ARRB research outcomes and current programs

Dr James Grenfell, Principal Professional

Sustainability and Material Performance

Portfolio Leader - Safe and Sustainable Development

ARRB

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TT1897 Project Outline

Title: National Design Procedures for Lightly Bound Cemented Materials in Flexible Pavements

Key Contributing Staff: Dr James Grenfell, Dr Geoff Jameson, Phil Hunt, Dr Didier Bodin, Danielle Garton, Jun Yan Lu, Dr Michael Moffatt,

Project Timeframe: Aug. 2015 – Dec. 2020

Project Objective:
The purpose of project was to improve understanding of the mechanisms of crack formation associated with Lightly Bound Cemented (LBC) materials and develop Austroads guidance in terms of the pavement design.

Acknowledgements:
Austroads funded project (Transport Infrastructure Program)

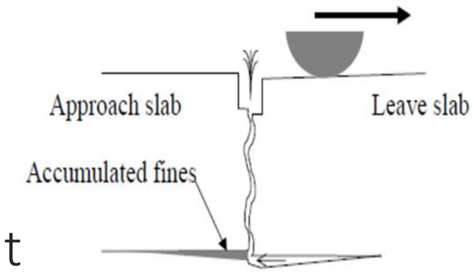
Lightly-Bound Cemented (LBC) Materials

- LBC are granular materials with moderate amounts of stabilising binder to improve modulus
- It is common practice to categorise LBC materials with a 28-day UCS of 1.0 to 2.0 MPa
- Road agencies have identified the potential to increase the use of granular bases treated with 1–2% cementitious binders
- Improves rut resistance and stiffness when used with thin bituminous surfacings
- LBC bases have shown good performance (no block or crocodile cracking) if appropriately designed and constructed

Properties and design requirements

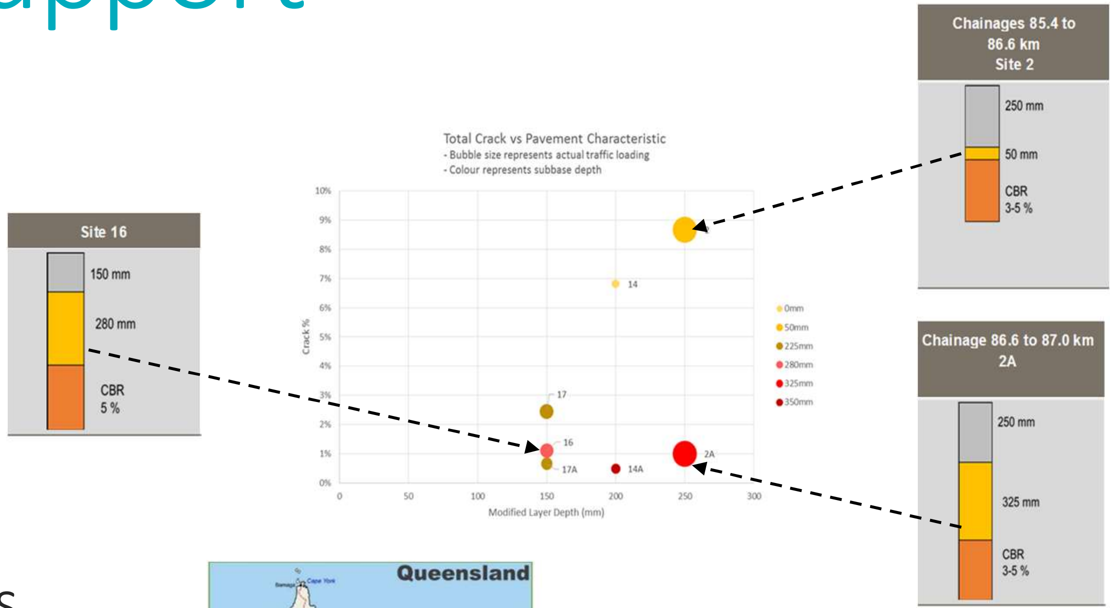
- LBC are susceptible to shrinkage and fatigue cracking, but different cracking from heavily bound materials
- LBC have low strength not economic to design to inhibit fatigue cracking. No need for an LBC fatigue relationship

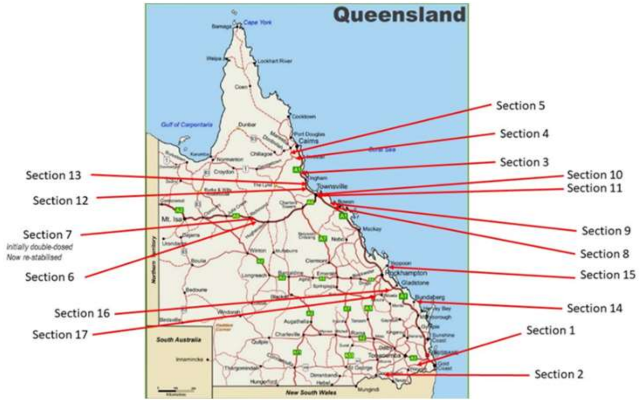
- Need a method to determine LBC design moduli
- <u>LBC bases</u> need to be designed to inhibit the development of macro-cracking from fatigue-induced micro-cracking
- <u>LBC subbases</u> may not need to be designed to inhibit the development of macro-cracking



Effect of subbase support

- Understanding in-service performance is important, in particular the propensity of LBC bases to crack
- Understand total crack length versus LBC base thickness
- Underlying subbase depth affects performance





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Mimicking field behaviour in the lab

- The Extra-large wheel tracking (XL-WT) device was used to replicate field behaviour
- The XL-WT was used to apply heavy wheel loading to LBC slabs to induce cracking
- After trafficking slabs were investigated to determine cracking characteristics

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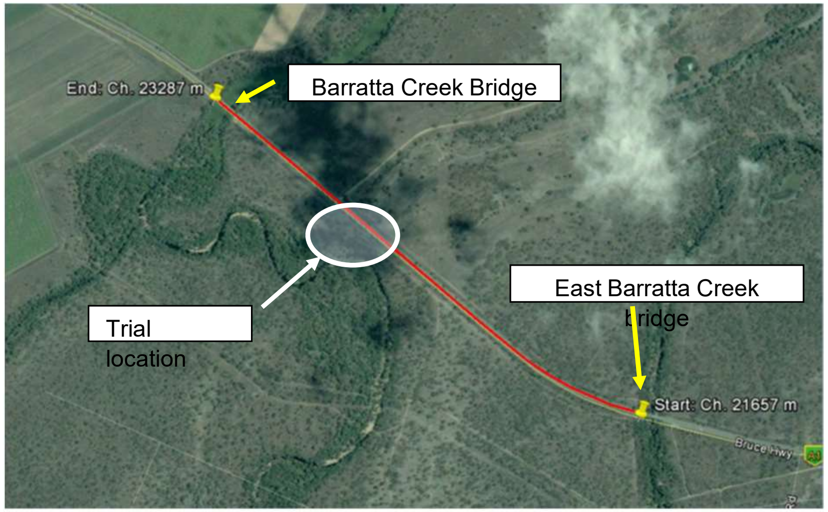
Field Trial Sites

Barratta Creek - 100 m section of Bruce Highway between Ayr and Townsville

- 250 mm of in-situ cement stabilisation with 2% type GB cement content
- Pavement constructed in March 2017 and surface deflections were monitored over first year of opening to traffic



Sprayed seal
250 mm Cement treated base
300-320 mm Sandy Gravel Subbase
Subgrade – Sandy Clay

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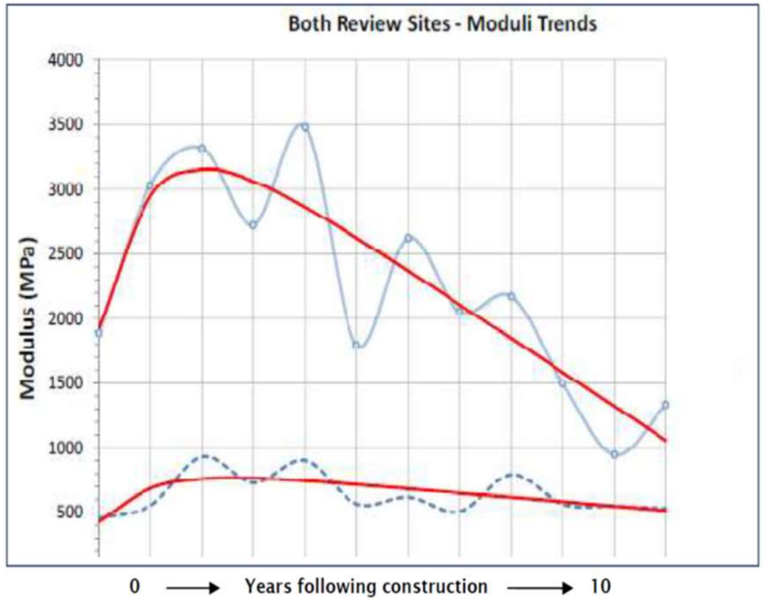
Maximum cracked LBC modulus

- Host materials base or upper subbase quality (e.g. CBR ≥ 30%)
- Proposed maximum vertical modulus of 600 MPa, horizontal 300 MPa based Australian and NZ back-calculated moduli
- No sublayering



ME design method for LBC materials

When designed to inhibit macro-cracking:

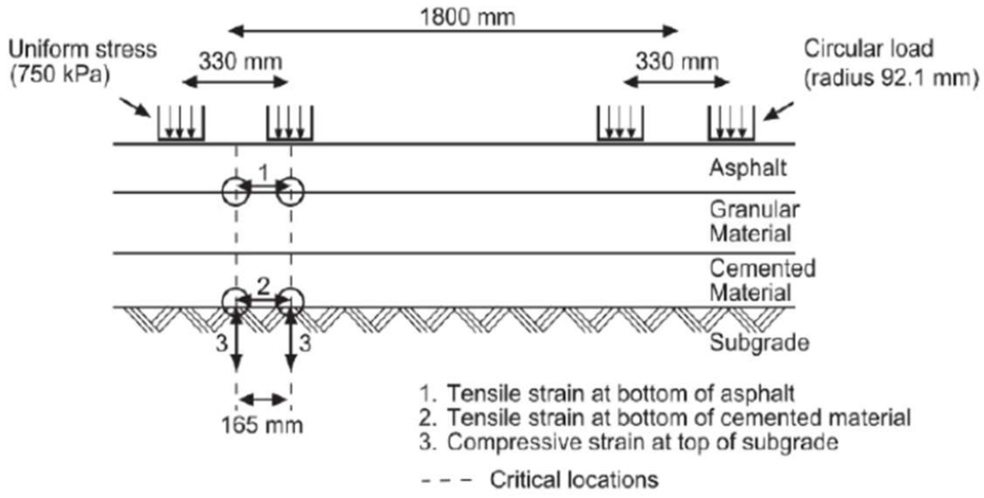
- Consider minimum layer thickness
- Consider minimum support to the LBC layer

Select a trial pavement composition

Determine LBC moduli in cracked state

Follow Austroads ME method to determine:

- Allowable traffic loading in terms of permanent deformation
- Allowable traffic loading in terms of asphalt fatigue cracking



Final outcome

- Improvement in design method, leading to potential thickness reductions
- Queensland Department of Transport and Main Roads (TMR) is considering the outcomes of the project for new and rehabilitated pavements
- TMR is planning to publish an update of its Pavement Design Supplement - that incorporates the new design method recommended by this project

