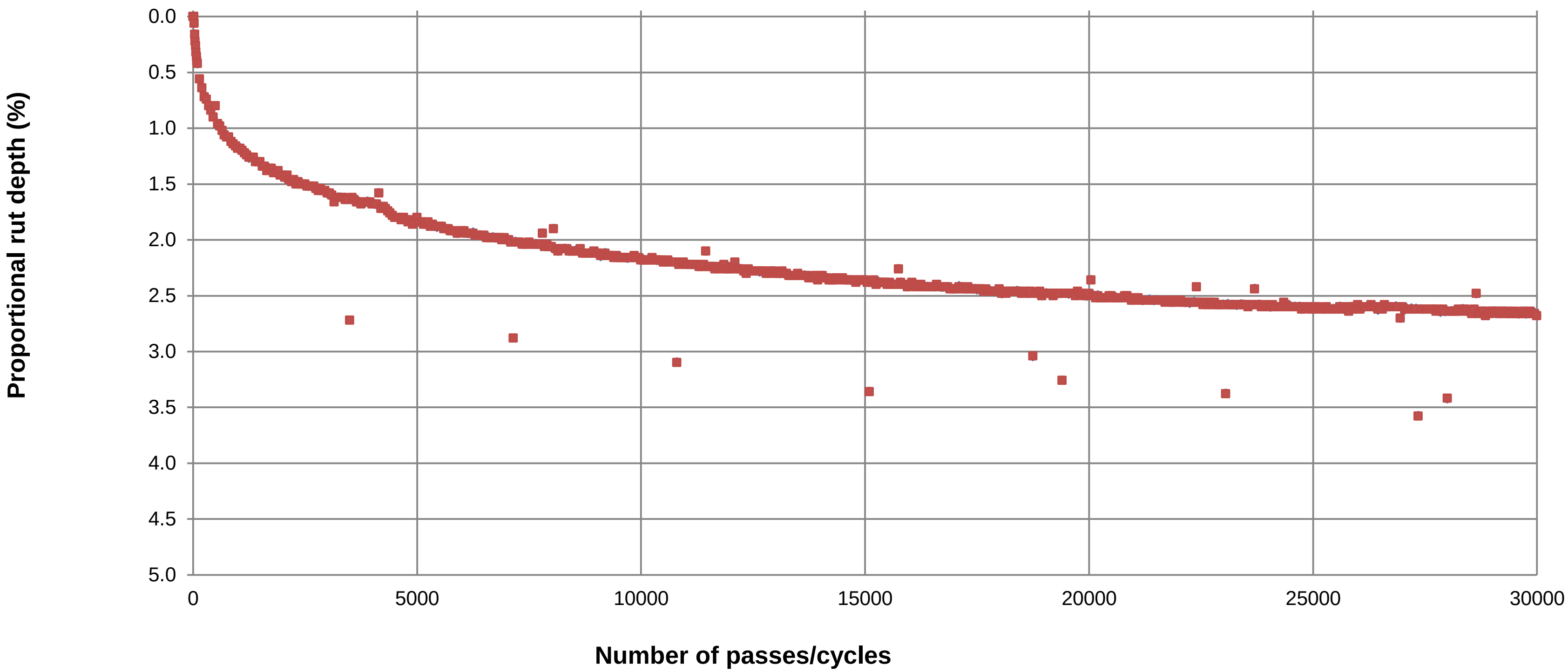
EME2 Wheel tracking results



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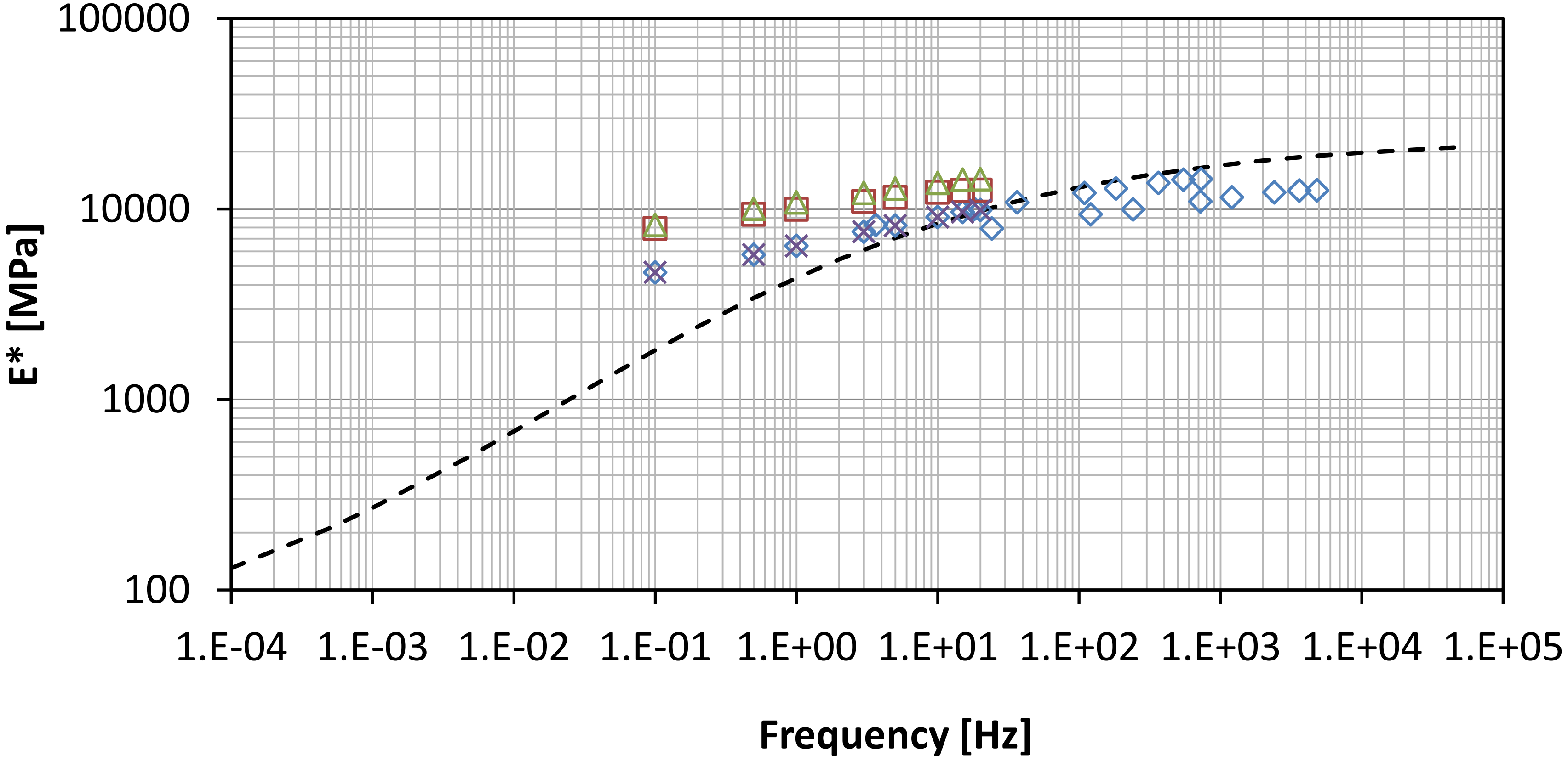
EME2 Modulus Master Curve



EME2 Mix Design Validation

Properties to be tested by European Laboratory

Property	Test method	Note	Limit	Value
Air voids in specimens compacted by gyratory compactor at 100 gyratory cycles	EN 12697-31		Maximum	6%
Water sensitivity	EN 12697-12		Minimum	70%
Wheel tracking at 60 °C and 30 000 cycles(1)	EN 12697-22	Large size device, 2 slabs	Maximum	7.5%
Minimum stiffness modulus at 15 °C and 10 Hz(1)	EN 12697-26 Method A	Two point bending trapezoidal specimens	Minimum	14 000 MPa
Fatigue resistance at 10 °C, 25 Hz and 10^6 cycles(1)	EN 12697-24 Method A	Two point bending trapezoidal specimens 3 strain levels, 6 specimens for each strain level	Minimum	130 με

Specimens shall be compacted to an air void content of 3–6% (mensuration).

EME2 Brisbane Trial - March 2017

Location

EME2 mix was placed on Gateway North on the Brisbane outskirts.

Pavement Composition

- 160 mm thick layer of unbound granular material treated with a cementitious stabilising agent. Sealed with CRS 60 emulsion with 10 mm aggregate.
- EME2 base layer design thickness was 110 mm. Placed in one layer on top of the working platform seal.

Mix Design

- EME2 trial mix design was prepared by Boral and verified by TMR.

EME2 Brisbane Trial

EME2 Brisbane Trial

Full Pavement Thickness

- Subgrade (design CBR 7%)
- 160mm improved layer unbound granular material
- 10mm Primer seal
- 110mm EME2 asphalt (placed in 1 layer)
- 50mm DG14HS asphalt
- Seal 10mm PMB
- 50mm SMA 14 asphalt

Production

- EME2 mix production: 100 tonnes per hour, with a total of approximately 700 tonnes with a production temperature between 180º C and 190ºC.
- Paving took place in a northbound direction in one single layer.

EME2 Brisbane Trial

Placement

- A material transfer vehicle (MTV) was used to received the asphalt mix from the trucks and remix it before depositing it into the hopper of the paver.
- Advantages of using an MTV include**:**
  - Prevents trucks from bumping the paver resulting in an uneven compacted surface.
  - Increasing the material buffer available to the paving operation, which could improve the continuity of the paving process.
  - Remixing the material preventing heat segregation and therefore, improving homogeneity of compaction.

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EME2 Brisbane Trial

EME2 Brisbane Trial

- During the trial several different tests were performed to ensure quality control. TMR mix requirements for daily routine of testing consist of four test:
- Particle size distribution
- Binder content
- Maximum density
- Compaction tests

EME2 Brisbane Trial

EME2 Finished Surface

EME2 Brisbane Trial

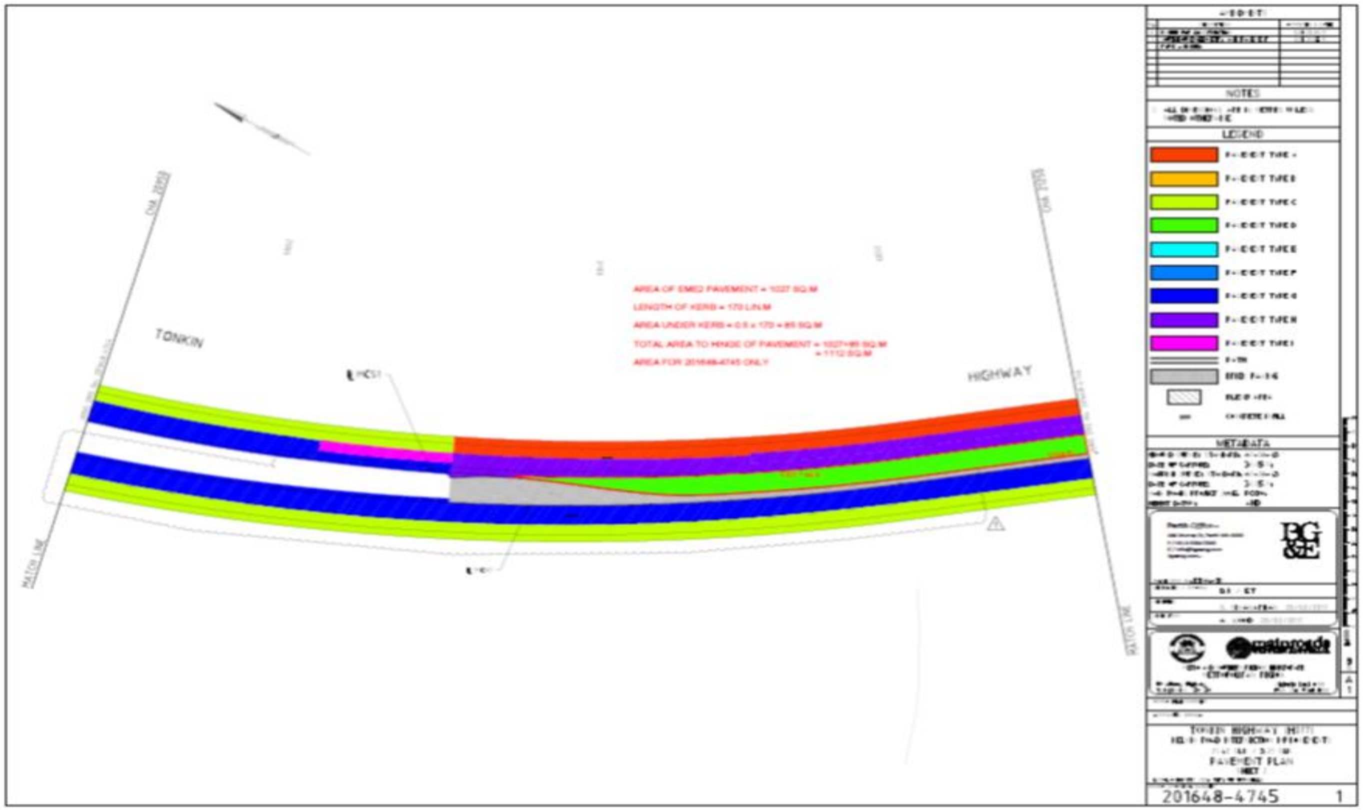
Learned Knowledge

- 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. A good practice should cover the dust especially during the wet season.

