

Making Low-Cost Granular Roads More Resilient

Asian Development Bank: Green Roads Webinar Series

Dr James Grenfell, Principal Engineer

Presentation Outline

- Australian situation
- Mechanical Stabilisation
- Cementitious Stabilisation
- Foamed bitumen stabilisation
- Permeable and Pervious Pavements
- Concluding Remarks

Australian situation

Australia in perspective

- Area 7,700 km²
- ~90% of USA
- Population
 - Australia: 25 million
 - USA: 325 million
- 5% live in top half
- 85% live in urban areas



Australian Road Network

Length of Road:

Australia: 810,000 km

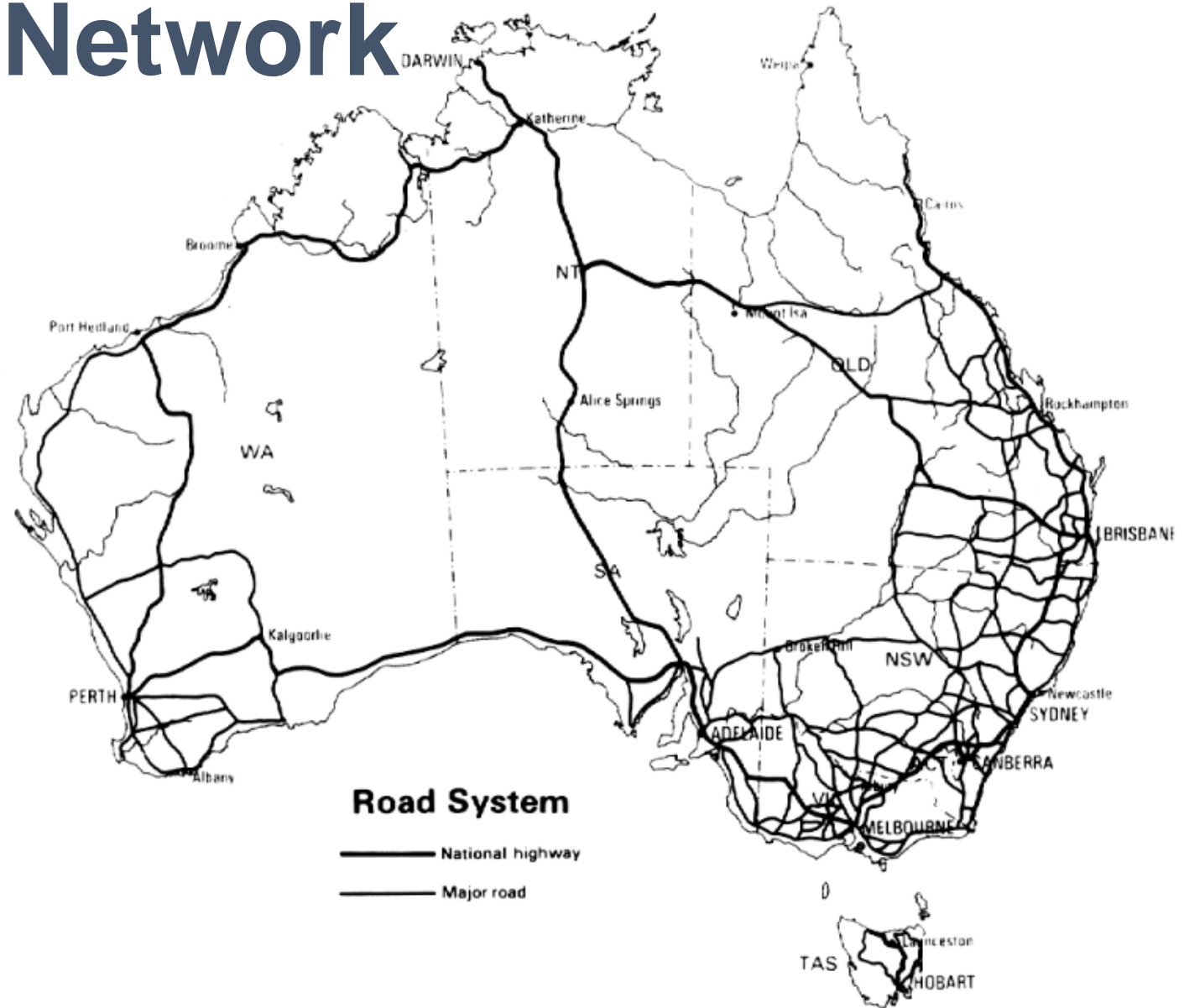
USA: 6,400,000 km

Per Cent Sealed

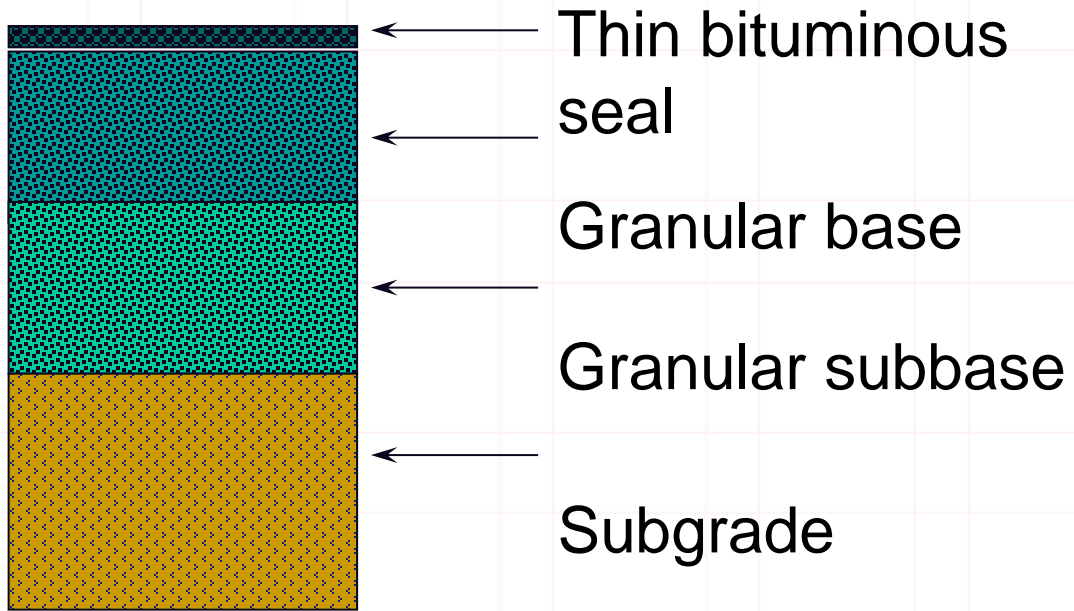
Australia: 39%

USA: 65%

90% of transport tasks conducted on 20% of road network



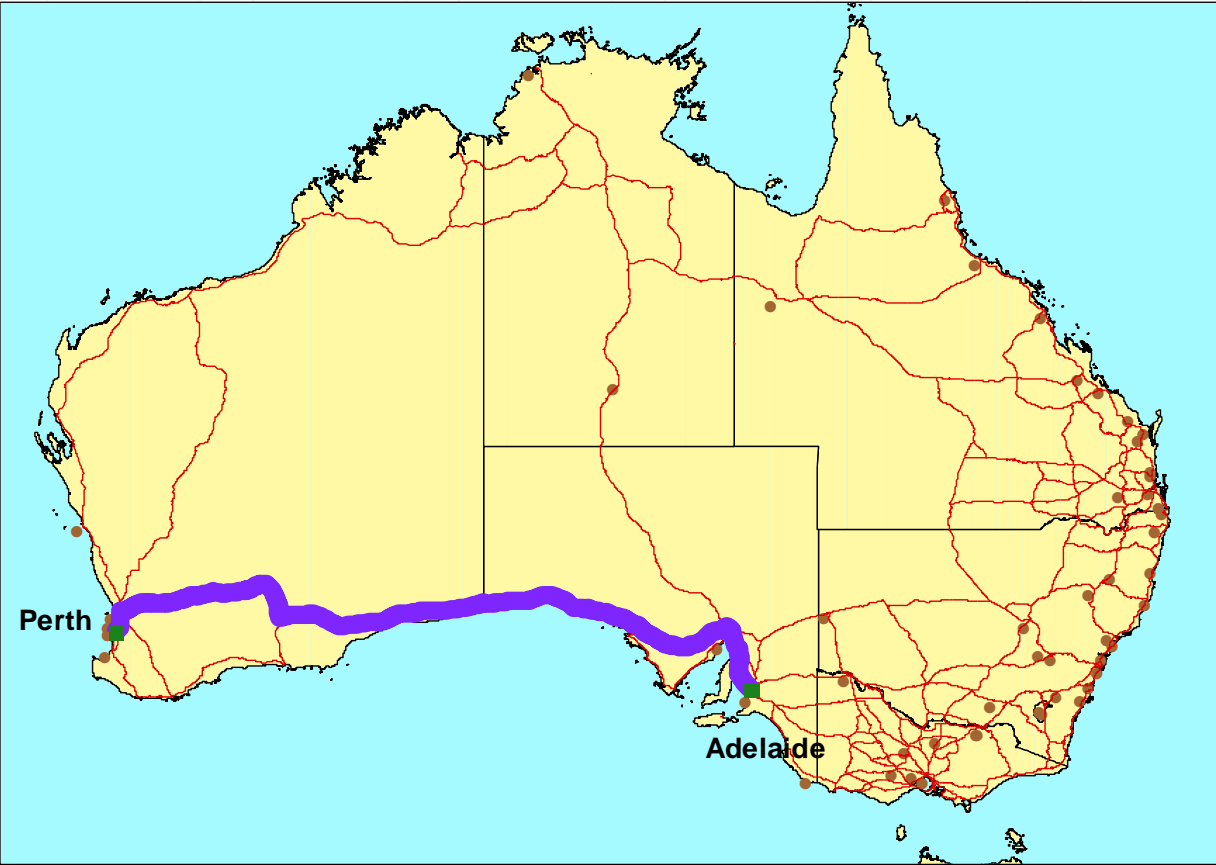
Typical Aussie Pavement



Impacts of extreme weather



Loss of connectivity