Context

Suite of projects - Improving the Design and Performance of Foamed Bitumen Stabilised Pavements

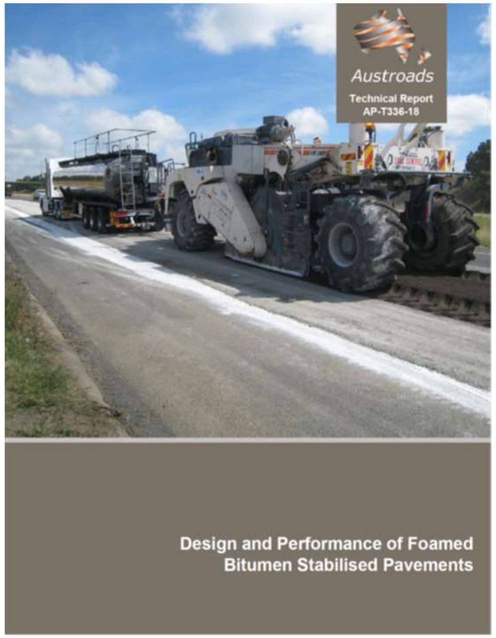
TT1825 Mix Design and Field Evaluation of Foamed Bitumen Stabilised Pavements

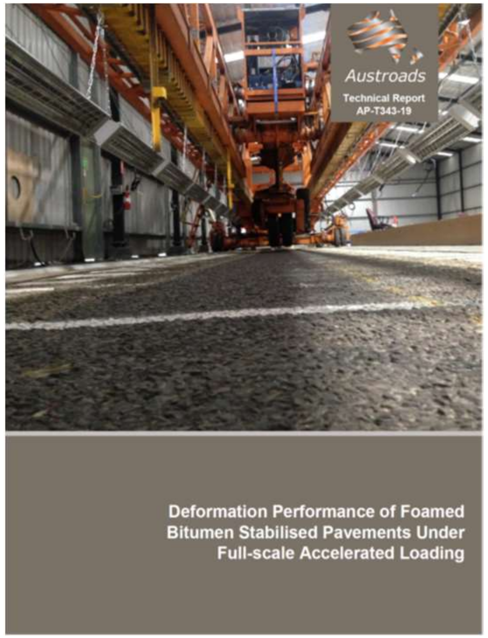
TT2046 Improving the Cost Effectiveness of Foamed Bitumen Stabilised Pavements

a) Deformation

b) Fatigue

APT6157 Maximising the use of sustainable rehabilitation treatments





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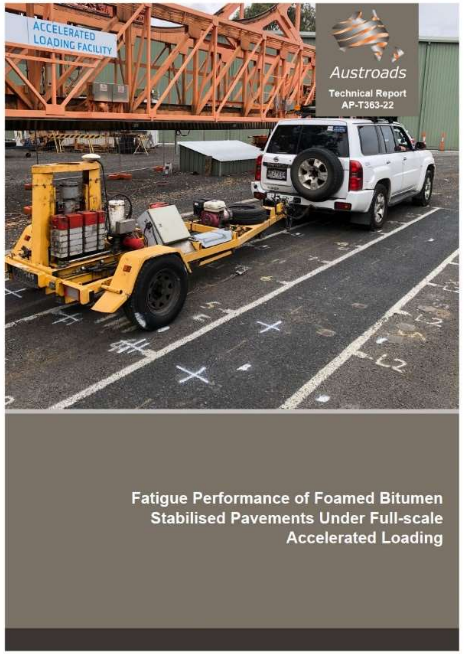

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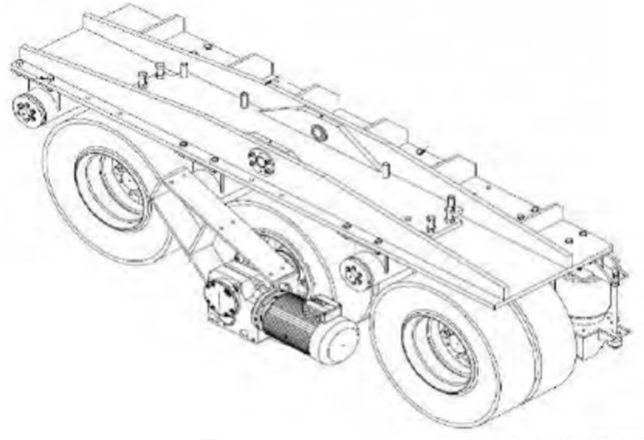
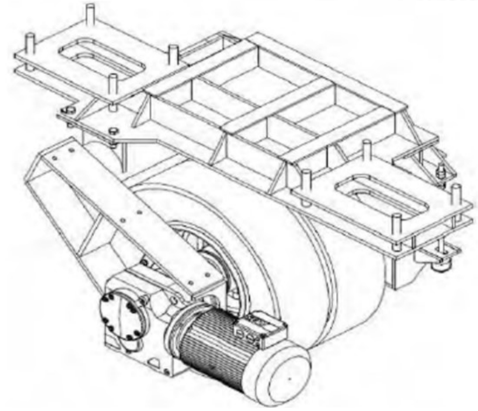
Deformation of FBS with high RAP content

ALF full-scale pavement testing (Austroads TT2046)

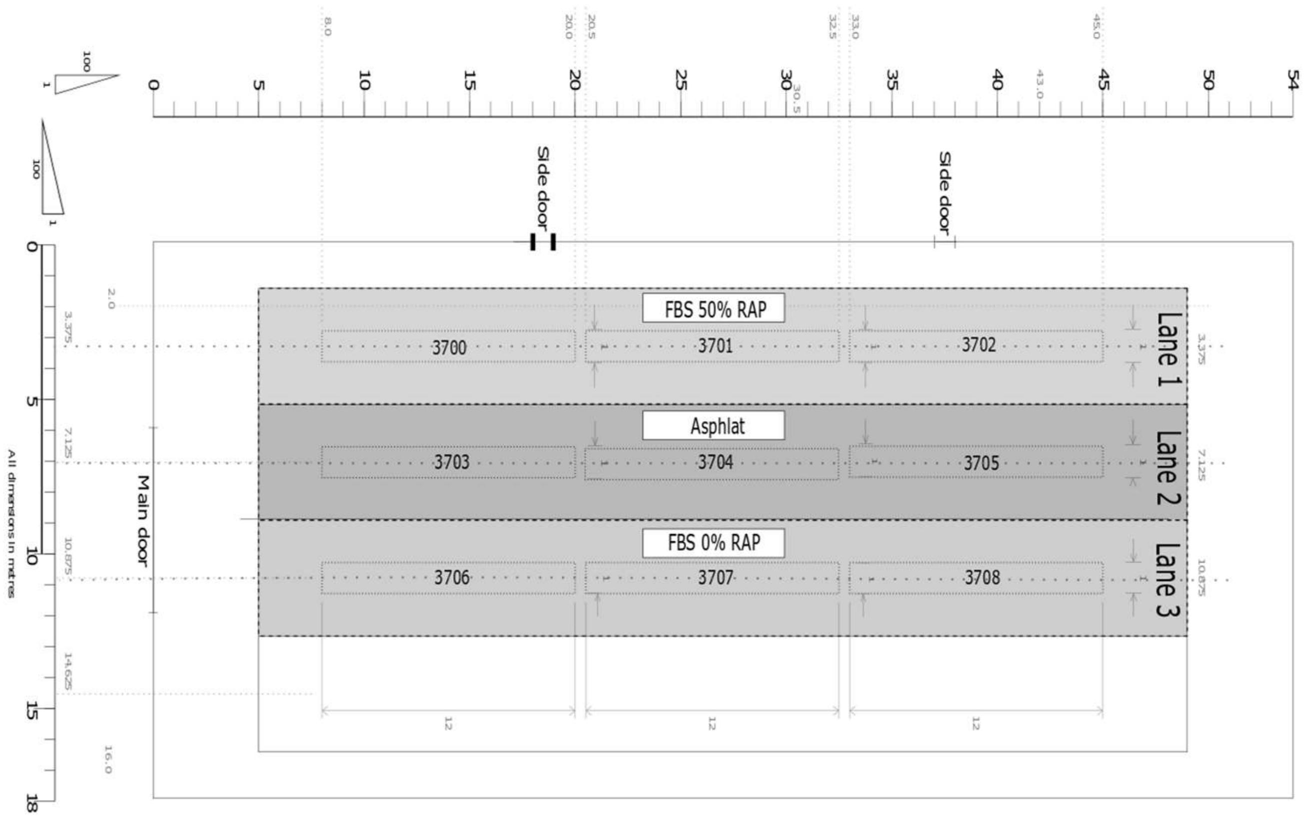
- 12 m x 3.75 m test sections
- Load up to 80kN (single, tandem and triaxial)
- Controlled loading & climatic condition

