Category 2: Industry Excellence in Consulting, Research or Education

Characterisation of the Fatigue Performance of Foamed Bitumen Stabilised Materials

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2021 AustStab Awards of Excellence

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Project Outline

Project Title:
Maximising the Use of Sustainable Rehabilitation Treatment

Key Contributing Staff:
Dr Negin Zhalehjoo, Dr Didier Bodin,
Dr Geoff Jameson, Dr Michael Moffatt

Project Timeframe:
August 2018 – December 2021

Source: ABC News
Floodwaters demolished pavements in Rockhampton, QLD

Project Objective:
This ground-breaking project mainly aims to improve the design of Foamed Bitumen Stabilised (FBS) materials for new pavements and rehabilitation treatments by the development of a new laboratory fatigue relationship to predict the performance of these materials.

Acknowledgements:
Austroads funded project (Transport Infrastructure Program)

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Typical Australian Pavement

Over 90% of the Australian's 330 000 km sealed road network:

Sprayed seal unbound granular pavements

Thin bituminous seal

Granular base

Granular subbase

Subgrade

- More frequent adverse weather & annual growth in traffic loadings
- Pavement structures facing faster deterioration

Solution ?

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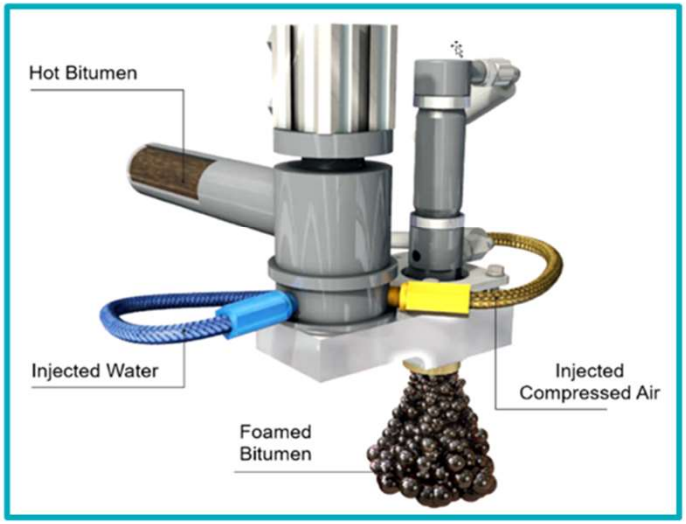
Foamed Bitumen Stabilisation

❑ What is foamed bitumen?

- Hot bitumen, water, and air
- Coating of wet materials
- Sudden expansion of foamed around 15 to 20 times its original volume.
- Foamed bitumen collapses very rapidly
- Coating of the fine particles by bitumen