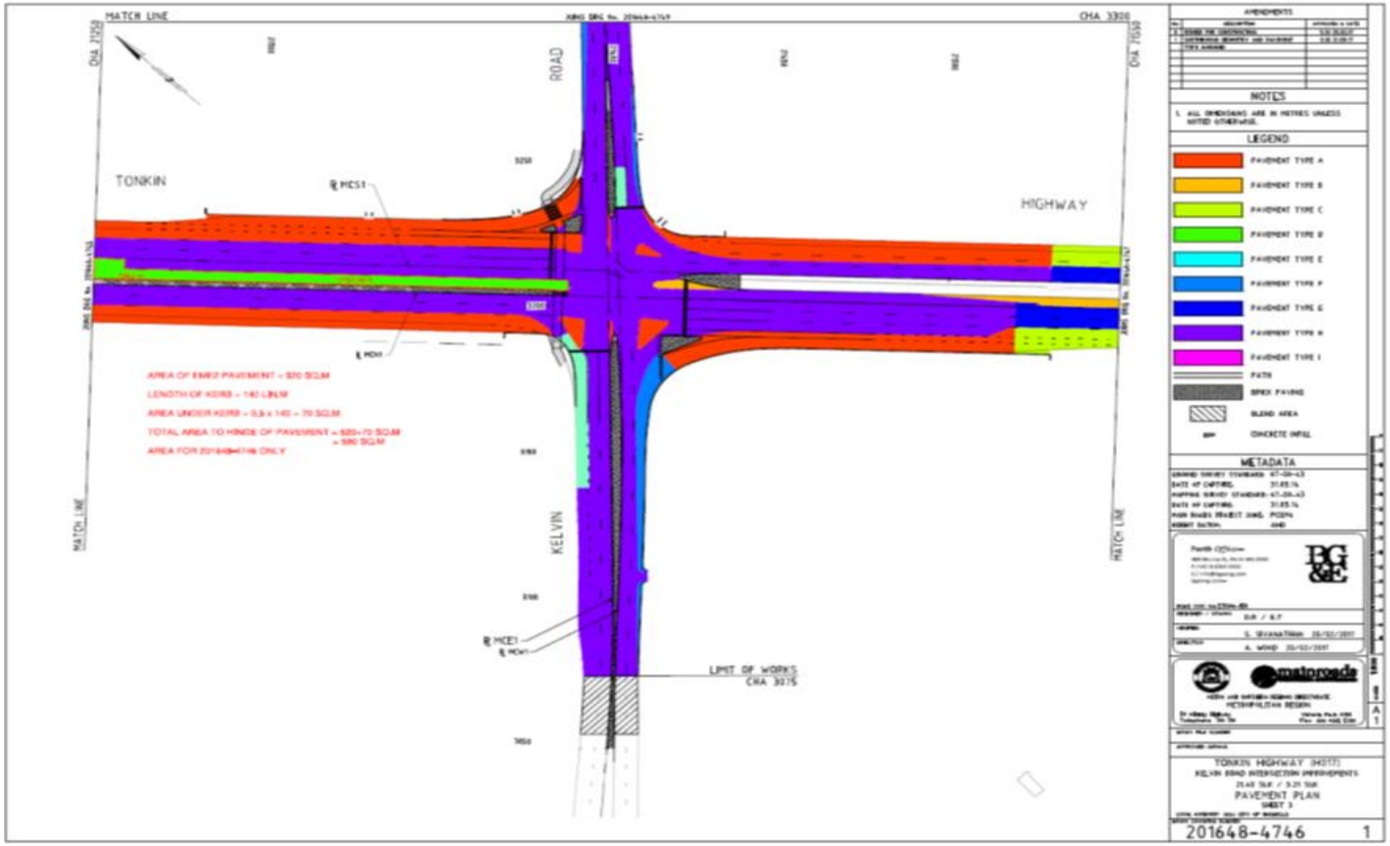
EME2 Perth Trial Location

- EME2 mix was placed on the new southbound right turn pocket on Tonkin Highway with Kelvin Road Orange Grove WA 6109. The geographic coordinates for the trial section are: 32°01’46.4”S 116°00’22.1”E.

EME2 Perth Trial Location



EME2 Perth Trial Location



Thank you

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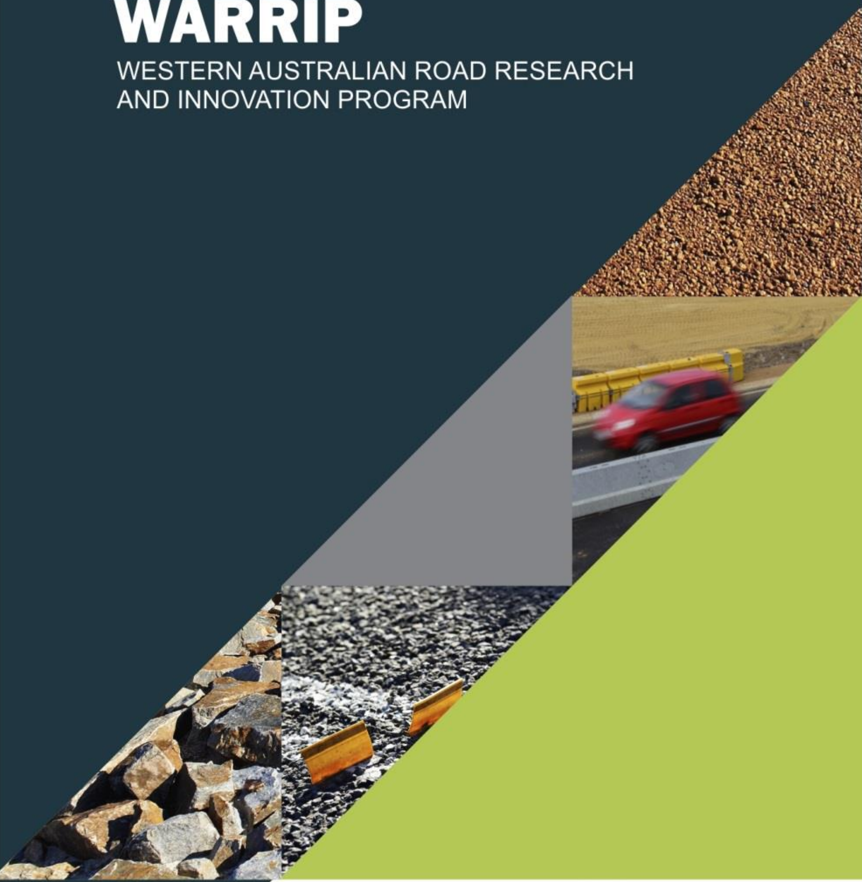

EME2 Pre-trial Pavement Design

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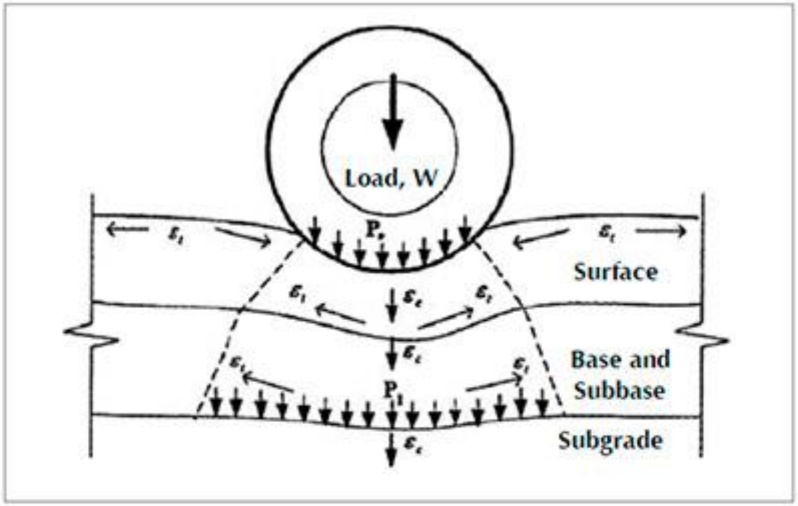
EME2 Pre-trial Pavement Design

- Pavement design concepts
- High modulus asphalt (EME2)
- Performance-based asphalt design
- Interim design approach

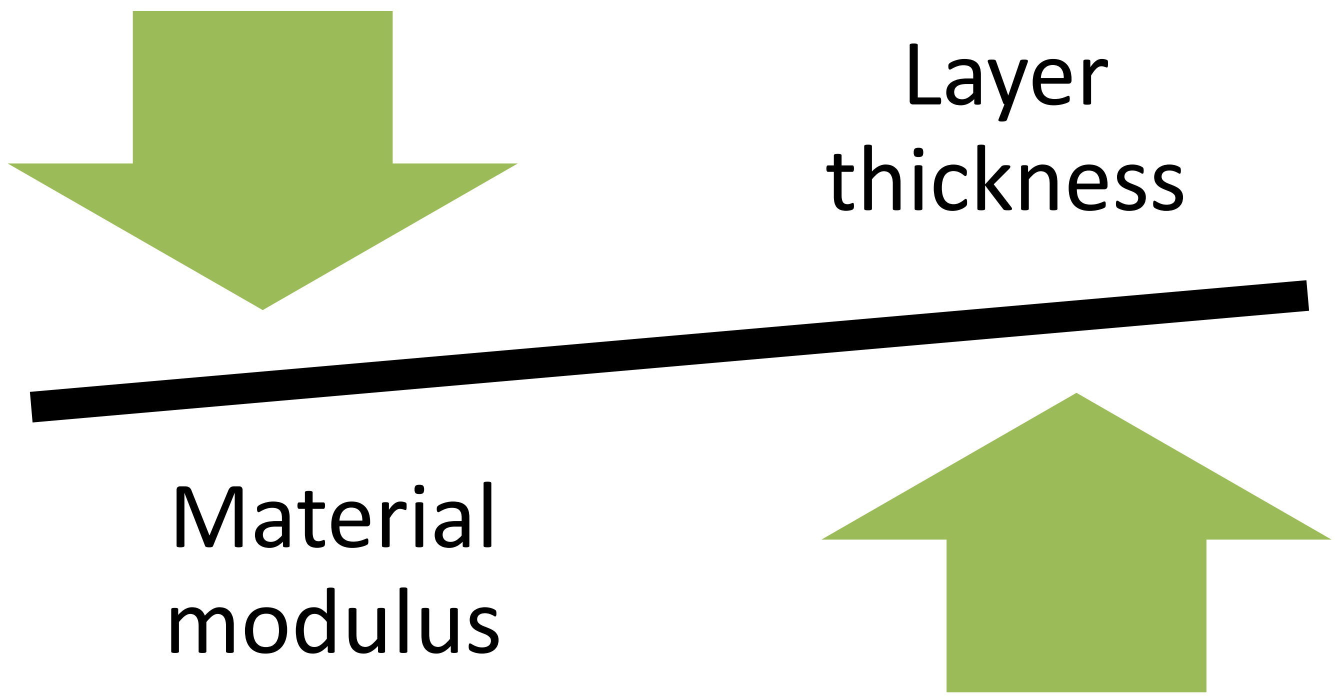
Pavement Design Concepts

- Minimise subgrade vertical compressive stress/strain
- Limit horizontal tensile strain in bound layers
- Manage the development of horizontal shear stress



Source: Du, Shen & Cross (2008)

Pavement Design Concepts



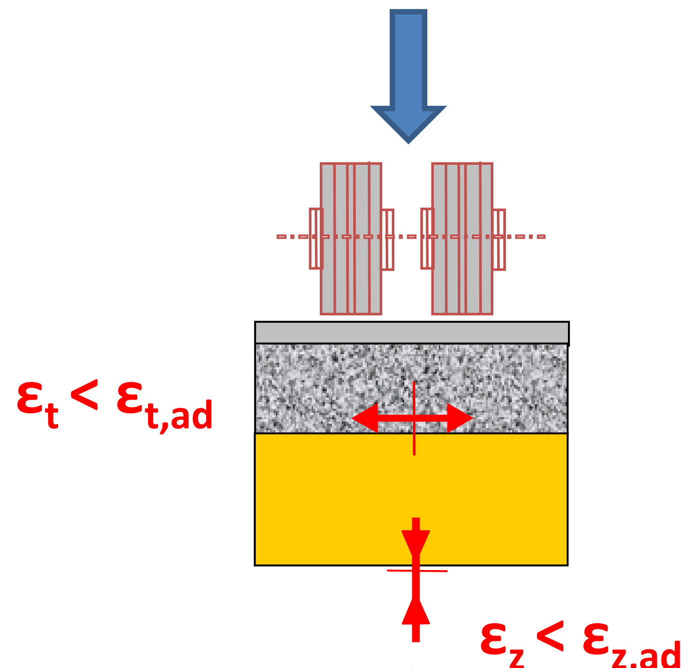
High Modulus Asphalt (EME2)

- Enrobés à module élevé “asphalt with an elevated modulus”
- French technology developed in mid-1970s
- High performance structural asphalt for heavy-duty pavements
- High rut resistance → incorporates hard grade bitumen
- High fatigue resistance → richness modulus > 3.4

Performance-based Asphalt Design

- Mechanistic structural design approach incorporating mix specific characteristics

Source: Dupuy (2017)



$$\varepsilon_{t,ad} = \varepsilon\,(NE, \theta_{eq}, f)\; k_r\, k_c\, k_s$$

Performance-based Asphalt Design

- Mechanistic structural design approach incorporating mix specific characteristics

Performance Characteristic	Test Method
Air voids in specimens compacted by gyratory compactor at 100 cycles	AS/NZS 2891.8
Stripping potential of asphalt – tensile strength ratio	AG:PT/T232
Wheel tracking at 60°C and 30,000 cycles (60,000 passes)	AG:PT/231
Wheel tracking at 60°C and 5,000 cycles (10,000 passes)	AG:PT/231
Flexural stiffness at 50 ± 3 με, 15°C and 10 Hz	AG:PT/T274
Fatigue resistance at 20°C, 10 Hz and 1 million cycles	AG:PT/T274
Richness modulus	ERN13 (draft) Section 4

Interim Design Approach

- Compatible with existing Austroads mechanistic design procedure
  - Guide to Pavement Technology Part 2: Pavement Structural Design (2012)

Design speed (kph)	WMAPT (°C)	Binder Volume (%)	Design Modulus (MPa)	Parameter - k
90	29	13.5	5 500	3921
80	29	13.5	5 300	3989
60	29	13.5	4 800	4134
50	29	13.5	4 500	4231
30	29	13.5	3 800	4496
10	29	13.5	2 500	5228

For illustrative purposes only

Site Conditions		Design Parameters	
WMAPT (°C)	29	Design traffic (ESA)	$3.8 * 10^7$
Heavy vehicle speed (kph)	10	SAR5/ESA	1.13
Design Subgrade CBR (%)	10	SAR7/ESA	1.64
Design period (years)	40	Reliability (%)	95

Wearing course	14 mm intersection mix	40
Waterproofing seal		
Base course	14 mm intermediate	50
	20 mm intermediate	220
Subbase	Limestone	150
Subgrade	Sand	∞

Traditional pavement = 460 mm

Wearing course	14 mm intersection mix	50
Base course	14 mm EME2	210
Subbase	Limestone	150
Subgrade	Sand	∞

High modulus pavement = **410 mm**

Site Conditions		Design Parameters	
WMAPT (°C)	29	Design traffic (ESA)	$1.3 * 10^8$
Heavy vehicle speed (kph)	80	SAR5/ESA	1.13
Design Subgrade CBR (%)	12	SAR7/ESA	1.64
Design period (years)	40	Reliability (%)	95

Wearing course	10 mm open grade	30
	10 mm dense grade	40
Waterproofing seal		
Base course	14 mm intermediate	50
	20 mm intermediate	190
Subbase	Limestone	150
Subgrade	Sand	∞

Wearing course	10 mm open grade	30
	10 mm dense grade	40
Base course	14 mm EME2	185
Subbase	Limestone	150
Subgrade	Sand	∞

Traditional pavement = 460 mm

High modulus pavement = **405 mm**

References

- Austroads, 2012, *Guide to Pavement Technology Part 2: Pavement Structural Design*, Austroads.
- Department of Transport and Main Roads, 2015, *High Modulus Asphalt (EME2) Pavement Design*, Technical Note 142, Queensland Government.
- Du, J.C., Shen, D.H. and Cross, S.A, 2008, *Pavement Rutting Dynamic Prediction Model*, International Journal of Pavement Research and Technology, Vol. 1 (2), pp. 64-71.
- Dupuy, P, 2017, *High Modulus Asphalt (EME2)*, presentation to Main Roads Materials Engineering Branch, 28 April 2017, Welshpool.
- Main Roads Western Australia, Draft, *High Modulus Asphalt (EME2) Mix Design*, Engineering Road Note 13, Government of Western Australia.

