NZ Guide to Pavement Evaluation and Treatment Design

Rehabilitation guide

NZ TRANSPORT AGENCY
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New Zealand Government

Pavement investigations

Historical Data

The RAMM database and local knowledge should be used to find out:

- The pavement life (in years) achieved, i.e. when was the last 1st coat seal or heavy maintenance applied;
- Past traffic during the pavement life calculated in terms of number of ESAs;
- Is there a loaded and unloaded direction for calculating ESAs;

Historical Data continued

The RAMM database and local knowledge should be used to find out:

- Pavement cross-section information (thickness of surfacing and aggregate layers);
- Past rehabilitation treatment types (e.g. granular overlay, cement stabilisation or asphalt overlay) and their performance; and
- Plans from previous construction – particularly for sites showing poor early life performance.

Visual Data

A detailed site inspection is required:

Take any historical records during field inspection.

Record:

- Location and type of faults exhibited
- Effectiveness of drainage
- General geometrics (crossfall, super, shoulder support)
- Presence and location of services

Want to know where and what defects are on site!

Detailed Investigation

Three generic levels of investigation depending on the complexity and risks:

- Level 1 is minimal investigation. Low traffic, RAMM data and local knowledge suggest design;
- Level 2 is average level of investigation, at least one test pit to determine pavement depths and material quality; or
- Level 3 is high level of investigation, significant distress and high traffic and/or recently constructed pavements. More investigation is required to develop pavement solutions that will not fail early.

Testing of pavement and materials

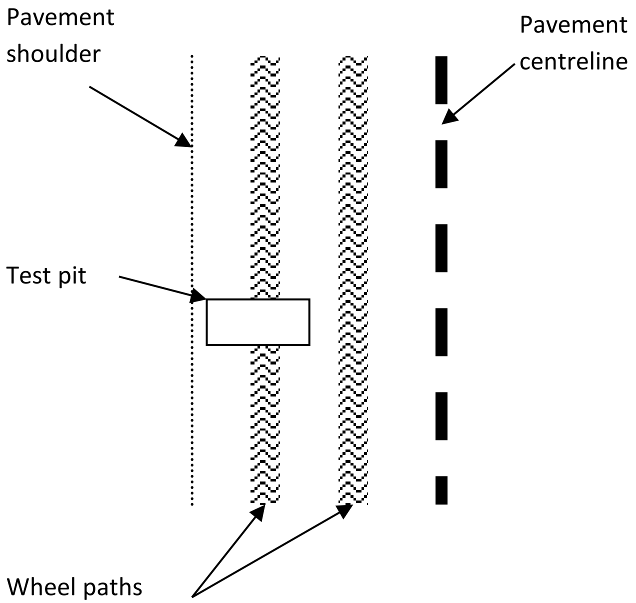
Risk of pavement rehabilitation against traffic volume

One Network Road Classification	Investigation Level 1	Investigation Level 2	Investigation Level 3
National, National (high volume), Regional, or Arterial	Preliminary investigation only	Preliminary investigation only	Minimum requirements
Primary Collector or Secondary Collector	Preliminary investigation only	Minimum requirements	Possible as supplementary
Access and Access (low volume)	Minimum requirements	Possible as supplementary	Possible as supplementary

Test pits

Because of the significant financial consequences of pavement failures the minimum number of sample test pits shall be either:

- three test pits for treatment lengths up to 200 m,
- five test pits for treatment lengths between 200 and 500 m, and
- every 100 m for treatment lengths 500 m or greater.



Technical Advice Note 17-03

Use of traffic speed deflectometer results

- This technical advice note details the methodology to convert the traffic speed deflectometer (TSD) data to the more familiar falling weight deflectometer (FWD) output, enabling any TSD data collected to be directly compared to any historically collected FWD dataset.
- Need to standardise the recorded loads

Design subgrade California Bearing Ratio

- For the majority of soil types, best correlation with CBR is achieved when the Scala DCP mm/blow is calculated from a weighted average of blows/50 mm for the first three 50 mm intervals using weightings of 0.7, 0.2 and 0.1 for each interval.
- A full description on the origin of these calculations can be found in Smits (1990).
- Smits' weightings correspond very closely to those determined from a vertical stress distribution beneath a CBR plunger.