Source: Wirtgen Group brochure, WLB10S- WLM30

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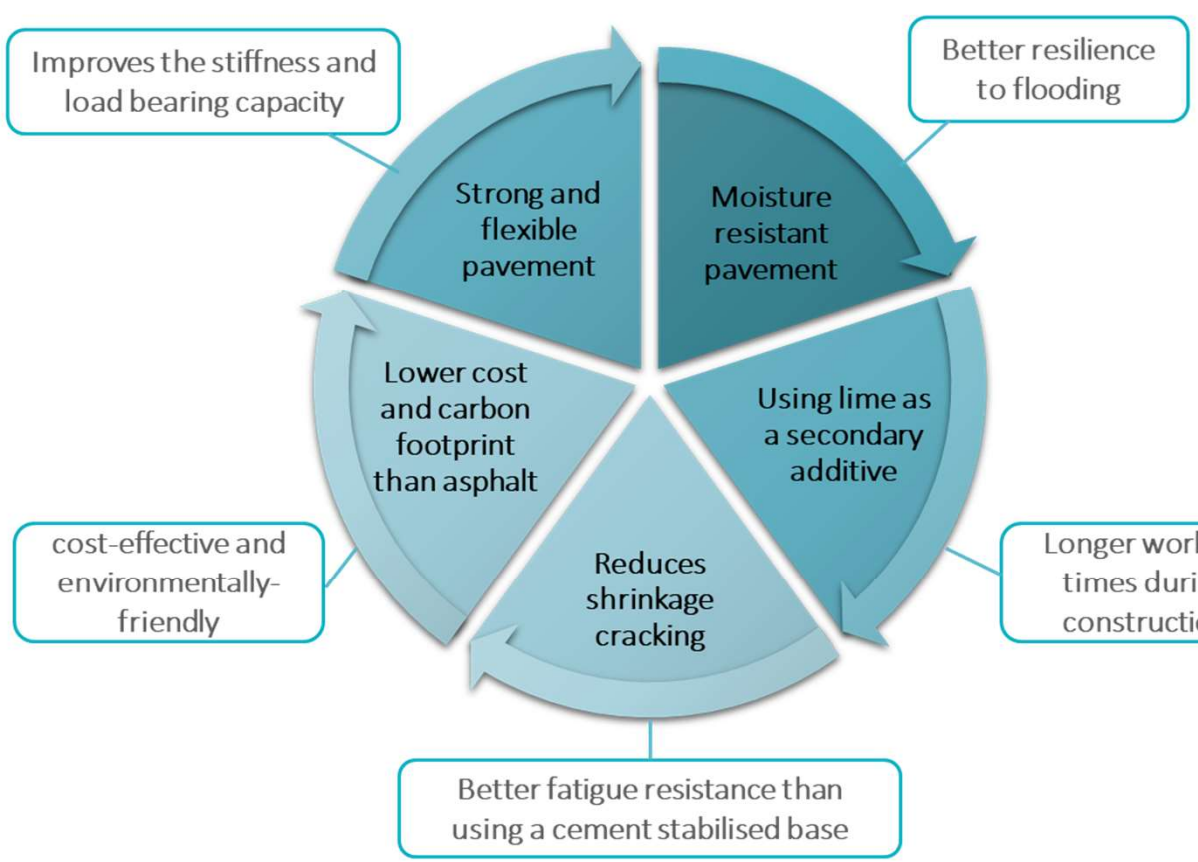
Benefits of Foamed Bitumen Stabilisation



Source: Queensland Department of transport and Main Roads

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Gap: Fatigue Performance of FBS Materials!?

- Austroads research showed that fatigue cracking is a potential failure mechanism for FBS materials.
- To date asphalt performance relationship has been adopted for FBS materials. Is this a right approach?

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

Fatigue relationship for **asphalt**:

Slope=5

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

Fatigue relationship for **FBS materials**:

????

Fatigue relationship for **cemented materials**:

Slope=12

$$K = 240FS + \frac{919300}{E} - 285$$

- **Better understanding the fatigue performance of FBS materials**
- This project aimed to develop a laboratory flexural fatigue test procedure and a new fatigue relationship for FBS materials.

Main research questions?

- Slope of the performance relationship ?
- What is the effect of E (FBS materials modulus) and other influencing parameters on fatigue?

N= *allowable number of repetitions of the load-induced tensile strain*
ε= *load-induced tensile strain at the base of the layer (microstrain)*
k= *model constant*

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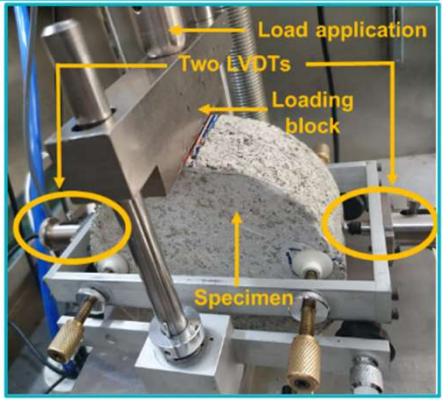
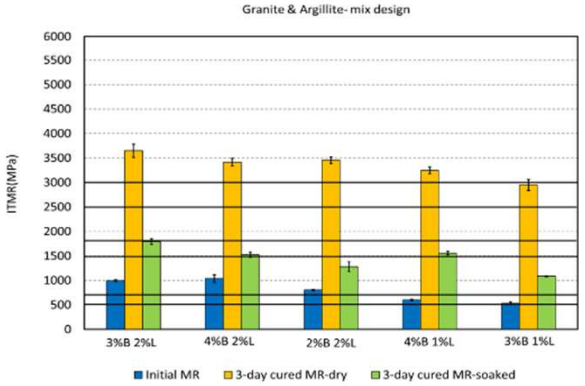
Experimental Program – FBS Mix Design

