In-situ Stabilisation – TMR Experience

Pavement stabilisation processes adopted in Queensland
Agenda

1. Lime stabilisation of Subgrade
2. Foamed bitumen stabilisation of existing unbound granular pavements
Lime Stabilisation
Why did TMR invest on research, trial and establish a new approach to Lime Stabilisation
Expansive soils in Queensland

- Information supplied by the Department of Natural Resources, Queensland and adapted from the Atlas of Soils, CSIRO.
Toowoomba-Cecil Plains Road. ‘Black soil country’
Shrink/Swell effects of expansive soils
Pavement failures due to expansive soils
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
What is lime stabilisation

• It is the means of enhancing soil strength and stiffness properties by adding lime (hydrated lime or quicklime).

• Stabilisation can take place in soils containing a suitable amount of clay with the appropriate mineralogy to produce long-term permanent strength gains.
Definitions

Limestone
• Calcium carbonate – CaCO$_3$
• Finely ground and sold as agricultural lime
• No application in civil engineering

Quick lime
• Calcium oxide – CaO
• Produced by ‘burning’ limestone in a kiln

Hydrated lime
• Calcium hydroxide – Ca(OH)$_2$
• Produced by adding water to quicklime
Limestone
Chemical reactions

- **Burning**
  - \( \text{CaCO}_3 + \text{heat (>1000}^\circ\text{C}) \rightarrow \text{CaO} + \text{CO}_2 \)

- **Slaking**
  - \( \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{heat} \)

- **Pozzolanic reaction**
  - \( \text{Ca}^{++} + \text{OH}^- + \text{soluble clay silica} \rightarrow \text{Calcium Silicate Hydrate} \ (\text{CSH}) \)
  - \( \text{CA}^{++} + \text{OH}^- + \text{soluble clay alumina} \rightarrow \text{Calcium Aluminate Hydrate} \ (\text{CAH}) \).
Trial section (windrow to stabilise lower layer)
What did TMR achieve from research in Lime Stabilisation
Road Foundation Resilience to Flooding
Oakey Pittsworth Road Project
Significant reduction in swelling/shrinkage effects
Significant increase to strength of Road Foundations
Cunningham Highway, Freestone Creek – Lime stabilisation

- Subgrade stabilisation to widen existing road
- Construction 1998 (13 years old)
- Wearing surface 100mm asphalt
- After seven years (2005), further 100mm asphalt
- Pavement performing very well.
Flinders Highway Lime Stabilised Subgrade (5% Lime)
Toowoomba-Cecil Plains Road Floodway FB/CMSB/LSS
Unconfined Compressive Strength (UCS)

After 13 yrs Lime Stabilisation UCS (Mpa)

Core No. | MPa
--- | ---
2 Top | 5.5 MPa
2 Bot | 8.1 MPa
6 Mid | 2.9 MPa

Diagram showing the UCS values for different core locations after 13 years of lime stabilisation.
Documentation of findings, Technology Transfer and Project Linked Training
Transport and Main Roads Technical Standard

MRTS07A

Insitu Stabilised Subgrades using Quicklime or Hydrated Lime

April 2011
Technical Note issue No.39

- Lime treatment of clay subgrades
- Located in:
Testing protocol for lime stabilisation

• Not available on Transport and Main Roads (TMR) website
• Available from Herston Material Laboratory
• Contains details for testing
• Table 3 contains limits of
  - Sulfate content (water soluble) < 0.3%
  - Organic content < 1%
  - Ferric oxide < 2%.
Structural design of granular pavement depth over lime stabilised subgrade

TMR vs Austroads
Comparison of required granular cover over lime-stabilised subgrade

<table>
<thead>
<tr>
<th>Pavement Layers</th>
<th>Subgrade CBR 3%</th>
<th>Subgrade CBR 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMR</td>
<td>Austroads</td>
<td>TMR</td>
</tr>
<tr>
<td>Required Granular Cover</td>
<td>260mm</td>
<td>290mm</td>
</tr>
<tr>
<td>Lime Stabilised Subgrade</td>
<td>300mm</td>
<td>300mm</td>
</tr>
</tbody>
</table>

*Considered as capping layer for subgrade CBR less than 3%.