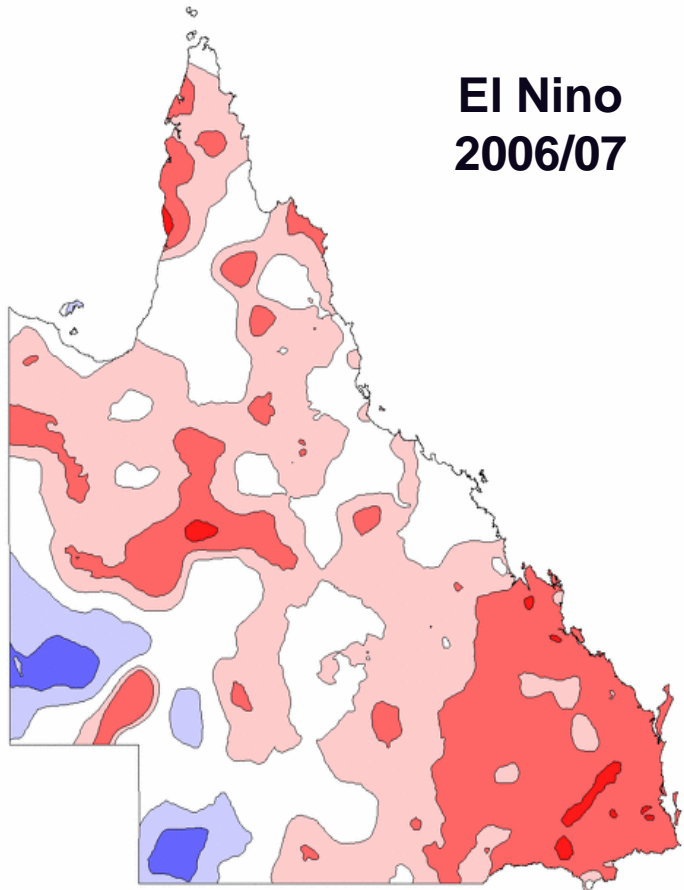
Direct Route



Detour

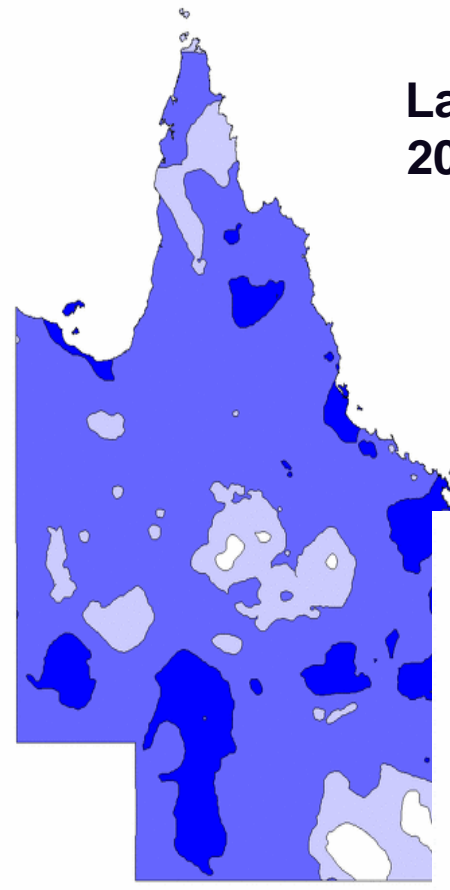
Environmental risks

El Nino
2006/07



<http://www.bom.gov.au>

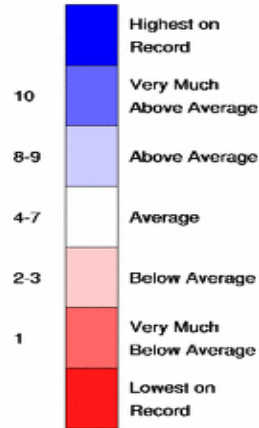
La Nina
2010/11



<http://www.bom.gov.au>

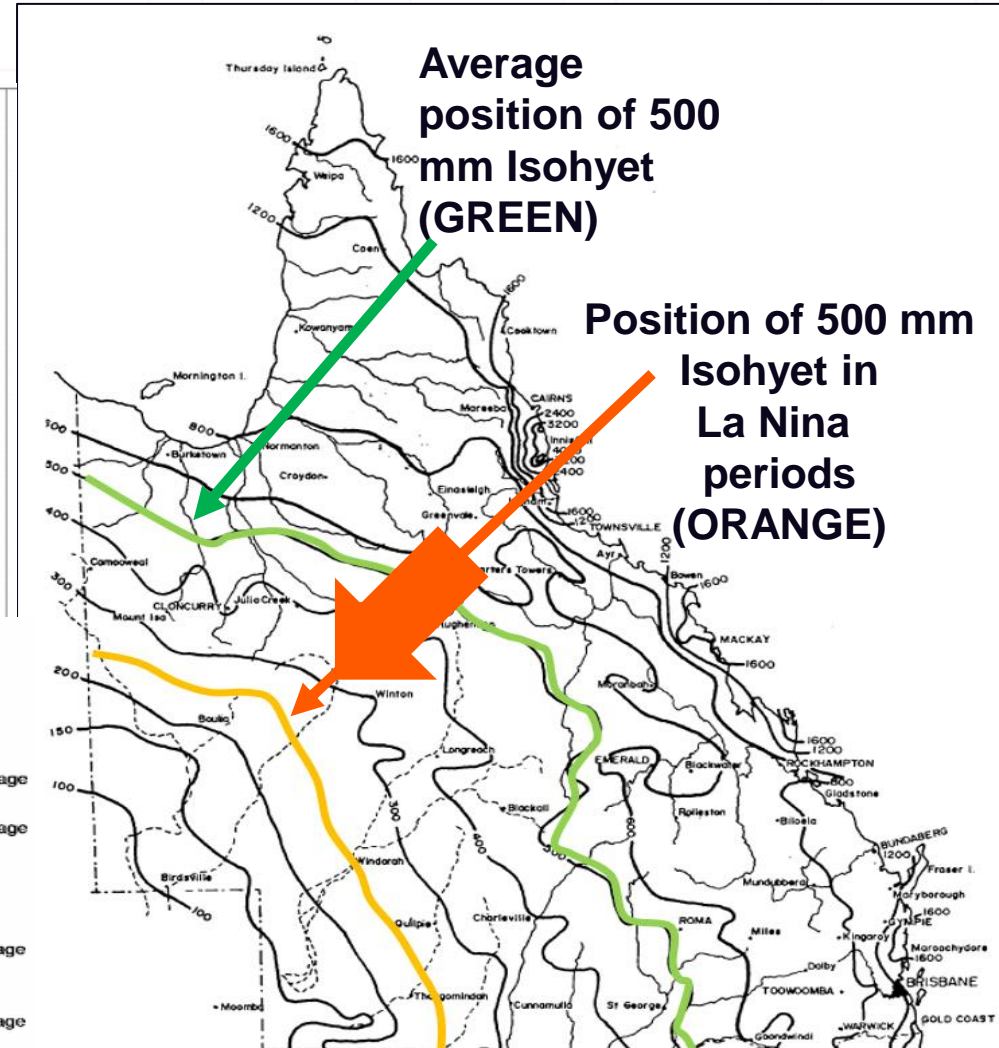
Source: Toole (2018)

Rainfall Decile Ranges

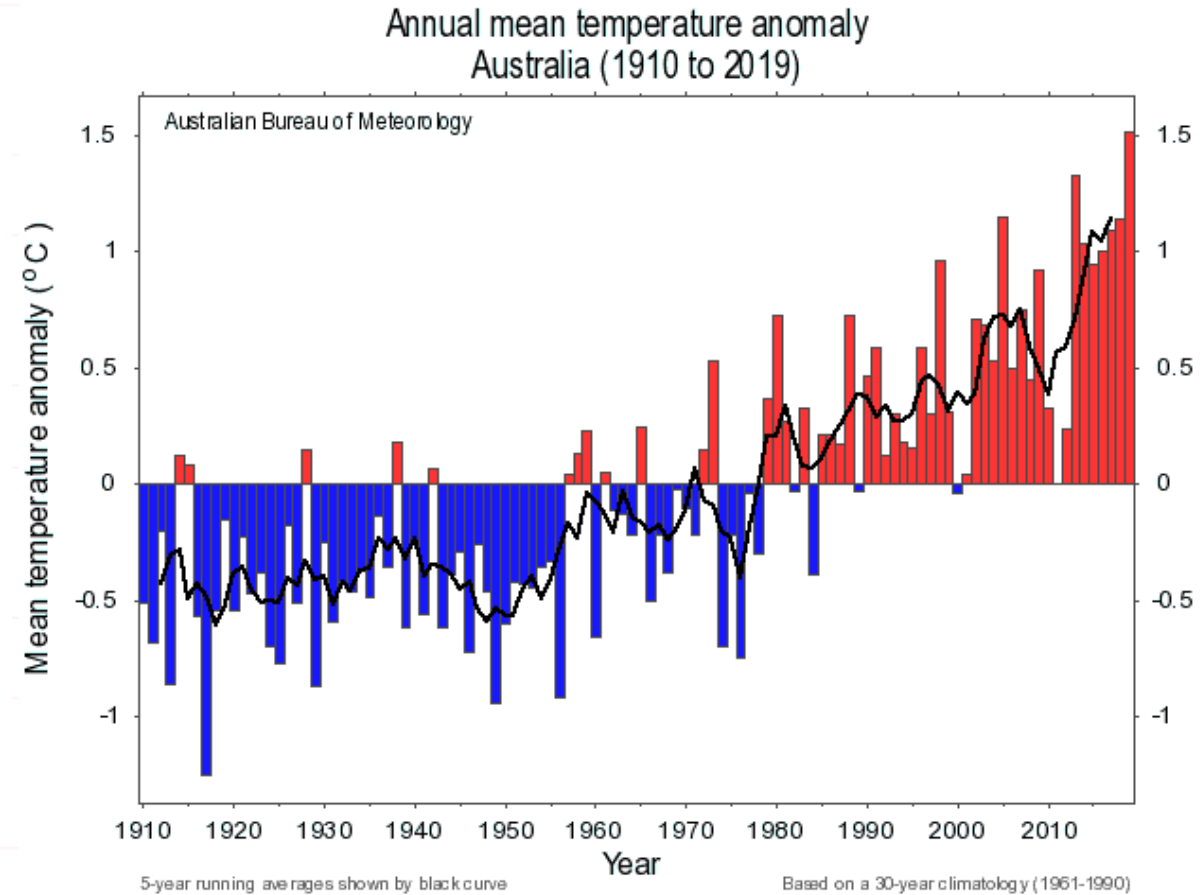
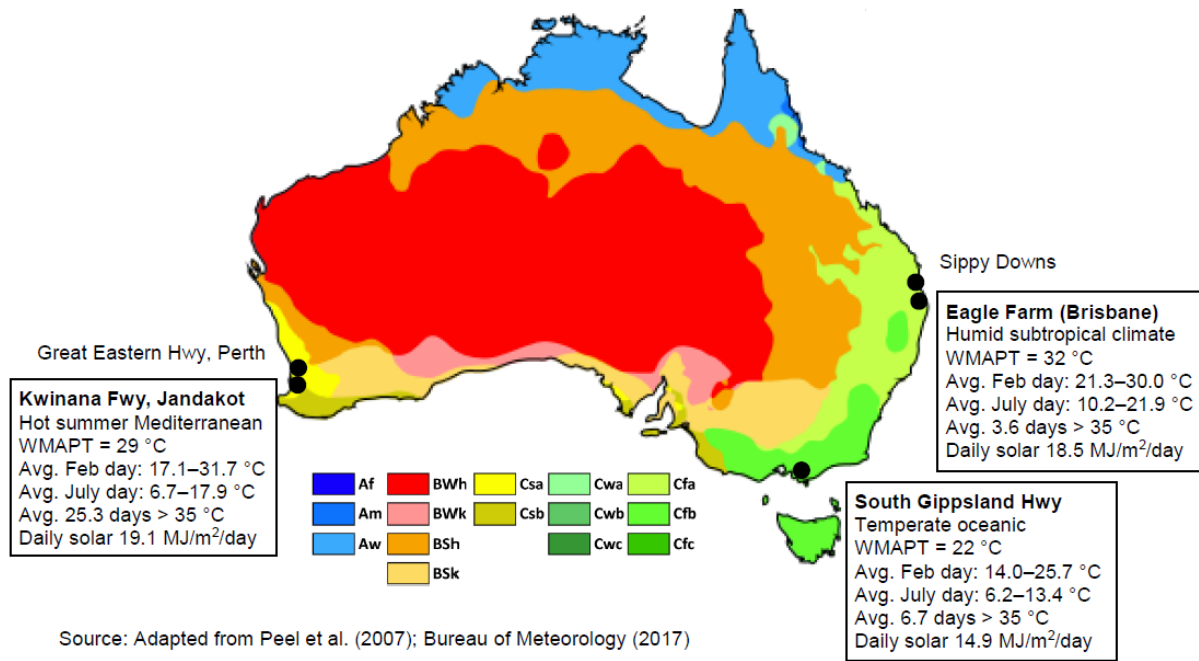


Average
position of 500
mm Isohyet
(GREEN)

Position of 500 mm
Isohyet in
La Nina
periods
(ORANGE)



Climatic Conditions



Source: Beecroft (2018) & BOM (2020)

Mechanical Stabilisation

How do your roads perform?



Corrugations



Shape



Rutting



Potholes



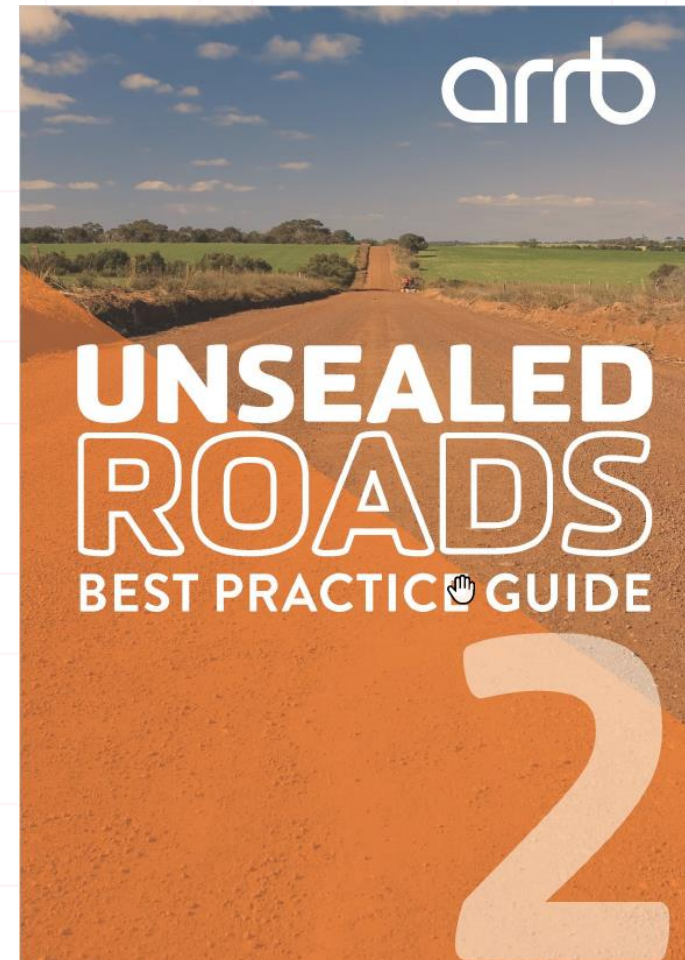
Dust

Best Practice Guide to Unsealed Roads

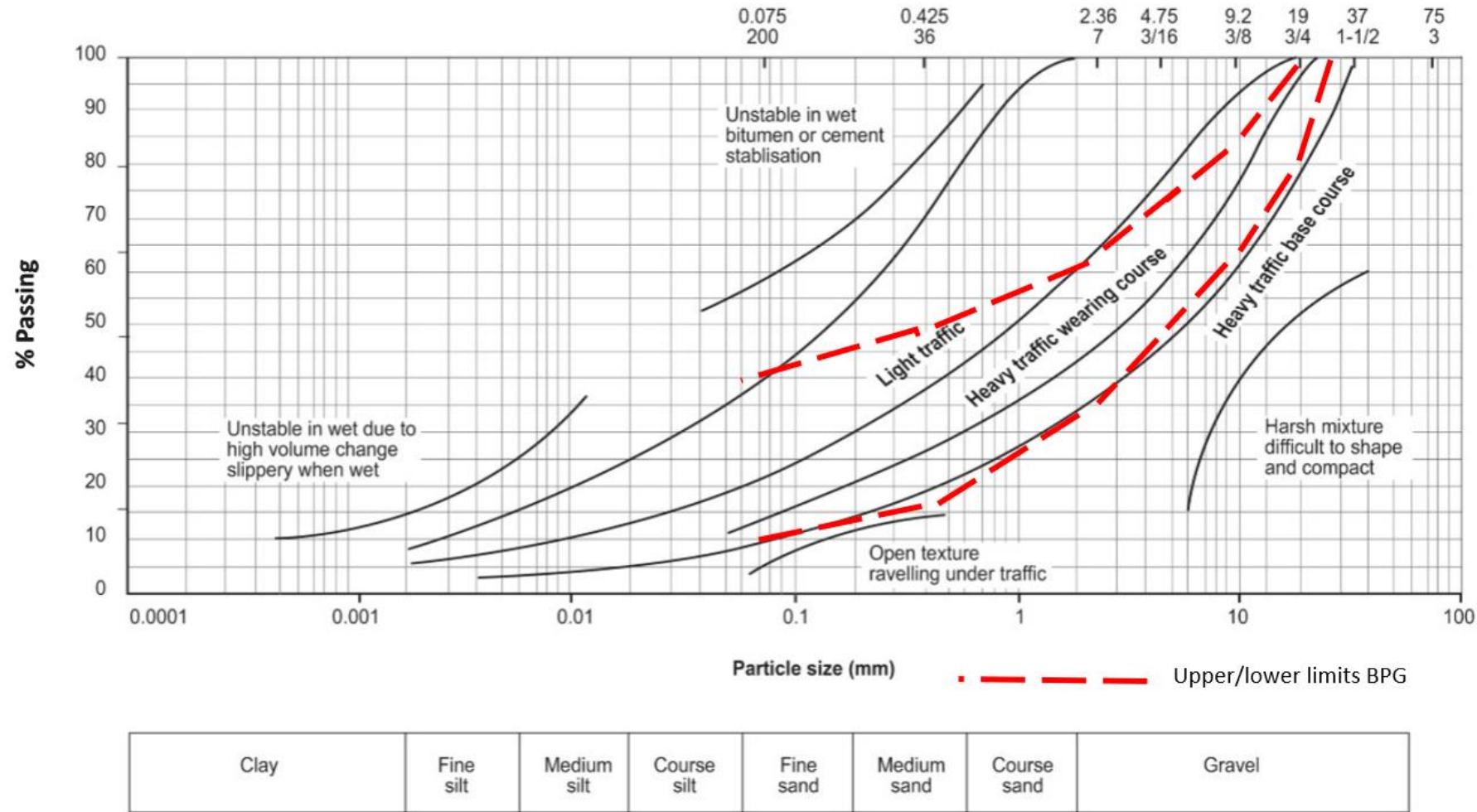
- 1. Introduction
- 2. Asset Management
- 3. Design
- 4. Construction
- 5. Operations & Maintenance