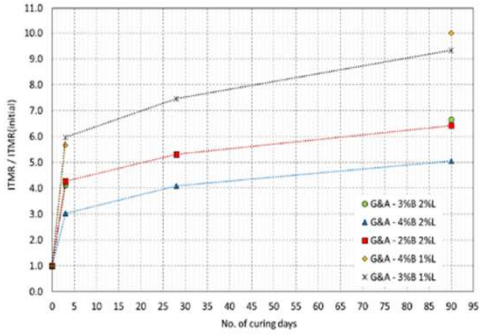
FBS mix design

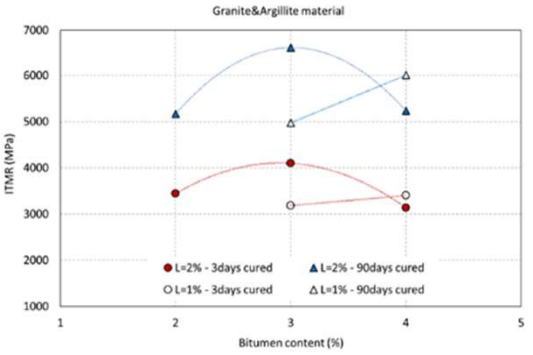
Testing & assessments of 16 FBS mix combinations

- Effect of binder contents (foamed bitumen and hydrated lime) on the mechanical properties of FBS materials
- Effect of the curing on the mechanical properties of FBS materials
- Defining the optimum binder content resulting in the optimum mechanical properties









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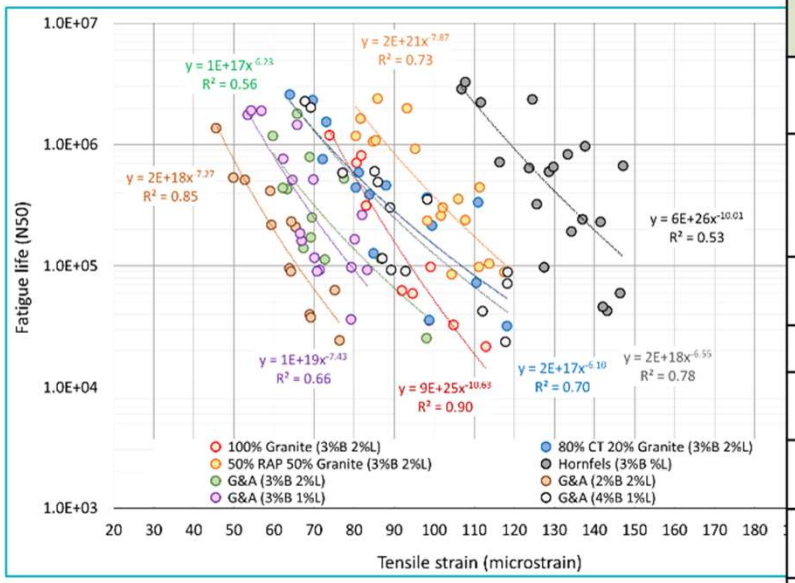
Laboratory Fatigue Testing

- Four-point bending test on 90-day cured laboratory prepared FBS beam specimens
- Testing includes ⟹
  1. Flexural fatigue
  2. Flexural modulus
  3. Flexural strength



Tested FBS Mix	Strain Damage Exponent
50% Granite 50% RAP (3%B 2%L)	7.9
20% Granite 80% previously cement treated materials (3%B 2%L)	6.1
100% Granite (3%B 2%L)	10.6
Hornfels (3%B 2%L)	10.0
Granite&Argillite (3%B 2%L)	6.2
Granite&Argillite (2%B 2%L)	7.3
Granite&Argillite (3%B 1%L)	7.4
Granite&Argillite (4%B 1%L)	6.6
Average slope	7.8

