Review of insitu foam bitumen stabilisation practices in Queensland

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What is foam bitumen?

- Hot bitumen + water = foam bitumen
- Enables coating of wet materials
- Foam collapses relatively quickly, coating predominantly the finer particles of the material.

Process of foaming the bitumen
Binder requirements

- **Class 170 Bitumen – 3.5%**
  - Equivalent to penetration of 80 – 100
  - Inclusion of a bitumen foaming agent.

- **Hydrated lime – 2%:**
  - Superior early strength and performance.
Expansion ratio

Maximum volume after foaming
Volume after collapse of foam
Expansion ration = \( V_1/V_2 \)
Half life – time

- $V_1$: Maximum foamed volume
- $V_2$: Half of maximum foamed volume
Important for the assessment of the foamed bitumen quality: As the percentage of added water is increased, the parameters “half-life” and “expansion” develop in opposite directions.
Why foam bitumen?

- Provides resilience to flooding
- Strong and flexible
- Significantly reduces or eliminates shrinkage cracking
- Improved fatigue performance
- Provides longer working time.
Resilience to flooding
Resilience to flooding
Resilience to flooding
Resilience to flooding
How can we achieve a long performing foam bitumen pavement

• Activities to complete during:
  - Pre-construction
    ▪ Investigation, sampling and mix design.
  - Construction
    ▪ Understanding specification and implementing the requirements.
    ▪ Strict control on key construction aspects.
  - Post-construction
    ▪ Learnings from projects and feed back through project linked training – Pre-start meetings.
    ▪ Continuous research.
Laboratory testing

- Material prepared at 70% Overall Moisture Content (OMC)
- Binder incorporated into the material
- Samples compacted using Marshall Compaction (50 blows)
- Tested for indirect tensile resilient modulus:
  - After 3 hours curing at 25°C
  - After 3 days accelerated curing at 40°C
  - After soaking in water under vacuum for 10 minutes.
## Transport and Main Roads method

### Preferred mix design requirements

Foam bitumen stabilised base

<table>
<thead>
<tr>
<th>Daily Equivalent Standard Axles (ESAs) in Design Lane for Year of Opening</th>
<th>Min. Cured Modulus (MPa)</th>
<th>Min. Soaked Modulus (MPa)</th>
<th>Min. Retained Modulus Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100</td>
<td>2500</td>
<td>1500*</td>
<td>0.40*</td>
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<tr>
<td>100 – 1000</td>
<td>3000</td>
<td>1800*</td>
<td>0.45*</td>
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<tr>
<td>&gt; 1000</td>
<td>4000</td>
<td>2000*</td>
<td>0.50*</td>
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</table>

* May require adjustment for certain situations: for example, floodways
The effect of grading on the Indirect Tensile Resilience modulus
The effect of grading on the Indirect Tensile Resilience modulus (cont.)
Insitu stabilisation performance issues

Discussion of issues relating to the performance of insitu stabilised pavements.
Foamed bitumen stabilised pavements – South East Queensland

- Gladfield – Cunningham Highway
- Rainbow Beach – Rainbow Beach Road
- Inglewood – Cunningham Highway
- Allora – New England Highway
- Beenleigh – Beenleigh Connection Road
- Beaudesert – Beaudesert – Boonah Road
- Redland Shire – Various roads.
Gladfield – built 1997

- 250mm outer wheel path + 200mm inner wheel path stabilised with 4% bitumen and 1.5% cement
- CBR 3 (expansive) subgrade
- Pavement life (prior to fatigue) ~ 2.5 years
- Approximate traffic to failure ~ 2.5E06 ESAs
- Site has been overlaid with 160mm granular material.
Inglewood – built 1998

- 200mm stabilised layer with 4% bitumen and 1.5% quicklime
- Insitu subgrade strength CBR 5-20
- 3 year prior to the onset of fatigue cracking (only in areas with insitu CBR 5-8)
- Calculated fatigue life similar to that achieved in the field.
Inglewood (2001) – fatigue cracking
Inglewood (2001) – Cement treated base cracking
Pulverising prior to stabilisation

Breaks up wearing course (seal or thin asphalt) and any patches.
Pulverising prior to stabilisation (cont.)