Appendices:

- Environmental Considerations
- Signs and Delineation
- Detailed Geometric & Drainage Design
- Typical Road Defects & Maintenance Treatments
- Best Practice Grading Operations
- Generic Maintenance Specifications



Required properties – unsealed wearing courses



Wearing course requirements

Grading and Plasticity have been found to be well described by:

Shrinkage Product (weighted linear shrinkage):

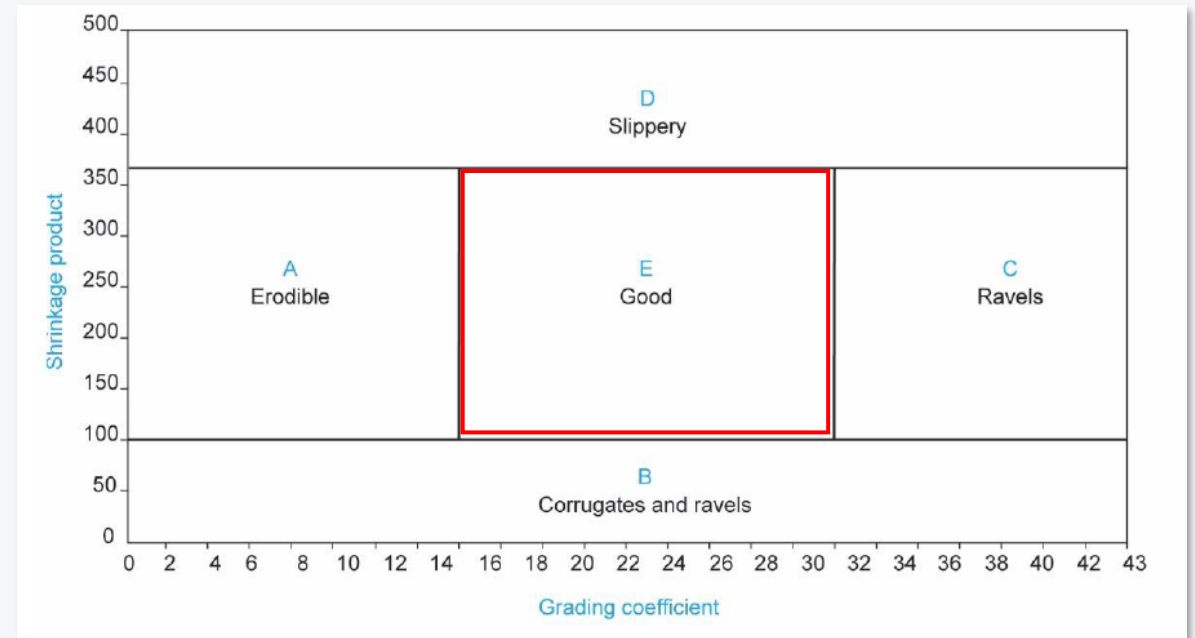
$$S_p = LS \times \% \text{passing } 0.425\text{mm or}$$

$$S_p = PI/2.5 \times \% \text{passing } 0.425\text{mm (estimate)}$$

Grading Coefficient:

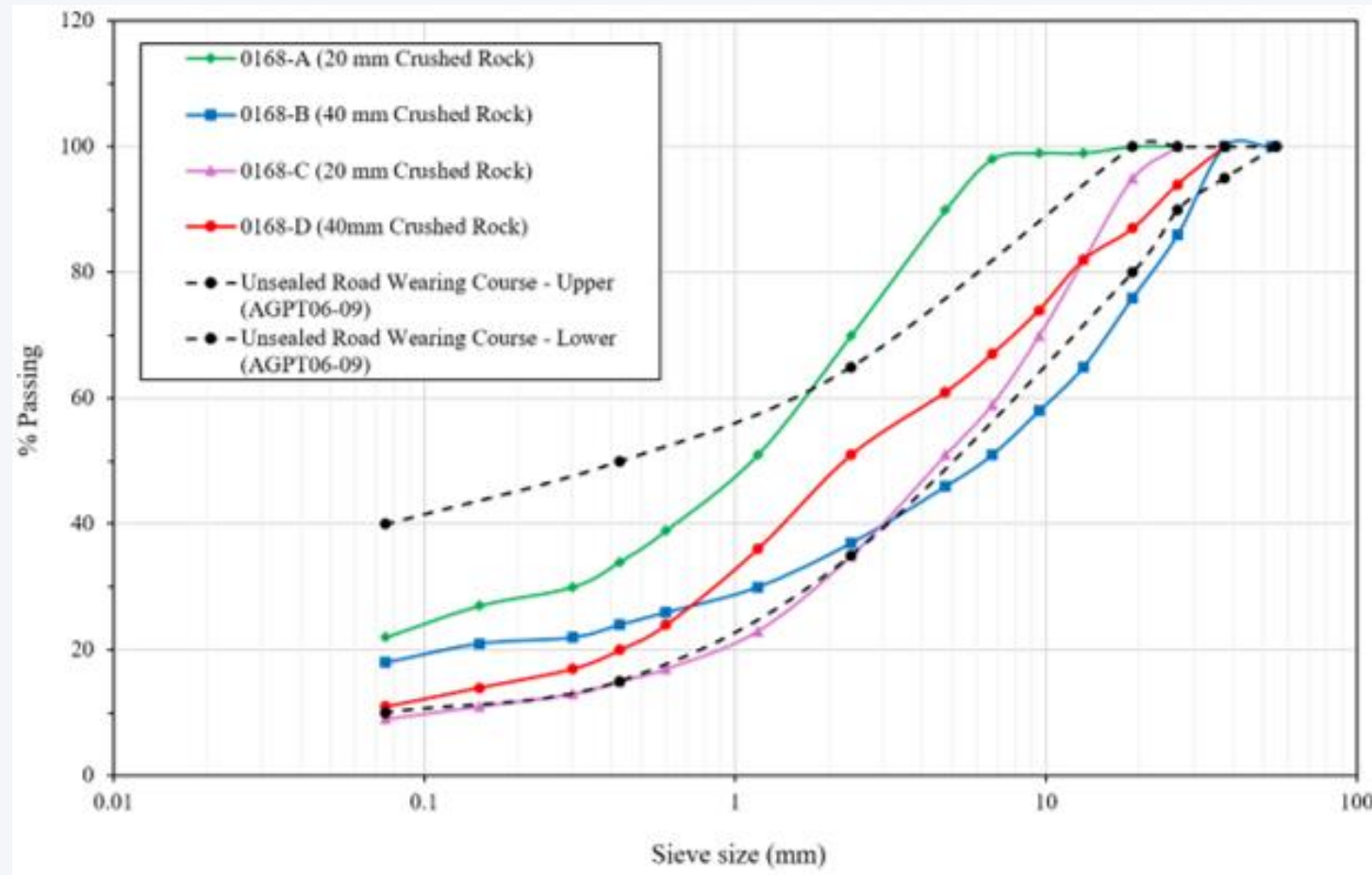
$$G_c = ((P_{26.5\text{mm}} - P_{2\text{mm}}) \times P_{4.75\text{mm}}) / 100$$

These parameters, when plotted, enable a good assessment of expected material performance.