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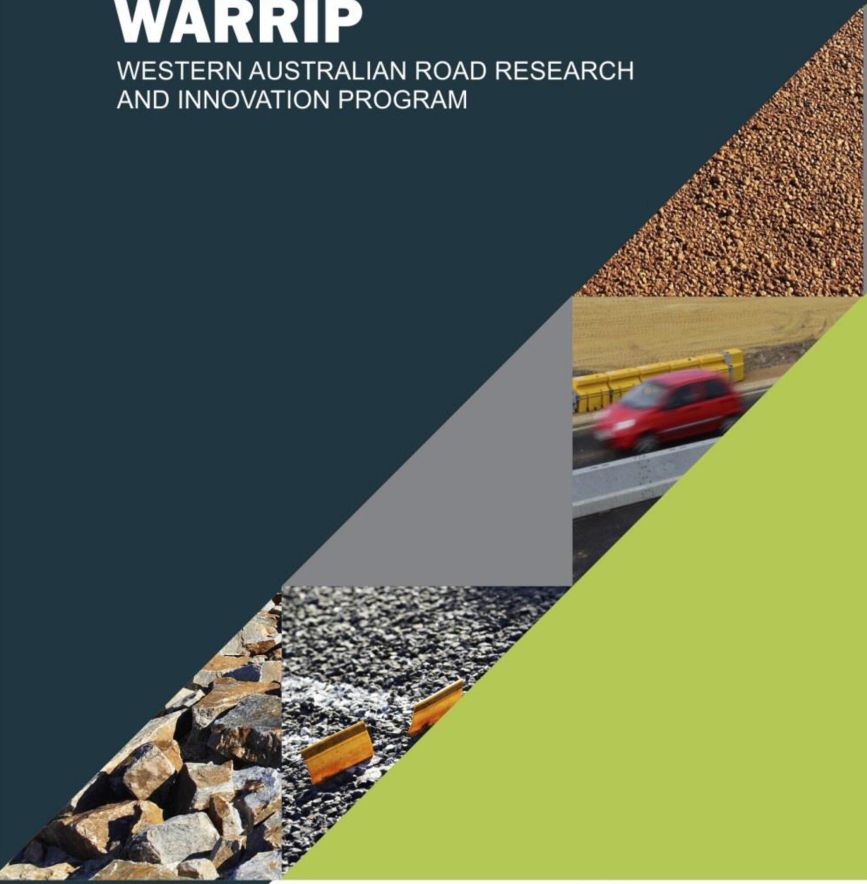

EME2 Workshop

Production and Construction of EME2 Trial

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Mix Details

- Enrobés à Module Élevé Class 2 (EME2)
- Produced : Downer Asphalt Plant - Gosnells
- Aggregate : Holcim Granite to Specification 511- Gosnells
- Bitumen : SAMI – Produced in Brisbane 15/25 Pen
- A Production and Placement trial only
- Tonkin/Kelvin Intersection Turning Pockets

Plant Production

- Just like a Normal Asphalt mix with tighter controls
  Heating of binder lines prior to 15/20 Pen
  - Extended preheating and extended shutdown times
  - Running mix with other binder or aggregates to heat plant
  - Production rate comfortable at 75% max production (100 t/h)
  - Batching temperature in Draft Specification 514 tolerance ranging between 175°C-190°C

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Plant Production

- 3 semi trailers of 15/25 Pen for the yard trial and 2 days site trial
- 0.3% adhesion agent for trial production at SAMI
- Direct feed of binder from tankers to plant

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Plant Sampling - Bitumen

- Very important for EME2 asphalt
- 2 sample increments for 100 ton yard trial
- 3 sample increments per day per tanker, targeted at:
  - 5000 L
  - 10000 L
  - 15000 L
- On transfer during production

Plant Sampling - Asphalt

- Production testing
  - PSD
  - Binder Content
  - Max Density, and
  - Production Moisture
- No laboratory compaction testing…yes not even Marshalls

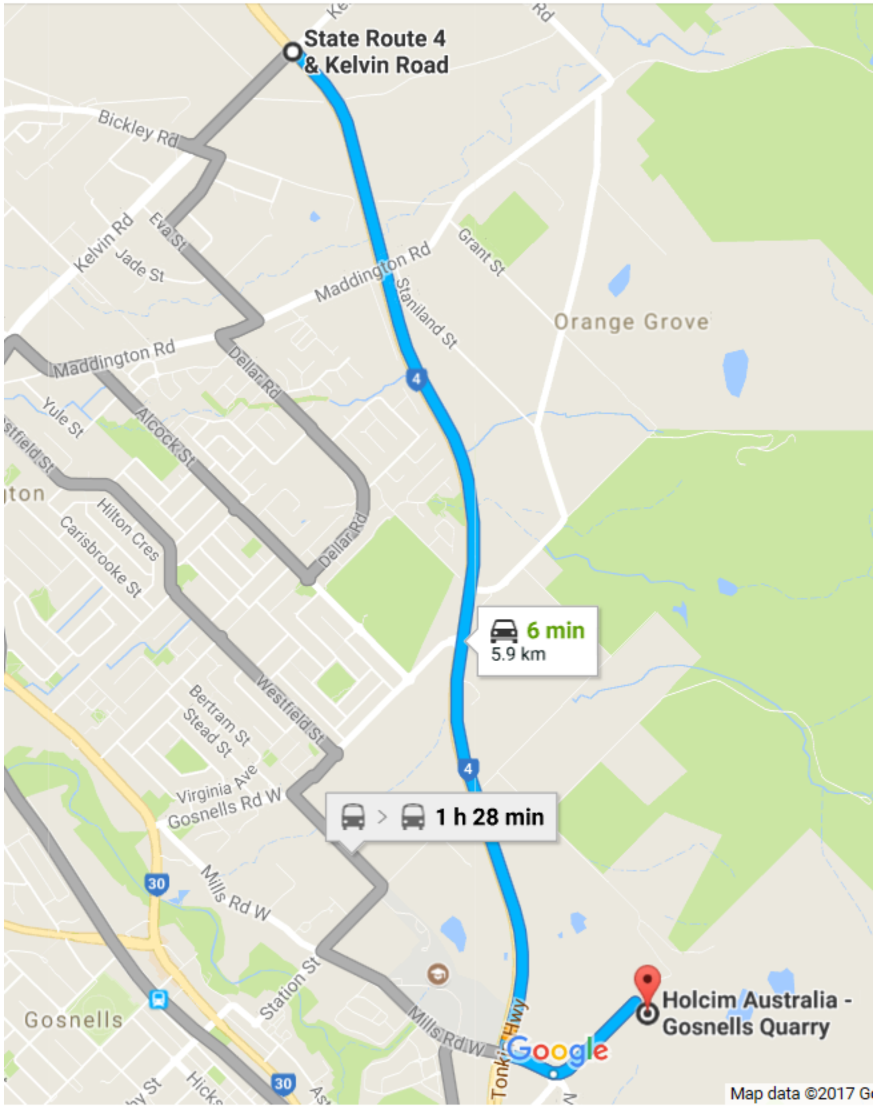
Plant Sampling - Asphalt

- Bulk Sample for performance testing off site
  - Workability - 100 cycle gyratory
  - Tensile Stripping Ratio
  - Resilient Modulus
  - Wheel Tracking
  - Flexural Stiffness @15°C (Beam Modulus)
  - Beam Fatigue Testing
  - Hamburg Wheel Tracker Testing

Transportation

Pros

- Under 6.0km from the Downer Asphalt Yard exit to Site
- Low amount of heat loss
  - Covered trucks
  - Short distance
  - Good climatic conditions



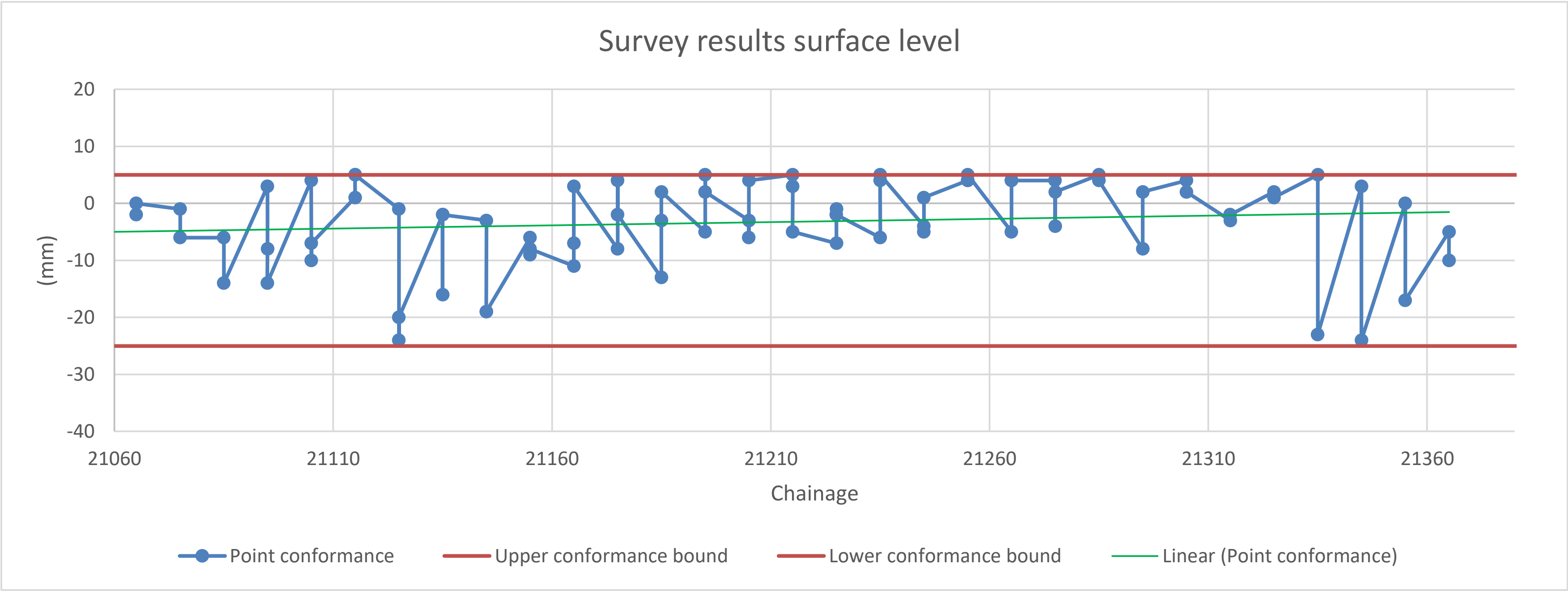
Transportation

Cons

- Waiting for trucks
  - Close Distance
  - Direct Blending
  - Improved day 2 with additional trucks

Subbase

- Subbase Levels were good and in Specification



Subbase

- Subbase quality was variable
  - Spalled areas
  - Late cutting
- Not Primed
  - Binder Logistics
  - Rain
  - Dryback
  - **WE WANT PRIMED SUBBASE!!**

Construction

- 26 and 27 of April 2017
- 26.1°C and 26.7°C days, low wind, sunny, no rain
- 2 layers of 14mm EME2
- 210mm thick (2@105mm)
- 2 x 3.5m wide turning pockets
- One edge against existing basecourse
- One side unconfined
- One hot joint
- 100t yard trial, 1000t over 2 days.