Breaks up wearing course (seal or thin asphalt) and any patches.
Wet spots or unsuitable material

- Pre-pulverising will usually reveal unsuitable material or wet areas
- Address issue (for example, drainage) and remove and replace where necessary.
Rainbow Beach – built 1998

• Trial to assess foam bitumen against bitumen emulsion stabilisation
• 3 x 200m sections of foam bitumen stabilisation constructed using 3, 4 and 5% bitumen + 1.5% quicklime
• Still performing adequately and showing few signs of distress.
Rainbow Beach – 2003
New England Highway

- 17 km project stabilised in 1999
- Less than 1% of pavement showing signs of minor distress.
New England Highway (cont.)

Modulus testing of extracted cores.

![Bar chart showing resilient modulus for dry and soaked cores at different locations (Top, Middle, Bottom).]
Importance of layer thickness

Bending stiffness = $E\cdot I = f(t^3)$
IMPORTANCE OF LAYER THICKNESS

Bending stiffness = $E \times I = f(t^3)$
Fatigue failure seen two years after being opened to traffic
Stabilisation practices in Queensland
NACOE strategic objectives

COST SAVINGS
Delivering economic benefits to the Queensland network through cost-effective and higher performing pavements, refined asset management practices, efficient management of structures and by optimising road safety and network operation outcomes.

COLLABORATION
Working in partnership with industry, universities and government bodies to leverage research and resources, helping to deliver mutually beneficial outcomes.

DEVELOPMENT
Developing the capabilities of staff and disseminating learnings to regions.

IMPLEMENTATION
Facilitating trials, establishing research tools and infrastructure to help implement new technologies and practices in Queensland.
Stabilisation practices in Queensland

- **Objective**
  - Optimise capital investment and maximise performance of stabilised pavements in Queensland.

- **Approach**
  - Review of stabilisation practices across the state
  - Documentation of national and international best practice
  - Exploration of factors contributing to good and/or poor performance
  - Validation/modification of current technical guidance documents.

- **Outcomes**
  - NACOE technical report
  - Transport and Main Roads technical note outlining “best practices”
## Stabilisation practices in Queensland (cont.)

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<thead>
<tr>
<th>Material type</th>
<th>Stabilisation binder</th>
<th>Subgrade</th>
<th>Unbound</th>
<th>Modified</th>
<th>Bound</th>
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<td>Insitu</td>
<td>Plant-mix</td>
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<td>PC + fly ash (FA)</td>
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<td>2015-17</td>
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<td>Pozzolanic</td>
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<td>Polymer + PC/lime</td>
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Stabilisation practices in Queensland (cont.)

• Presentation outline
  - Queensland versus ‘best’ practice
  - Performance of state-controlled road network
  - Factors influencing roughness and rutting
  - The way forward.
# Queensland versus ‘best’ practice

<table>
<thead>
<tr>
<th>Characteristic</th>
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<th>Asphalt Academy</th>
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<td>70% OMC (Marshall)</td>
<td>NA (Marshall/Gyratory)</td>
<td>NA (vibratory hammer)</td>
<td>65% - 85% OMC (VH)</td>
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<td>Indirect tensile modulus</td>
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<td>Indirect tensile strength</td>
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<td>2.5% - 3.5%</td>
<td>2.0% - 4.0%</td>
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<td>1.7% - 2.5%</td>
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<td>Cement</td>
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<td>Failure criteria</td>
<td>Fatigue</td>
<td>Fatigue</td>
<td>Permanent deformation</td>
<td>Fatigue + deformation</td>
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Queensland versus ‘best’ practice
(cont.)
Performance of I-FBS network (cont.)
## Performance of I-FBS network (cont.)