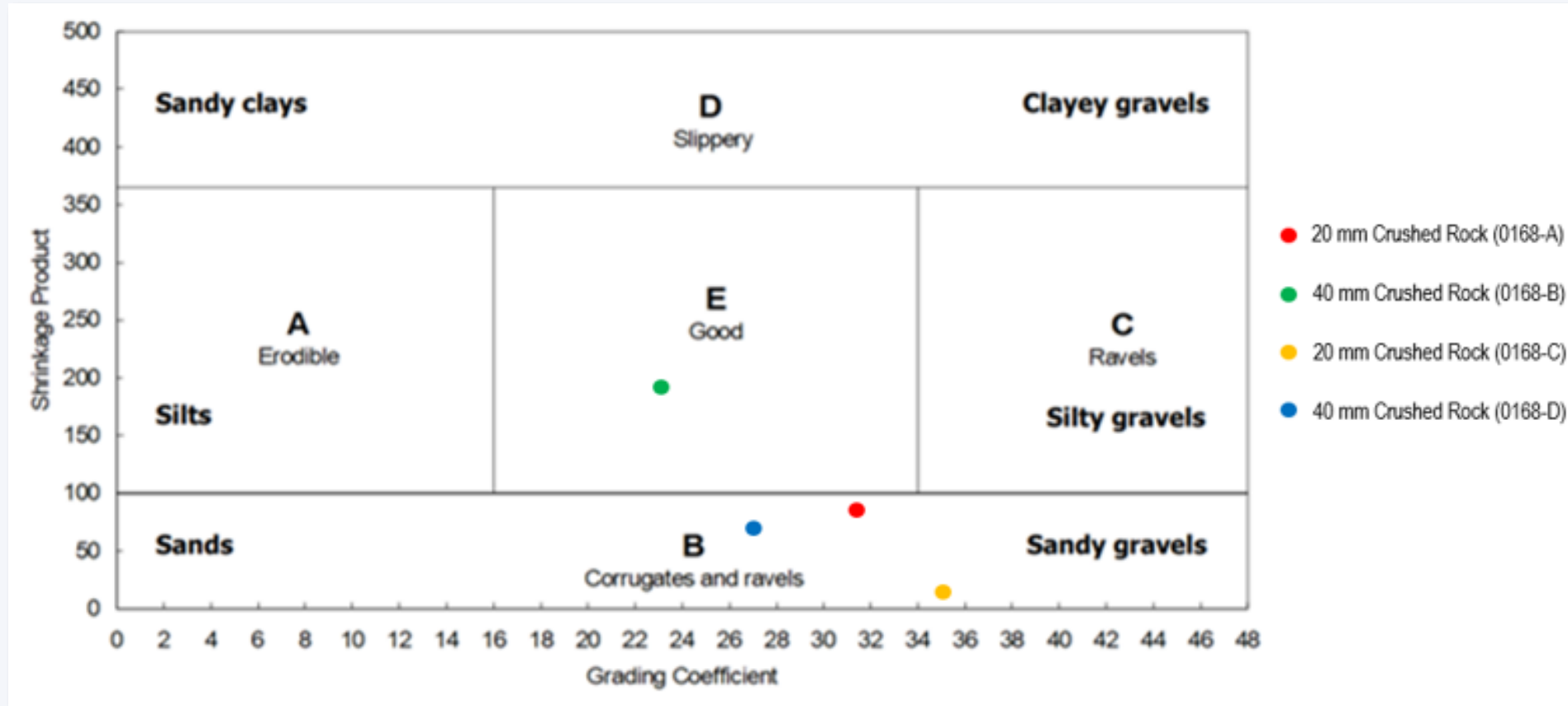
Results and Findings

Grading of four source materials before optimisation treatment



Results and Findings

Performance of four source materials before optimisation treatment



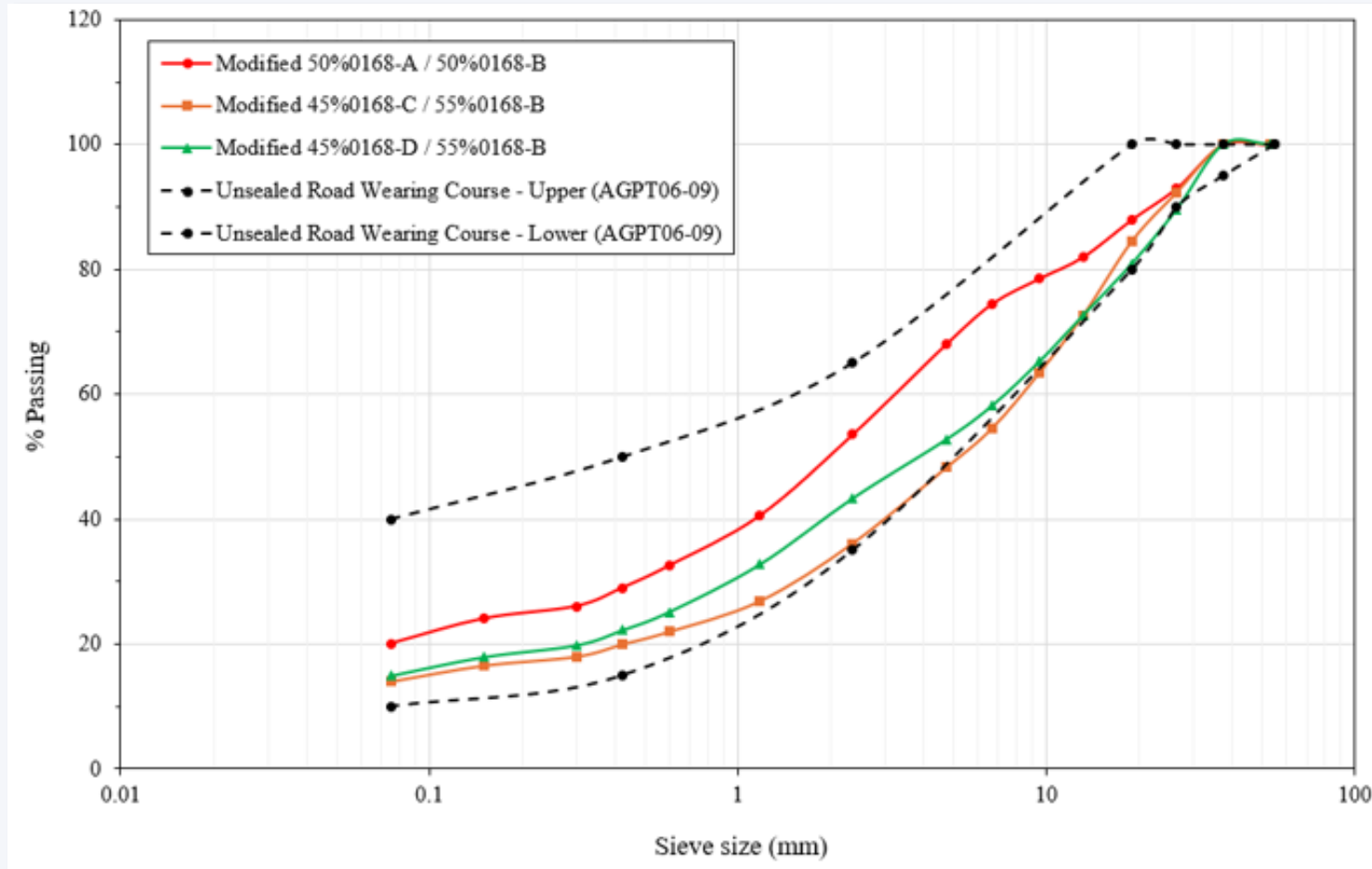
Results and Findings

Additional properties of four source materials before optimisation treatment

Parameter	Austroads AGPT06-09		Typical specification (South Africa)			0168-A	0168-B	0168-C	0168-D
	More than 500 mm annual rainfall	Less than 500 mm annual rainfall	Rural roads	Urban roads	Haul roads				
	Limit	Limit	Limit	Limit	Limit				
OMC (%)	-	-	-	-	-	7.5	13	8	8.5
MDD (t/m ³)	-	-	-	-	-	2.12	1.97	2.27	2.24
Shrinkage product	-	-	100-365	100-240	100-365	95.2-102	192	12-15	72-80
Grading coefficient	-	-	16-34	16-34	16-34	31.5	23	35.19	27.45
Aggregate crushing value (%)	-	-	-	-	-	24.1	23.4	16.5	26.6
Soaked CBR (%)	Minimum 40%		≥ 15	≥ 15	≥ 40	80	50	290	170
Unsoaked CBR (%)	-	-	-	-	-	80	70	250	140

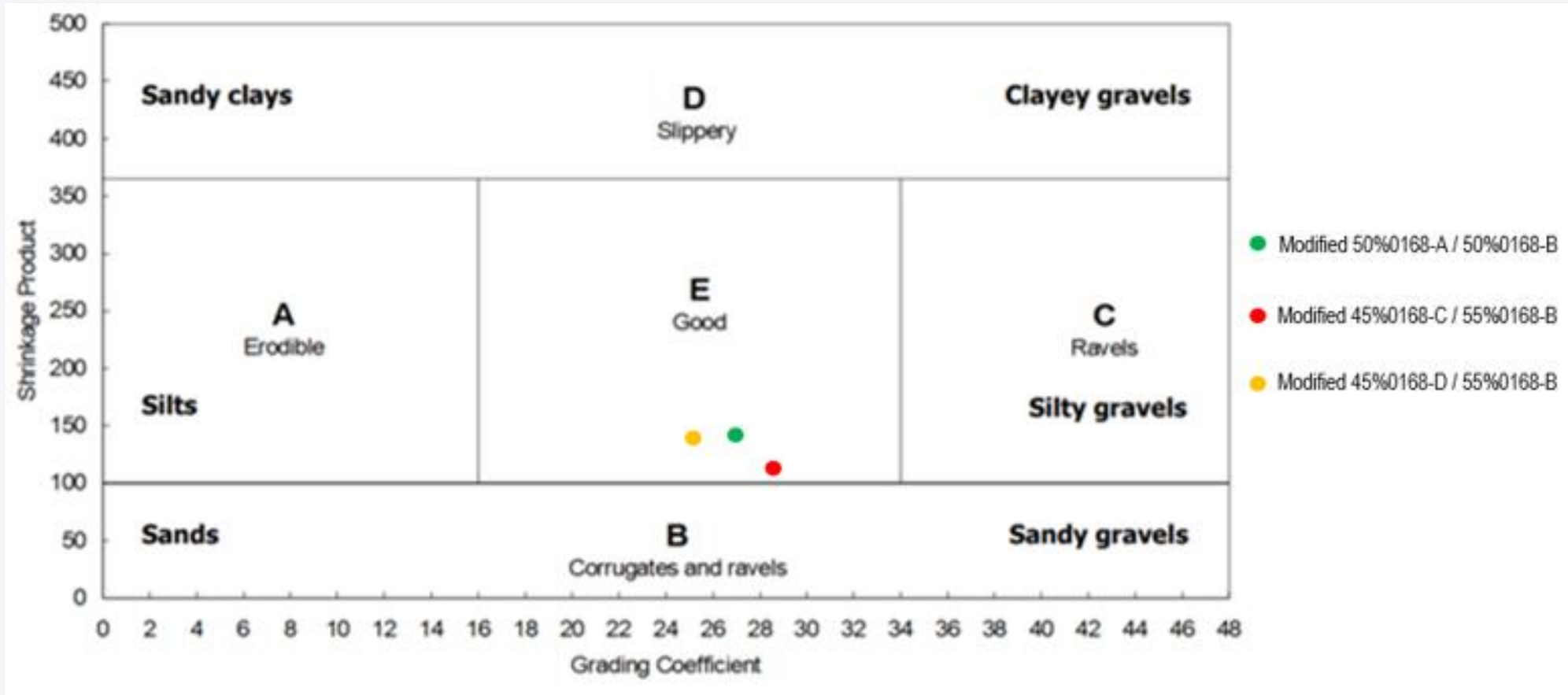
Results and Findings

Grading of source materials after optimisation treatment



Results and Findings

Performance of source materials after optimisation treatment



Results and Findings

Additional properties of source materials after optimisation treatment

Parameter	Austroads AGPT06-09		Typical specification (South Africa)			50%0168-A / 50%0168-B	45%0168-C / 55% 0168-B	45%0168-D / 55%0168-B
	More than 500 mm annual rainfall	Less than 500 mm annual rainfall	Rural roads	Urban roads	Haul roads			
	Limit	Limit	Limit	Limit	Limit			
Shrinkage product	-	-	100-365	100-240	100-365	143.6	111.0	138.0
Grading coefficient	-	-	16-34	16-34	16-34	27.3	28.5	25.0
Aggregate crushing value (%)	-	-	-	-	-	23.8	20.3	24.8
Soaked CBR (%)	Minimum 40%		≥ 15	≥ 15	≥ 40	65	158	104

Project methodology

Mechanical stabilisation of recycled crushed concrete
with recycled crushed glass

1

Project initiation
Literature review
Scoping
Stakeholder
consultation



2

Laboratory study



3

Field
demonstration/vali
dation



4

Performance
monitoring



Recycled crushed concrete

- The project was partially funded by the NSW EPA under the Civil Construction Market Program.
- Project uses two recycled materials:
 - Recycled crushed concrete
 - Recycled crushed glass
- Council receives large amount of C&D waste material from its own projects.
- Processed into DGB/DGS 20 under NSW EPA Resource Recovery Order 2014, Recovered Aggregate

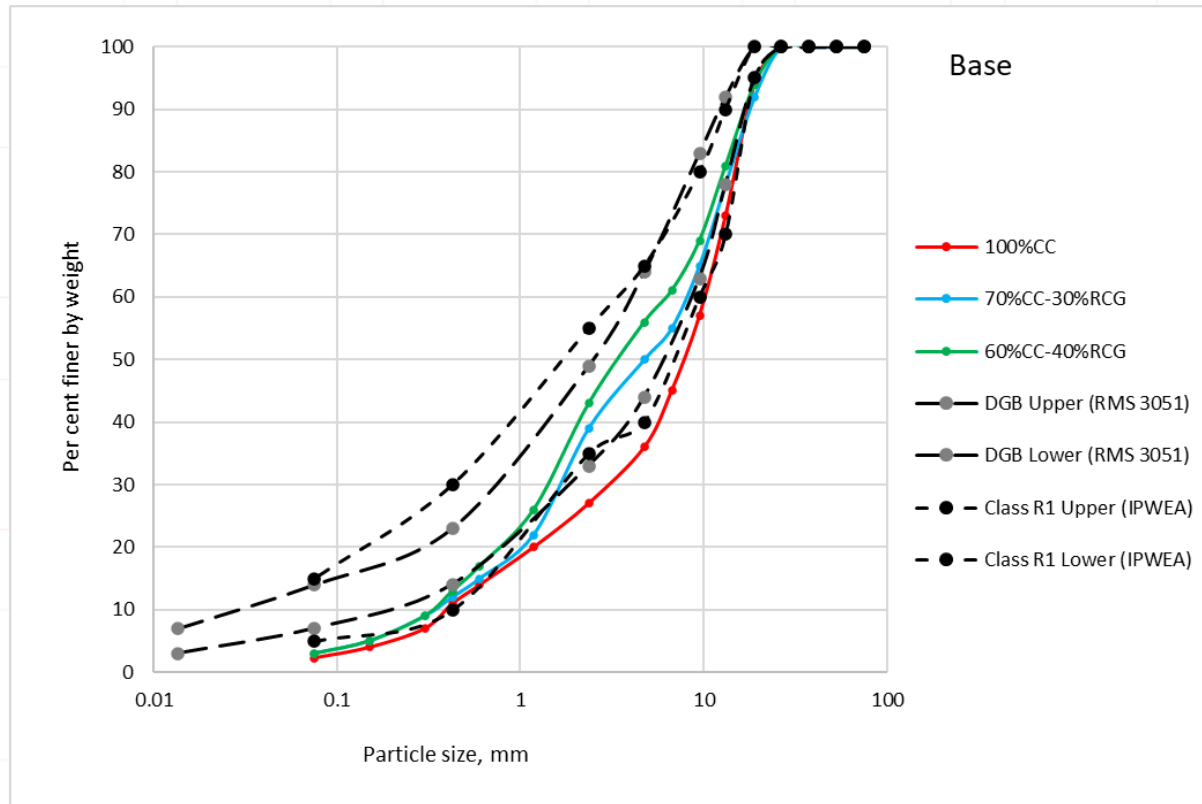


Recycled crushed glass

- Council collects approximately 8,500 tonnes of glass each year.
- Small pieces of glass are much trickier to recycle, potentially useable material that usually goes to waste.
- Potential to be incorporated into asphalt, concrete, etc.
- Great possible solution to the issue of wastage.
- Cost-effective option providing sustainable outcomes for our community.



Gradings from materials blending



- 100 % recycled crushed concrete has poor grading
- Grading improvements with increased recycled crushed glass content
- Grading improvements lead to:
 - Compaction improvements
 - Performance improvements

Permanent deformation testing



- Austrack (Extra-large Wheel tracker)



Sample preparation

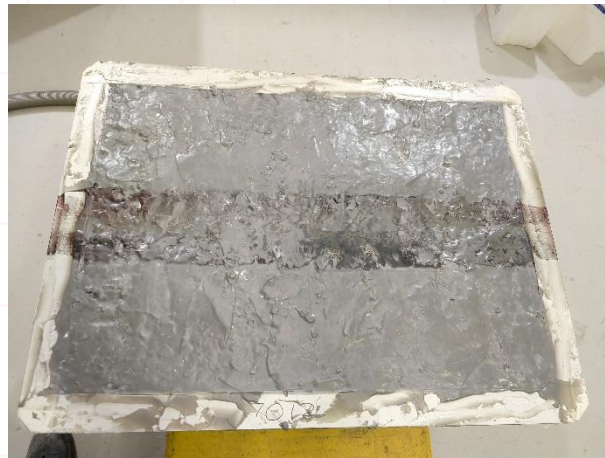


Trafficking

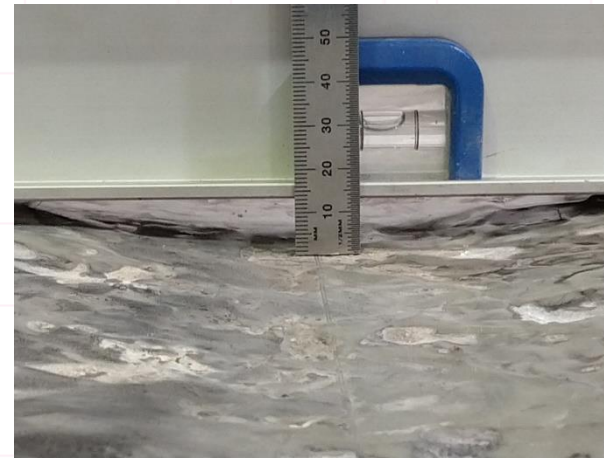
100% Recycled Crushed Concrete



Surface after compaction



Sealed surface after wheel tracking



Sealed surface after wheel tracking



View from the right side when unmoulding

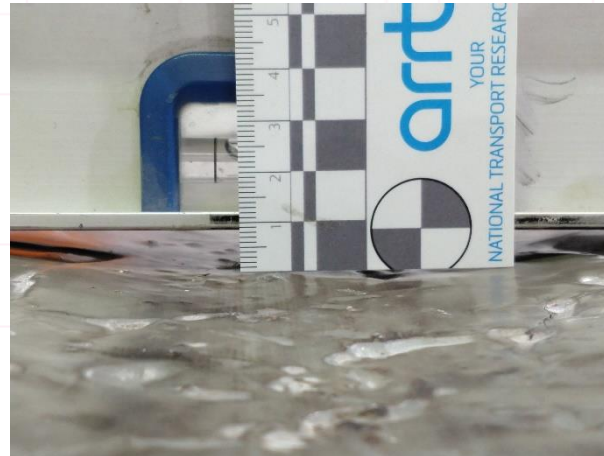
70% Recycled crushed concrete – 30% Recycled crushed glass