Expertise

- French
  - Monsieur Pierrick Dupuy
  - Reunion Island
  - Had no issues with our processes
- Downer Infrastructure Services
  - Eric Clauss
  - Project Manager
  - EME2 experience

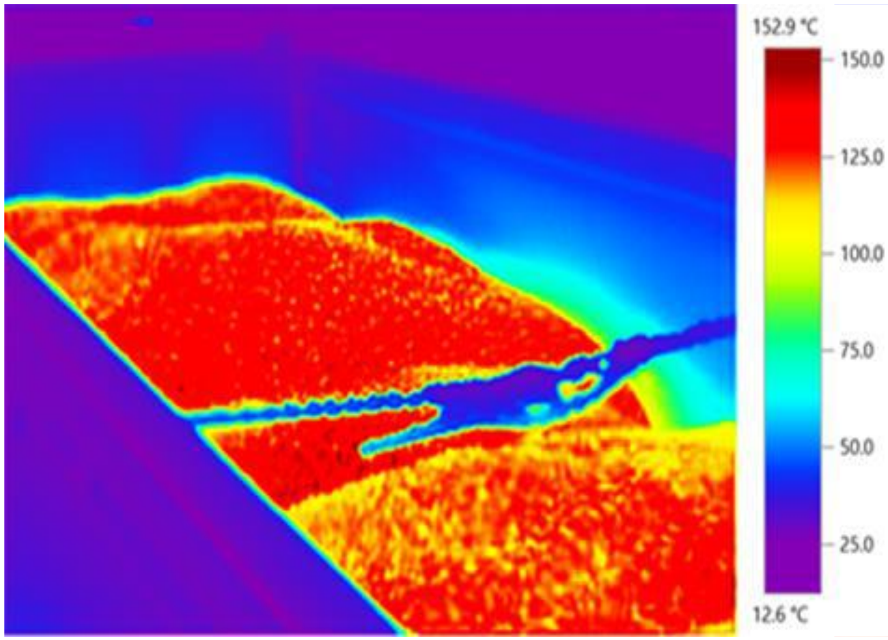
Placement

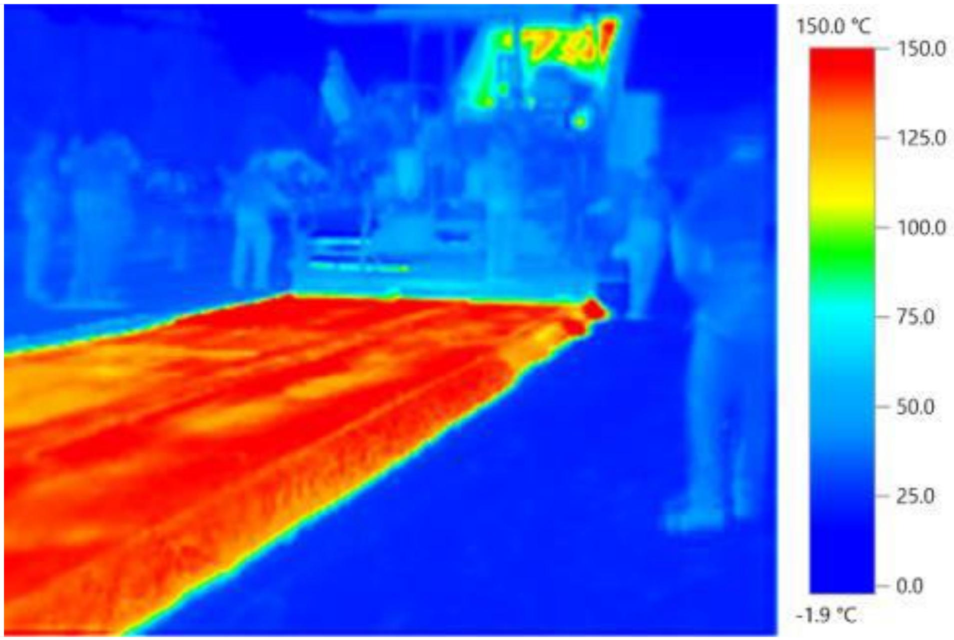
- Paver tamper set to medium
- Preheating of screed
- Bulking factor 25% loose

Mix Temperature

- Mix in truck at plant
  - Within Draft Specification 514
  - Probe - 169°C – 183°C
- Mix Delivery to site
  - Within Draft Specification 514
  - Probe - 162°C – 180°C
- Back of Paver
  - Infrared - Typically 135°C-155°C
  - Probe Internal – Typically 150°C+

Mix Temperature





Compaction

- Order of rollers
  - Steel Drum,
    - 9 ton, 2 passes static, 3 passes medium vibe
  - Multi rubber tyre
    - 14 ton, 4-6 passes
  - Steel Drum
    - 7 ton, 4 static passes

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Compaction

- Rollers as close to paver as possible
- Overlapping of all 3 rollers

Compaction

- Indent from first roller pass

Compaction

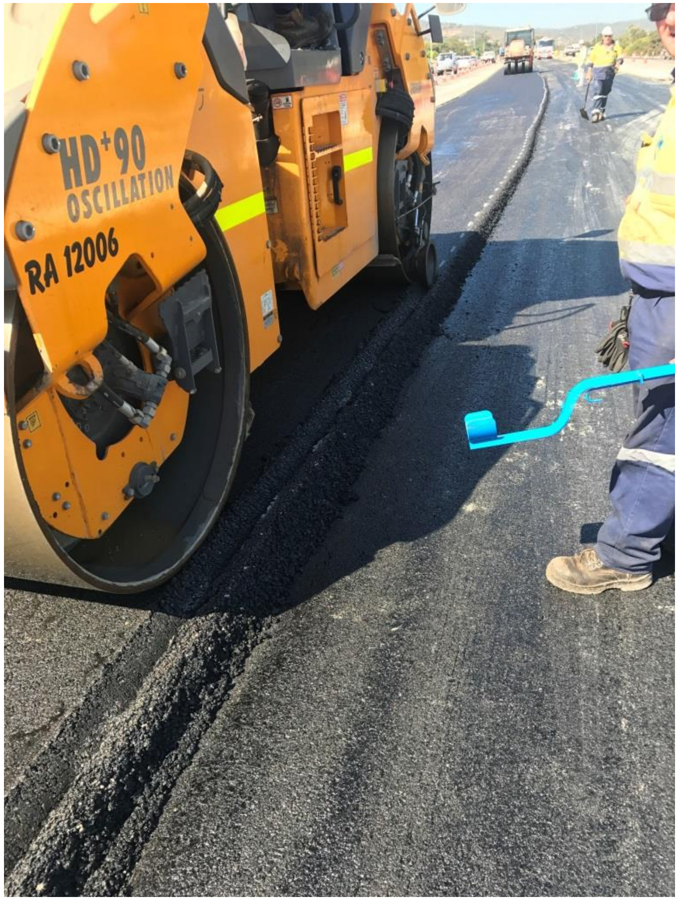
- Marks from Rollers

Joints

- Critical for EME2 asphalt
- Cutting, and Pressing of Joints
- Tacking joint edge
- Overlapping joint
- Butting up, rolling and pressing of joints not throwing mix

Joints

- Cut



Joints

- Cut
- Clean

Joints

- Cut
- Clean, and
- Press

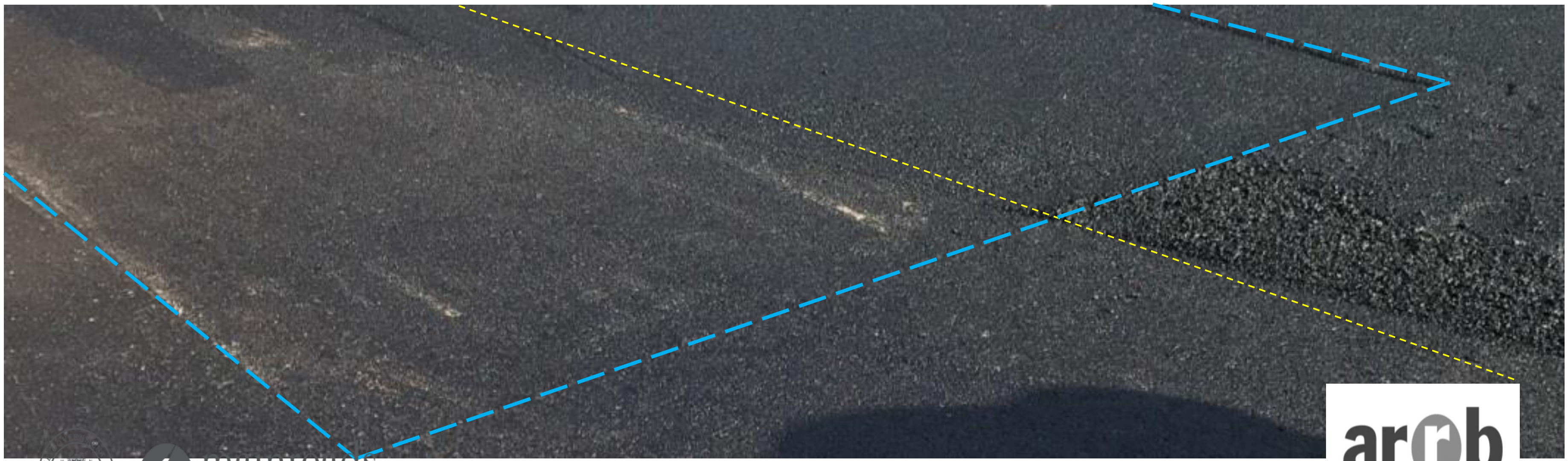
Joint Overlapping

- 2 Techniques
  - “Standard Practice” racking and flicking edge
  - Butting up, rolling and pressing of joints

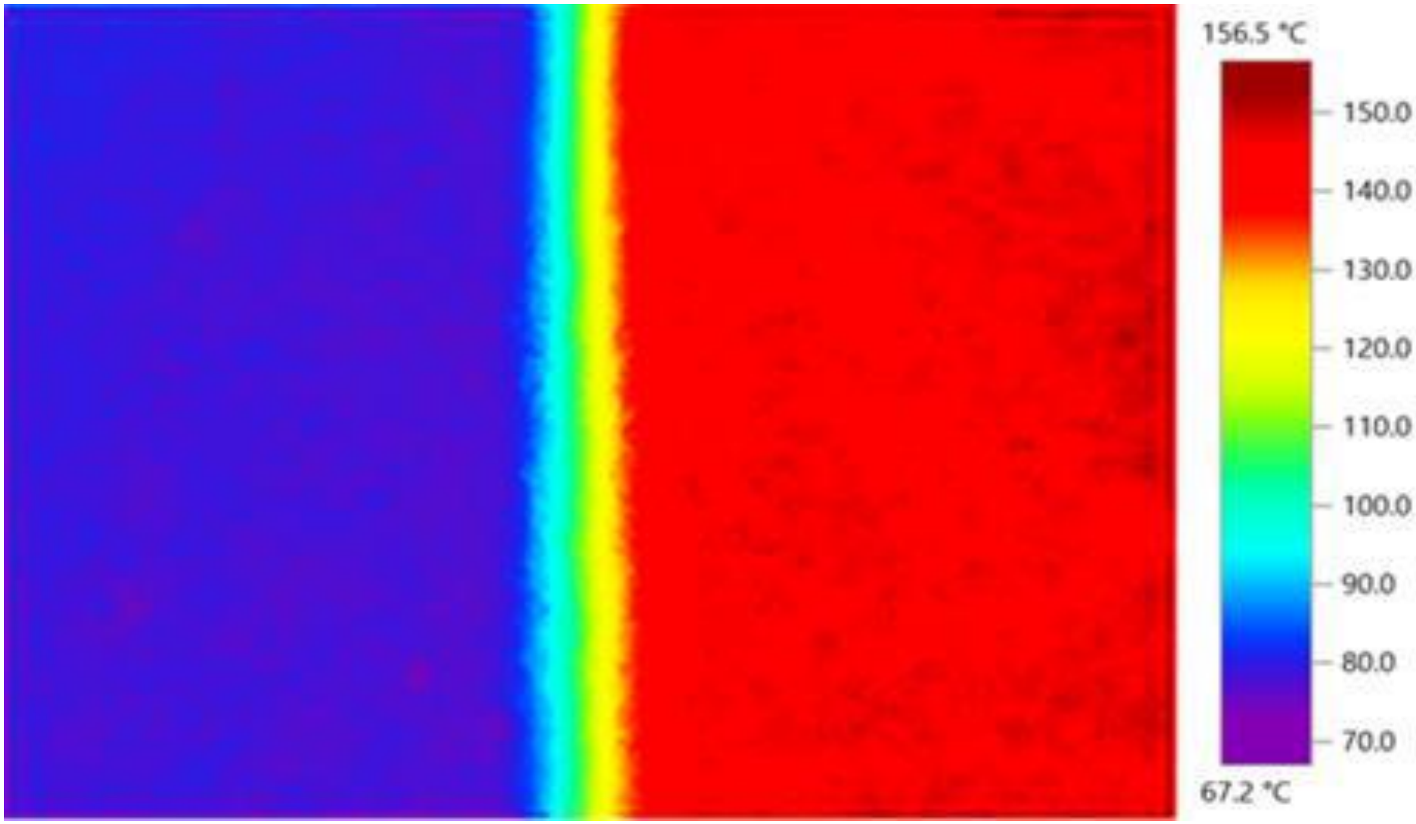
Joint Overlapping

Compacting Joints

- Overhang one steel roller
- Compact over rolled joint



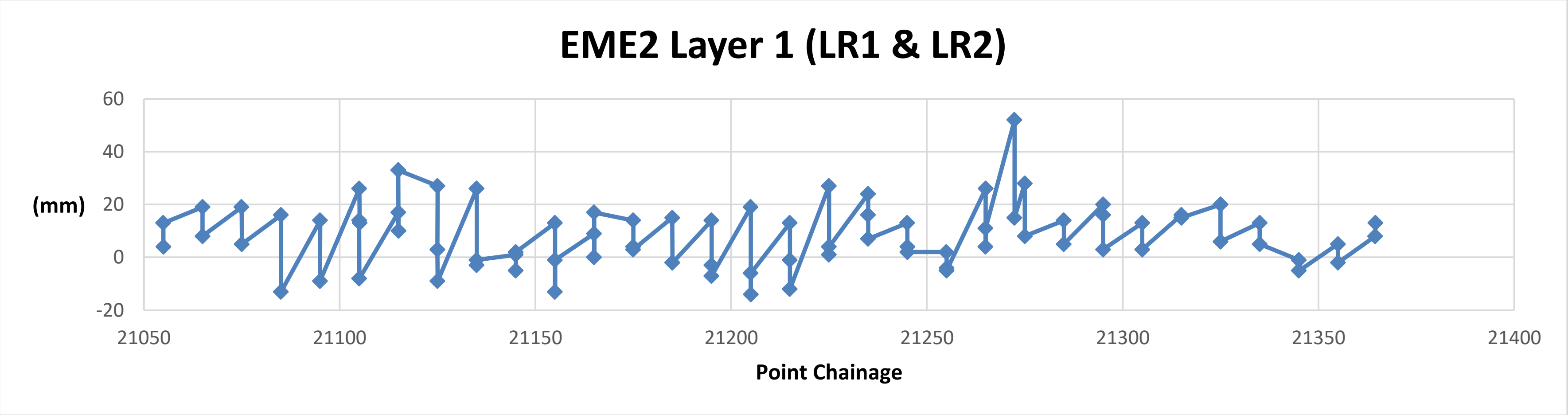
Joint Temperature

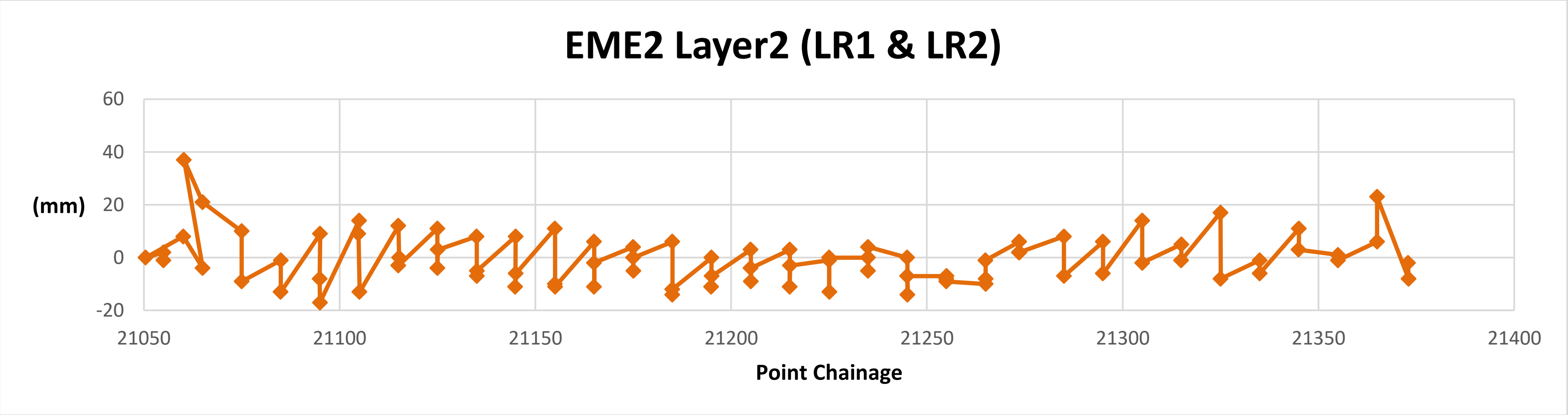


Finished Joints

What Joint??????????

