NZ Transport Agency & NZIHT

18th ANNUAL CONFERENCE

"12 Years Later - Where are we at with Foamed Bitumen – A Contractors Perspective"

Allen Browne - Group Technical Manager Hiway Group

2003/2004 GS360 Foamed Bitumen Bar Fitout

Mar 2006
Coronet Peak Rd

FB Modelling Protocol from 2006

Design Analysis

(i) Determination of Steady State Resilient Modulus

TP4 + 30% AP40 3.5% Bitumen, 1.0 Cement

Phase 1: $MR_{phase\ 1} = (\log(ITS_{equ}) \times 3950 - 7000) \times TSR \times F_{drainage}$

Phase 2: $MR_{phase\ 2} = \dfrac{MR_{phase\ 1} \times TSR}{(0.5 \times UCS_{equ}) + 0.7}$

		Sensitivity Analysis with larger UCS
$MR_{phase\ 1}$ =	2585 MPa	2585 MPa
ITS_{equ} =	310 kPa	310 kPa
TSR =	0.91	0.91
$F_{drainage}$ =	1	1
$MR_{Phase\ 2}$ =	1272 MPa	1001 MPa
UCS_{equ} =	2.3 MPa	3.3 MPa

where:

$MR_{phase\ 1}$ = Resilient Modulus during Phase 1

ITS_{equ} = ITS at equilibrium moisture content from design briquettes

TSR = tensile strength retained (ratio soaked to unsoaked ITS)

$F_{drainage}$ = Drainage factor determined from Table 4.9

$MR_{Phase\ 2}$ = Steady State Equilibrium Modulus

UCS_{equ} = UCS at equilibrium moisture content, assumed

Table 4.9 - Drainage Factors Fdrainage for estimating field stiffness values of bitumen stabilised material

Drainage Quality	Mean Annual Rainfall (mm)			
	<200	200 to 600	600 to 1000	>1000
Very good	1.4	1.3	1.2	1.1
Good	1.3	1.2	1.1	1
Fair	1.2	1.1	1	0.9
Poor	1.1	1	0.9	0.8
Very poor	1	0.9	0.8	0.7

NZ Supplement to Austroads manual recommends pavement design parameters of:

Phase 2 Resilient Modulus 800 MPa

Anisotropic (conservative?)

No Sublayering (unconservative?)

Poissons Ratio = 0.3

frequently asked:

Is there a better means of modelling??

Thoughts on FB - Circa 2010

- Valuable comparative data provided on active filler / stiffness of layer to introduce crack failure in FBS
- Future research should better categorise “safe zone” for FBS stiffness.
- Don’t design FB Base in isolation of total pavement structure / support
- Function of stiffness, modular ratio and strains so optimum / permissible FBS properties will vary depending on each specific pavement system.
- For now: Do not exceed 1.5% cement
- Design FBS ITS values of >600 kPa – Danger Danger
- Design FBS ITSM values > 5,000 MPa – “ “ “ “

Further Thoughts on FB – Circa 2011

Should We be Considering Other Limits?

Maximum cement % = 1.0% 1.25% 1.5%

Maximum ITS – 500 kPa 600 kPa??

Maximum Stiffness (E) 2,000? 3,000? 5,000MPa??

Correlate stiffness to curing/dryback?

Maximum Depth of FB Layer? 250mm?? 300mm??

Maximum Modular Ratio - 5? 10?

Different requirements for new aggregates versus recycled?
Different requirements for traffic loading / pavement hierarchy

Link base aggregate properties to modified properties?

Grading / plasticity / moisture sensitivity

NZTA / NPTG FB Workshop September 2015

- Prelude to production of the NZTA Rehab/Design Guides
- Industry Comment on use of FB
- NZTA Perspective on FBS
- Review NZTA Technical Note on FB
- Discuss sites where FBS Should / Should not be used
- Agreement on what FBS should look like
- Binder Quantities – Bitumen & Cement or Lime
- Grading Envelope
- Construction – Process & Quality Assurance
- Test Methods for FBS
- Mix and Pavement Design Philosophy
- Opening to Traffic & Surfacing

NZTA Guide to Pavement Evaluation & Treatment Design – July 2017

Foamed bitumen stabilisation

- Portland cement limited to 1% or 1.25% where justified
- The underlying pavement layers need to follow the methodologies of Austroads (2012), particularly in regard to modulus gain for different material types over subgrade.
- The achieved modulus is limited to five times the underlying modulus, up to a maximum of 800 MPa.

Foamed bitumen stabilisation

- The foamed bitumen layer shall not be sublayered unless this is required to meet the requirement that the achieved modulus is less than five times the underlying modulus.
- If sublayering is required and the Foamed Bitumen Stabilised (FBS) layer thickness is 220 mm or greater, then the FBS layer can be split into two sublayers.
- The lower layer would have a modulus of 400 MPa and the upper would have a modulus of 800 MPa.