Design California Bearing Ratio

- The design CBR is then the tenth percentile of the results obtained over the treatment length.
- Determination of subgrade strength complicated by the strength variations that often occur with depth.
- Where strength decreases with depth, the subgrade may be sublayered
- For subgrade strengths that are constant or improve with depth, the support at the design subgrade level governs the pavement design.

Design California Bearing Ratio

Simple conversion of

$$\textit{Resilient modulus}\ (\text{MPa}) = 10 \times CBR$$

cannot be assumed

Subgrade sensitivity

The subgrade sensitivity is a measure of the loss of strength that occurs when the soil is disturbed or remoulded. Sensitivity is defined

$$Shear\ Strength\ Ratio = \frac{Undisturbed\ shear\ strength}{Remoulded\ shear\ strength}$$

the subgrade is defined as insensitive or normal when the shear strength ratio is less than two, moderately sensitive when it is between two and four and sensitive or worse when it is greater than four.

Problem definition

Problem definition in pavement rehabilitation design is vital:

- All the data needs to reviewed,
- Most sites fall in between simple and complex analysis needs,
- On more complex sites, development of a mechanistic model may be required to assist,
- More complex sites are often early failures and care is needed to separate design, materials and construction issues.

Root cause analysis

A root cause analysis integrates and interprets the various failure mechanisms, the existing pavement structure, and the traffic history to determine the root cause or causes of the pavement failure.

New Zealand Precedent Strain Design

For rehabilitation treatments, the vertical compressive strain, computed at the top of the subgrade, shall not exceed the design strain (ε_{des}) as defined by the following equation

$$\varepsilon_{des} = \varepsilon_{cvs}\left(\frac{N_F}{N_P}\right)^{-0.23}$$

where:

N_F = Future design traffic (ESA),

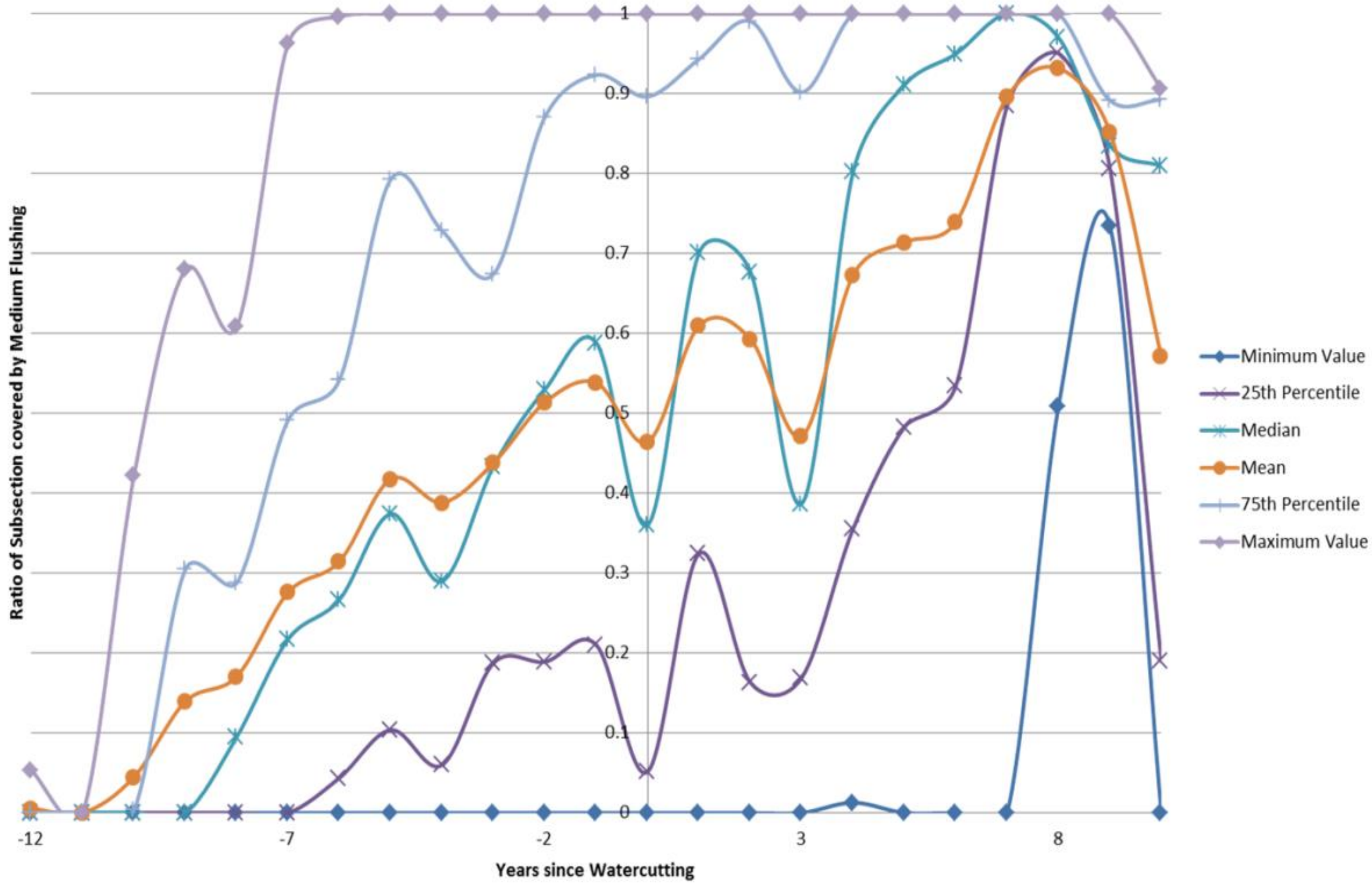
N_P = Historic traffic loading of pavement (ESA), and