EME2 Levels


EME2 Layer 1 (LR1 & LR2)
(mm)
60
40
20
0
-20
21050
21100
21150
21200
21250
21300
21350
21400
Point Chainage


EME2 Layer2 (LR1 & LR2)
(mm)
60
40
20
0
-20
21050
21100
21150
21200
21250
21300
21350
21400
Point Chainage

Surface Finish

- Similar to a 10mm DGA

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Surface Finish

- Flush patches
- No issue

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Tack coating

- Didn't meet requirements of Specification
  - Streaking/tram tracked
  - Not even
  - Applied with works truck
- Has been rectified and truck now sprays evenly

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Density Testing

- Conformance - Cores to AS2891.2
- Standard Specification 201 frequency
- Research - Nuclear Thin Layer Gauge
- Site compaction Indication – Downer Pavement Quality Indicator

Wearing course

- No Seal
- Tack coated
- 50mm of 14mm Intersection Mix with A15E PMB

Lessons Learnt

- Just Like Normal Asphalt
- Vertical tank for Binder
- Pickup grid should occur more frequent for levelling software (5m)
- Increase of loose bulking factor
- Tight compaction train
- Rollers Overlapping
- Temperature control of whole process
- Coring next day

Lessons Learnt

- Rollers off if too hot and mobile
- Roller tyres to be wet
- Don't leave roller stationary on mat
- Multi to have skirts
- Joints are critical
  - Offset roller so one drum is overhanging unsupported edge
  - Cutting of joints as per Specification 510/Draft Specification 514
  - Overlapping of joints as per Specification 510/Draft Specification 514,
  - Butting up, rolling and pressing of joints <u>not throwing mix</u>

Thanks

- Downer
- SAMI
- ARRB
- Main Roads Laboratory Staff
- Main Roads Contract team on Tonkin/Kelvin
- Pierrick Dupuy
- WBHO

Questions

- Please have a think and ask any questions at the end of all presentations

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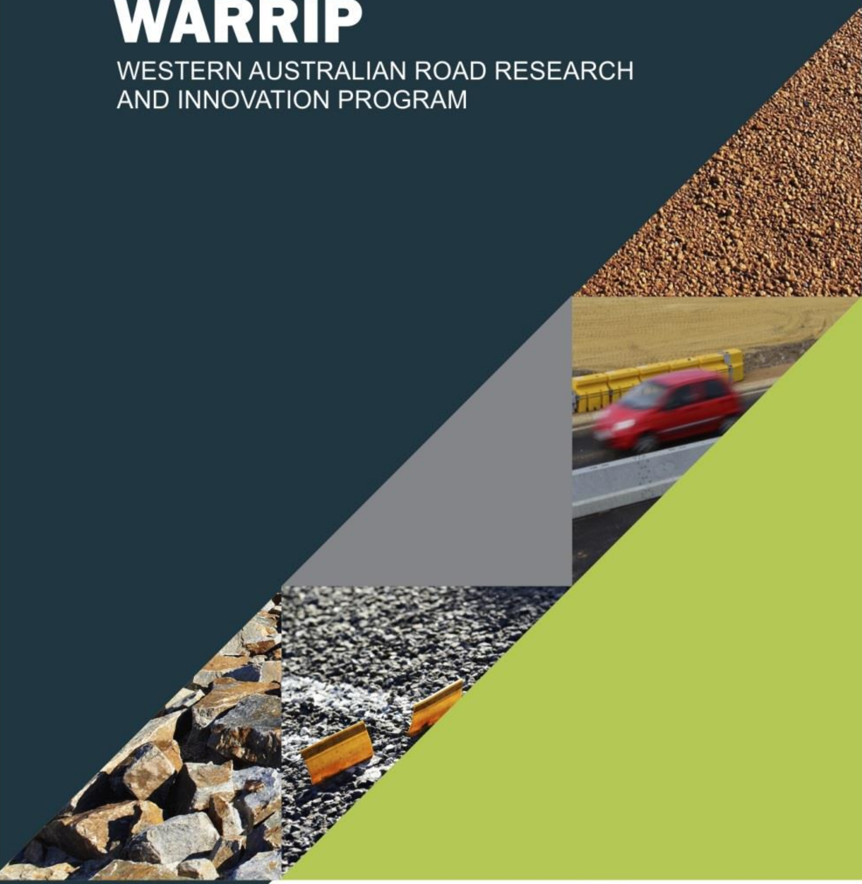

EME2 Workshop

Binder, Mix and In-situ Properties of EME2

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Mix Properties #1

Property	Variation from Target	Property	Variation from Target
Binder Content	- 0.1 to +0.2		
PSD Passing 13.2	- 3 to +1	PSD Passing 1.18	-1 to +2
9.5	- 6 to +1	0.6	-0.9 to +1.7
6.7	-5 to +6	0.3	-0.6 to +1.7
4.75	-5 to +3	0.15	-0.7 to +1.1
2.36	-2 to +3	0.075	-0.7 to +0.8

Mix Properties #2

- Particle Coating 100%
- Moisture Content 0% and 0.1%
- Maximum Density 2.483 to 2.499 t/m^3
- Air Voids after 100 cycles gyratory compactor were 3.0% and 3.2% (Limit ≤ 6.0%)

Binder Samples #1

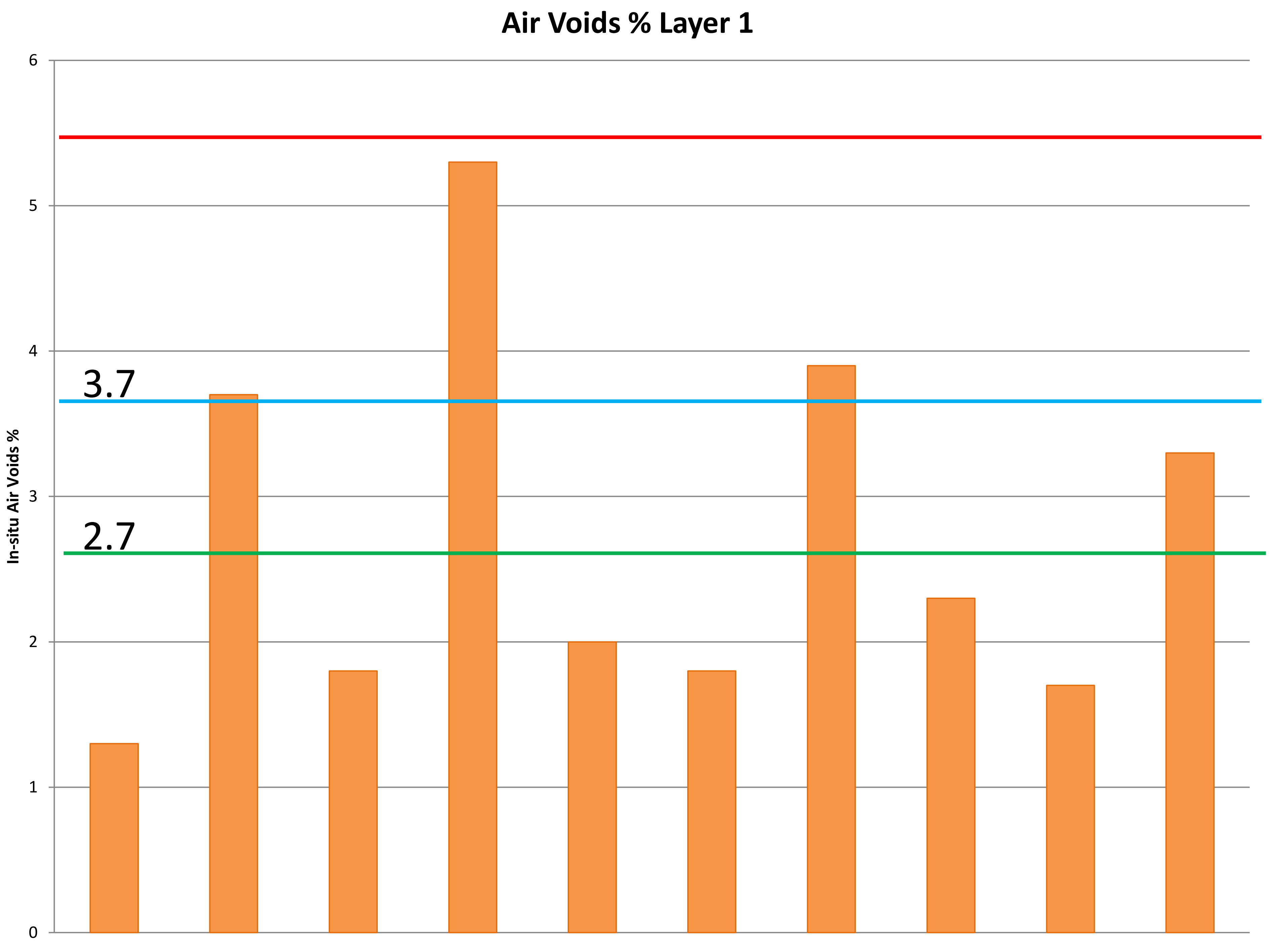
- Pre-trial 12/4 - 2 samples, 1 full test
- Trial 26/4 – 6 samples, 3 full tests
- Trial 27/4 – 6 samples, 3 full tests