Austroads Design for Subgrade CBR 1%  
DESA = 3x10^6 ESAs

Granular base

Subgrade CBR 3%  
(include 300mm capping)
Benefits of lime stabilised subgrade

- Increase subgrade stiffness.
- Forms a water resistant layer.
- Reduce the Plasticity Index (PI) of the pavement.
- Constructability- provides a temporary construction platform for civil works.
- Improves the compaction of the overlying pavement layers.
- Overlying pavement thicknesses are considerably reduced due to a stronger subgrade.
- Reduced number of defects seen on the overlying base.
Recent Major Lime Stabilisation Projects - Flood damaged roads

- Oakey Pittsworth Road
- Gore Highway (Pampas to Condamine River)
- Toowoomba Cecil Plains Road
- Flinders Highway
- Cunningham Highway (17B)- Freestone Creek to ‘8 mile’ intersection.
- Warrego Highway (18B)
List of research work by TMR (helping students to complete under graduate Thesis)

- Reduction of amelioration period
- Effect of temperature on working time (to be carried out)
- Working time – comparison of Lime Vs GB Cement
- Effect of moisture on strength results (to encourage more moisture during lime stabilisation)
- Comparison of the effect of variation of fly ash on strength (Archer Flat Trial)
- Use of triple blends for subgrade stabilisation
Foamed Bitumen Stabilisation
What is foamed bitumen?

Foamed bitumen is produced in the expansion chamber.
Characteristics

• Non-continuously bound (spot welds)
• Millions of individual elastic points
• Fine particles immobilised
Binder Requirements

Class 170 Bitumen – 3.0%
• Equivalent to Pen 80 – 100
• Inclusion of a bitumen foaming agent

Hydrated Lime – 2%
• Superior early strength & performance
Benefits of Foamed Bitumen Stabilisation

- Moisture resistant pavement - offers better resilience to flooding.
- Strong and flexible pavement - foamed bitumen improves the stiffness and load bearing capacity.
- Reduces shrinkage cracking.
- Better fatigue resistance than using a cement stabilised base.
- Using lime as a secondary additive provides longer working times during construction.
Foamed Bitumen Stabilised Pavements

Past projects in 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
Foamed Bitumen Stabilised Pavements

Recent projects in Queensland

- Warrego Highway 18C (Yaralla)
- Gore Highway
- Bruce Highway (Isis River South)
- Oakey Pittsworth Road
- Beaudesert- Boonah Road
- Flinders Highway
- Smith Street (Proposed stabilisation in November 2014)
Project specific benefits

- Gore Highway - Project savings by reducing bitumen content
  - 0.5% reduction of bitumen content = $15,000/km.
  - Increased productivity (more m$^2$/day).
  - 21 days savings at $25,000/day = $525,000
  - Total savings of $40,000/day

- Flinders Highway - Optimising bitumen design rate from 3.0% to 2.5% through modulus mix design resulted in savings of $\text{360,000}$ or $26,000/km.

- Optimisation of lime in the lime stabilised subgrade from 8% to 5%. Cost savings of $\text{1,362,300}$ or $48,700/km was achieved.
Gore Highway 28A
List of research work by TMR with QUT

• Working time of foamed bitumen using Lime as an additive as compared to cement
• Stock Pile time (for Plant mix)
• Optimisation of additive contents (reduction of both bitumen and lime)
• Changing cure temperature from 60°C to 40°C
• Field Density Vs Marshall Densities
• Servo Compaction Vs Marshall Compaction
• Using Lime/Fly Ash Vs Lime (to be carried out)
• Effect of mixing time on modulus
• Effect of grading Vs Soaked Modulus (for example, Modified C)
Performance of Stabilised pavement and Subgrade

Performance

- Depth
- Additive Content & Mix Design
- Construction
ADVANTAGES

Water Proof

Structural Strength

Long term performance
A Vision of the Future
Resilience!

Reduction in ..

- Maintenance
- Road user costs
But must have construction control
Summary

Work closely with the regions to achieve long performance pavements i.e. win-win situation for both TMR and Industry.
A Vision of the Future- Foamed Bitumen Stabilised Pavement on Lime Stabilised Subgrade – Core From Flinders Highway 2014
Thank you