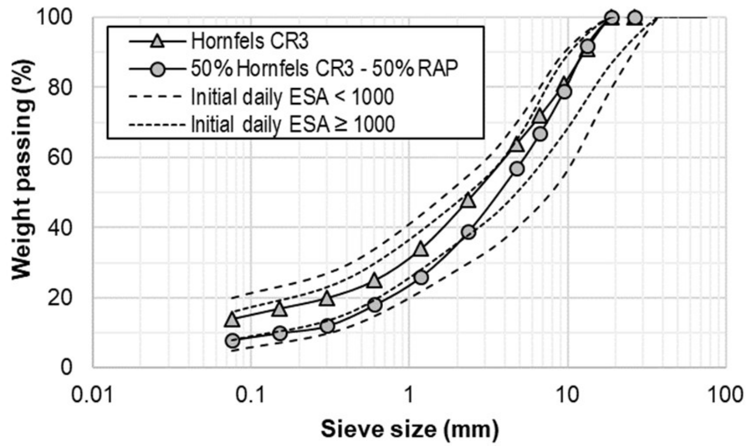




Load type: dual wheel, single axle
Total load: 50 kN

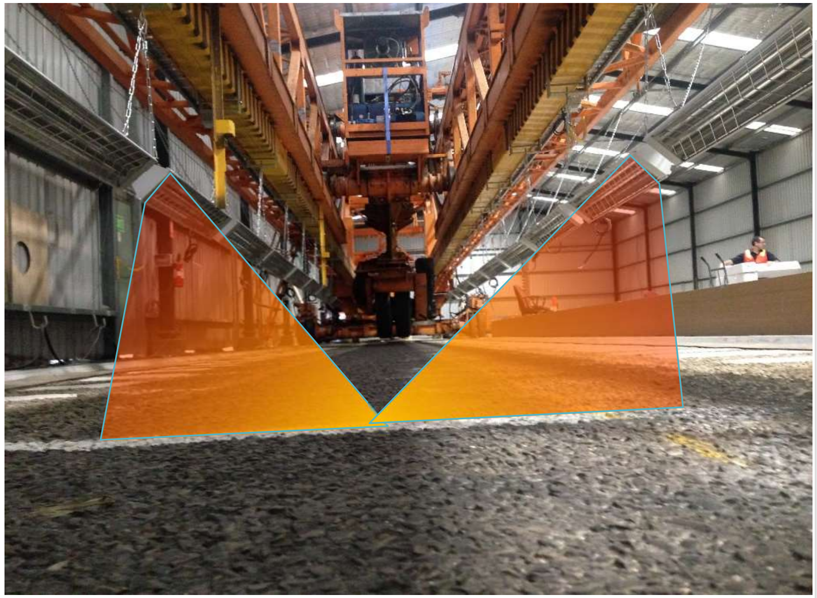
Experimental design

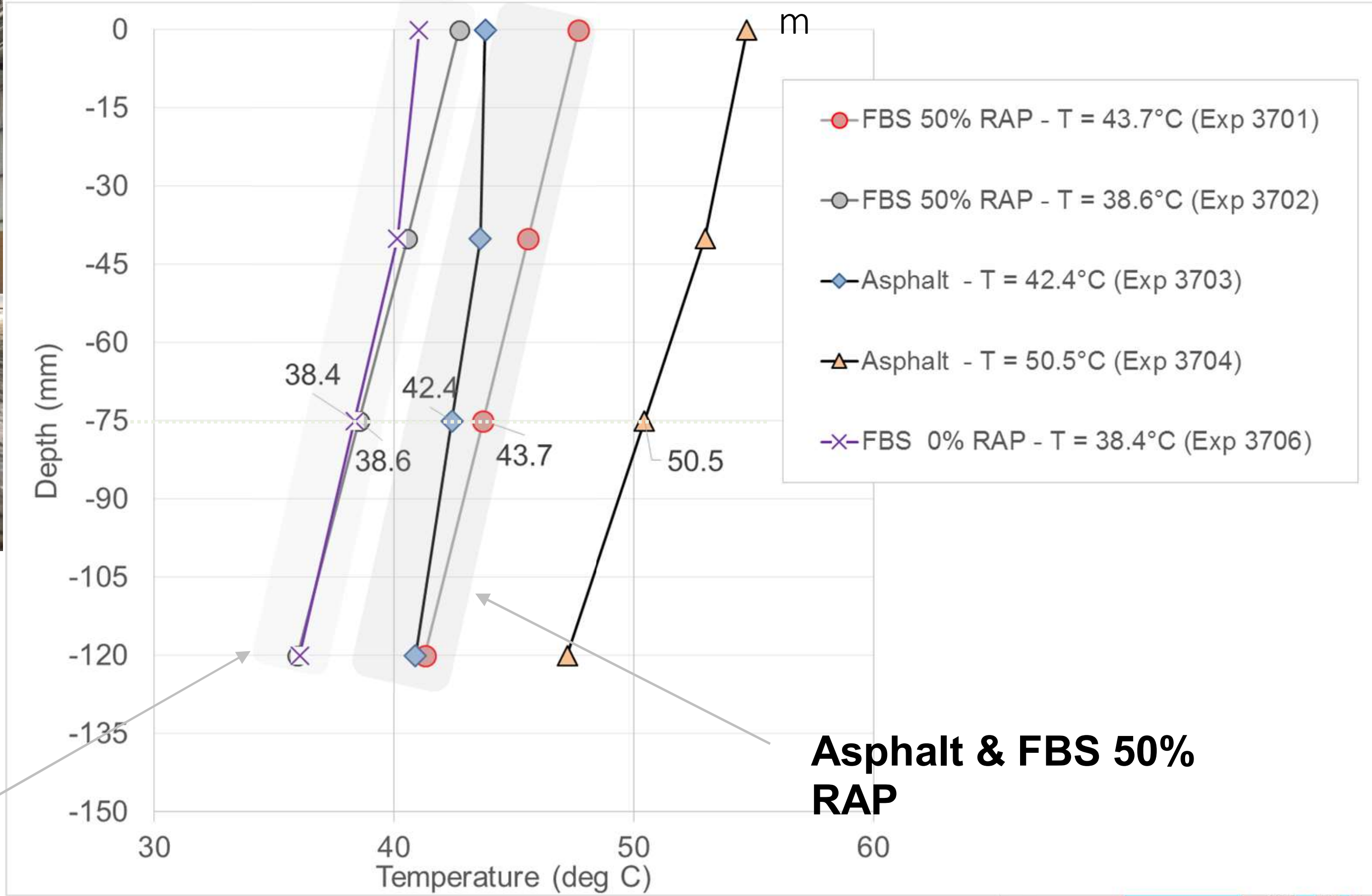




Simulated Climatic Conditions

Mid-depth 75mm/150mm

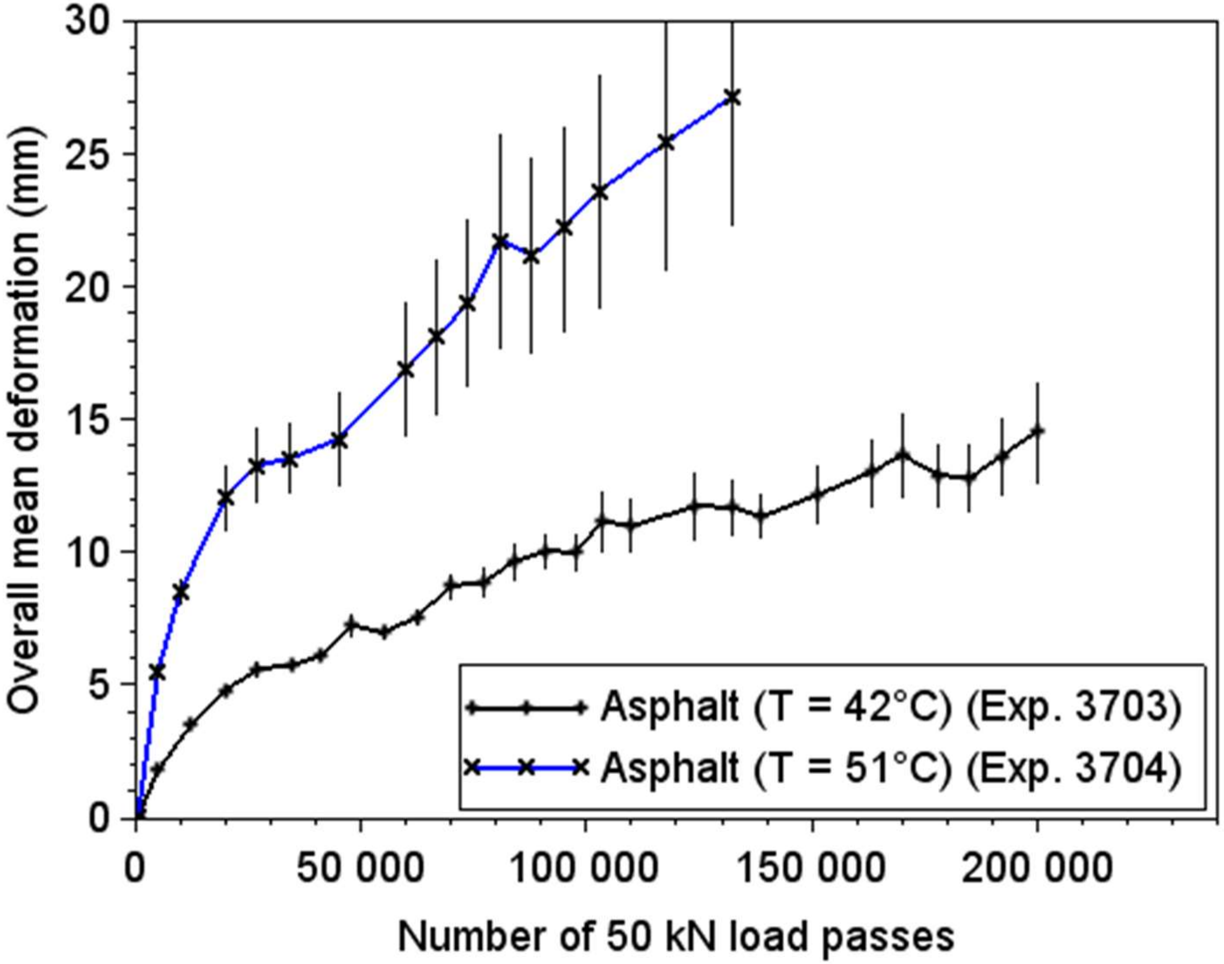


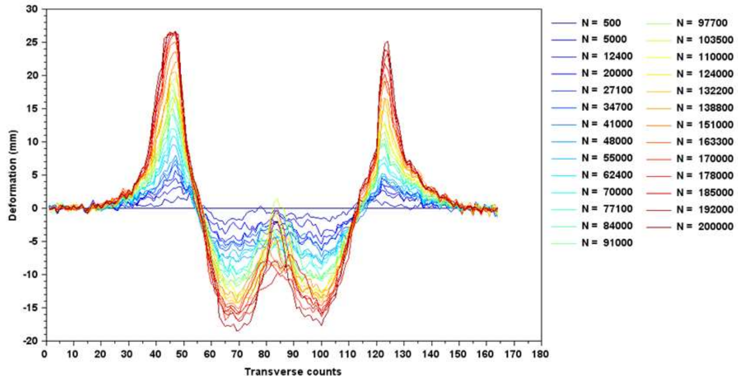


FBS 50% RAP

Effect of Temperature on Performance

Asphalt control test sections





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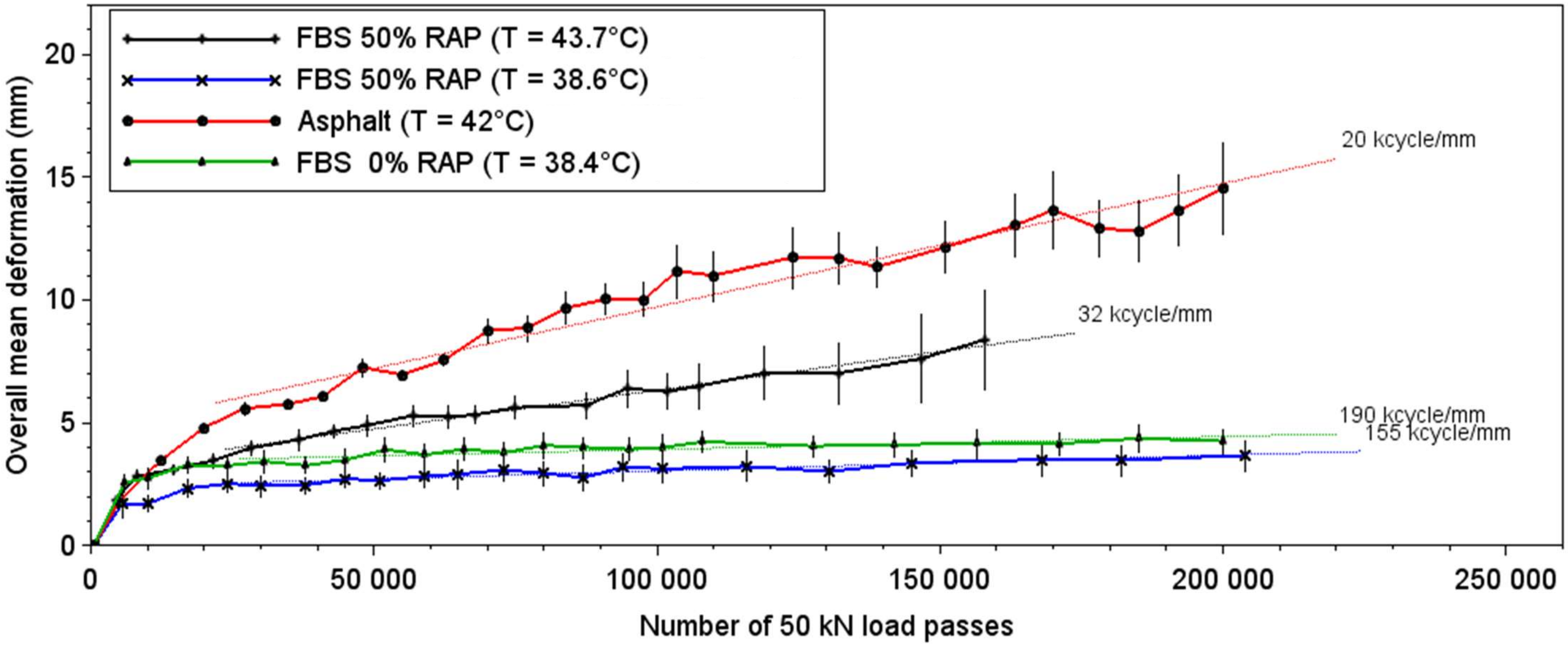