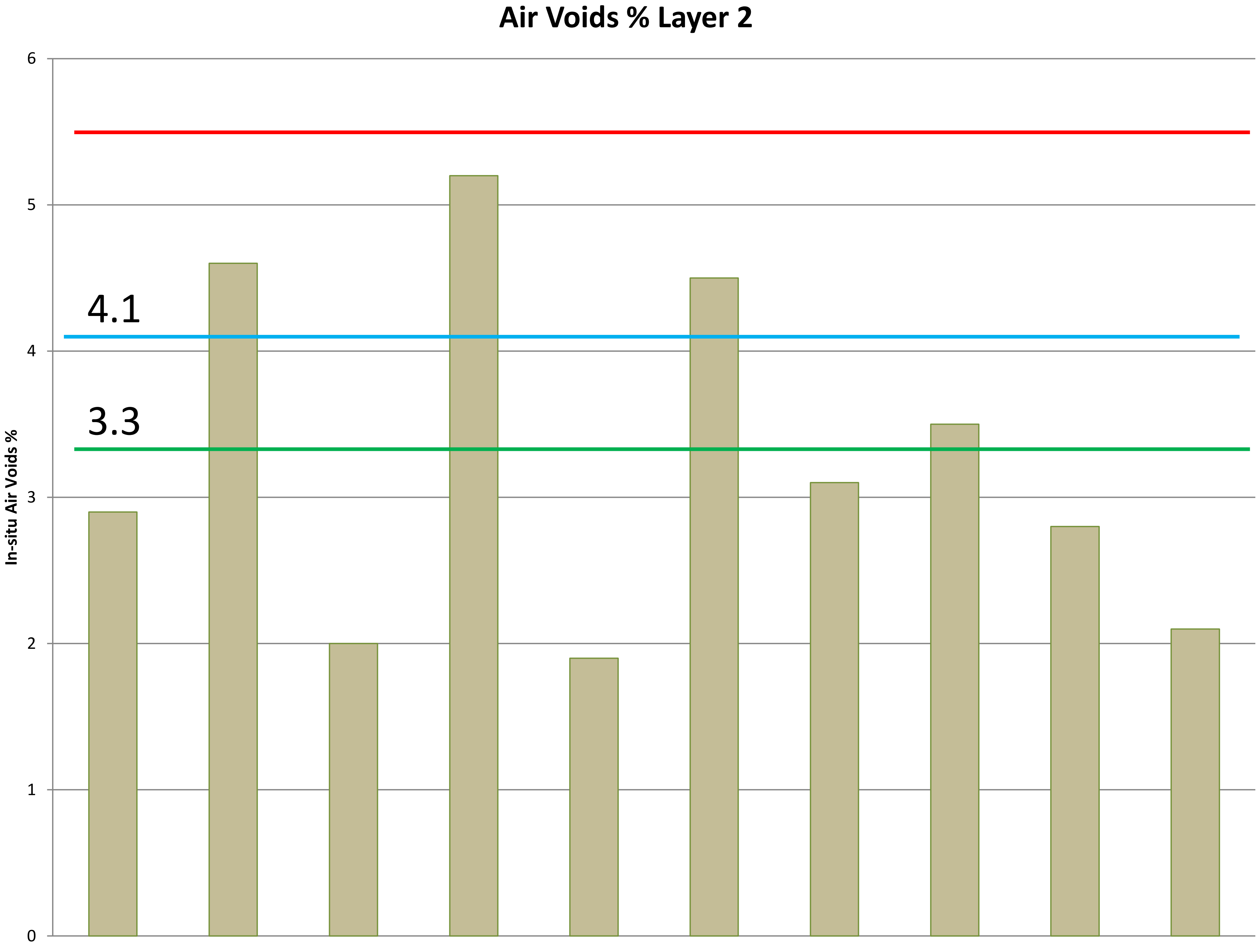
Binder Samples #2

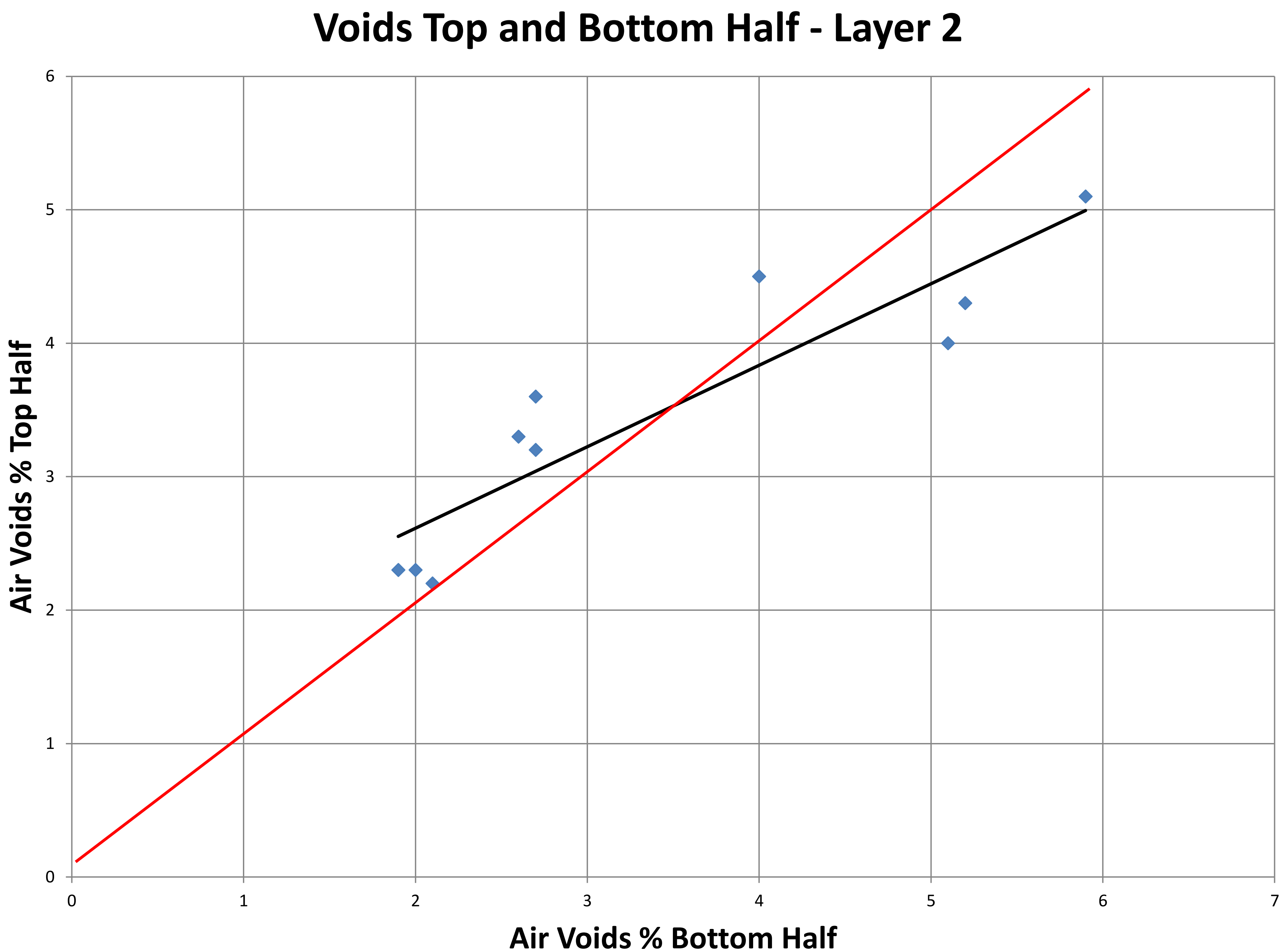
Date	V60	V135	Pen	SP	V60 after RTFO	SP after RTFO
12/4	14781	2.69	18	73	47924	78.5
26/4 am	11019	2.52	19	71	40549	77.5
26/4 pm	10477	2.45	20	71	44074	78
27/4 am	10025	2.31	19	70.5	34444	76.5
27/4 pm	5802	1.87	22	67.5	34827	77

Filler

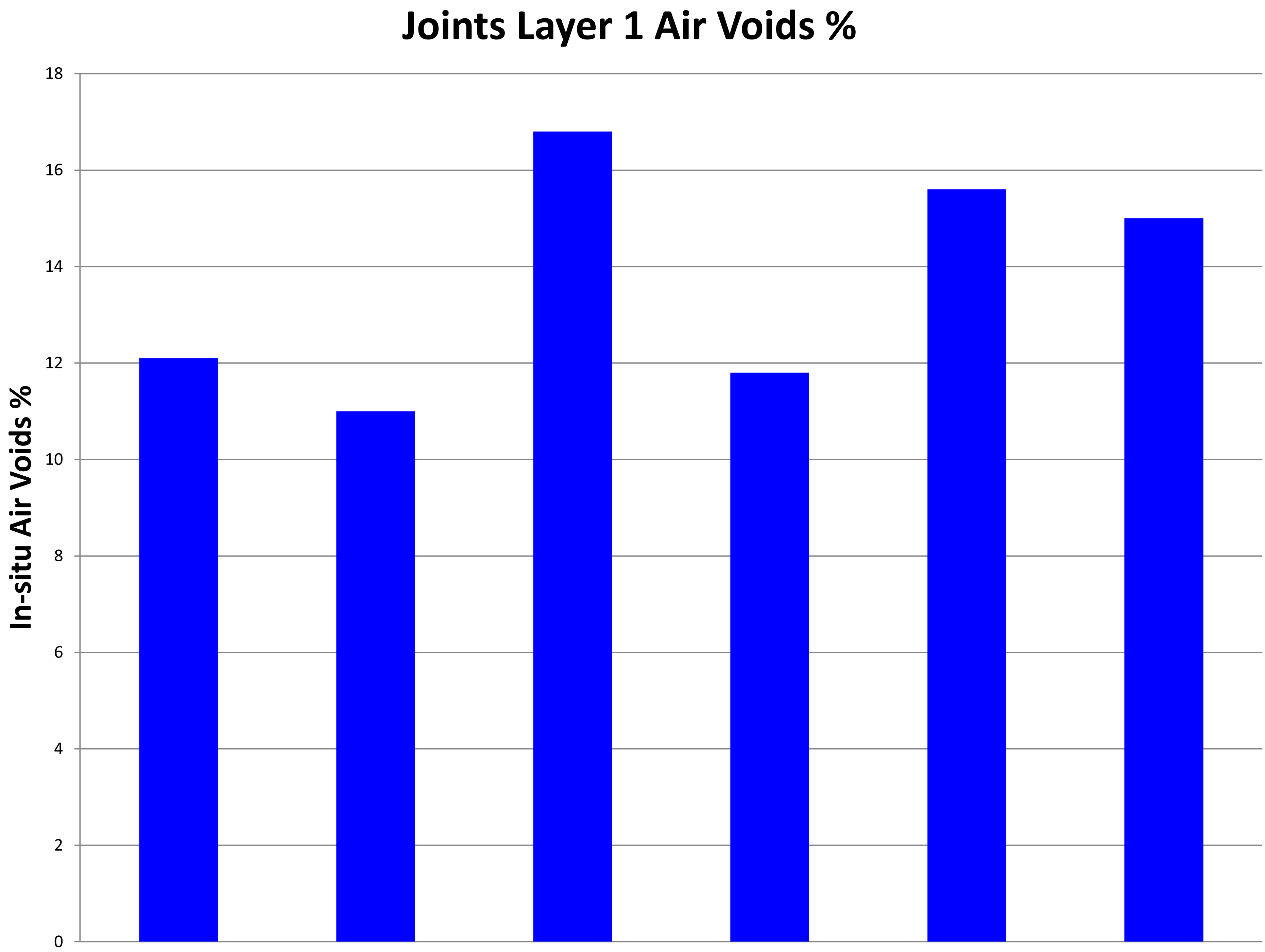
Property	Results	Limits
Voids in dry compacted filler	33 %	28 – 45
Softening point supplied bitumen	72.5 °C	56 - 72
Softening point mastic (bitumen + filler)	76.0 °C	
Delta ring & ball	3.5	8 - 16


Air Voids % Layer 1
In-situ Air Voids %
6
5
4
3
2
1
0
3.7
2.7


Air Voids % Layer 2
In-situ Air Voids %
0
1
2
3
4
5
6
4.1
3.3



Voids Top and Bottom Half - Layer 2
Air Voids % Top Half
Air Voids % Bottom Half
0
1
2
3
4
5
6
0
1
2
3
4
5
6
7



Joints Layer 1 Air Voids %
In-situ Air Voids %
0
2
4
6
8
10
12
14
16
18

Joints Layer 2 Air Voids %
In-situ Air Voids %
0
2
4
6
8
10
12
14
16
18

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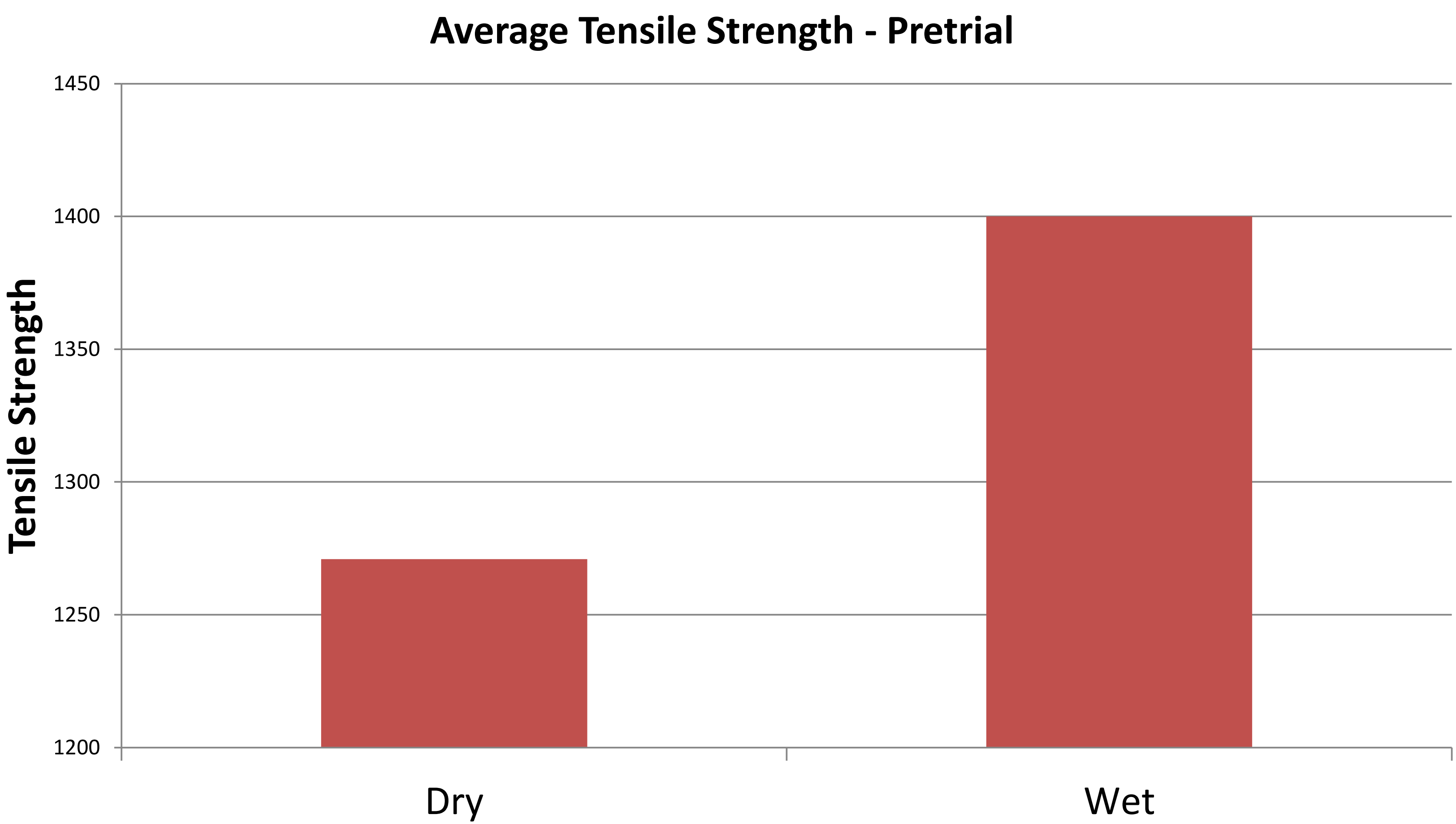
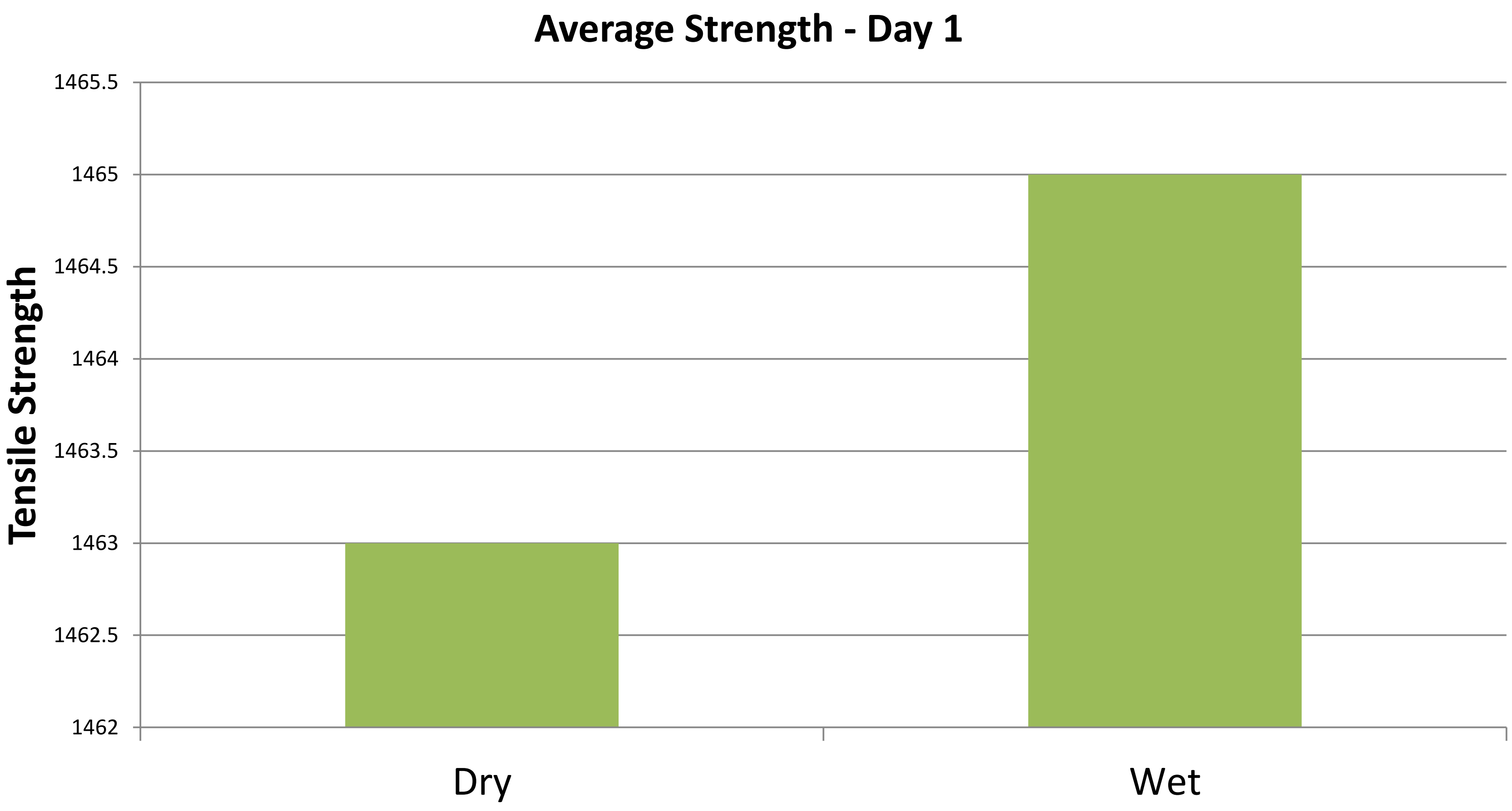
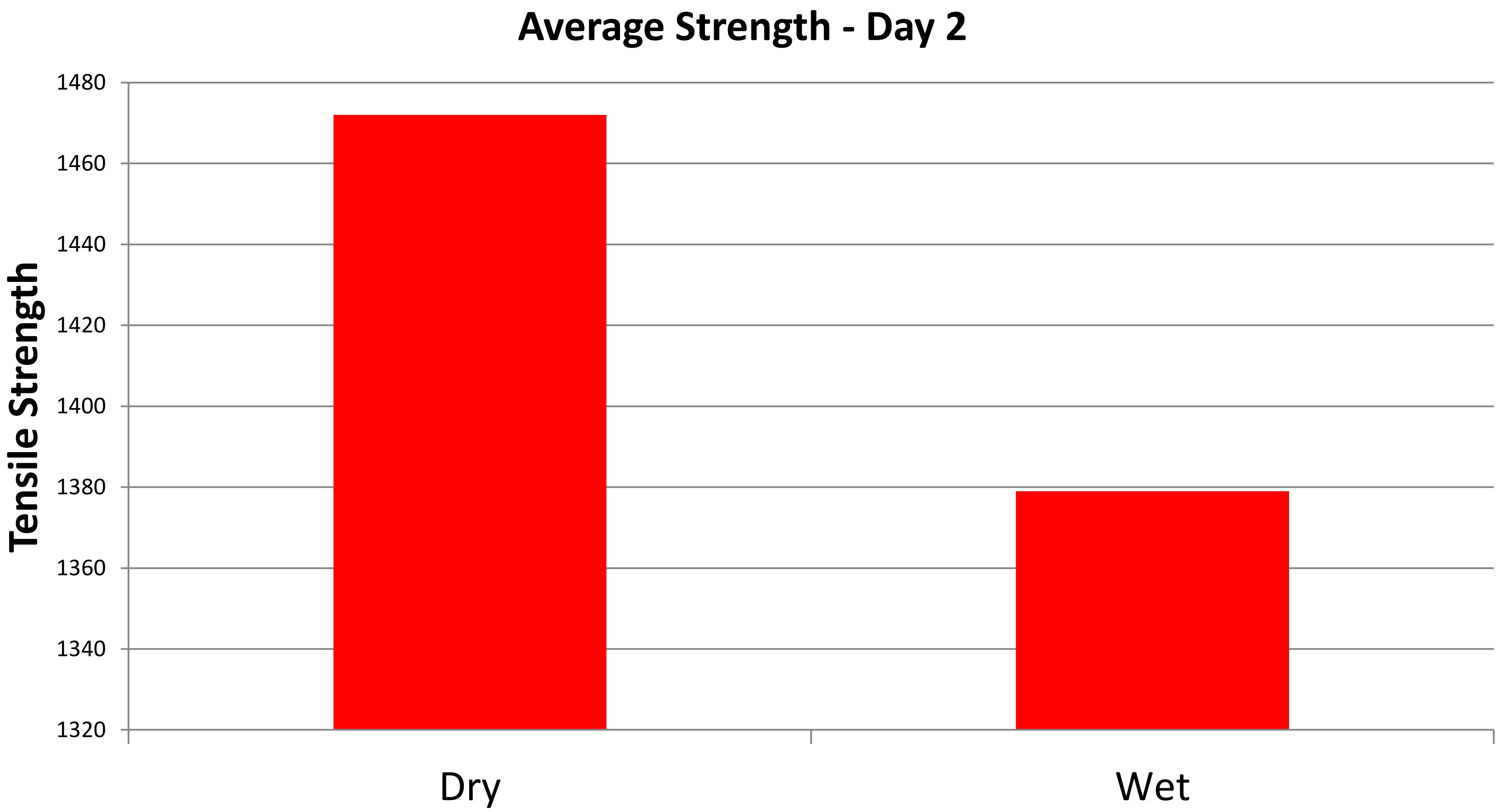
Performance Tests – Moisture Sensitivity