Foamed bitumen stabilisation

- Sublayering foamed thicknesses of less than 220 mm shall not be considered acceptable.
- The underlying support shall have a stiffness greater than 100 MPa with a thickness greater than 100 mm; construction on a less stiff subbase shall not be acceptable.

Foamed bitumen stabilisation

- The modulus of foamed bitumen material under asphalt greater than 60 mm must meet the Austroads requirements for a premium aggregate in Table 6.5 in Austroads Part 2.
- Asphalt thicknesses greater than 40 mm must be modelled for fatigue performance. Poisson's Ratio shall be equal to 0.3.
- The degree of anisotropy is 2.
- The foamed bitumen layer shall be equal to or thicker than the basecourse thickness required by Figure 8.4.

Foamed bitumen

- The reactivity of the proposed foamed bitumen and cement additives with the aggregate shall be tested according to TG2 using a two phase design life but with the modifications from Wirtgen (2004) reproduced below.

$$MR_{Phase\ 1} = (\log ITS_{equ} \times 3950 - 7000) \times TSR \times F_{drainage}$$

$$MR_{Phase\ 2} = \frac{MR_{Phase\ 1} \times TSR}{(0.5 \times UCS_{equ}) + 0.7}$$

NZ TRANSPORT AGENCY

New Zealand Government

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Takes T/19 ITS testing, plus UCS test and assessed mean average rainfall/Drainage Quality Factor

NZTA Rehab Guide 2017 – Key Changes / Clarifications

- Changes to active filler - look to reduce to 1.0%
- Changes to sub-layering protocol & more specific substrate requirements
- Limit FB modulus to min of a) 800MPa **or** b) 5 x underlying sublayer
- Subbase must be ≥100mm thick and E ≥100MPa
- Not sublayered unless constrained by underlying and at least 220mm thick
- Limiting modulus for FB under ≥60mm overlying asphalt – compliance with Austroads Part 2, Table 6.5 (Premium Aggregate). i.e. <500MPa constraint.
- Asphalt surfacing 40mm or more must be modelled mechanistically.
- Thickness of layer ≥ Requirement of Fig 8.4 Premium Basecourse

Austroads Part 2, Table 6.5

Table 6.5: Suggested vertical modulus (MPa) of top sublayer of high standard base material

Thickness of overlying bound material	Modulus of overlaying[1] bound material (MPa)				
	1000	2000	3000	4000	5000
40 mm	500	500	500	500	500
75 mm	500	500	480	460	440
100 mm	500	450	410	390	360
125 mm	450	390	350	310	280
150 mm	400	330	280	240	210
175 mm	360	270	210	210	210
200 mm	310	210	210	210	210
225 mm	260	210	210	210	210
>=250 mm	210	210	210	210	210

Overlying bound material is either asphalt or cemented material or a combination of these materials.

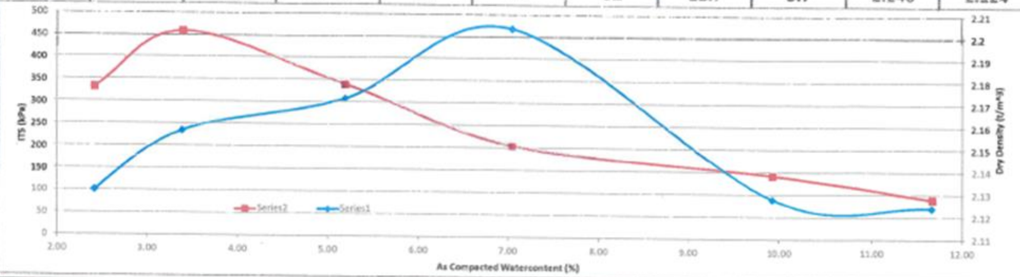
NZTA Roadshow Currently Underway

Location	*Date*	*Meeting Room*
Wellington	*24/10/2017*	*NZ Transport Agency Chews Lane, Room 2.32*
Christchurch	*1/11/2017*	*NZ Transport Agency, Room MR3.01*
Nelson	*22/10/2017*	*Quality Inn Nelson. Brougham Room, 40 Waimea Road*
Dunedin	*23/11/2017*	*NZ Transport Agency Dunedin, Room Awarua*
Auckland	*29/11/2017*	*NZ Transport Agency Auckland HSBC, Room 11.18*
Hamilton	*30/11/2017*	*NZ Transport Agency Hamilton, Meeting Room Waikato 1.26*