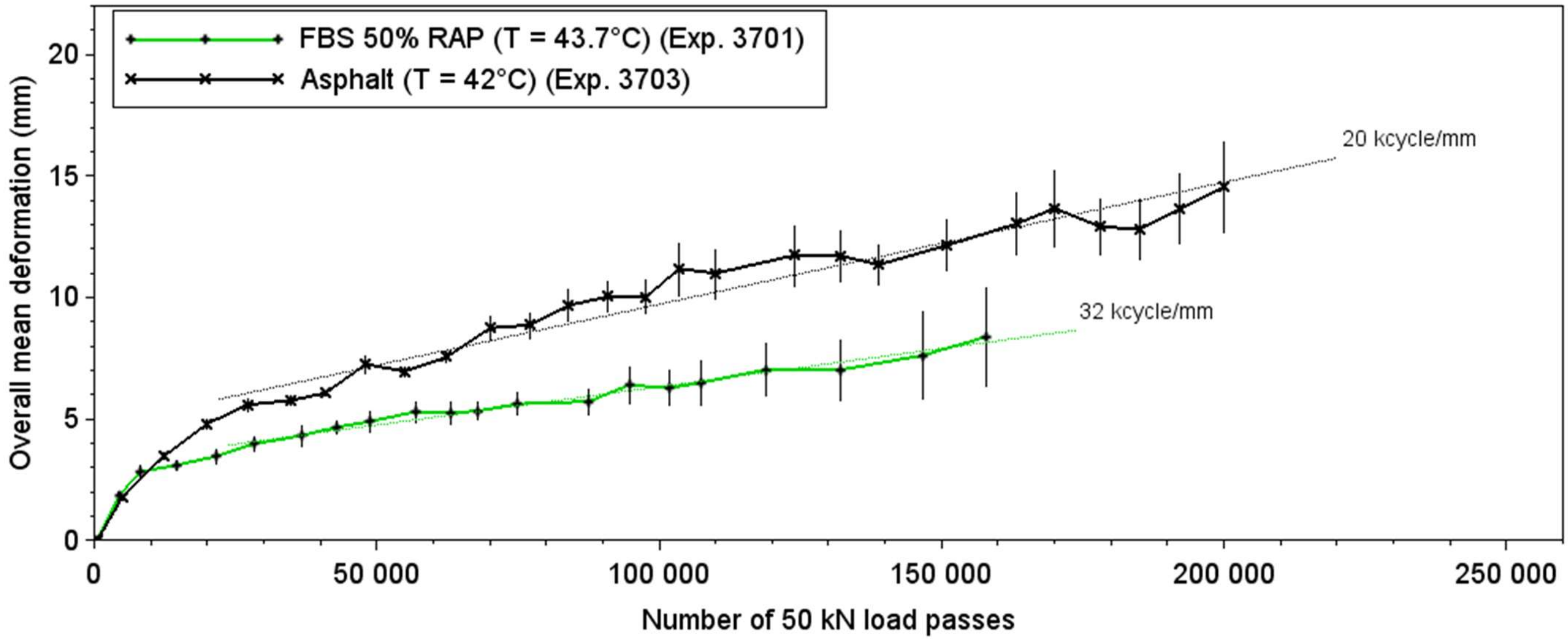
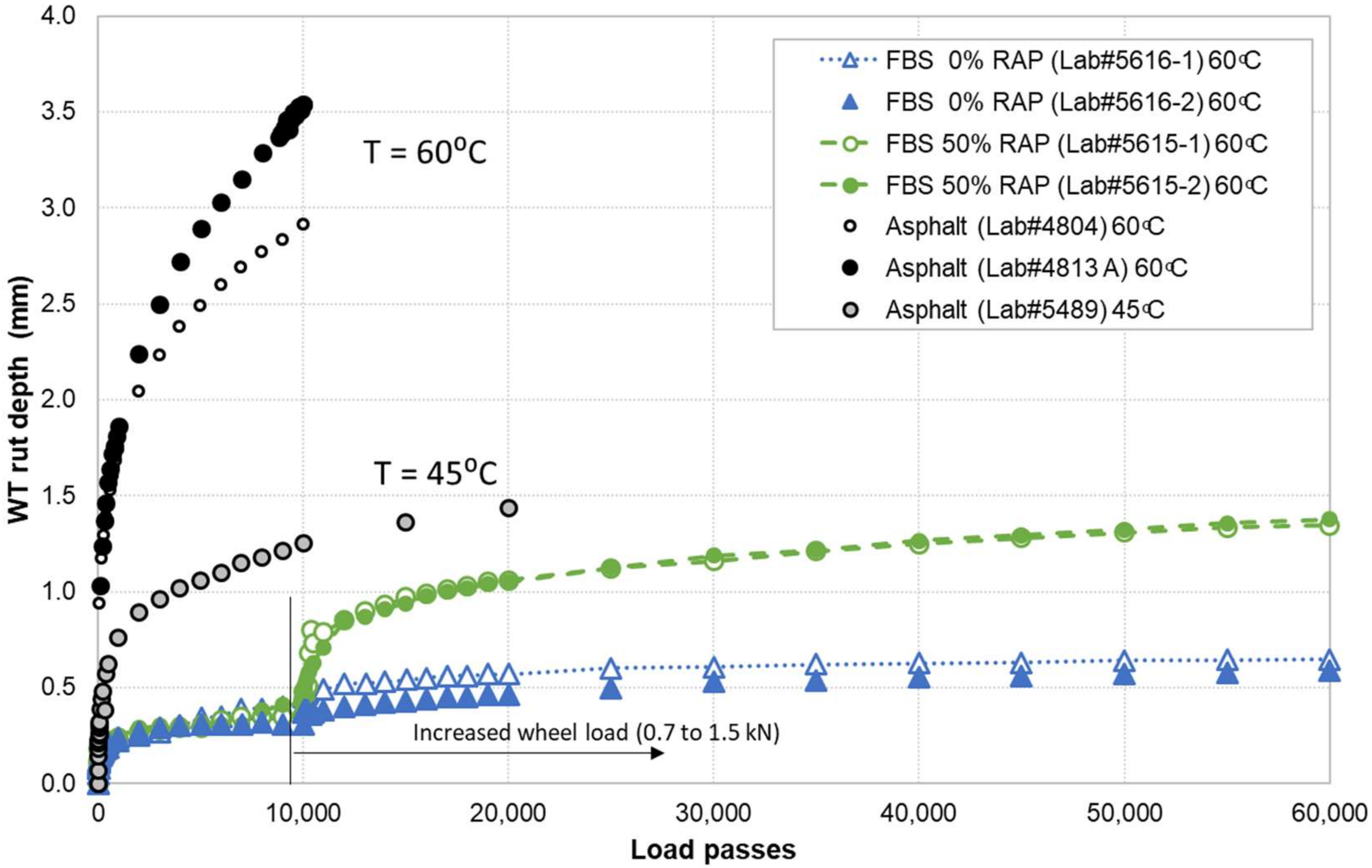
Overall Performance Results



FBS with 50% RAP vs Asphalt



Laboratory Wheel-tracking Performance



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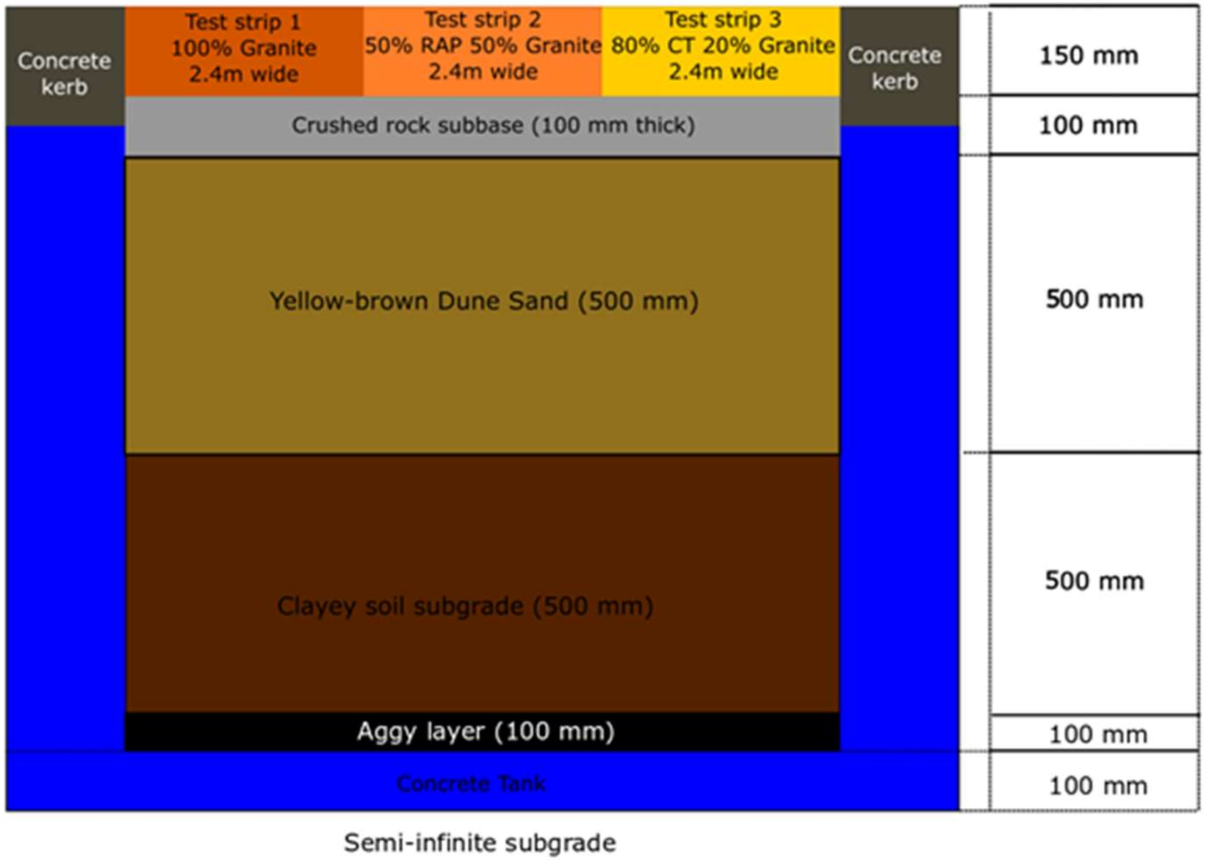
ALF Fatigue Pavement

Test pavement structure



Materials

3 lanes constructed

Test strip	Material
1	Mix 1: Control, 100% Class 3 Granite crushed rock
2	Mix 2: 50% RAP, 50% crushed rock
3	Mix 3: 80% Cement Treated, 20% crushed rock

