Graham Salt, Allen Browne

Quantifying Improvements to Pavement Life from Basecourse Stabilisation

“Before and After” Case Histories: Queenstown District
Road Testing Locations

- Coronet Peak Road
- Crown Range Road
- Malagans Road
- Glenorchy-Queenstown Road
Foamed Bitumen Stabilisation
Stabilisation case histories for a number of local roads are presented, with the relevant parameters from laboratory design to construction and then in situ (FWD) post construction measurement. These compare design expectations with as-constructed properties and relate them to the construction practices adopted. The natural and modified material parameters from the local roads are then compared with corresponding values achieved elsewhere in recently stabilised roads throughout New Zealand.

NZTA Research into Pavement Life – discrete distress modes
The prediction of pavement life for these case histories is assessed, using recognised Austroads mechanistic procedures but calibrated using relationships being established from recent New Zealand research and performance review. Practices which provide certainty in performance and maximise pavement life are discussed and the way in which the post-construction testing and analyses can be used to optimise the percentages of stabilser used.

Stabilising is an effective solution for the local materials in view of their issues including frost susceptibility, in aggregates with marginal gradings or excessive fines.
- FOAMED BITUMEN RECYCLING
Building Experience; Delivering Value

Diagram showing the process of creating foamed bitumen:
- Hot bitumen
- Water
- Air
- Expansion chamber with foam nozzle
- Foamed bitumen

Diagram of a construction vehicle.
Building Experience; Delivering Value
Building Experience; Delivering Value

- **Strength:** Similar to a cemented pavement
- **Flexibility:** A visco-elastic material that resists plastic deformation
- **Uniformity:** Can provide uniform base from a patched pavement
- **Environmental:** Complete recycling of pavement materials
- **Fast construction time:** Reduced road user inconvenience
- **No shrinkage cracking:** Minimal amount of water
- **Rate of gain of strength:** Pavement can be trafficked immediately
- **Temperature susceptibility:** Superior resistance to freeze-thaw cycles
- **Lower permeability medium:** Resistance to pumping
• Basic requirements:
  – Wet sieve analysis – 5 to 22% passing 75um
  – Reasonably well graded
  – PI of less than 15
  – Moisture condition not significantly wet of optimum

  – New Zealand experience has found that more often than not these requirements are met
  – If not use supplementary fines/aggregate to correct grading or prehoe with lime to correct high plasticity
Pavement Life Prediction: Distress modes

- Rutting
- Roughness
- Shear Instability (shoving, common in QLDC are due to silty basecourses, exacerbated by frost heave)
- Cracking (from repeated horizontal tensile strain at base of the 200 mm thick FBS layer)
- Flexure of the surfacing, ie chipseal layers or thin AC surfacing, includes shear stresses from traction and often results in top-down cracking

Pavement Life Prediction: Analysis

- in situ testing – deflection (whole bowl) before and after
- multi layer elastic model of in situ deflection data
- mechanistic approach with calibration to observed performance of NZ pavements
• Coronet Peak Road (RP 4.81 to 6.36) Undertaken 2006
  – Area: 27,500 m²
  – Client: Queenstown Lakes District Council
  – Traffic: 6 x 10⁵ ESA
  – Design: 1% cement, 3.5% bitumen, 200 mm
  – Construction time: 2 weeks

• Existing upper aggregate layers were deep; in places 300 mm+ to an old chip seal layer.
  – FWD testing illustrated low central deflection (90%ile 0.61 mm) but very high curvature.
  – Site observations; extensive shallow shear and rutting with comprehensive freeze-thaw damage to existing pavement.
    • Temperature range from -15°C to 20°C with many freeze-thaw cycles through winter
## Building Experience; Delivering Value

<table>
<thead>
<tr>
<th>Resilient Modulus (MPa)</th>
<th>Mix Design Modulus</th>
<th>On-site Achieved Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 (Ideal Conditions)</td>
<td>1500</td>
<td>1285</td>
</tr>
<tr>
<td>Phase 2 (Steady State)</td>
<td>1000</td>
<td>981</td>
</tr>
<tr>
<td>Indirect Modulus (MATTA)</td>
<td>1516 (10%ile 3 tests)</td>
<td>1470 (10%ile 6 tests)</td>
</tr>
</tbody>
</table>

*Prior to Rehabilitation*
Analysis of deflection bowls:
Comparison of pavement life predictions

(i) Existing pavement life assuming that existing surfacing was smoothed, but no structurally improvement made, (using in situ data from testing prior to rehabilitation) versus:

(ii) Expected pavement life from in situ testing after rehabilitation
Building Experience; Delivering Value

PAVEMENT STRUCTURAL EVALUATION: Coronet Peak Rd 4.807 - 6.357 (22/12/2005 5:06:00 p.m.)