Moisture / Density / ITS Foamed Bitumen mix design curves

Mix Detail: **3.0% Bitumen & 1.0% Cement**

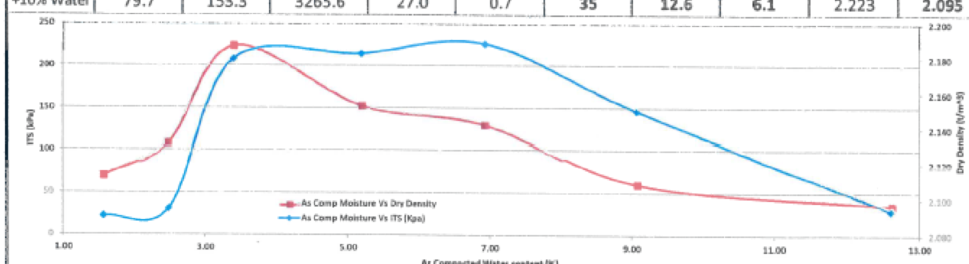
Block ID	Height (mm)	Diameter (mm)	Mass (g)	Ring Load (div)	Load (P, KN)	ITS (Kpa)	Moisture (%) As Comp.	Moisture (%) Post Test	Bulk Density (t/m3)	Dry Density (t/m3)
NATURAL *	-	-	-	-	-	-	1.4	-	-	-
+1% Water	86.0	152.3	3398.0	275	6.9	335	2.4	1.9	2.170	2.131
+2% Water	84.7	152.0	3408.6	371	9.3	460	3.4	2.8	2.218	2.157
+4% Water	83.5	152.0	3419.2	272	6.8	342	5.2	3.9	2.257	2.172
+6% Water	78.6	152.1	3301.8	155	3.9	207	7.0	4.9	2.312	2.203
+8% Water	78.2	152.6	3179.6	107	2.7	143	9.9	5.2	2.240	2.128
+10% Water	77.2	152.8	3179.6	67	1.7	91	11.7	5.7	2.246	2.124



Demonstrates optimum density does not always correspond to maximum ITS strength

Mix Detail: **3.0% Bitumen & 1.0% Cement**

Block ID	Height (mm)	Diameter (mm)	Mass (g)	Ring Load (div)	Load (P, KN)	ITS (Kpa)	Moisture (%) As Comp.	Moisture (%) Post Test	Bulk Density (t/m3)	Dry Density (t/m3)
NATURAL	91.4	150.0	3415.8	60	1.5	70	1.6	1.1	2.115	2.091
+1% Water	91.3	150.0	3450.7	94	2.4	110	2.5	2.1	2.139	2.095
+2% Water	86.9	150.1	3449.6	183	4.6	224	3.4	2.9	2.243	2.180
+4% Water	86.1	150.1	3463.6	124	3.1	153	5.2	4.1	2.273	2.183
+6% Water	84.4	150.2	3451.5	104	2.6	131	6.9	5.4	2.308	2.189
+8% Water	82.3	151.1	3386.1	47.0	1.2	60	9.1	6.8	2.296	2.151
+10% Water	79.7	153.3	3265.6	27.0	0.7	35	12.6	6.1	2.223	2.095



Test Methods:

New Zealand Situation Currently

- Some resistance to FB for Capital Works Projects
- Cautious acceptance for SH rehabs
- Demand for TLA Rehabilitations with appropriate design checks / protocols
- Concern that some practitioners have not seen “good foaming”

Consider:

- Designing to inferred dependable modulus – even if <800MPa.
  - **Maximum value??**
- Caution on extremely stiff substrates where FB layer is not loaded while curing and/or has very little flexure. Evidence that rather than reduce over time – the modulus may increase (AMA E values extremely high).
- Not many examples of *recycled basecourse* FB failures through marginally inadequate substrate (gross modular ratio’s aside such as shell rock) – have pushed envelope in some TLA sites with admirable results.

New Zealand Situation Currently

More ***Consider:***

- Grading of older aggregates is typically more suitable for FB than the coarser ‘virgin’ M/4 basecourse. May need to manage plasticity – here the pretreatment with lime or KOBM integral.
- ITS testing is conservative for FB as non-continuously bound. Particularly for SI aggregates with reduced broken faces. Insitu modulus as demonstrated by FWD testing is superior
- Representative sampling for obtaining mix design aggs is critical
- Foaming Agent for optimising modified properties

- Differentiate between greenfields / Capital works project (virgin aggs) and potentially more variable recycled aggs (TLA / State Hiways etc)
  - Manage proportions of surfacing , plasticity, localised structural problems

Foamed Bitumen in Australia

- On the rise for state highways / expressways many major projects coming/arrived to market

- Modelled differently to NZ – Asphalt performance characteristics
- Binder constituents typically similar – 3 to 3.5% bitumen, up to 2% hydrated lime (NSW/Qld) or up to 1.2% cement/blend (Tas/Vic/SA)