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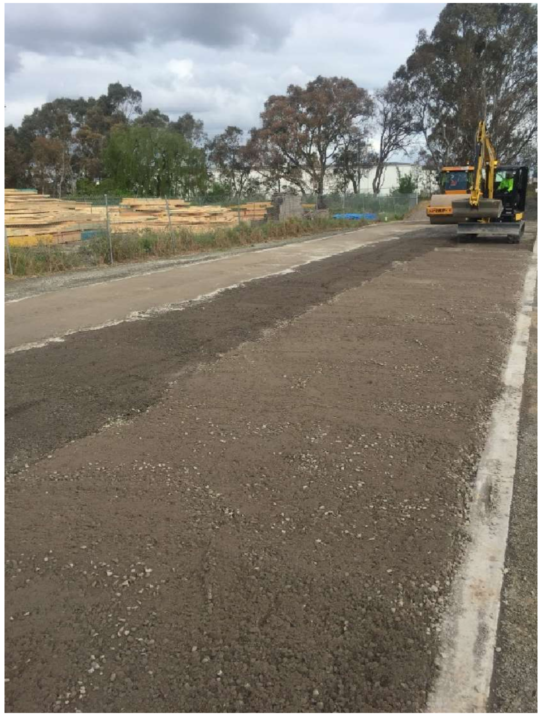
Paving materials





Stabilisation

Preparation for Trafficking

Positioning of ALF

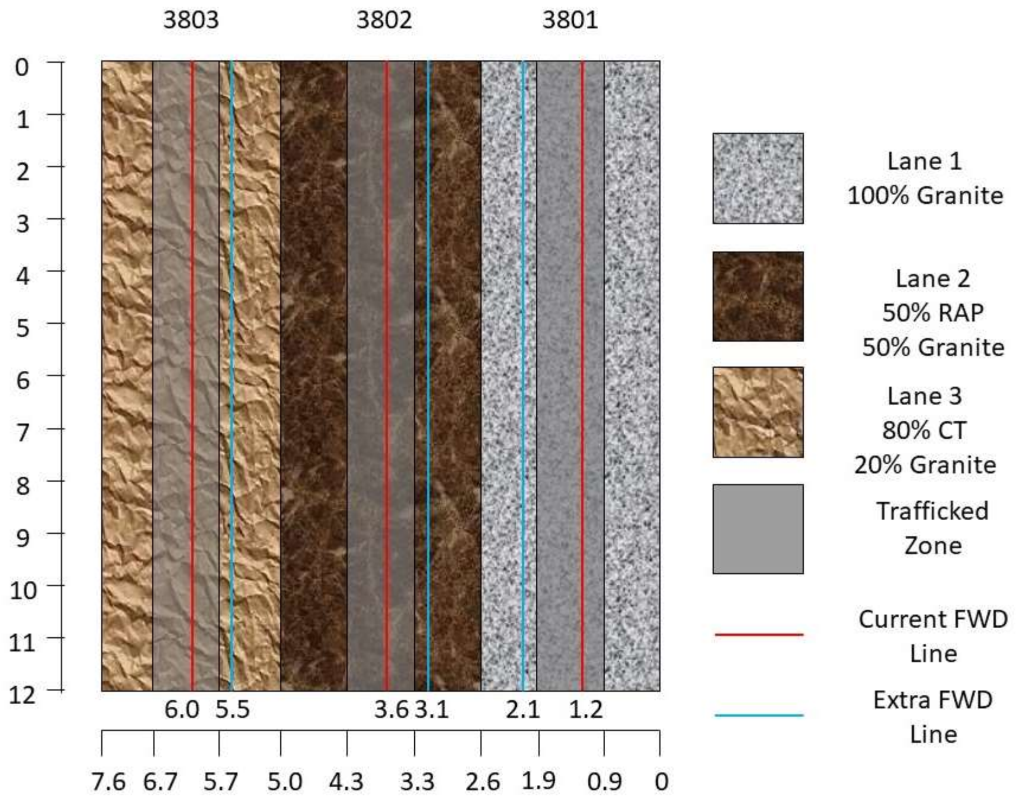
Trafficking

Cycles in each lane

Experiment	3801	3802	3803
Lane	Lane 1	Lane 2	Lane 3
Material	100% Granite	50% RAP/50% Granite	80% CT/20% Granite
Current cycles	1,403,000	1,403,000	883,300
Next cycling period	Complete	Complete	Complete
Monitoring carried out at	0, 500, 10000, 30000, 60000, 178000, 286000, 395000, 500000, 607000, 700000, 799000, 954000, 1092000, 1193000, 1353000, 1403000	0, 500, 10000, 30000, 60000, 172000, 286000, 430000, 500000, 646000, 800000, 911000, 1013600, 1114000, 1242000, 1403000	0, 500, 10000, 30000, 60000, 178000, 286000, 420000, 500000, 600700, 717000, 883300

FWD

FWD to monitor damage and continued curing



Pavement Failure Investigation

Post-trafficking

Pavement Investigation

- Test pavement trenching (29/03/2020)
- Analysis failure mechanism(s)
- Coring
  - *Trafficked*
  - *Untrafficked areas*

- Granular and subgrade evaluation
  - *Moisture content*
  - *Subgrade in-situ CBR*

Laboratory Characterisation

- Cores resilient modulus testing

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Post-trafficking failure investigation

Trenching

Fatigue Performance of Cemented Materials under Accelerated Loading – Influence of vertical Loading on the Performance of Unbound and Cemented Materials
Austroads Project No. TT1065
Austroads Publication No. AP–T102/08 - Richard Yeo

Trench faces investigation

Observations

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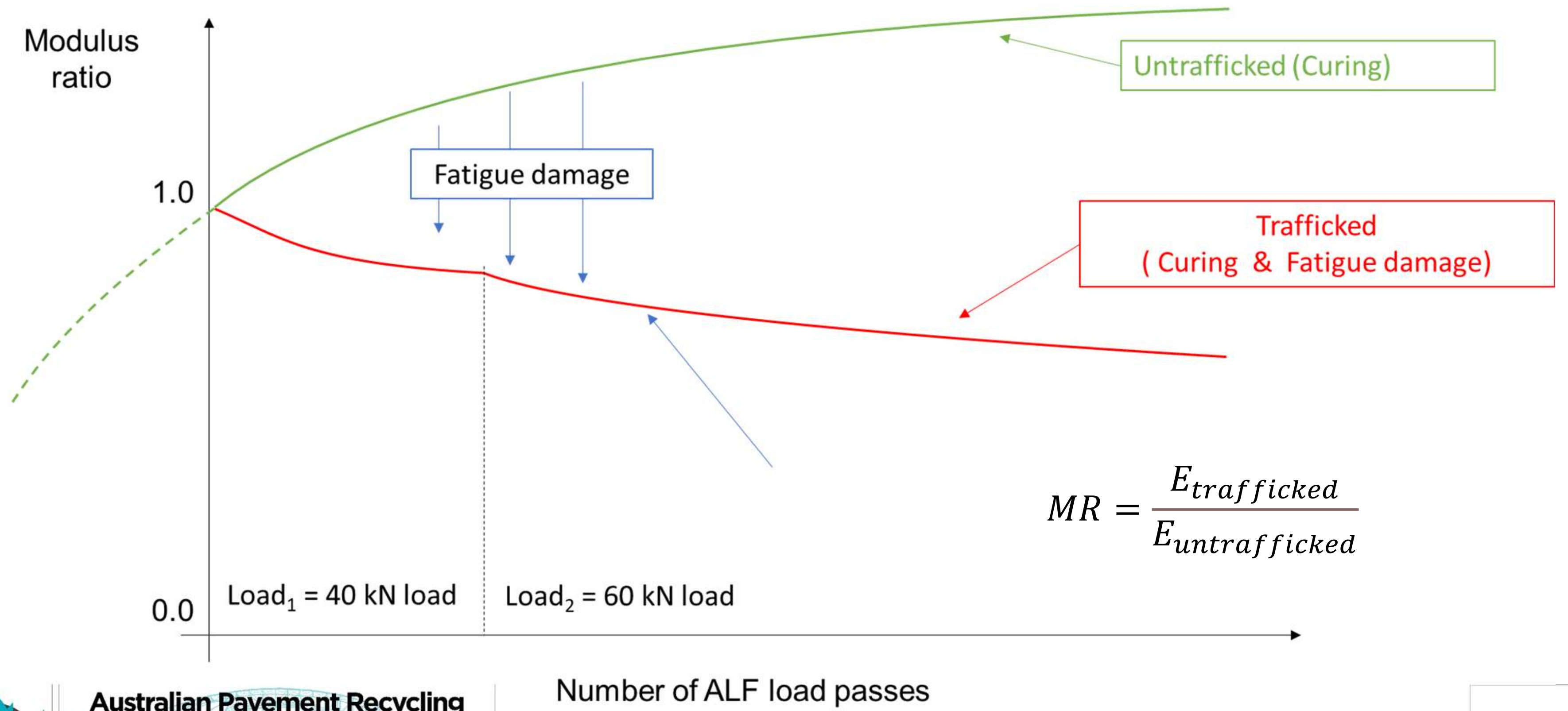
Damage Analysis

Curing vs load induced damage



$$MR = \frac{E_{trafficked}}{E_{untrafficked}}$$

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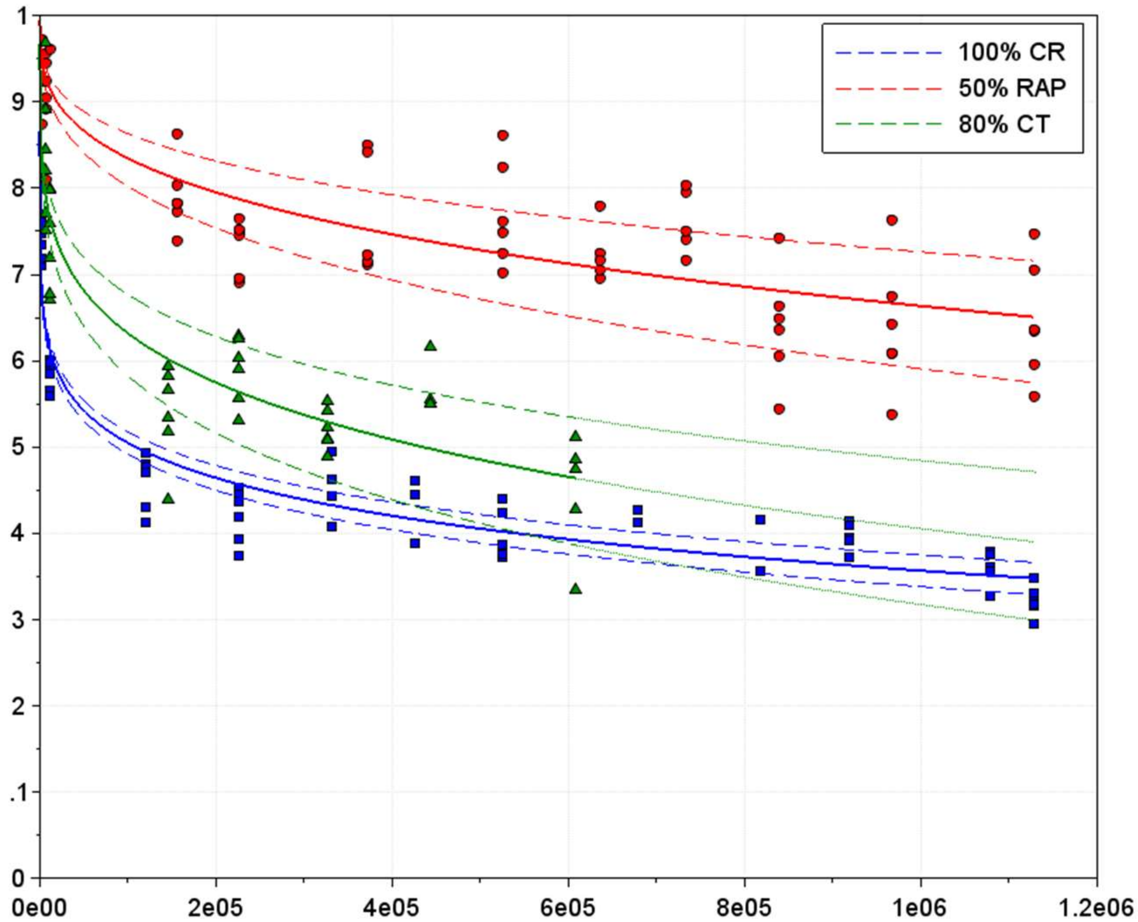
Damage Analysis

Preliminary analysis results



Summary

Overview

Permanent Deformation

Foam bitumen stabilised base performs well.