Layer 1 Modulus (MPa) - Logarithmic Scale

- Standard Central Deflection (mm)
- Normalised Curvature
- Normalised Modular Ratio

Granular Overlay - Austroads (GMP-Rigorous) All Layers (mm)

Total Life (Years) - Rutting IAL Model (Uncalibrated)

Total Life (Years) - Roughness IAL Model (Uncalibrated)

Total Life (Years) - Flexure Model

Total Life (Years) - Basecourse Shear Instability Model

Total Life (Years) - Cement/FBS Base Cracking

Chainage
Building Experience; Delivering Value
Pre-rehabilitation if resurfaced $\rightarrow 0.1\ MESA$

Coronet Peak Road 4.807 - 6.357 (22-12-2005)

- Red: Total Traffic (MESA) - Rutting IAL Model (Uncalibrated)
- Yellow: Total Traffic (MESA) - Roughness IAL Model (Uncalibrated)
- Green: Total Traffic (MESA) - Flexure Model
- Blue: Total Traffic (MESA) - Basecourse Shear Instability Model
- Purple: Total Traffic (MESA) - Cement/FBS Base Cracking

The 10 percentile design life is the minimum of all 5 distress modes.
Coronet Peak Road 4.807 - 6.357 (18-3-2009)

1.7 MESA →

- Parameter: Total Traffic (MESA) - Rutting IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Roughness IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Flexure Model
- Parameter: Total Traffic (MESA) - Basecourse Shear Instability Model
- Parameter: Total Traffic (MESA) - Cement/FBS Base Cracking
Building Experience; Delivering Value

- **Crown Range Rd (RP 9.5 to 10.5) Undertaken 2010**
  - **Area:** 7,500 m²
  - **Client:** Queenstown Lakes District Council
  - **Traffic:** State Highway 1 MESA
  - **Design:** 1.5% cement and 2.7% bitumen to 200mm
  - **Construction time:** 4 days in total
  - **Date:** March 2010
  - NZ’s highest sealed road; freeze-thaw failures. Extensive pot holing, rutting, cracking. Very fine Shotover river aggregates prone to pumping.
## Crown Range Road

<table>
<thead>
<tr>
<th>Resilient Modulus (MPa)</th>
<th>Mix Design Modulus</th>
<th>On-site Achieved Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 (Ideal Conditions)</td>
<td>2500</td>
<td>2040</td>
</tr>
<tr>
<td>Phase 2 (Steady State)</td>
<td>1160</td>
<td>830</td>
</tr>
</tbody>
</table>
## Crown Range Road

<table>
<thead>
<tr>
<th>Dry Density Achieved (t/m³)</th>
<th>% of briquettes (Dry Density)</th>
<th>% of plateau MDD</th>
<th>% of NZ Heavy MDD (Lab compacted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.13</td>
<td>101</td>
<td>105</td>
<td>95</td>
</tr>
</tbody>
</table>
Building Experience; Delivering Value

PAVEMENT STRUCTURAL EVALUATION: Crown Range Rd 9.325 - 10.225 (18/11/2009 1:18:00 p.m.)