Surface after compaction



Sealed surface after
wheel tracking

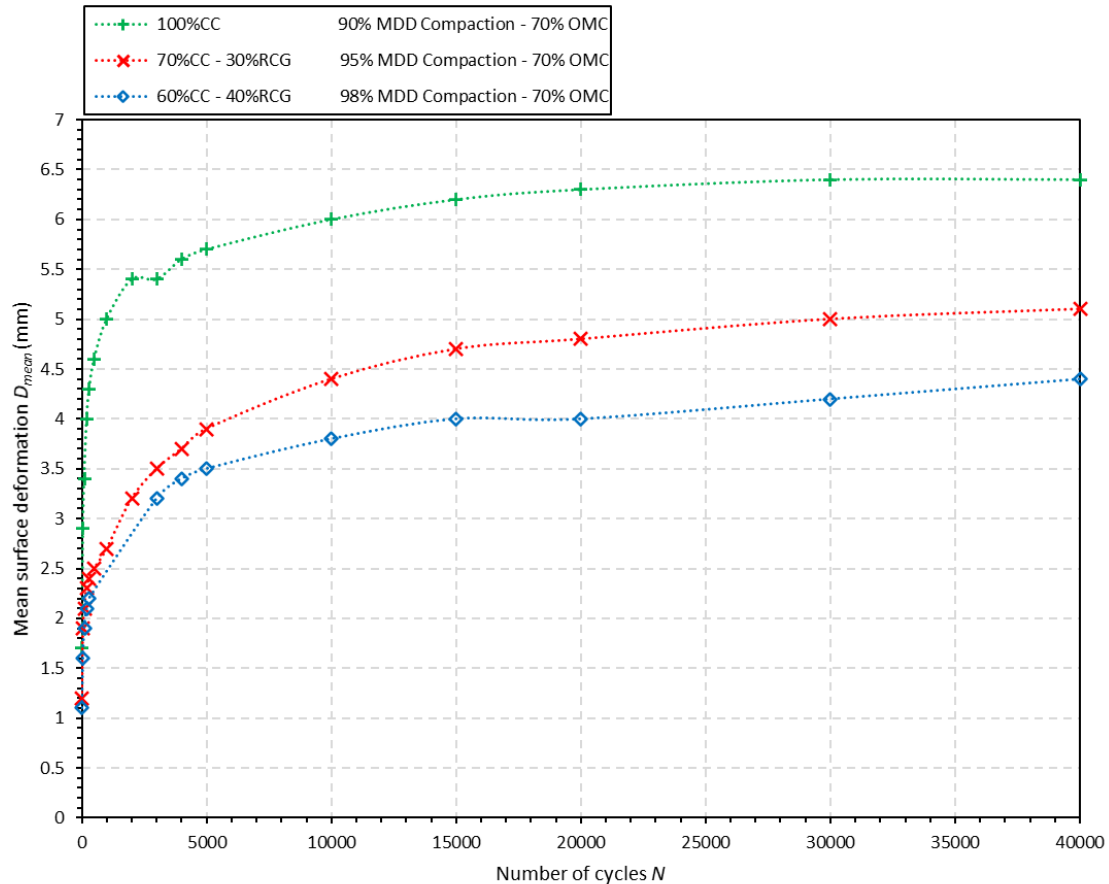


Sealed surface after
wheel tracking



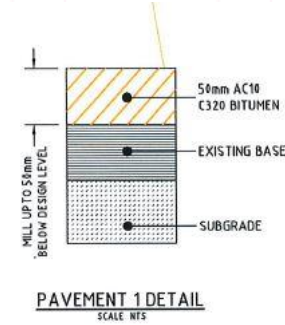
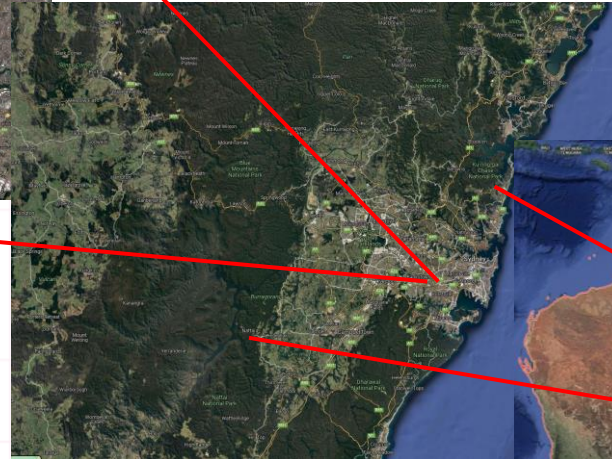
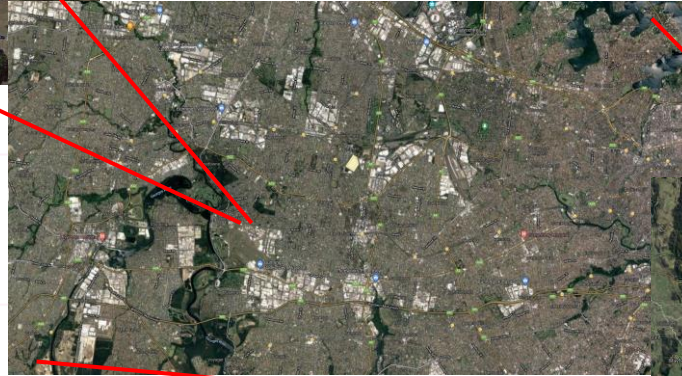
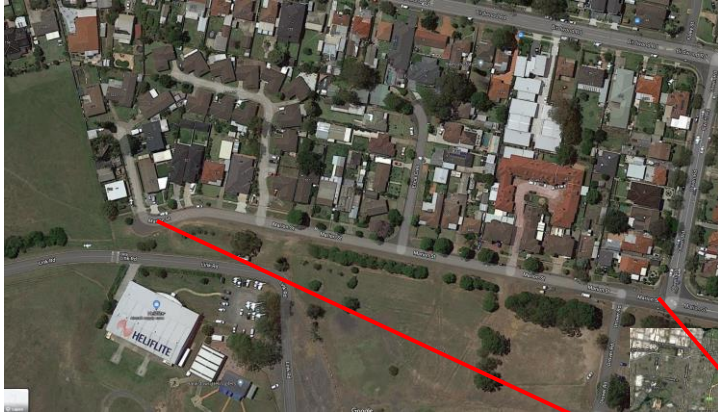
View from the right side
when unmoulding

Permanent deformation performance

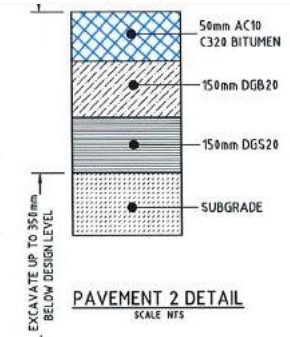


- Samples tracked to minimum 40,000 cycles.
- Decreased rut depth seen with greater recycled crushed glass content.
- Increase recycled crushed glass content leads to improved compaction and improved rutting performance.
- All well within acceptable range.

Field trials



PAVEMENT 1 DETAIL
SCALE NTS
Existing structure



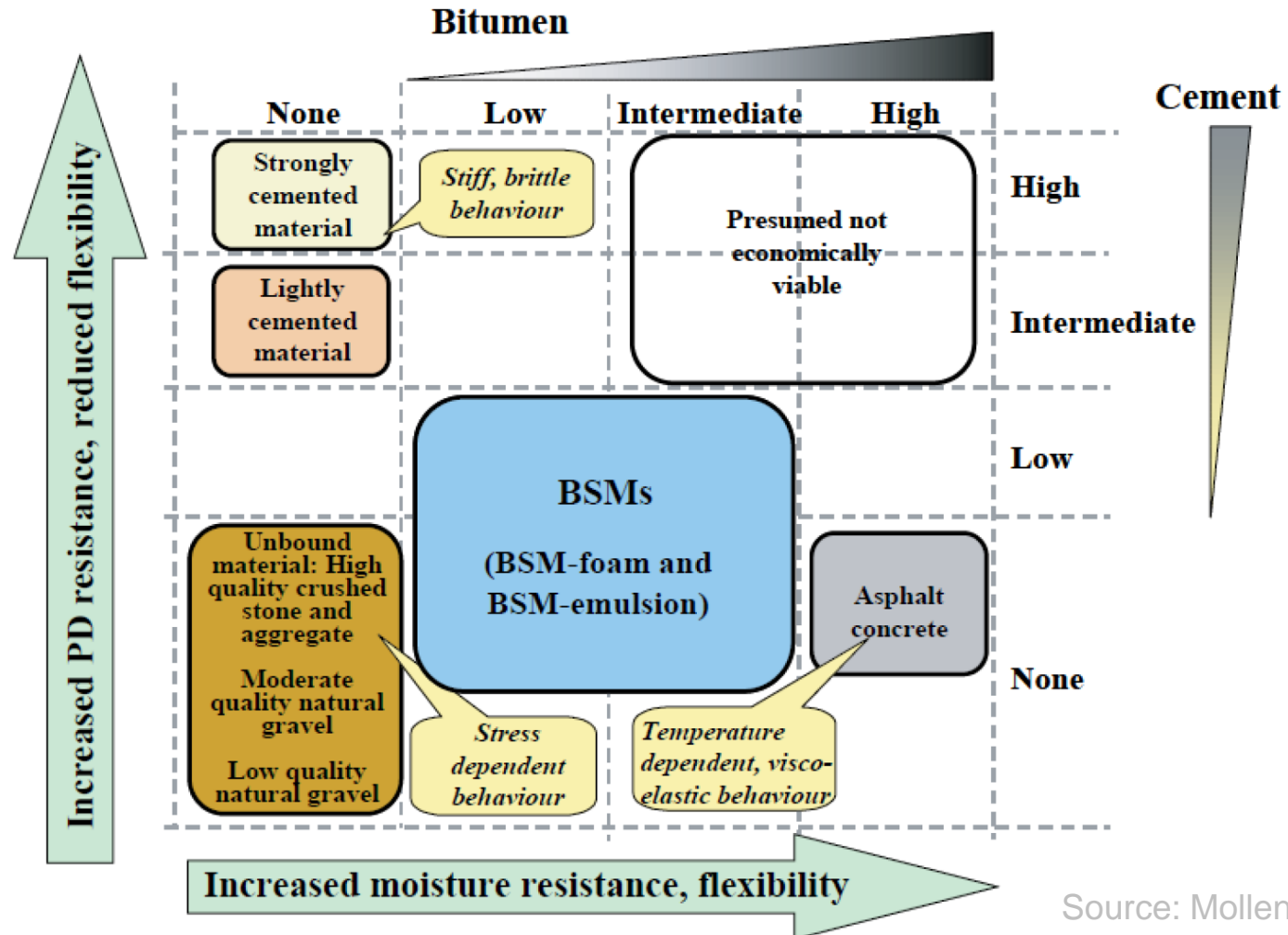
PAVEMENT 2 DETAIL
SCALE NTS
New structure – incorporating recycled materials

Construction of field trial



Cementitious Stabilisation

Stabilised Pavement Materials



Source: Mollenhauer (2016)

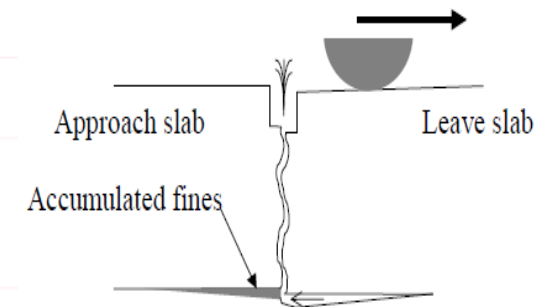
Lightly-Bound Cemented (LBC) Materials

- 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



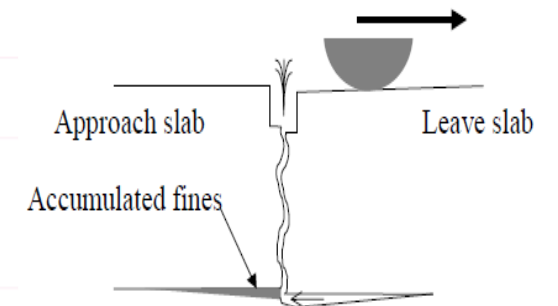
Properties and design requirements

- 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



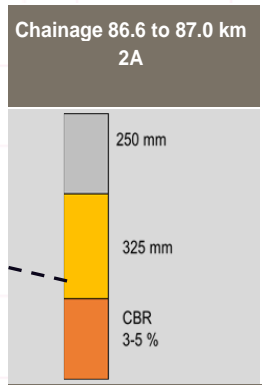
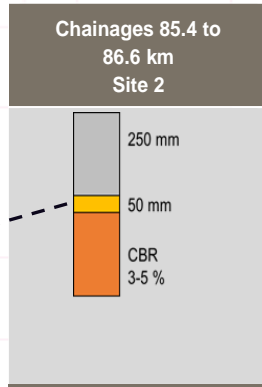
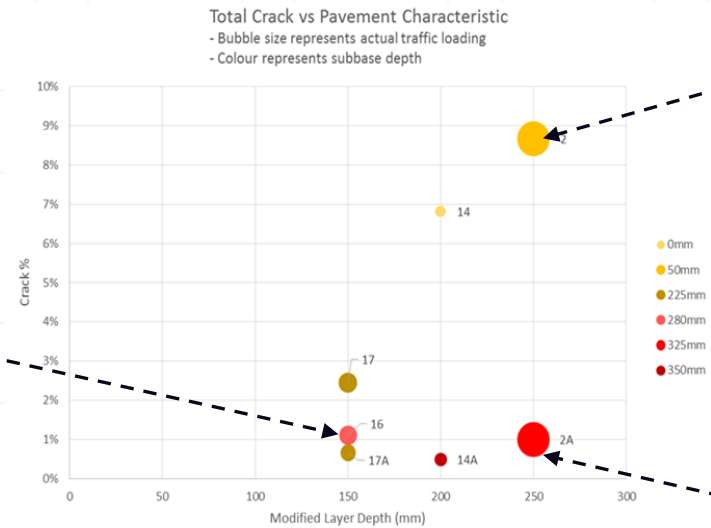
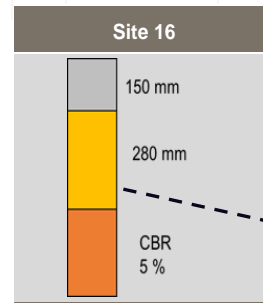
Properties and design requirements