Performance Tests – Moisture Sensitivity

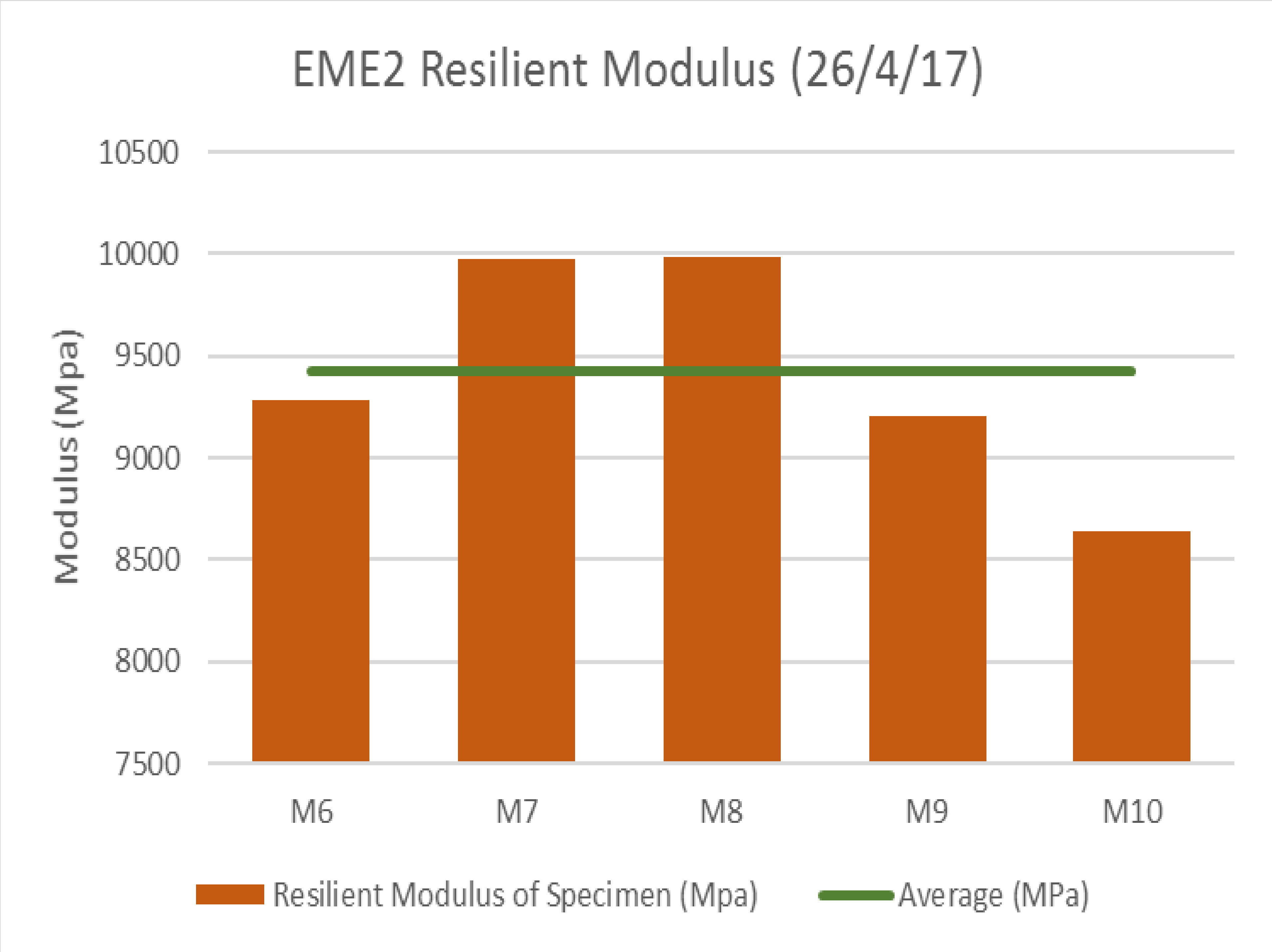


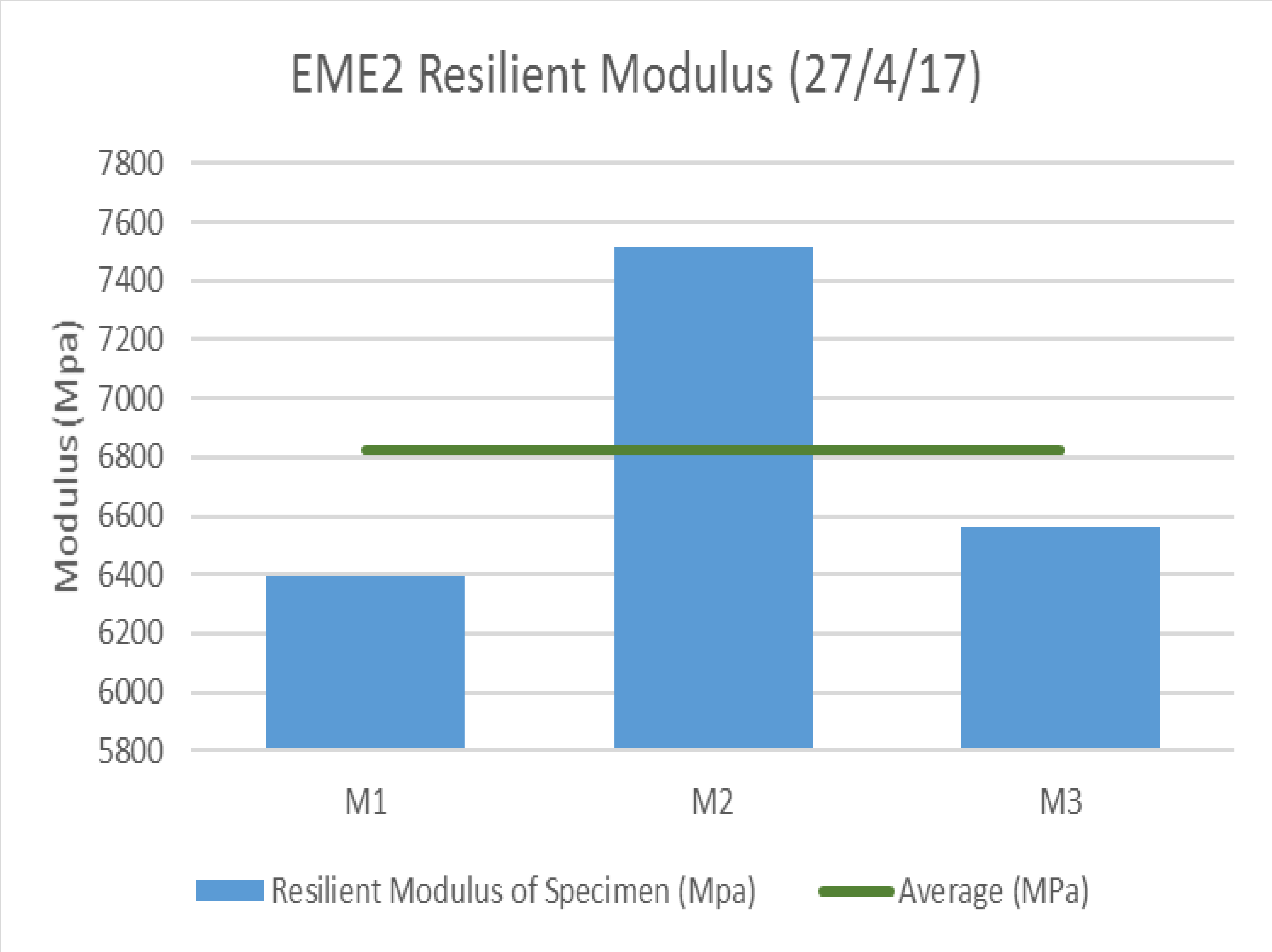
Performance Tests – Moisture Sensitivity