<table>
<thead>
<tr>
<th>Condition criteria</th>
<th>Roughness (counts/km)</th>
<th>Rutting (mm)</th>
<th>Fatigue cracking (%)</th>
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<tr>
<td>Excellent</td>
<td>≤ 60</td>
<td>≤ 10</td>
<td>≤ 5</td>
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<td>Good</td>
<td>60 – 110</td>
<td>10 – 15</td>
<td>5 – 10</td>
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<tr>
<td>Mediocre</td>
<td>110 – 200</td>
<td>15 – 20</td>
<td>10 – 20</td>
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<tr>
<td>Poor</td>
<td>&gt; 200</td>
<td>&gt; 20</td>
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<tr>
<th>Network characterisation</th>
<th>Roughness (%)</th>
<th>Rutting (%)</th>
<th>Fatigue cracking (%)</th>
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<td>Excellent</td>
<td>79.8</td>
<td>91.8</td>
<td>92.3</td>
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<td>Good</td>
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<tr>
<td>Poor</td>
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<td>1.4</td>
<td>4.0</td>
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Performance of I-FBS network (cont.)
Performance of I-FBS network (cont.)

[Graph showing performance metrics over chainage (m) for Beaudesert-Boonah Road (212)].

- D0 (EB OWP)
- D900 (EB OWP)
- Curvature (EB OWP)
- DR (EB OWP)
Performance of I-FBS network (cont.)

![Graph showing performance metrics]

- D0 (µm)
- D900 (µm)
- Curvature (µm)
- DR
Performance of I-FBS network (cont.)
Performance of I-FBS network (cont.)

Mt Lindsay Highway (25B) Chainage = 12.8 km

Bruce Highway (10N) Chainage = 97.1 km
## Performance of I-FBS network (cont.)

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I-FBS performance factors

• Combined ANalysis Of VAriance (ANOVA) and multivariate linear regression.

• Categorical variables:
  - Environmental zone
  - Surfacing type
  - Bitumen content
  - Secondary binder type and content
  - Pavement thickness
  - Daily traffic.

• Continuous variables:
  - Pavement age
  - Design life
  - Cumulative traffic
  - Estimated remaining life
  - Stabilised layer thickness
  - Stabilised layer modulus
  - Subgrade bearing capacity
  - Estimated vertical strain
  - Estimated tensile strain
  - Mean curvature value
  - Annual maintenance expenditure.
Roughness performance factors

- I-FBS layer thickness
- Cumulative ESAs
- Mean curvature value
- I-FBS layer modulus
- Vertical subgrade strain
- Subgrade CBR.
Roughness performance factors

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Roughness performance factors

- I-FBS layer thickness
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- I-FBS layer modulus
- Vertical subgrade strain
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Rutting performance factors

- Pavement age
- Cumulative ESAs
- Mean curvature value
- I-FBS layer modulus
- Vertical subgrade strain.
Rutting performance factors

- Pavement age
- Cumulative ESAs
- Mean curvature value
- I-FBS layer modulus
- Vertical subgrade strain.
Rutting performance factors

- Pavement age
- Cumulative ESAs
- Mean curvature value
- I-FBS layer modulus
- Vertical subgrade strain.

![Graph showing curvature value vs. average rutting](image-url)
The way forward

- Reinforce ‘best practice’

- Validate performance models
  - Incorporation of Traffic Speed Deflectometer data for broader network analysis (underway).

- Financial and environmental sustainability
  - $60 to $120 per m3; ≈ 60% less than full depth asphalt
  - Recycle insitu material except where previously stabilised.

- Treatment selection guide
  - Increased shear strength and reduced moisture susceptibility.
The way forward

Anticipated traffic

Flood/inundation

Economic assessment advised

See Pavement Design Supplement (2013)

Anticipated traffic

100-3000 ESA/day

Low risk

Moderate risk

High risk

Subgrade CBR

Evaluate in situ material

Alternative treatment

Preliminary treatment recommended

Subgrade CBR

Estimate allowable strains

< 5%

5% - 10%

> 10%
The way forward

1. **% passing 0.425mm**
   - < 10%
   - 10% - 30%
   - > 30%
     - Preliminary treatment recommended

2. **% passing 0.075mm**
   - < 5%
   - 5% - 25%
   - > 25%
     - Preliminary treatment recommended

3. **Plasticity index**
   - > 10%
   - < 10%
     - Conduct detailed mixture design

   - Preliminary treatment recommended
Thank you