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



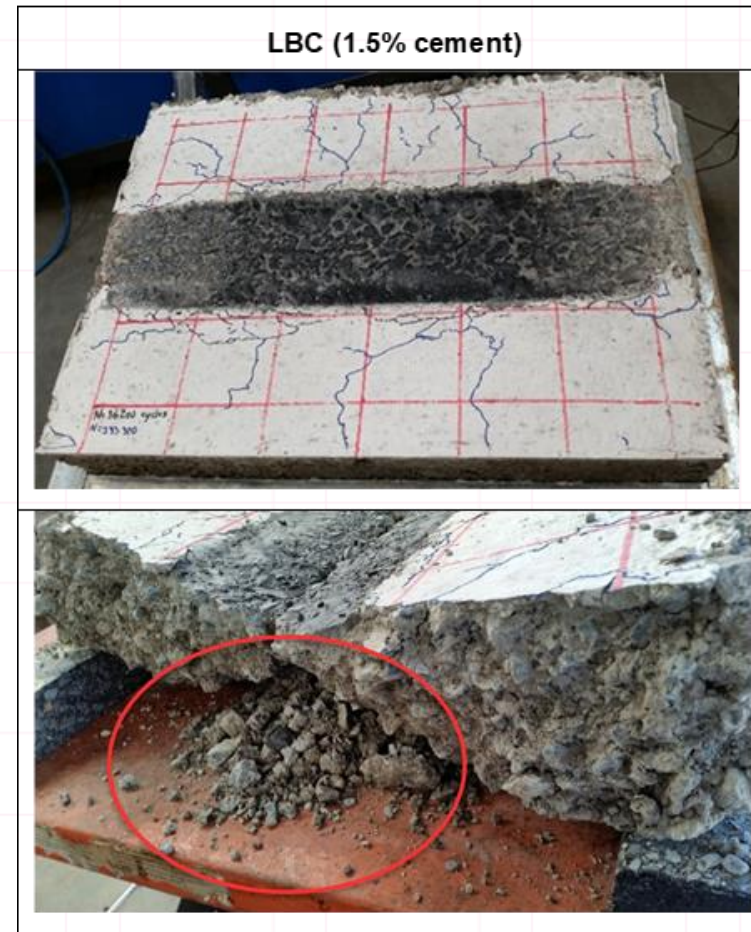
Effect of subbase support

- 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



Mimicking field behaviour in the lab

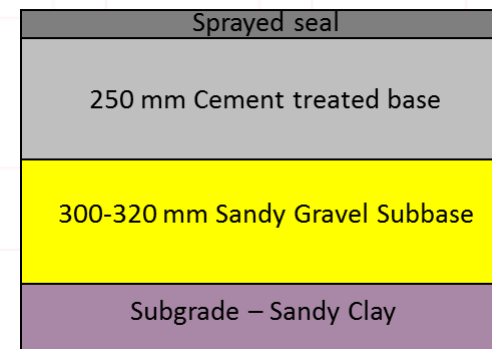
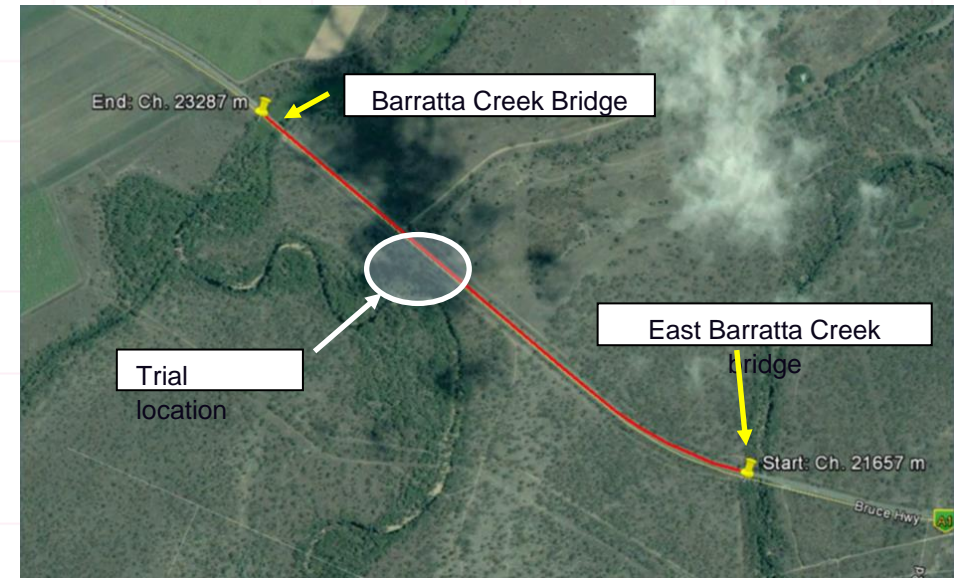
- The Extra-large wheel tracking (XL-WT) device was used to replicate field behaviour
- The XL-WT was used to apply heavy wheel loading to LBC slabs to induce cracking
- After trafficking slabs were investigated to determine cracking characteristics



Field Trial Sites

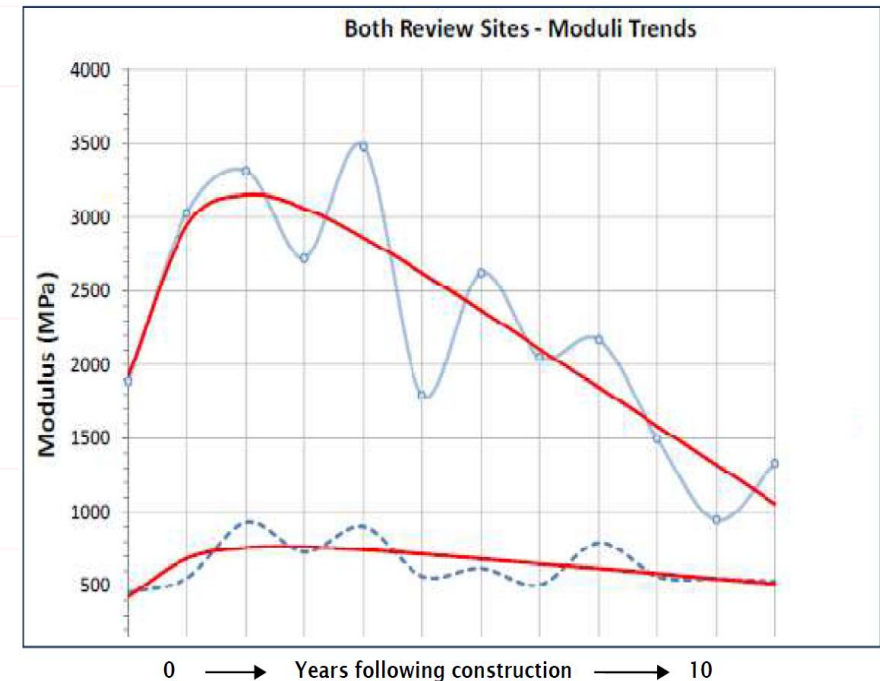
Barratta Creek - 100 m section of Bruce Highway between Ayr and Townsville

- 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



Maximum cracked LBC modulus

- Host materials base or upper subbase quality (e.g. CBR $\geq 30\%$)
- 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:

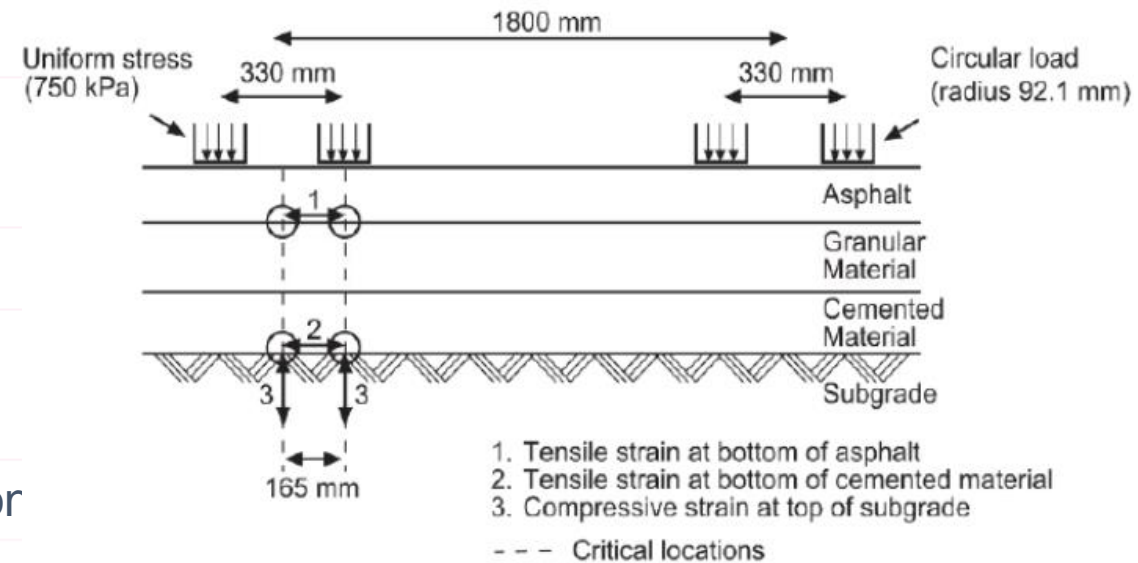
- Consider minimum layer thickness
- Consider minimum support to the LBC layer