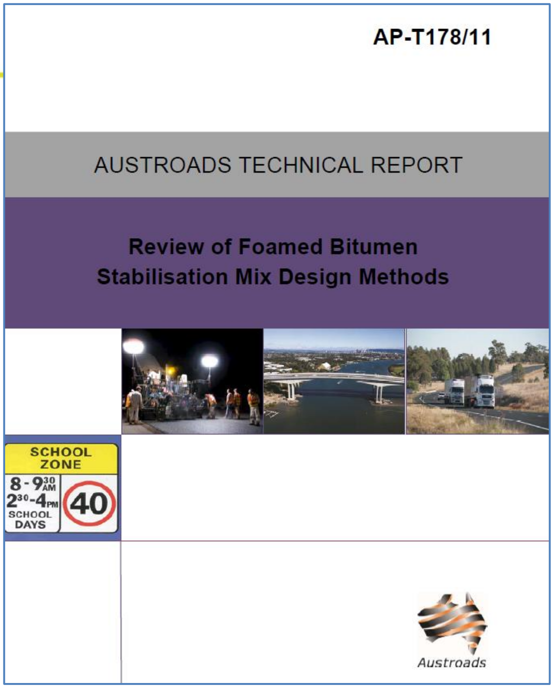
- Geoff Jamieson (ARRB Chief Scientist) quote at AustStab Conference
  - ***"Assessed 160km of FB pavements all >8 years life, typically 3.5% bitumen and 1.5-2.0% hydrated lime. >95% of this length is assessed as performing well"***

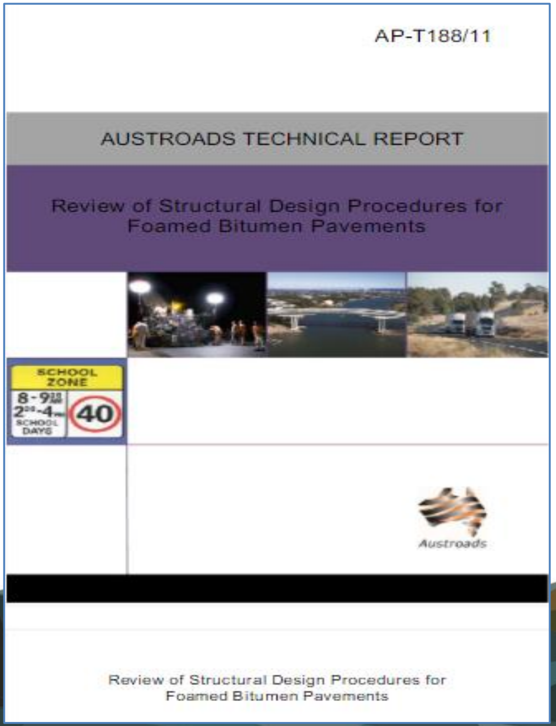
Foamed Bitumen in Australia

- Want to build on Qld experience and harmonise design methodologies.
- Mix design and pavement design protocol settled recently. AP-T178-11 & AP-T188/11
- ITSM leading to acceptable properties
- Rut Resistance for higher daily loading –
  - >1000 ESA/Day

Table A 4: Recommended limits for rut progression

Design traffic in first year of service (ESA/day)	Max rut depth at 2000 cycles (mm)	Max rate if rut progression (mm/kilocycle)
< 100	10	0.20
100−1000	7	0.15
> 1000	5	0.10





AP-T178-11

Mix Design Protocol

Modulus Targets

Table A 2: Suggested bitumen and secondary binder contents to commence mix design

Percent passing 4.75 mm sieve	Percent passing 0.075 mm sieve	Bitumen content (% mass)	Plasticity Index (%)	Hydrated lime[1] (% mass)
< 50	5–7.5	3.0	6–10	2.0
	7.5–15	3.5		
	15–20	4.0	3–6	1.5
> 50	5–7.5	3.5		
	7.5–15	4.0	< 3	1.0
	15–20	4.0		

1 Cement may also be used as a secondary binder, but appropriate percentages may vary from values listed for hydrated lime.

Table A 3: TMR minimum indirect tensile modulus values for design traffic conditions

Average daily traffic at year of opening to traffic (ESA)	Base and subbase	Base course			Subbase course		
	Initial modulus[1] (MPa)	Min cured modulus[3] (MPa)	Min soaked modulus (MPa)[4]	Min retained modulus ratio[5]	Min cured modulus (MPa)[3]	Min soaked modulus (MPa)[4]	Min retained modulus ratio[5]
< 100	500	2500	1500	0.40	2500	1500	0.40
100–1000	700	3000	1800	0.45	2500	1500	0.45
> 1000	700[2]	4000	2000	0.50	2500	1500	0.50

1 Samples initially cured at 25 °C for 3 hours prior to initial modulus testing.
2 Recommended supplementary wheel tracking testing to confirm curing time.
3 Samples cure at 40 °C for 3 days prior to cured modulus testing.
4 Cured modulus test samples conditioned in a water bath under vacuum of 95 kPa for 10 minutes prior to testing.
5 Retained modulus ratio = soaked modulus/cured modulus.