- Layer 1 Modulus (MPa) - Logarithmic Scale
- Standard Central Deflection (mm)
- Normalised Curvature
- Normalised Modular Ratio
- Granular Overlay - Austroads (GMP-Rigorous) All Layers (mm)
- Total Life (Years) - Rutting IAL Model (Uncalibrated)
- Total Life (Years) - Roughness IAL Model (Uncalibrated)
- Total Life (Years) - Flexure Model
- Total Life (Years) - Basecourse Shear Instability Model
- Total Life (Years) - Cement/FBS Base Cracking
Building Experience; Delivering Value

PAVEMENT STRUCTURAL EVALUATION: Crown Range Rd 9.472 - 10.492 (16/09/2010 2:43:00 p.m.) 9.4

Layer 1 Modulus (MPa) - Logarithmic Scale

Standard Central Deflection (mm)

Normalised Curvature

Normalised Modular Ratio

Granular Overlay - Austroads (GMP-Rigorous) All Layers (mm)

Total Life (Years) - Rutting IAL Model (Uncalibrated)

Total Life (Years) - Roughness IAL Model (Uncalibrated)

Total Life (Years) - Flexure Model

Total Life (Years) - Basecourse Shear Instability Model

Total Life (Years) - Cement/FBS Base Cracking

Lifetime ESA: 1,090.39
Model: (35 AC+200 FB), 125 UB, 140 UB, JUN 5G
X: 9.5036
Y: 8.855
Station: 9.5
Ordinate: 25
Total Life (Years) - Cement/FBS Base Cracking
Pre-rehabilitation


- Parameter: Total Traffic (MESA) - Rutting IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Roughness IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Flexure Model
- Parameter: Total Traffic (MESA) - Basecourse Shear Instability Model
- Parameter: Total Traffic (MESA) - Cement/FBS Base Cracking

Percentage of samples < X

Total Traffic (MESA)
Post-rehabilitation Chip Seal


- Red: Parameter: Total Traffic (MESA) - Rutting IAL Model (Uncalibrated)
- Green: Parameter: Total Traffic (MESA) - Roughness IAL Model (Uncalibrated)
- Blue: Parameter: Total Traffic (MESA) - Flexure Model
- Cyan: Parameter: Total Traffic (MESA) - Basecourse Shear Instability Model
- Purple: Parameter: Total Traffic (MESA) - Cement/FBS Base Cracking

Otherwise 2.5 MESA

Thin AC
0.2 MESA →

Percentage of samples < X

Total Traffic (MESA)
• Malaghans Rd (RP 1.4 to 3.2) Undertaken 2009
  – Area: 15,500 m² total
  – Client: Queenstown Lakes District Council
  – Traffic: Arterial 2.9 MESA
  – Design: 1.3% cement and 2.7% bitumen to 200mm
  – Construction time: 9 days in total
  – Date: December 2009

  – Arterial connecting Queenstown to Arrowtown; freeze-thaw failures. Extensive patch repair, rutting, cracking. Existing Fine Shotover River aggregates and new alignment sections comprising newly constructed Parkburn M/4 AP40 supplemented with fines.
Malaghans Road

<table>
<thead>
<tr>
<th>Resilient Modulus (MPa)</th>
<th>Mix Design Modulus</th>
<th>On-site Achieved Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 (Ideal Conditions)</td>
<td>1670</td>
<td>2010</td>
</tr>
<tr>
<td>Phase 2 (Steady State)</td>
<td>800</td>
<td>890</td>
</tr>
</tbody>
</table>
Malaghangs Road

<table>
<thead>
<tr>
<th>Dry Density Achieved (t/m³)</th>
<th>% of briquettes (Dry Density)</th>
<th>% of plateau MDD</th>
<th>% of NZ Heavy MDD (Lab compacted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.16</td>
<td>99</td>
<td>98</td>
<td>95</td>
</tr>
</tbody>
</table>
PAVEMENT STRUCTURAL EVALUATION: Malaghans Road 1.400 - 3.200 (2008) (14/06/2008 9:08:00 a.m.)

- Layer 1 Modulus (MPa) - Logarithmic Scale
- Standard Central Deflection (mm)
- Normalised Curvature
- Normalised Modular Ratio
- Granular Overlay - Austroads (GMP-Rigorous) All Layers (mm)
- Total Life (Years) - Rutting IAL Model (Uncalibrated)
- Total Life (Years) - Roughness IAL Model (Uncalibrated)
- Total Life (Years) - Flexure Model
- Total Life (Years) - Basecourse Shear Instability Model
- Total Life (Years) - Cement/FBS Base Cracking

Lifetime ESA: 2,659,993  Model: 150 UB, 125 UB, 125 UB, UN SG  X: 1.4127  Y: 7.387  Station: 1.425  Ordinate: 25  Total Life (Years) - Cement/FBS Base Cracking
Building Experience; Delivering Value

PAVEMENT STRUCTURAL EVALUATION: Malaghans Rd 1.400 - 3.200 (30/03/2010 7:05:00 p.m.)