B: Foamed Bitumen L: Hydrated Lime

FBS samples compaction

Four-point bending test

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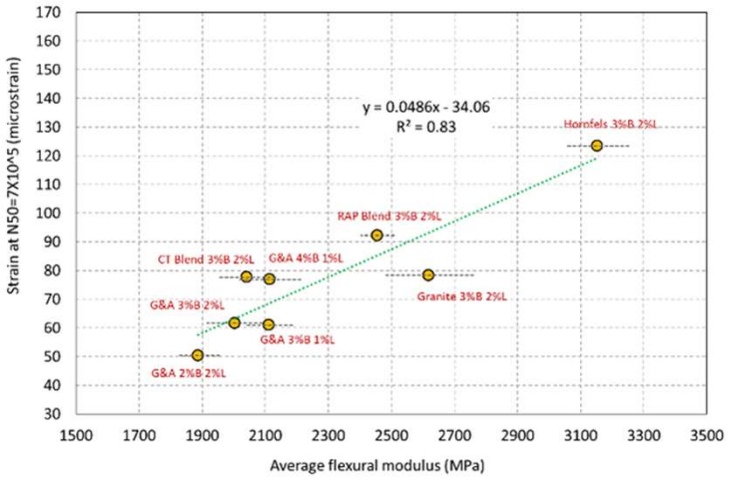
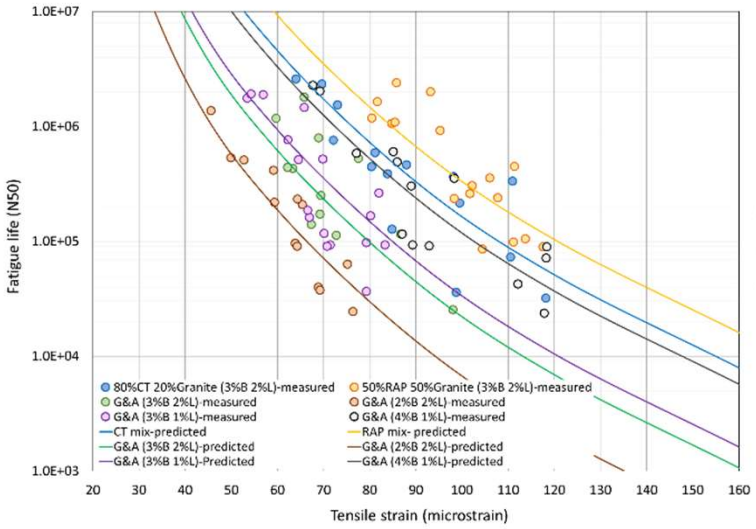
Development of Laboratory Fatigue Relationship for FBS

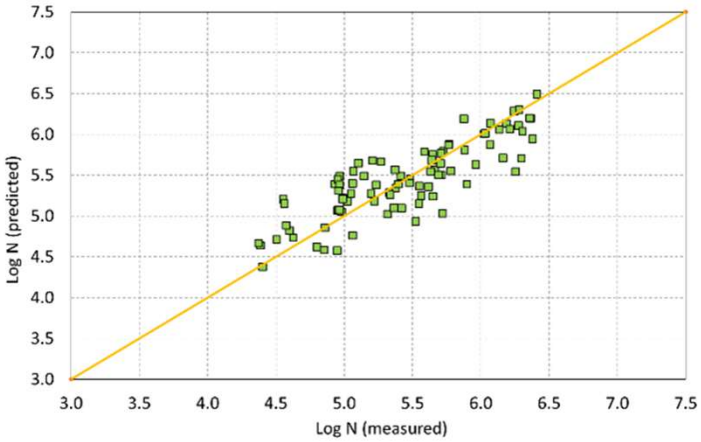
Tolerable strain at N=7 x 10^5 increases with the increase in flexural modulus (E)
(a different behaviour compared to asphalt!!)