Australian FB Projects coming to market

- Mackay Ring Road Qld >$10M insitu FB
- Bruce Highway, Yeppen Bridge to WBHO >$10M insitu FB
- Haughton River Qld > 150,000tonne Exsitu FB
- Waterford Tambourine Qld >$3M insitu FB
- WBHO Yeppen Qld >$2M insitu FB
- DM D'Aguilar Hwy Qld, $4M insitu FB
- Warrego Highway Qld > 70,000tonne Exsitu FB
- Toowomba 2nd Range Crossing Qld > $10M FB
- Cunningham Highway Qld >100,000tonne Exsitu FB
- Whitsundays Airport Qld $6M exsitu FB
- Newell Highway NSW >150,000tonne Exsitu FB
- Pacific Complete NSW >300,000tonne Exsitu FB
- VRSWA Alliance Vic ~$8M insitu FB
- Dunning to Boardwalk Vic $1M FB
- Friend in hand Rd 2016/17 FB trial successful and opening door VicRoads

- **Unique problem with Australia are the highly expansive black soils**

Expansive Black Soils

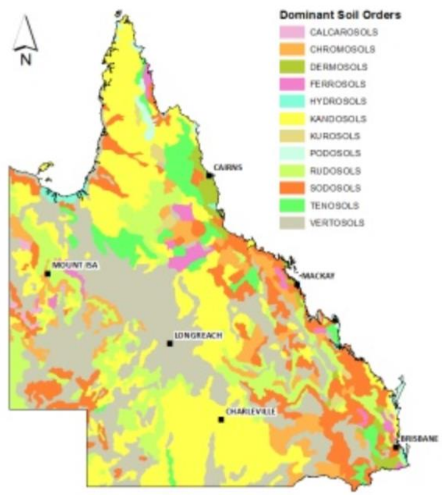
Expansive Black Soils

There is a variety of soils across Queensland. They are broadly grouped into soil orders based on the Australian Soil Classification system (ASC).

Vertosols

Vertosols are the most common soil in Queensland—characteristics include:

- brown, grey or black soils which crack open when dry
- they commonly form hummocky relief called gilgai

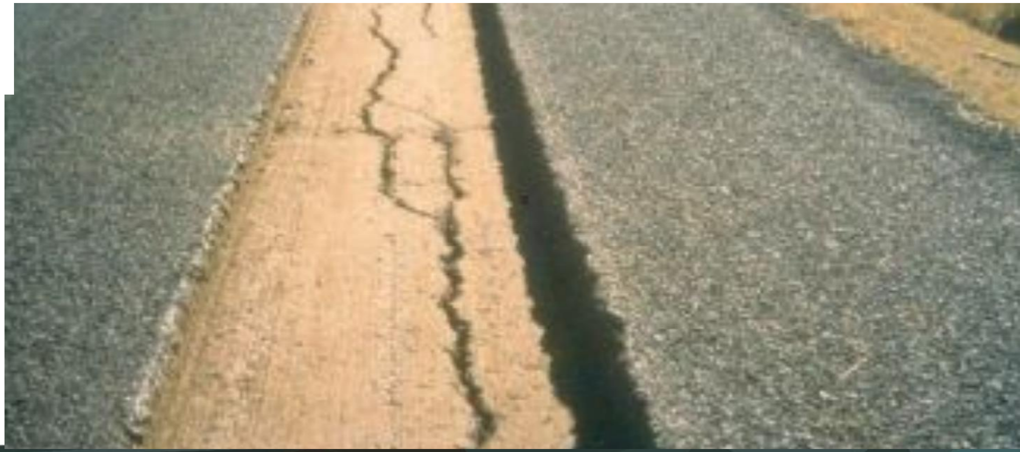


Dominant soils across Queensland (see large map)

Black soil subgrade characteristics

- Typically, the residual black soil subgrade exhibits the following characteristics:
  - Linear shrinkage 12-13
  - Liquid limit 45-65
  - Optimum Moisture Content (OMC) 20%
  - California Bearing Ratio (CBR) – unsoaked 12-20
  - CBR – soaked 2-4