ε_{cvs} = Existing vertical compressive strain at the top of the subgrade (microstrain).

Water cutting

Water cutting is a temporary treatment that has a detrimental affect on the pavement condition.

Impact water cutting has on medium flushing



Reasons for using Stabilizing Agents

- Improve engineering properties and characteristics of pavement materials
- Poor subgrade conditions (clay/silts/sands)
- Moisture control/workability
- Improve performance of subbase/base layers
- Dust control
- Recycling/rehabilitation
- Construction of superior pavement layers (e.g. foam/emulsion, Hi-Lab, etc.)
- Sustainability/cost (modify marginal materials)

Chemically modified, bound and foamed bitumen treated materials

Performance of stabilisation treatment depends

- On the underlying support
- Treated thickness
- Appropriate grading
- Quality control
- *In situ* materials different from laboratory testing
- Over stabilisation

Due to the risk of block and shrinkage cracking the NZ Transport Agency does not allow bound basecourses

Mix design

- If the proposed stabilisation treatment will incorporate the existing seal into the stabilised layer then laboratory mix design should include the appropriate proportion of the seal layer into the laboratory sample.
- As a general rule of thumb, the stabilised layer should contain no more than a third, by depth, of the seal layer.
- The design should also consider changes in mix proportions that might arise from geometric improvements that might be occur concurrent with any rehabilitation.

Bound treatment – limiting tensile stress

The *in situ* stabilisation depth and the overlay depth can be determined by checking the horizontal tensile stress at the base of the stabilised bound subbase layer is less than 50% of the stabilised flexural beam tensile strength or equal to the ITS obtained at the maximum dry density.

Field compaction will typically not achieve maximum dry density.

The stress can be determined by CIRCLY with an assumed high modulus of between 3,000 MPa to 10,000 MPa. The higher the modulus the greater the stress.

To rip or not to rip

There are two schools of thought for overlays

One viewpoint is that the existing seal has intrinsic strength and removing the seal weakens the pavement

- This approach would be used only where these treatments have provided good performance historically and the aggregate used in the overlay is demonstrated to have low moisture susceptibility.

The other point of view is that an overlay constructed with the existing seal intact has a high risk of trapped moisture.