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

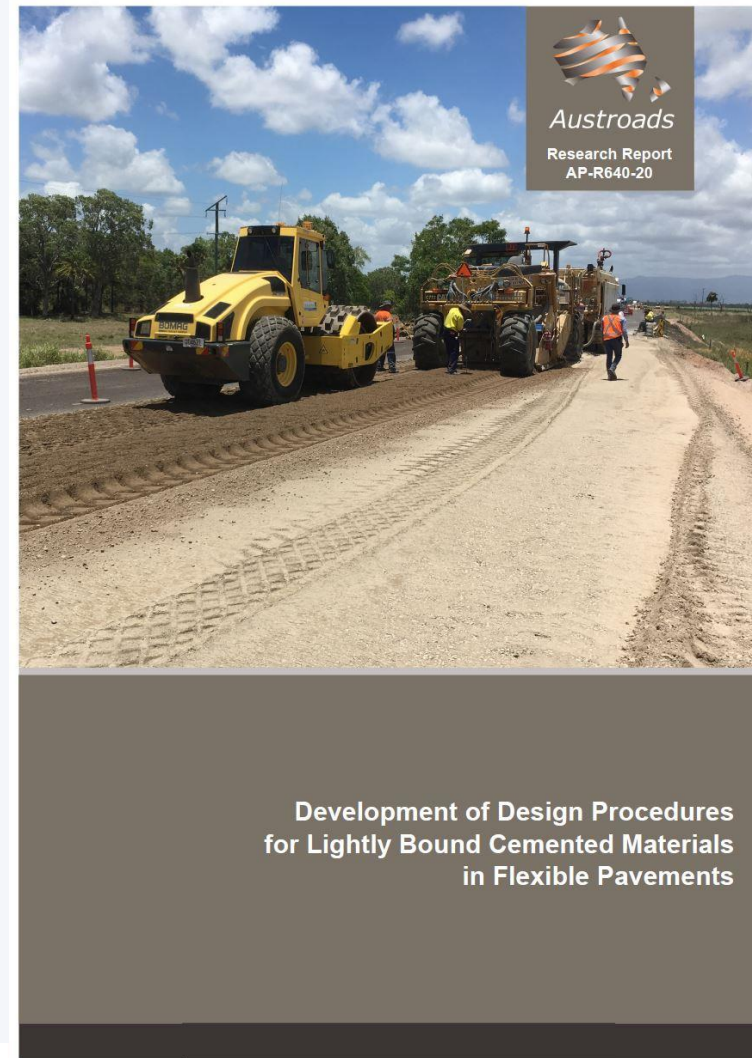


Final outcome

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



Foamed Bitumen Stabilisation

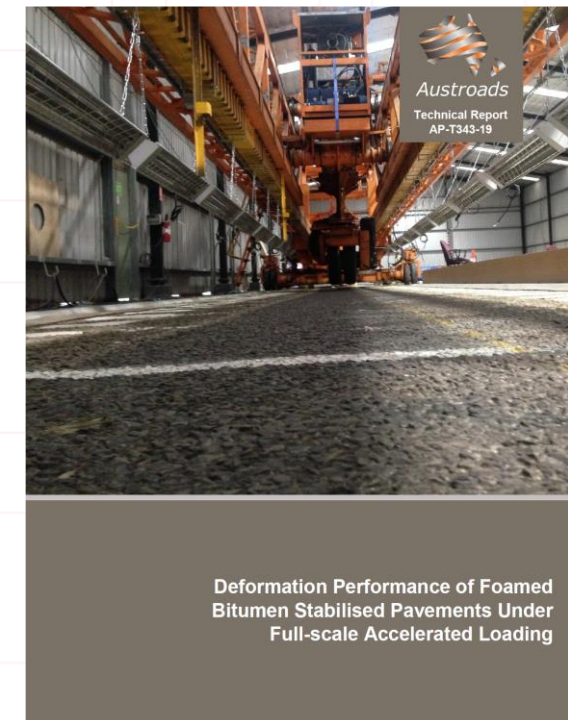
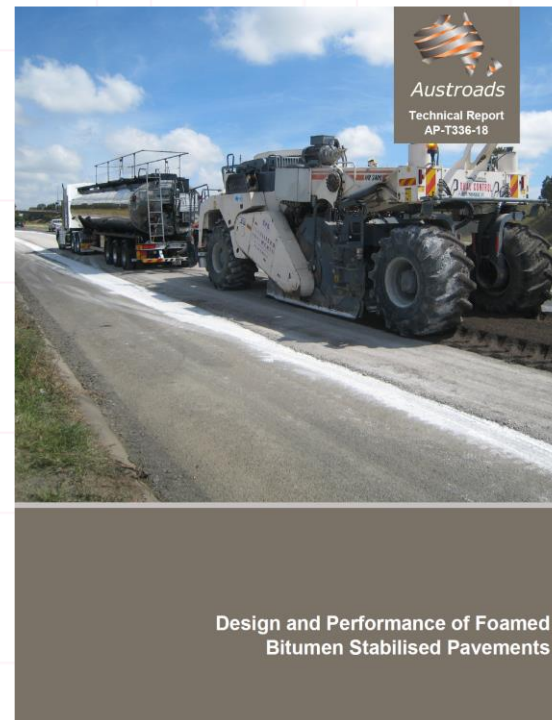
Improving the Design and Performance of Foamed Bitumen Stabilised Pavements

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



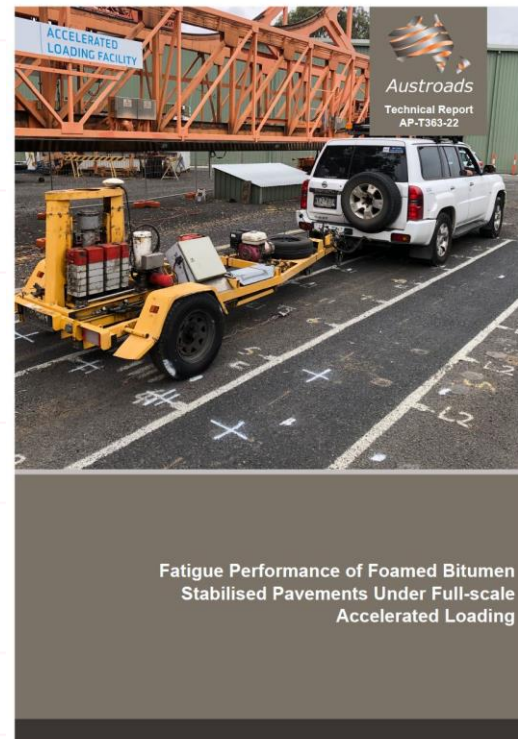
Improving the Design and Performance of Foamed Bitumen Stabilised Pavements

TT1825 Mix Design and Field Evaluation of Foamed Bitumen Stabilised Pavements

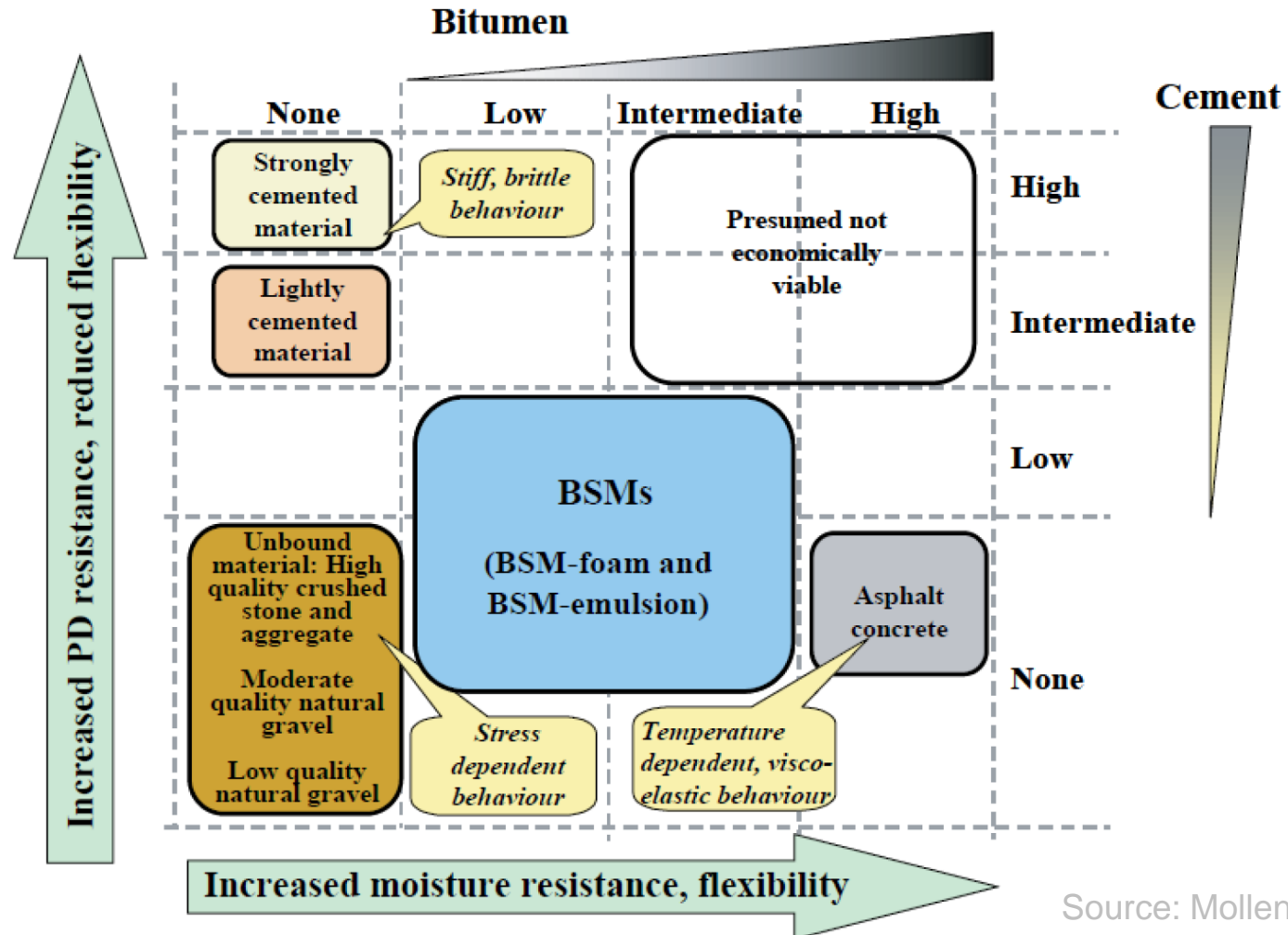
TT2046 Improving the Cost Effectiveness of Foamed Bitumen Stabilised Pavements

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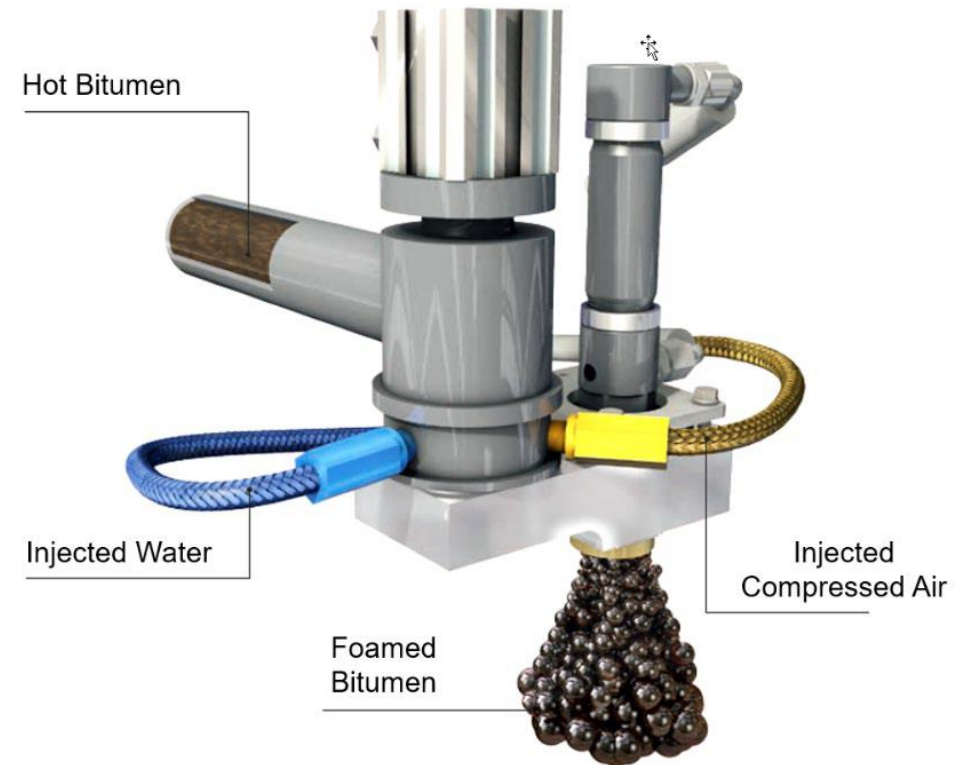
Stabilised Pavement Materials



Source: Mollenhauer (2016)

Foamed Bitumen Stabilisation (FBS)

- FBS introduces cohesion into non-plastic materials or to make a cohesive material less sensitive to loss of stability with increased moistures.
- Foamed bitumen is produced using air, water, and hot bitumen. After injecting small quantities of water and compressed air into hot bitumen, the water turns into vapour, resulting in the production of foamed bitumen.
- Particle size distribution (PSD) of the host material is an important factor affecting bituminous stabilisation.
 - Generally, well-graded PSD with a good particle shape (not rounded),
 - plasticity index (PI) of equal or less than 10, or
 - linear shrinkage of equal or less than 6



Source: Wirtgen Group (2017).

In-situ Stabilisation



Mt Lindesay Hwy at Camp Cable Rd (a few months after construction) 2017

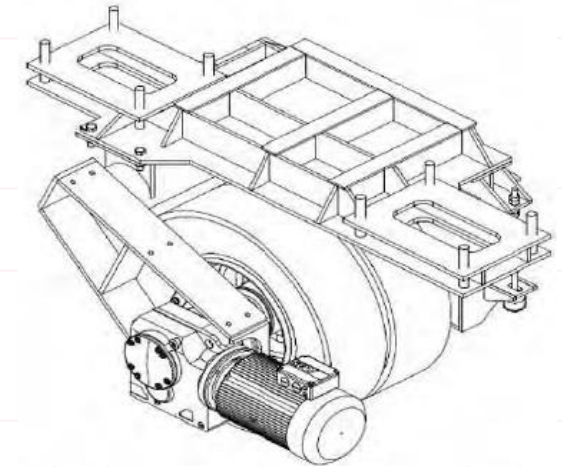
Source: Queensland Department of transport and Main Roads