Linear shrinkage greater than 8% and weighted linear shrinkage >50




JUST WATER

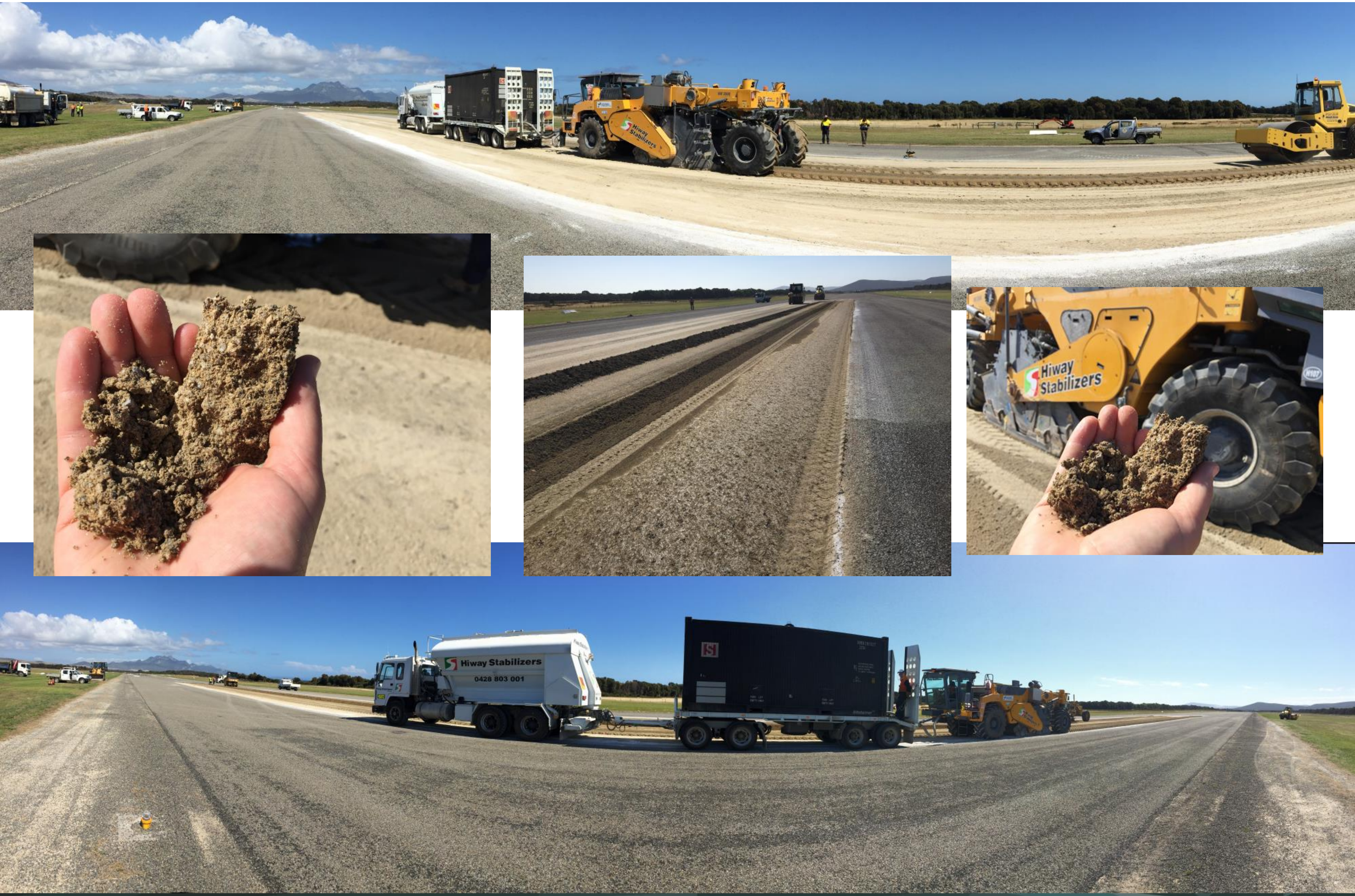
Foaming Agents used widely

Australia requires:
Target Expansion 12 (Min 10)
Target Half Life 45 (Min 20)

New Zealand:
Min Expansion 10
Min Half Life 6

Typically 0.2 to 0.5% by weight of bitumen

Flinders Island Runway
Granitic detrital Soils
CaO Prehoe
Separate active filler / bitumen


Hiway Stabilizers
Hiway Stabilizers
0428 803 001

12 Years Later - Where are we at with Foamed Bitumen

Tessellated Pavement State Reserve, Tasmania

tessellate

/ˈtɛsəleɪt/

verb

past tense: **tessellated**; past participle: **tessellated**

1. decorate (a floor or pavement) with mosaics.
2. cover (a plane surface) by repeated use of a single shape, without gaps or overlapping.