Good early life and long term performance

Incorporation of up to 50% RAP still performs

Fatigue Cracking

- Pavement Investigation
  - Subgrade conditions confirmed
  - Distress mechanism identified
  - Analysis based on back-calculated moduli
    - Temperature correction consolidated
    - Effect of curing characterised
    - Damage analysis

Foam bitumen stabilisation a cost effective treatment to provide flood resilience for granular pavements

Austroads APT6157 Project (2018-2022)

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Austroads publication no: AP-R666-22

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APT6157 Project Objective

The main objective of the project was to better understand the fatigue behaviour of FBS materials, and to develop a laboratory fatigue relationship to predict the performance of these materials.

Fatigue Characteristics

$$N = \left(\frac{k}{\mu\varepsilon}\right)^{Slope}$$

$$N = \frac{SF}{RF}\left[\frac{6918(0.856V_b + 1.08)}{E^{0.36}\mu\varepsilon}\right]^5$$

Asphalt mean laboratory fatigue relationship

FBS materials

Investigation of the laboratory fatigue relationship

Guide to Pavement Technology Part 2 (AGPT02)

Fatigue characteristics of cemented materials

$$N = RF\left(\frac{K}{\mu\varepsilon}\right)^{12}$$

- Three methods for deriving K:
  - Laboratory fatigue testing& shift factor
  - Laboratory measurement of **flexural modulus & strength**
    $\left(K = 240FS + \frac{919300}{E} - 285\right)$
  - Presumptive flexural modulus & strength

Four-point bending test to evaluate the flexural modulus, flexural strength, and flexural fatigue performance of FBS materials

Source: Austroads (2022)

Development of Laboratory Fatigue Relationship

- The model constant parameters were obtained through multi-linear regression analysis

$$N = \left(\frac{k_1}{\mu\varepsilon}\right)^{7.8}$$

$$k_1 = 266.2 \times \left(\frac{E}{10^3}\right)^{0.88} \times VB^{0.32} \times \left(\frac{FS}{E}\right)^{0.50}$$

Note: E is used as the symbol for the flexural modulus (FM)

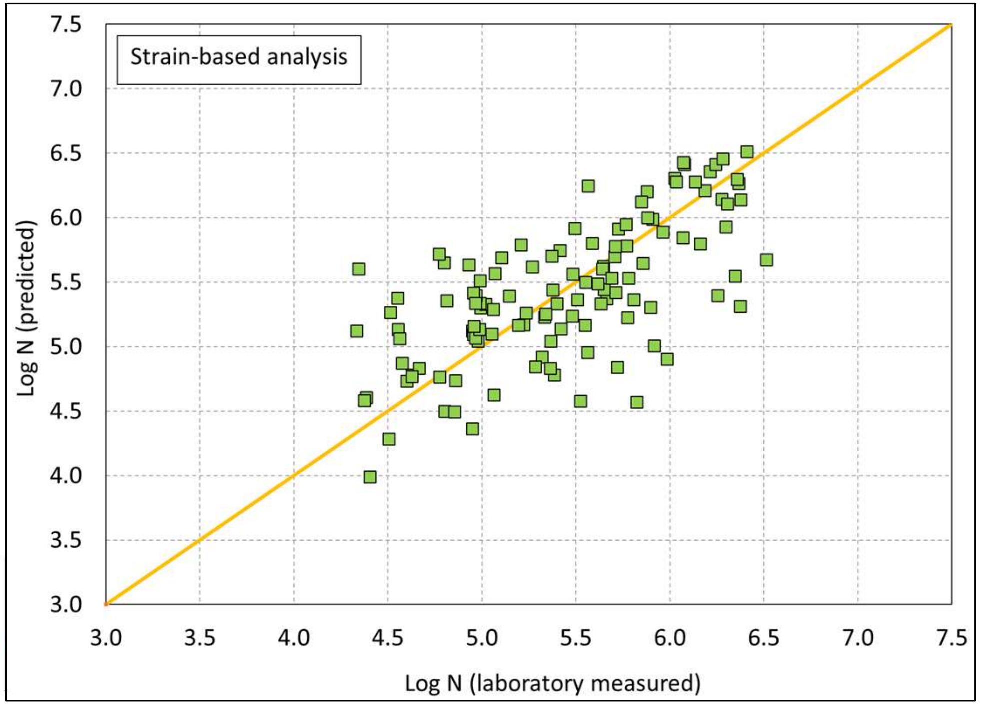
Development of Laboratory Fatigue Relationship

Prediction of Fatigue Life, Strain-based

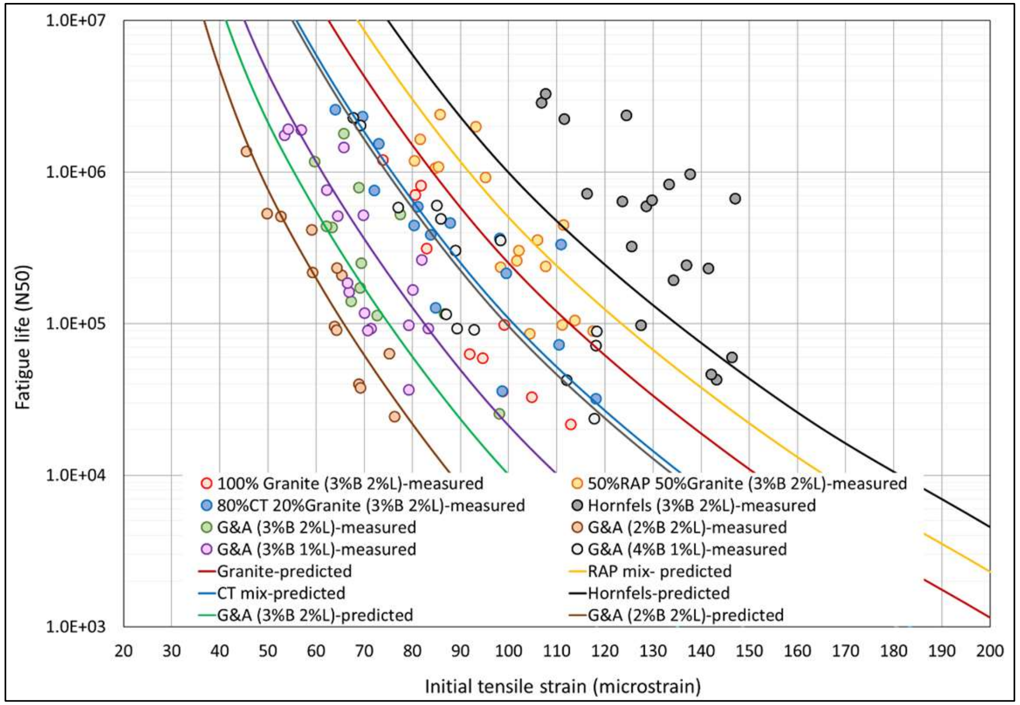
Section 7.4

- To examine the capability of the developed strain-based relationship in predicting the fatigue life
- There is an acceptable conformity between the predicted fatigue life and the laboratory measured life

Predicted versus measured fatigue life (strain-based analysis)



Laboratory-measured fatigue life (markers) and the predicted fatigue life (lines) in a plot against tensile strain



Developed Laboratory FBS Fatigue Relationship versus Asphalt Laboratory Fatigue Relationship

Asphalt laboratory fatigue relationship

- The fatigue life of the mixes was predicted using the Shell asphalt laboratory fatigue relationship (using the measured flexural modulus and volume of binder of each FBS mix).

$$N = \left(\frac{6918(0.856V_b + 1.08)}{E^{0.36}\mu\varepsilon}\right)^5$$

N = allowable number of repetitions of the load-induced tensile strain (from laboratory fatigue testing)

E = asphalt modulus (MPa)

με = load-induced tensile strain at the base of the asphalt (microstrain)

V_b = percentage by volume of bitumen in the asphalt (%); same as VB in this project for the FBS materials

Developed Laboratory FBS Fatigue Relationship

- The fatigue life predictions using the developed laboratory FBS fatigue relationship in this project

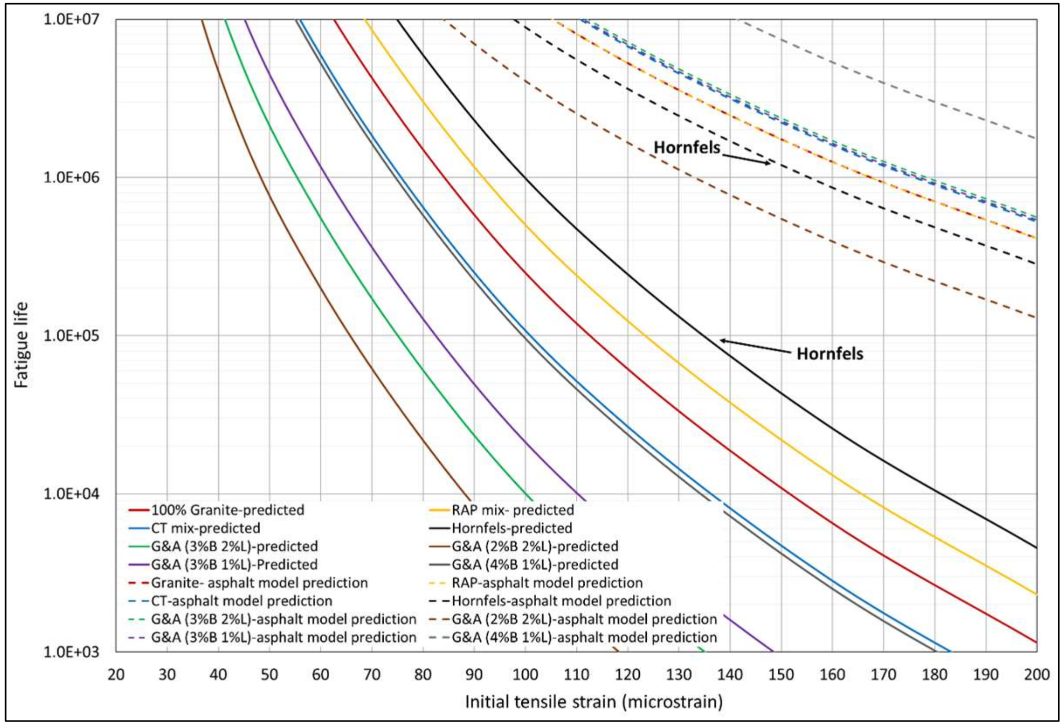
$$N = \left(\frac{k_1}{\mu\varepsilon}\right)^{7.8}$$

$$k_1 = 266.2 \times \left(\frac{E}{10^3}\right)^{0.88} \times VB^{0.32} \times \left(\frac{FS}{E}\right)^{0.50}$$

- The average strain damage exponent, unlike the asphalt fatigue relationship with an exponent of 5, is 7.8.
- Unlike the asphalt fatigue relationship that has a negative correlation with modulus, the fatigue life of the FBS materials increases with the increase in the flexural modulus of the materials.