- Layer 1 Modulus (MPa) - Logarithmic Scale
- Standard Central Deflection (mm)
- Normalised Curvature
- Normalised Modular Ratio
- Granular Overlay - Austroads (GMP-Rigorous) All Layers (mm)
- Total Life (Years) - Rutting IAL Model (Uncalibrated)
- Total Life (Years) - Roughness IAL Model (Uncalibrated)
- Total Life (Years) - Flexure Model
- Total Life (Years) - Basecourse Shear Instability Model
- Total Life (Years) - Cement/FBS Base Cracking
Post-rehabilitation

Malaghans Road 1.400 - 3.200 (30-3-2010)

- Parameter: Total Traffic (MESA) - Rutting IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Roughness IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Flexure Model
- Parameter: Total Traffic (MESA) - Basecourse Shear Instability Model
- Parameter: Total Traffic (MESA) - Cement/FBS Base Cracking

3 MESA
Building Experience; Delivering Value

- Glenorchy to Queenstown Rd (RP 5.80 – 6.20) Undertaken 2009
  - Area: 3,000 m² total
  - Client: Queenstown Lakes District Council
  - Traffic: 0.6 MESA
  - Design: (1.3% cement and 3% bitumen to 200mm)
  - Date: 2009

- Arterial connecting Queenstown to Glenorchy
Building Experience; Delivering Value
Glenorchy - Queenstown Road 5.800 - 6.200 (15-6-2008)

- Parameter: Total Traffic (MESA) - Rutting IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Roughness IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Flexure Model
- Parameter: Total Traffic (MESA) - Basecourse Shear Instability Model

0.3 MESA →

Pre-rehabilitation
Glenorchy - Queenstown Road 5.800 - 6.200 (30-3-2010)

- Parameter: Total Traffic (MESA) - Rutting IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Roughness IAL Model (Uncalibrated)
- Parameter: Total Traffic (MESA) - Flexure Model
- Parameter: Total Traffic (MESA) - Basecourse Shear Instability Model
- Parameter: Total Traffic (MESA) - Cement/FBS Base Cracking
Network Data - Layer 1 Modulus (MPa)

Moduli of Qtn sites compared to other sites in New Zealand (blue)
800 MPa design....
Compares uniformity of construction at each site with the range of uniformity found for all national highways.
Conclusions on FBS sites.

• For all 4 roads, at least 90% of their lengths should achieve their design 25 year life for rutting, roughness, shear instability and structural cracking (bottom-up)

• In particular, shear instability consistently shows a marked improvement.

• The chip-seal surfacings should all provide adequate flexural life.

• The 35 mm AC surface would be intended to last 8-10 years, but judging by typical observed performance of thin AC’s in the Auckland environment, only about 80% of the AC surfacing would last 8 years. (The model has not been calibrated locally.)

• The moduli achieved in the stabilised layers are in the same general range as achieved elsewhere in NZs, but are towards the lower end of the range, and all lower than the usually accepted 10 percentile design modulus of 800 MPa. This shortfall is not significant in 3 of these examples because the subgrades are relatively good, and rutting is not critical. The converse should be borne in mind. If modulus is low and AC is to be used, there will be a substantial reduction in life of the surfacing.

• If improved uniformity can be achieved, there is potential for at least doubling of pavement life by optimising percentages of stabilisers.
Post-rehabilitation, Coronet Peak Road 2010
Pre-rehabilitation, Crown Range Road 2009
Post-rehabilitation, Crown Range Road 2010
Building Experience; Delivering Value

Post-rehabilitation, 35 mm AC
Building Experience; Delivering Value

Post-rehabilitation, Malaghans Road 2010
Building Experience; Delivering Value

Pre-rehabilitation, Glenorchy-Queenstown Road 2008
Building Experience; Delivering Value

Post-rehabilitation, Glenorchy-Queenstown Road 2010