Foamed Bitumen in Fiji

- Commenced 2013 with first project 110,000m2
- New Zealand based campaign
- New Zealand 'rules' with NZ Consultants / Specifications
- Aggregates volcanogenic and have high innate plasticity
- Struggle with moisture sensitivity, extensive rainfall and overloads.
- Multigrade Bitumen M500_170 (previously C170)

FB in Fiji

2013
Introduce
FB to Fiji
100k m2

FB in Fiji

Allen Browne – Hiway Group

Mahogany lumber behemoths

Night works – downtown Suva

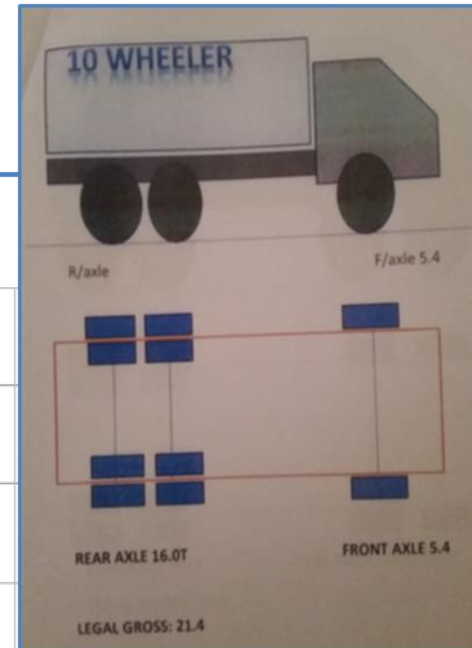
FB in Fiji - Overloads

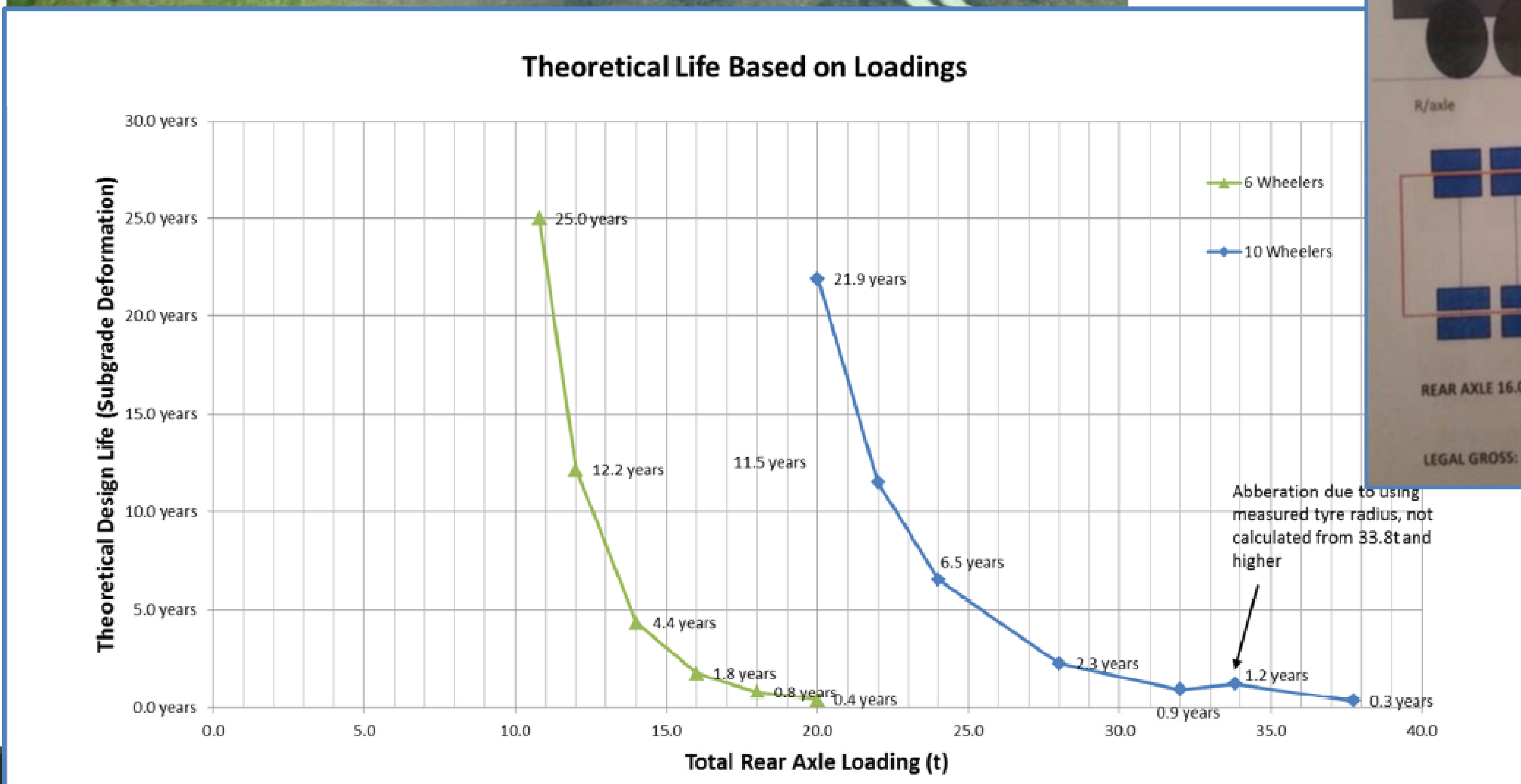
12 Years Later - Where are we at with Foamed Bitumen