Fatigue life versus tensile strain
Measured (markers) & predicted (lines)



Predicted versus measured fatigue life
R^2=71%
RMSE=0.29



- The results confirmed the significant need for a change of performance relationship for FBS materials.
- The predicted fatigue life of FBS materials are obtained using the preliminary developed model for these materials: $N = (\frac{k}{\mu\varepsilon})^{Slope}$
- k= f (flexural modulus(E), volume of binder (VB), air void (AV), flexural strength(FS)/E)

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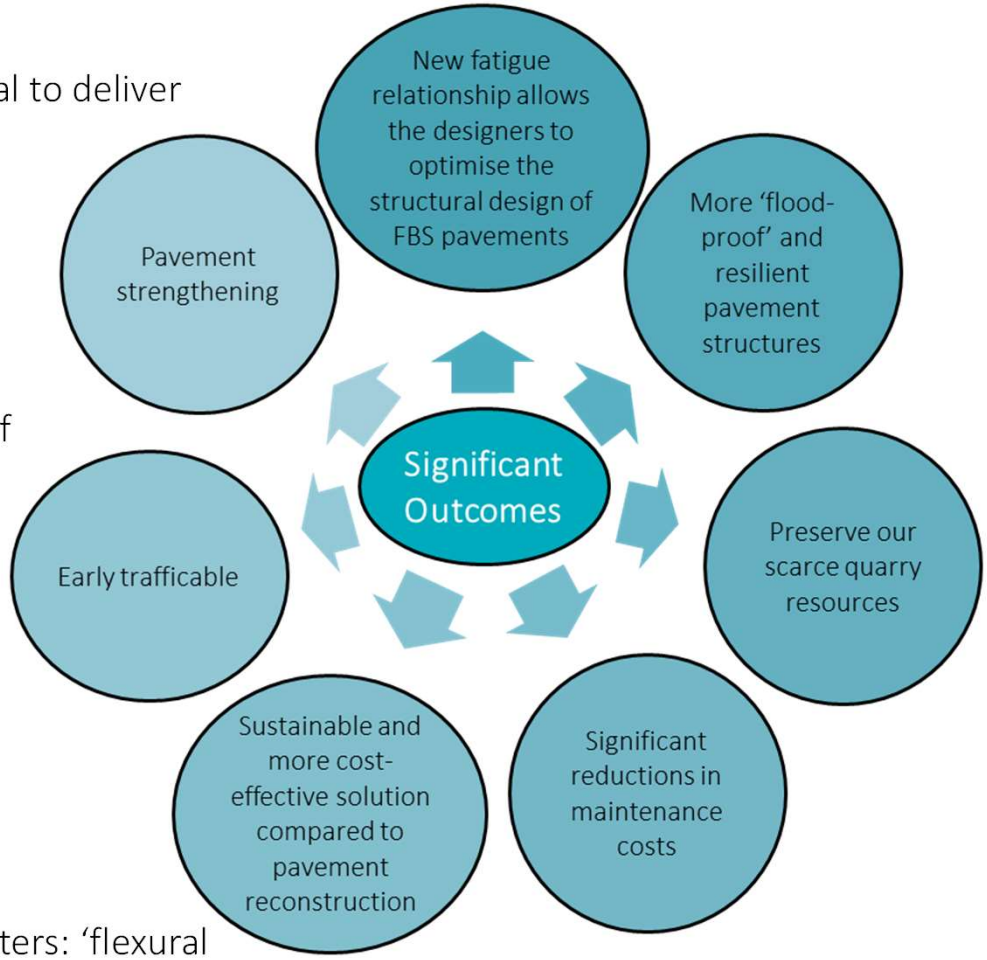
Summary

- In-situ foamed bitumen stabilisation has demonstrated its potential to deliver structural rehabilitation treatments or new pavements.
- Up to 100% of the existing pavement materials can be recycled in-situ using this stabilisation process. The previously stabilised materials and reclaimed asphalt pavement (RAP) can be also used (plant or in-situ).
- New results confirmed and demonstrated the need for a change of performance relationship to better take into account the effect of FBS mix properties.
- A new laboratory fatigue relationship to predict the actual performance of these materials is being developed.

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

- The results demonstrated that the strain damage exponent of the FBS mixes is different from current assumptions.
- k fatigue parameter is developed as a function of material parameters: 'flexural modulus, E', 'flexural strength, FS', 'volume of binder, VB', and 'air void, AV'.

$$k = f(E, \frac{FS}{E}, VB, AV)$$



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