Developed Relationship versus Asphalt Laboratory Fatigue Relationship

Fatigue life predictions using laboratory developed FBS fatigue relationship (lines) and Shell asphalt laboratory fatigue relationship (dashed lines)



NACoE P132 Queensland's foamed bitumen mix design and structural design procedure: review and improved methods

- Year 1 (2021-22)
  - Review recent FBS Austroads research findings
  - Identify areas of improvement for mix and structural design of FBS pavements and pathways for implementing new FBS fatigue relationship
  - Collect performance data from TMR FBS pavements
- Year 2 (2022-23)
  - Assess flexural performance of two FBS mixes from QLD
  - Evaluate the prediction of the Austroads (AP-R666-22) fatigue performance relationship
  - Investigate the effect of temperature on flexural modulus and fatigue for better characterisation in structural design (for selected QLD mixes)

NACOE O24: Using Recycled Materials in Stabilised Pavements

- ARRB Project Leader: Dr Negin Zhalehjoo
- ARRB Quality Manager: Dr James Grenfell
- TMR Project Manager: Meera Creagh

Project Objective:

The main objective of the first year of this research project is to evaluate the performance of recycled host material blends treated by foamed bitumen stabilisation and cement stabilisation using a laboratory testing program.

The summary of laboratory testing program:

1. Materials

The materials used for laboratory characterisation were recycled crushed concrete (RCC), crushed brick (CB), reclaimed asphalt pavement (RAP), and recycled crushed glass (RCG).

3 blends as below was used for the laboratory investigations.

1. Reference mix: Type 2.3, 100%RCC
2. Recycled blend: Type 2.3, 40%RCC, 20%RAP, 20%CB, and 20%RCG
3. Recycled blend: Type 2.3, 70%RCC, 10%RAP, 10%CB, and 10%RCG

The summary of laboratory testing program:

2. Major experimental testing program

- **Indirect Tensile Resilient Modulus (ITM) test on foamed bitumen stabilised materials**
  - **3% foamed bitumen, 2% hydrated lime**
  - **3-day and 14-day cured ITM (dry and soaked)**
- **Unconfined Compressive Strength (UCS) test on cement stabilised materials**
  - **1%, 2.5%, and 4% cement**
  - **7-day and 28-day UCS**

❑ The project assessed whether the resulting ITM and UCS from different blends can meet the mix design specification requirements.

❑ The project will continue in 2022-2023 by assessing a higher number of recycled blends.

-Note: Project's Laboratory testing were undertaken at TMR Laboratory

Paintback

paintback
paintback.com.au

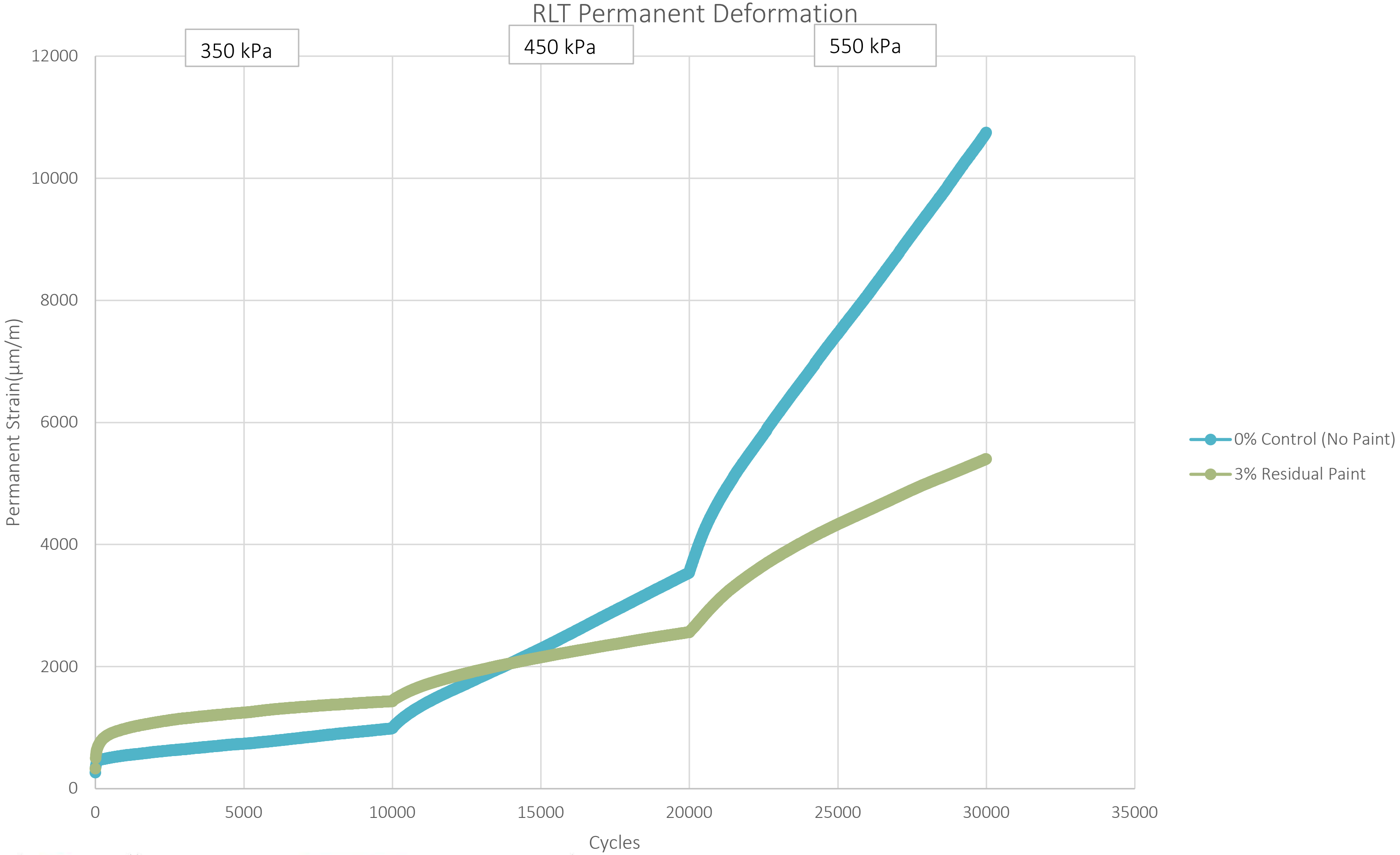
Water-based Paint Trials:

- Bitumen Emulsions
- Dust Suppressants
- Stabilisation for Granular Materials

Paint Solids Trial:

- Concrete (Kerb, Channel, Gutter)

Water-based Paint Trials – Soil Stabilisation



Permanent Strain:

- Less permanent strain as cycles and force increase. Suggests some binding effect or improvement.

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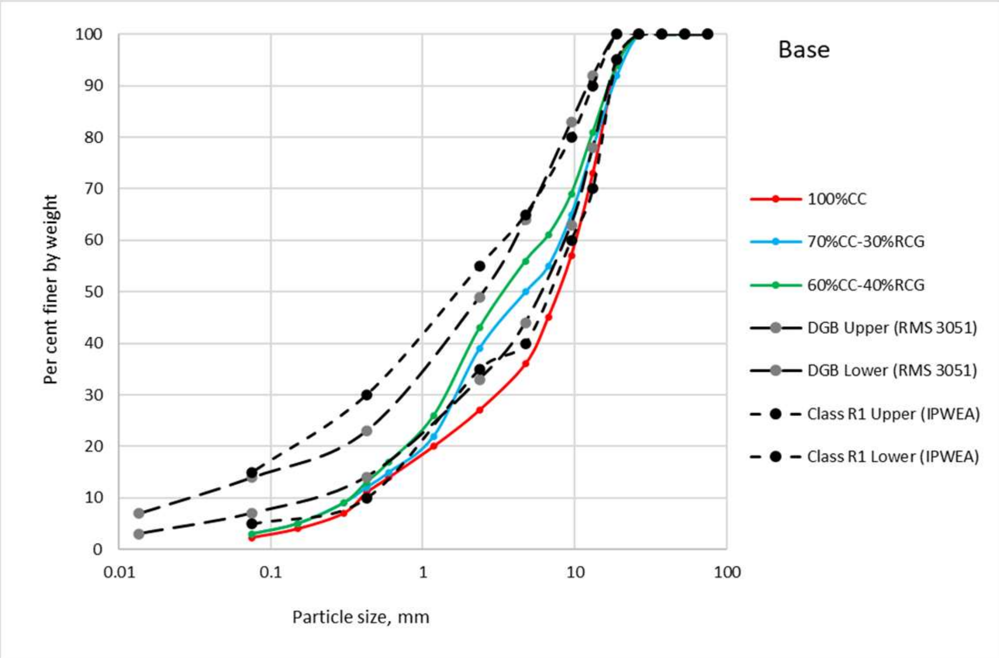
Glass in Road Base and Subbase for Canterbury-Bankstown City Council

Grading of raw materials



100 % recycled crushed concrete has poor grading

Grading improvements with increased recycled crushed glass content

Grading improvements lead to:

- Compaction improvements
- Performance improvements

Wheel Tracking Analysis of Fit for Purpose Materials

Assessment of granular material blends performance

Austrack (Extra-large Wheel tracker)

- Sample preparation

- Trafficking

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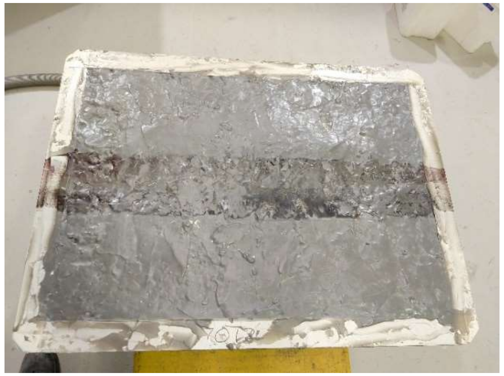
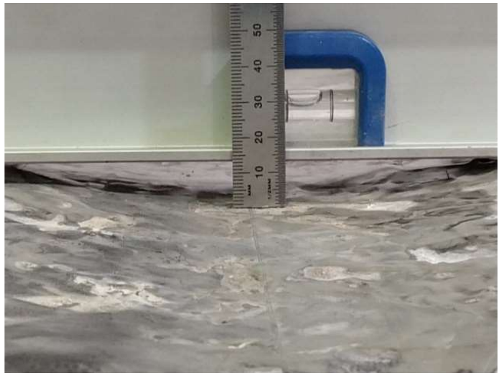
Glass in Road Base and Subbase