Legal axle pair = 16-tonne

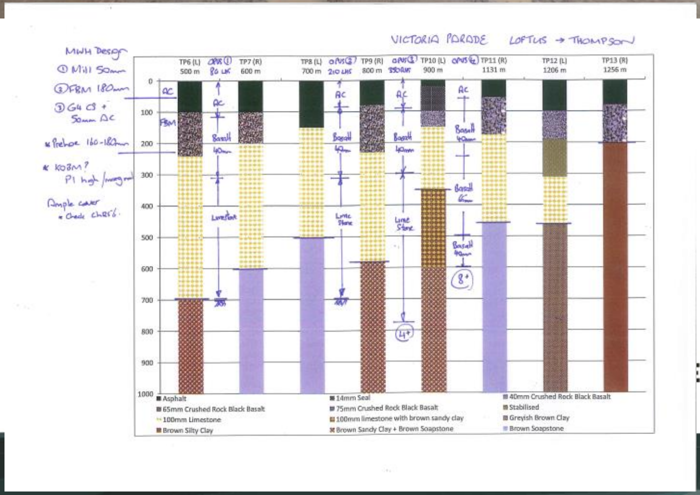
Measured axle pair = 40-tonne

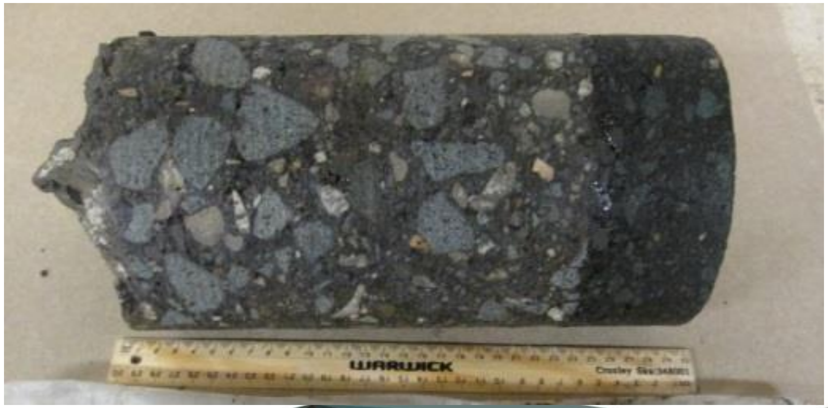
Transinsular Road (Existing) – Note flushing, shoving and cracking of the pavement in the loaded haul SB direction where overloaded truck have been travelling. Aggregate trucks travelling in NB direction are generally empty where pavement distress is noticeably reduced.





FB in Fiji – Moisture Sensitive & Variable Aggregates





Hazards…..

Fiji FB Performance

- Bit beyond Austroads intention……..
- Only SAC or FB capable of accommodating loading (magnitude and frequency)
- Foamed Bitumen cheaper and capable of utilising existing aggregate
- Loading scenario miles beyond Austroads loading
- Performance unarguable – but cost of upgrading network is prohibitive.
- Substantial work on weighbridge and penalties to bring loadings back to legal and an interim permissible overload is in place
- ***Foamed Bitumen Performance has been extensively evaluated and it is exemplary – performing well beyond its mandate***

Wrap Up

- Foamed bitumen is demonstrating some exemplary performances in NZ/Au/Fiji.
- Foamed bitumen is comprehensively being rolled out in Australia on the back of extensive research projects and performance testing.
- Recent amendments in New Zealand move towards improving treatment selection for major projects and design protocols for Foamed Bitumen
- Australia has confirmed their protocols are designing on basis of asphalt – yet binder contents typically 3% as per NZ similar to NZ
- Acknowledge some hiccups with FB in NZ (silver bullet for few years). Significant body of work performing beyond expectations.
- Still some lingering suspicion re Foamed Bitumen in some quarters – improving mix and pavement design protocols and understanding limitations / optimal use will help resolve.

Thank You

HIWAY GROUP

HIWAY STABILIZERS HIWAY GEOTECHNICAL HIWAY ENVIRONMENTAL

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