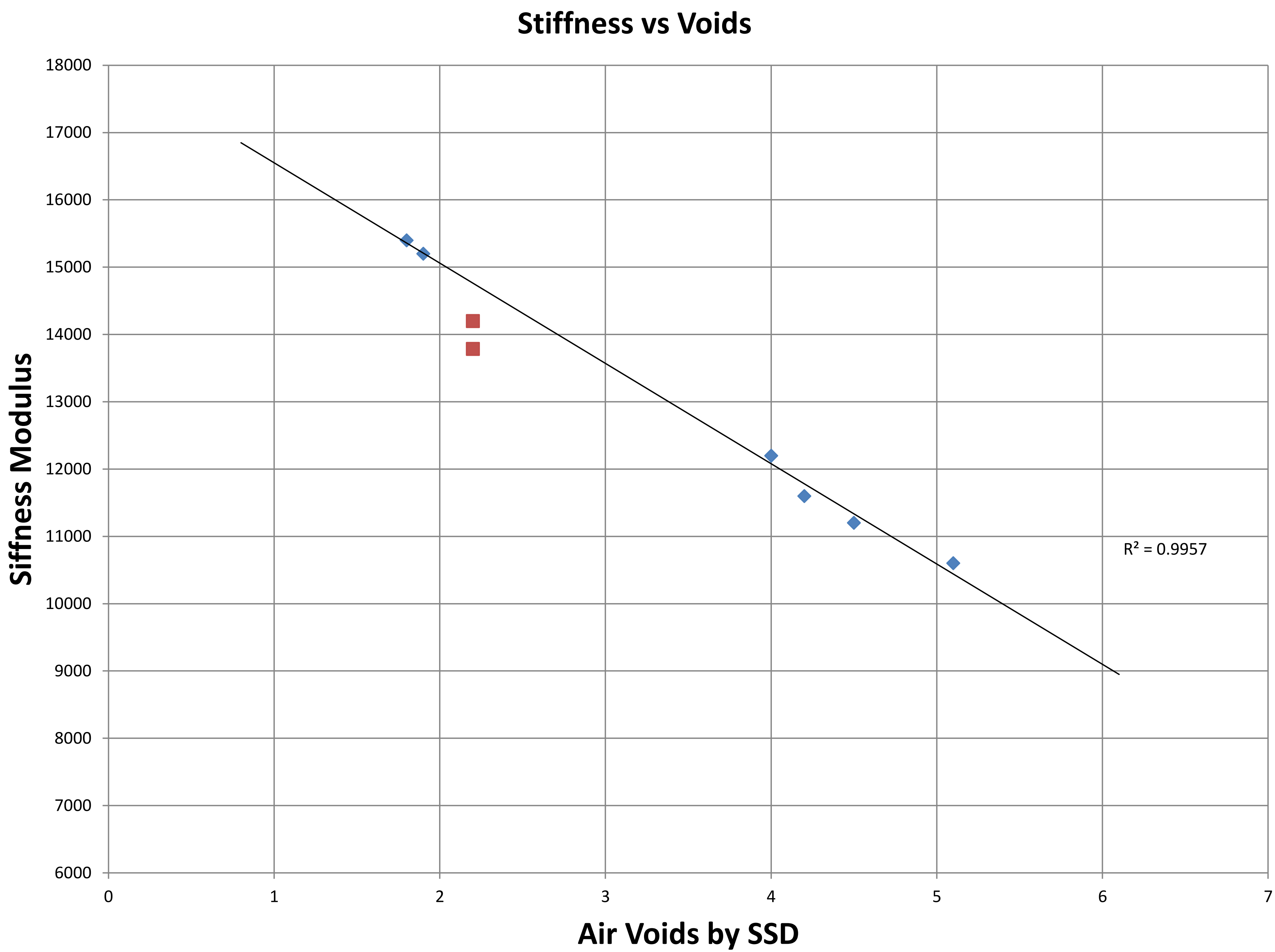


Rutting Data

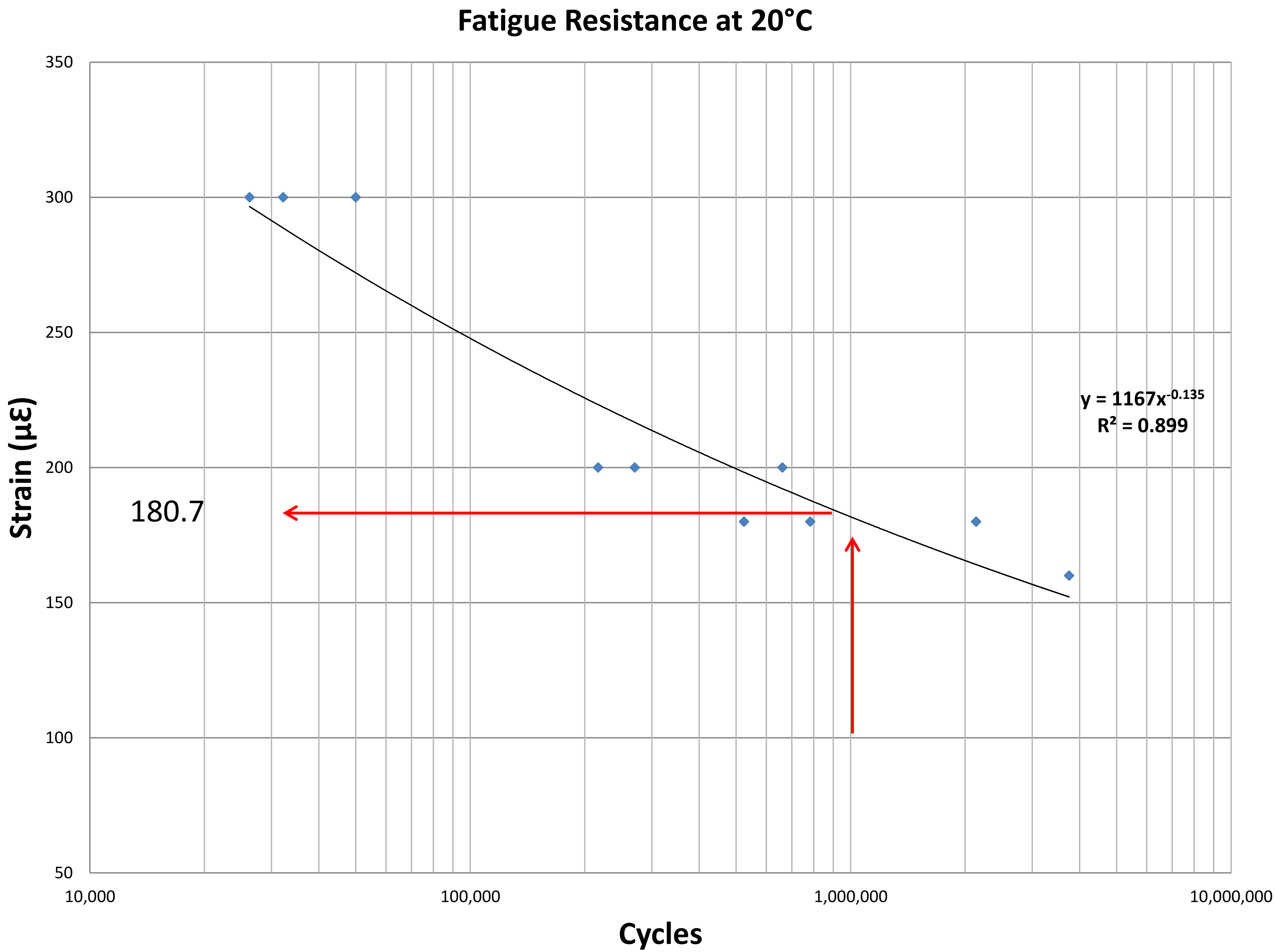
	10,000 Passes	60,000 Passes
Maximum Limit	2.0	4.0
Specimen 1	1.2	1.5
Specimen 2	0.4	0.6


EME2 Resilient Modulus (26/4/17)
10500
10000
9500
9000
8500
8000
7500
Modulus (Mpa)
M6
M7
M8
M9
M10
Resilient Modulus of Specimen (Mpa)
Average (MPa)


EME2 Resilient Modulus (27/4/17)
Modulus (Mpa)
7800
7600
7400
7200
7000
6800
6600
6400
6200
6000
5800
M1
M2
M3
Resilient Modulus of Specimen (Mpa)
Average (MPa)



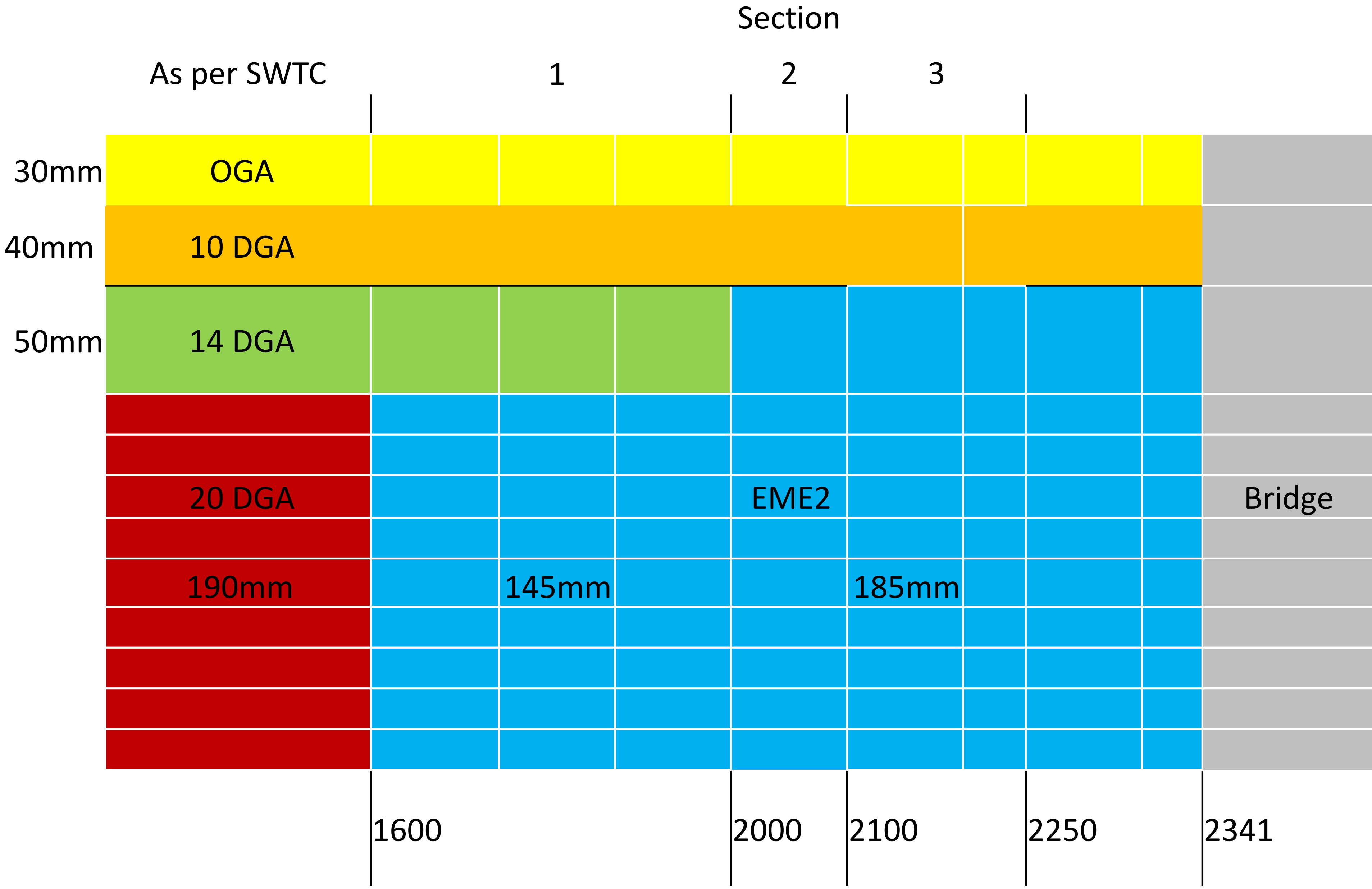
Stiffness vs Voids
Siffness Modulus
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
0
1
2
3
4
5
6
7
R² = 0.9957
Air Voids by SSD



Fatigue Resistance at 20°C
Strain (με)
350
300
250
200
150
100
50
180.7
y = 1167x^-0.135
R² = 0.899
10,000
100,000
1,000,000
10,000,000
Cycles

Lessons

- Handling and Storage of binder
- Construction of Joints
- Specification of Stiffness
- Measurement of Filler Stiffness



Northlink Stage 1

Bridge 1770
Northern
abutment

	Section		
	4	As per SWTC	
Bridge			
	Bridge 1771 South abutment	2700	

Where Next with EME Pavements?

- Northlink Stage 2
- Kwinana Freeway widening
- Mitchell Freeway widening
- Roe Hwy / Kalamunda
- Specification and Design

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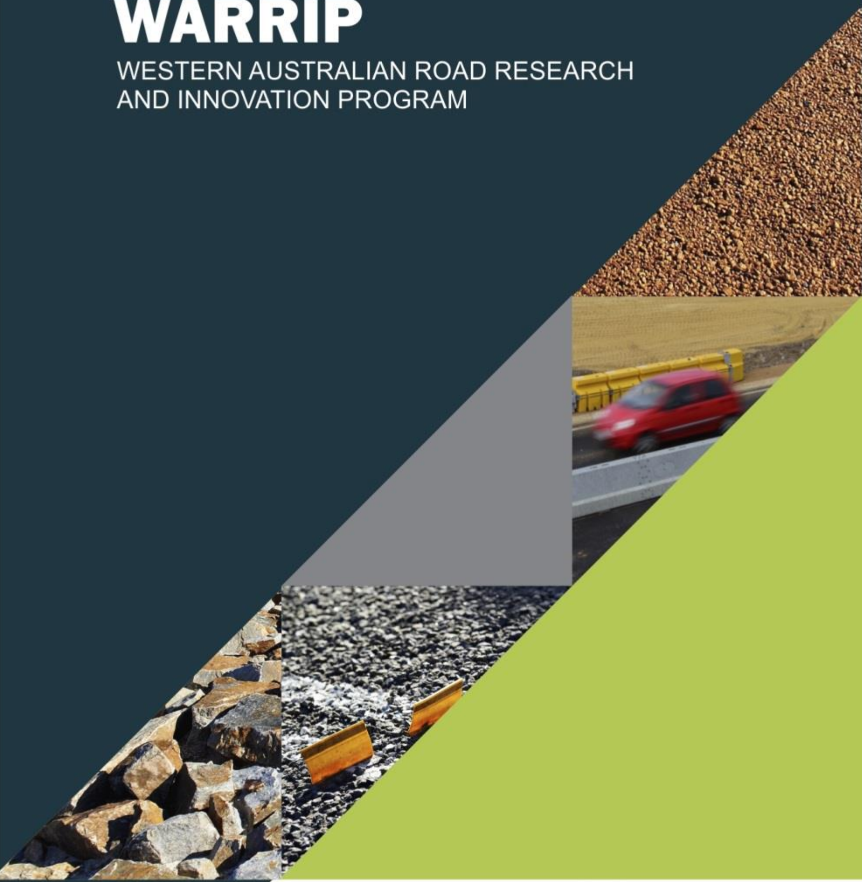

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QUESTIONS

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