100% Recycled Crushed Concrete

Surface after compaction



Sealed surface after wheel tracking



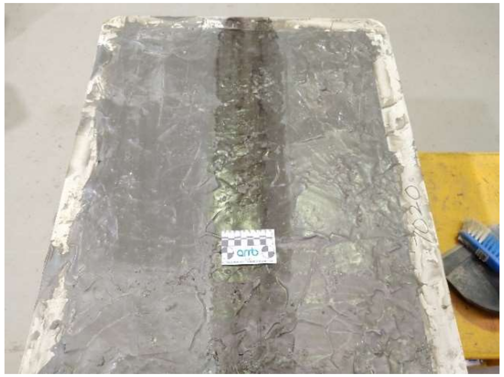
Sealed surface after wheel tracking

View from the right side when unmoulding

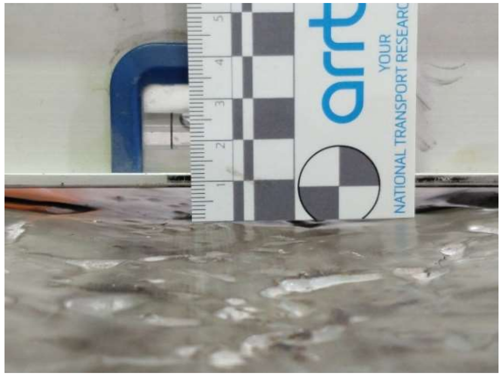
Glass in Road Base and Subbase

70% CC-30% RCG

Surface after compaction



Sealed surface after wheel tracking

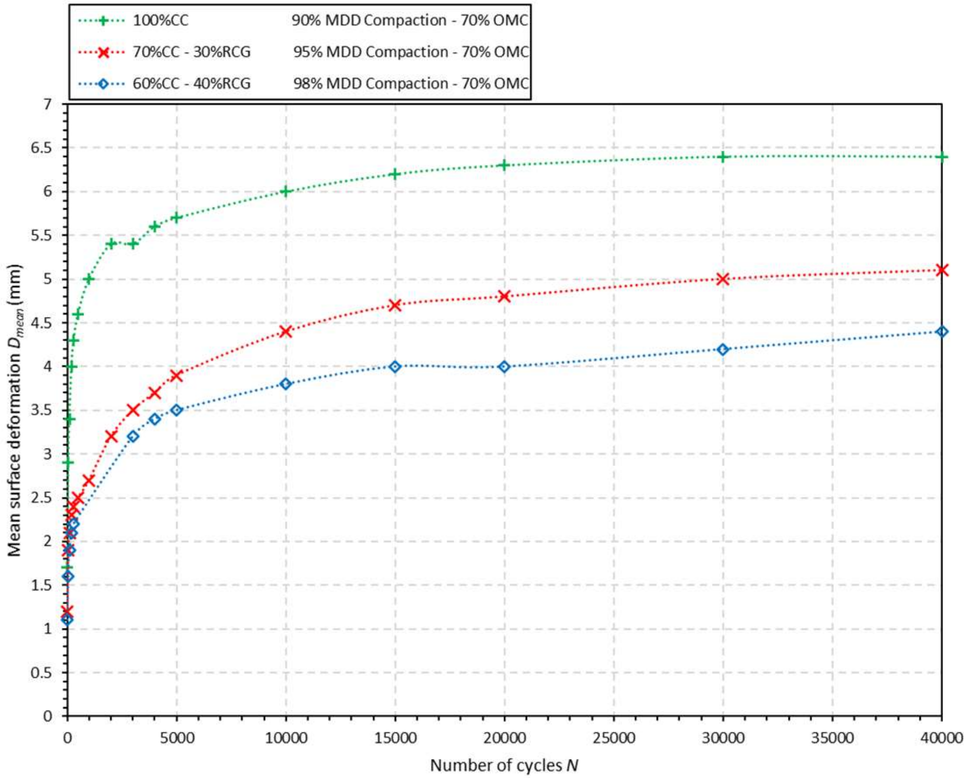


Sealed surface after wheel tracking

View from the right side when unmoulding

Glass in Road Base and Subbase

Rut Depth Comparison



Samples tracked to minimum 40,000 cycles.

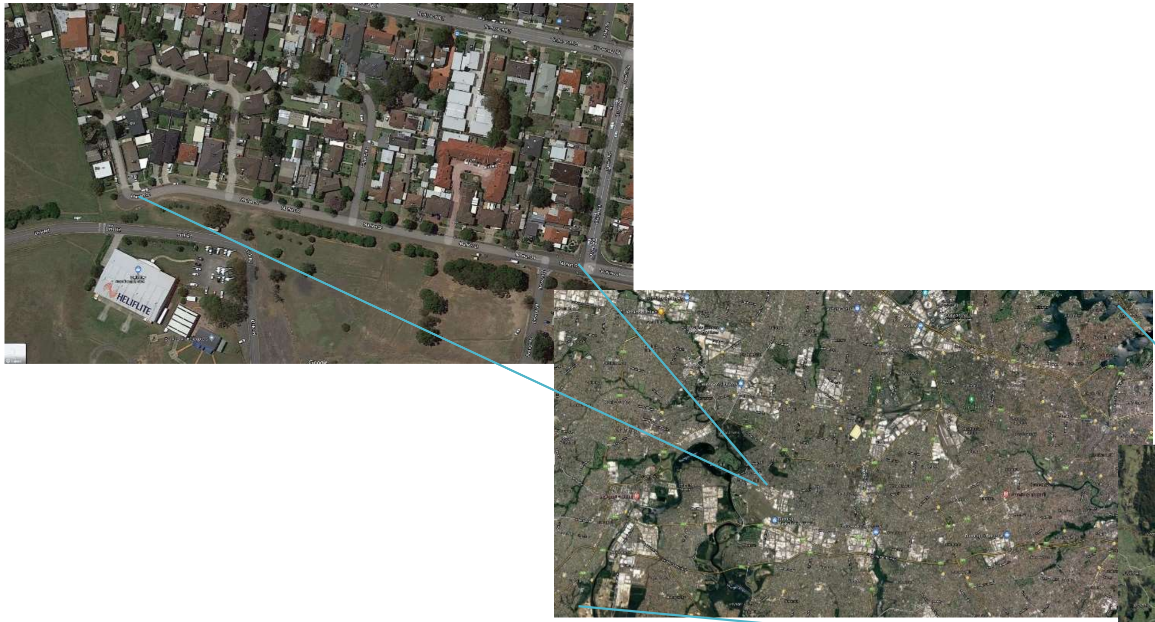
Decreased rut depth seen with greater recycled crushed glass content.

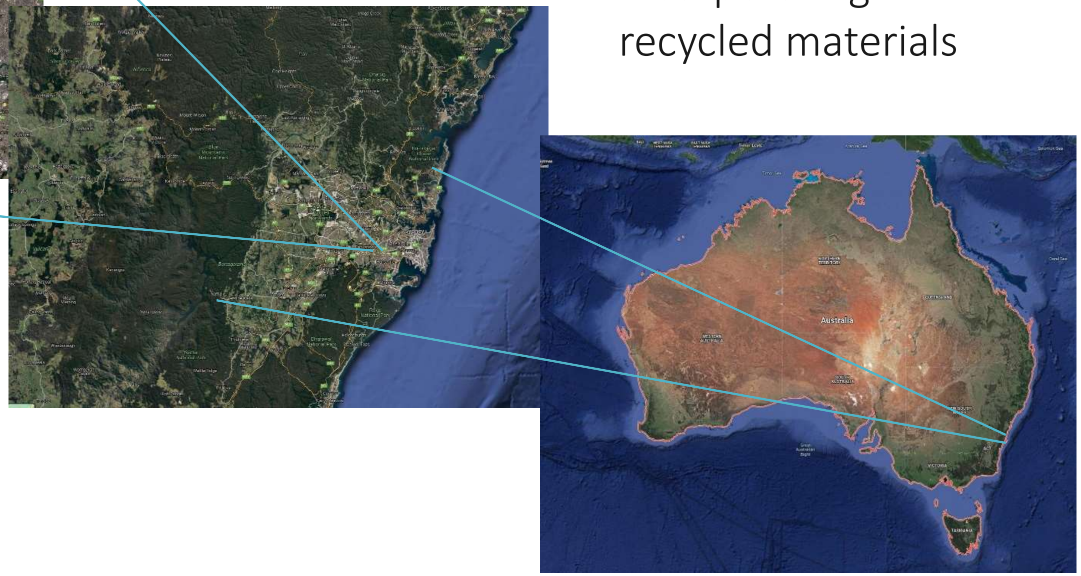
Increase recycled crushed glass content leads to improved compaction and improved rutting performance.

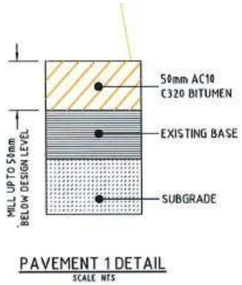
All well within acceptable range.

Ongoing work and Field trials

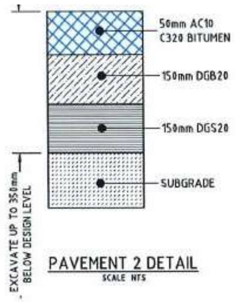
The move to sustainable materials solutions for Local Government Authorities







Existing structure



New structure – incorporating recycled materials

Australian Pavement Recycling and Stabilisation Conference
Pavement Recycling for Sustainable Roads
Novotel Brighton Beach, Sydney • 10th August 2022

Ongoing work and Field trials

Marion Street in City of Canterbury Bankstown on Sydney, NSW




Acknowledgments

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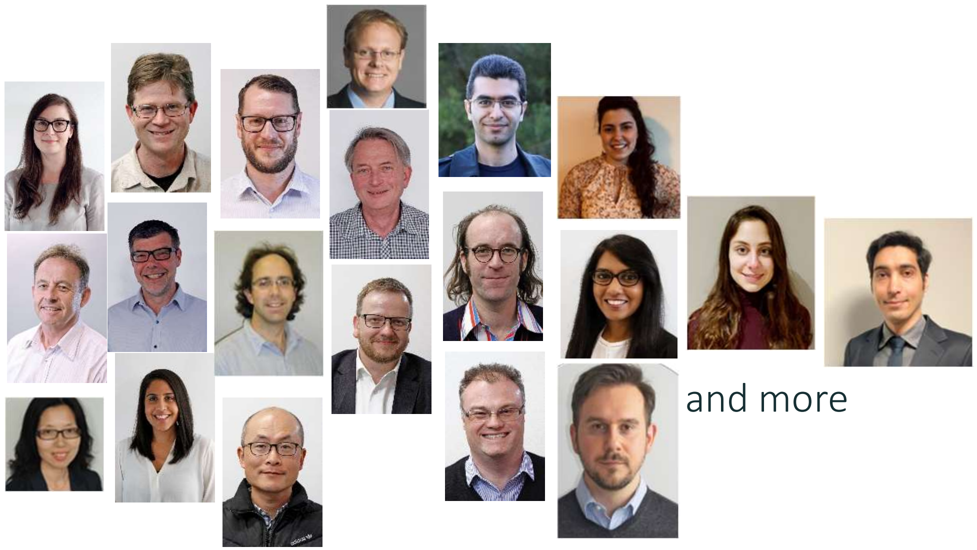
CANTERBURY BANKSTOWN

The arrb team



and more

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Pavement Recycling and Stabilisation Association