Stabilisation



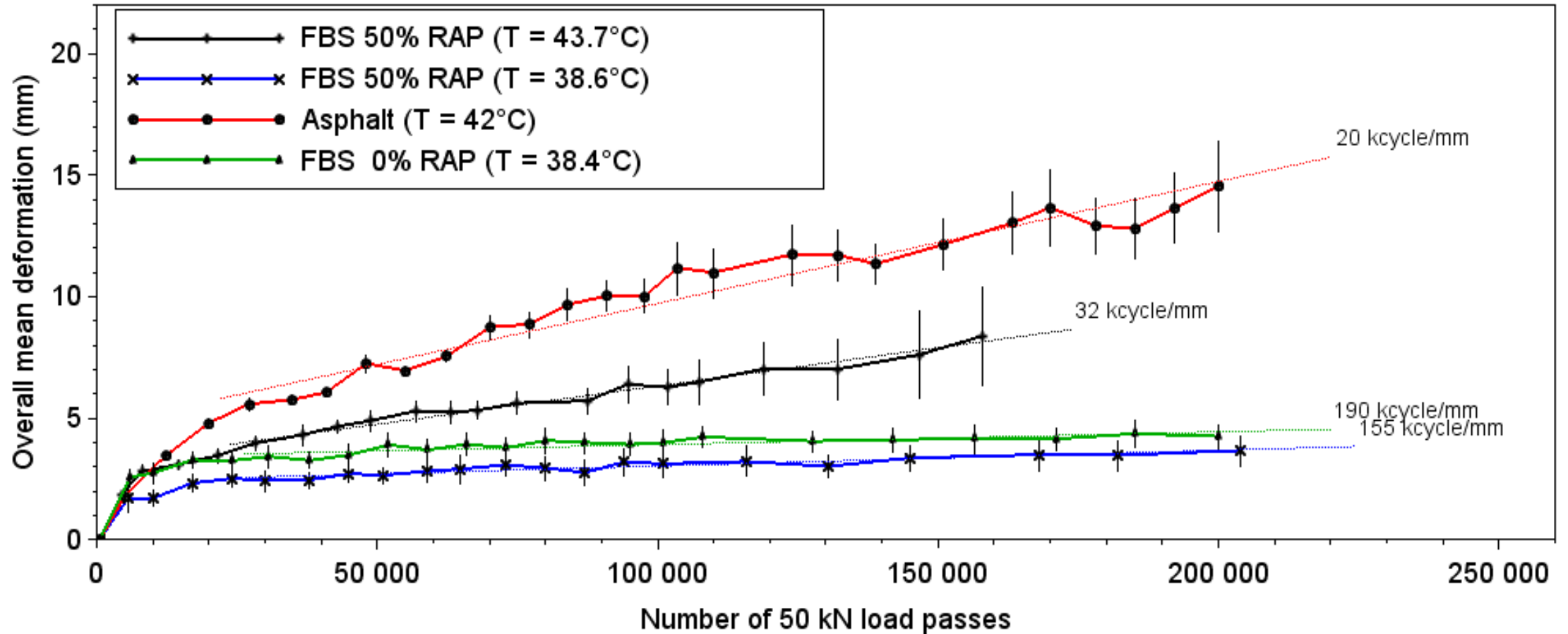
Testing of FBS under ALF

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



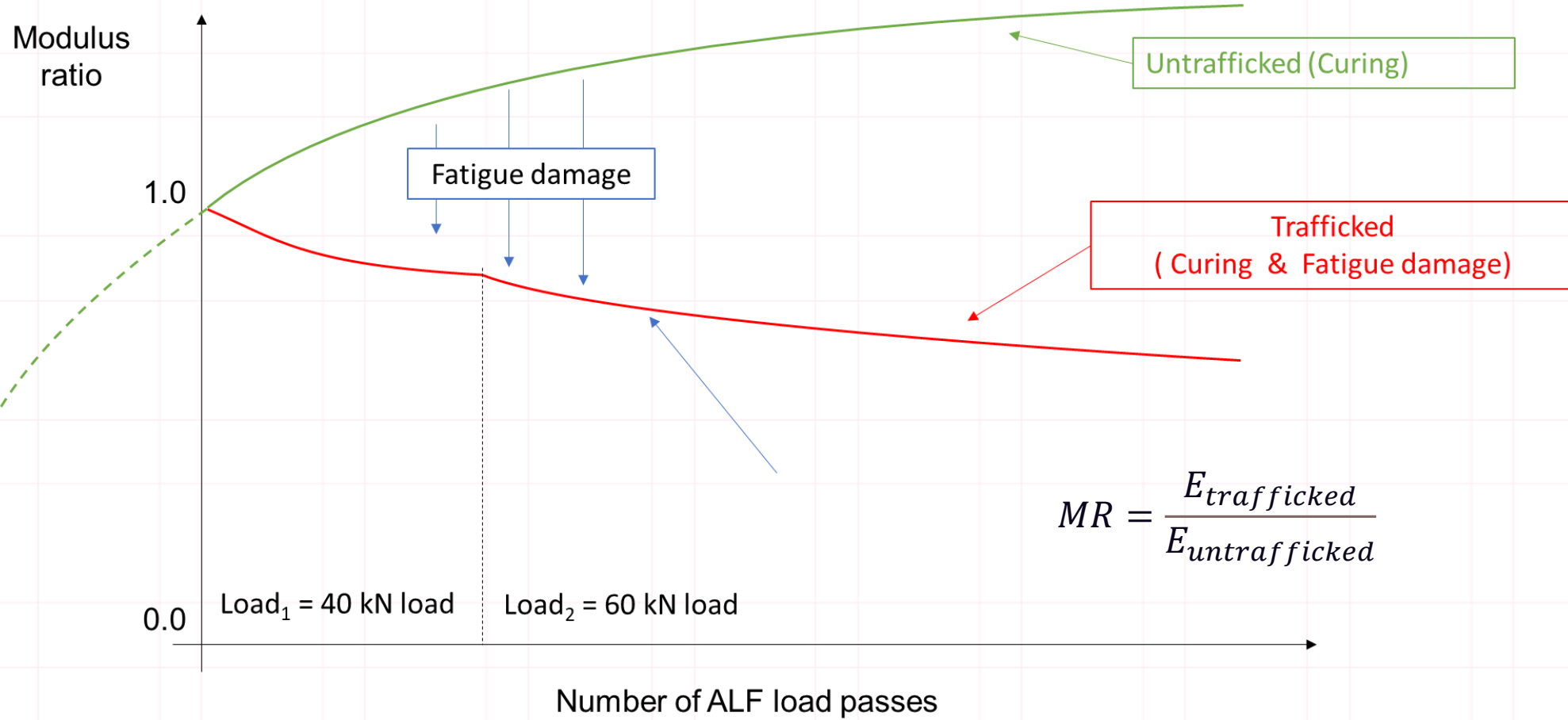
Load type: dual wheel,
single axle
Total load: 50 kN

Permanent Deformation Results

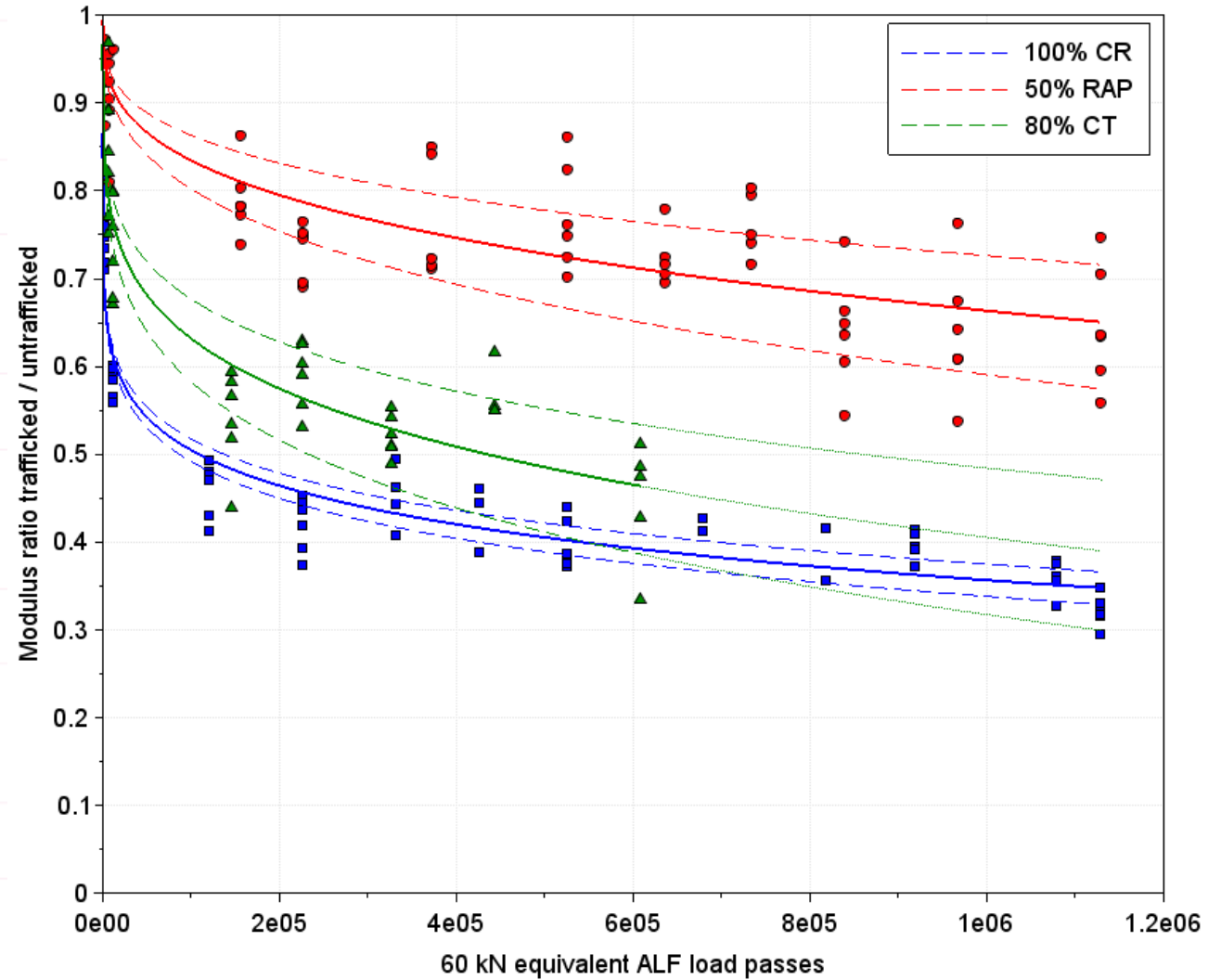


Damage Analysis

Curing vs load induced damage



Damage Analysis



Summary

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

Permeable and Pervious Pavements

Background

Challenge

- Substantial amounts of the Waka Kotahi network are granular pavements, water has significant effect on their performance
- Increasing peak stormwater events in urban, rural and mountainous environments
- Increased runoff exceeding the capacity of existing drainage system, causing flooding

Severe flooding event at SH1 Auckland Southern motorway at 27th Jan 2023



Source: Waka Kotahi NZTA Auckland & Northland, 2023

Solutions for enhancing resilience and climate adaptability of Waka Kotahi road network?

Project Objectives

Investigate the most appropriate permeable/ pervious treatments for different parts of the network in New Zealand, include:

1. Urban areas
2. Mountainous regions
3. Low lying regions

Pervious pavements – Potential in mountainous regions

Challenges around mountainous regions:

- 1. Maintaining a slope required in road
- 2. Subject to lateral water flows from the slope

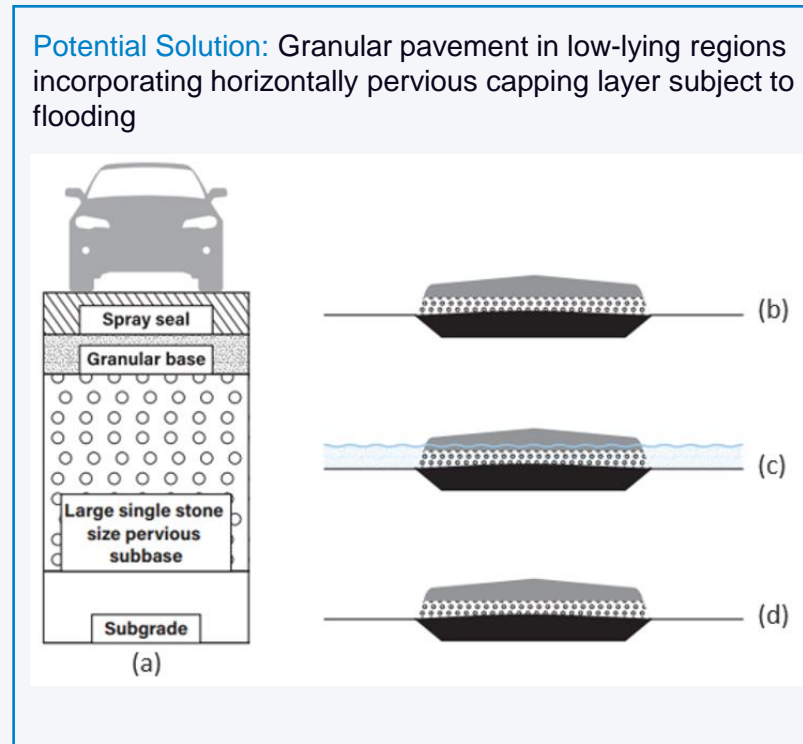
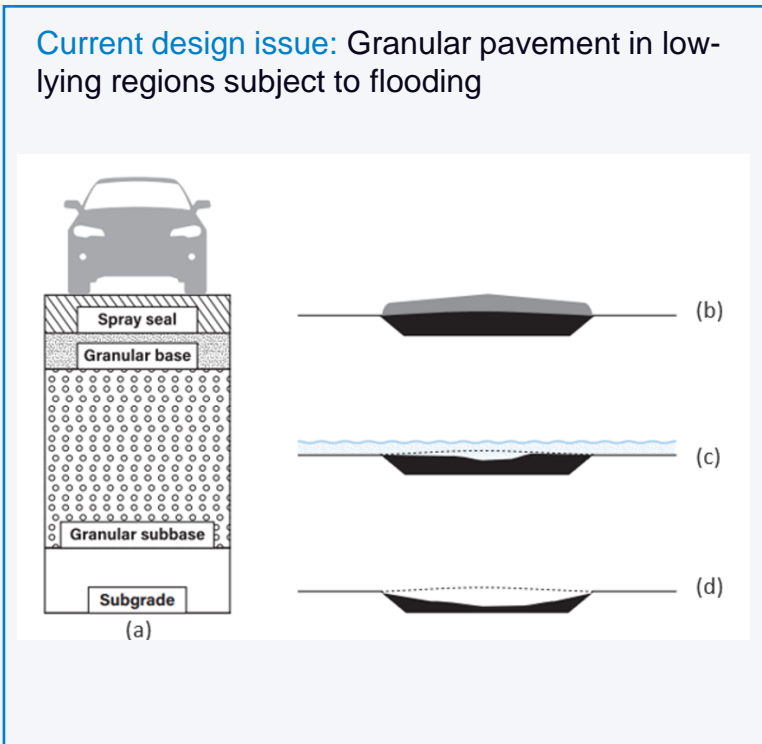
Current design issue: Granular pavement in mountainous regions subject to flooding

Potential Solution: Granular pavement in mountainous region with horizontally pervious capping layer subject to flooding

Pervious pavements – Potential in low lying regions

Challenges around low lying regions:

1. High water table
2. Lack of suitable materials
3. Cost



Concluding Remarks

Summary

Solutions exist to improve performance and resilience of low-cost granular roads:

- Materials selection
- Blending/mechanical stabilisation
- Chemical stabilisation
- Cementitious stabilisation
- Foamed bitumen stabilisation/bitumen emulsion stabilisation

Further work to be done to design granular pavements to be more resilient

NTRO

Thank you

 James.grenfell@ntro.org.au

 +61 448 130 300

 80A Turner St. Port Melbourne, Vic 3207

 ntro.org.au

Adelaide, Brisbane, Canberra, Launceston,
Melbourne, Perth, Sydney, and Wellington



THE CENTRE OF TRANSPORT INNOVATION