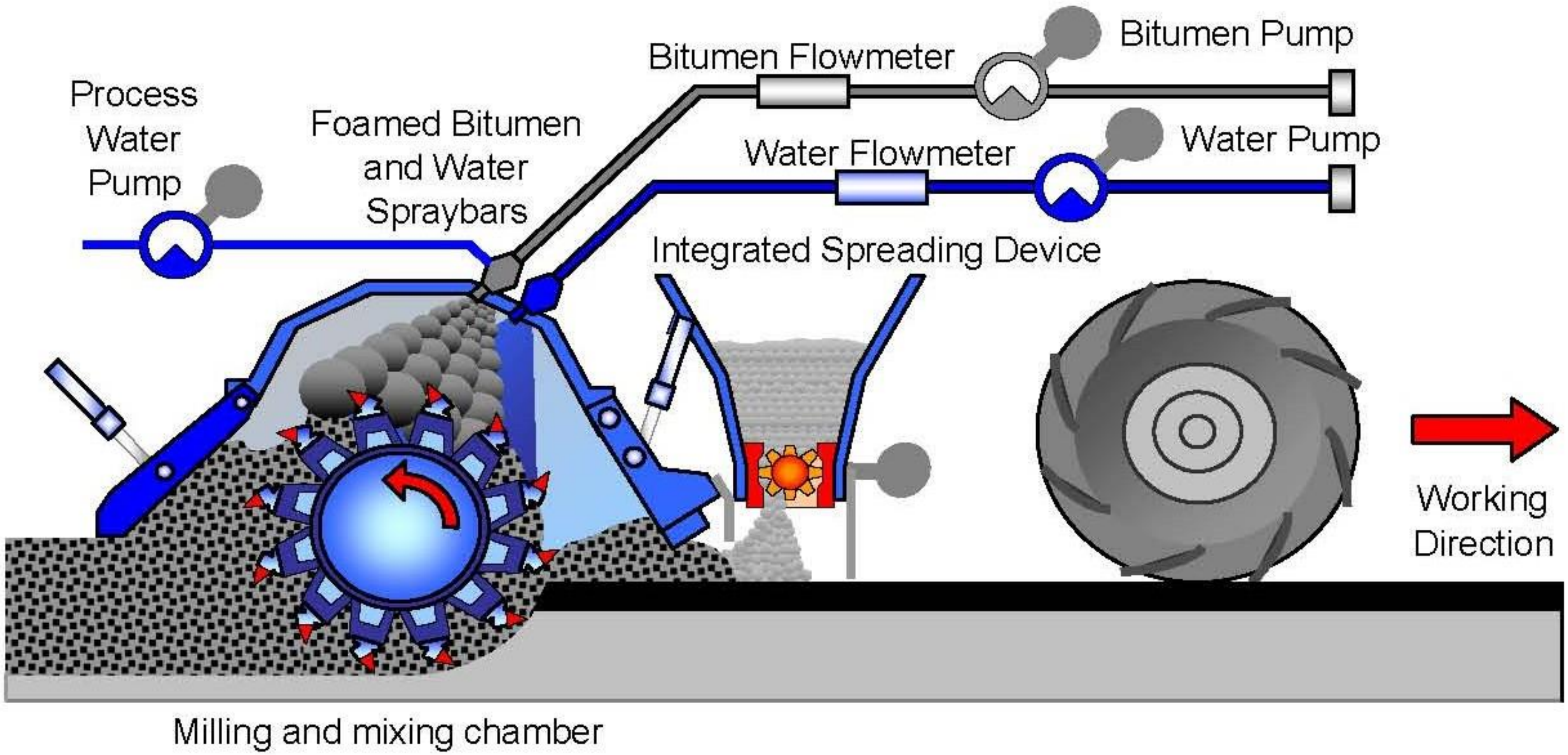
- If an unstable seal is removed the thickness of that seal should be replaced with equivalent granular material and an overlay thickness designed using the original pavement thickness.

Foamed Bitumen mechanics

150 mm

Spraybar with 16 nozzles where hot bitumen is foamed in expansion chambers & sprayed directly onto milled material within mill housing

Addition of Foamed Bitumen and Cement

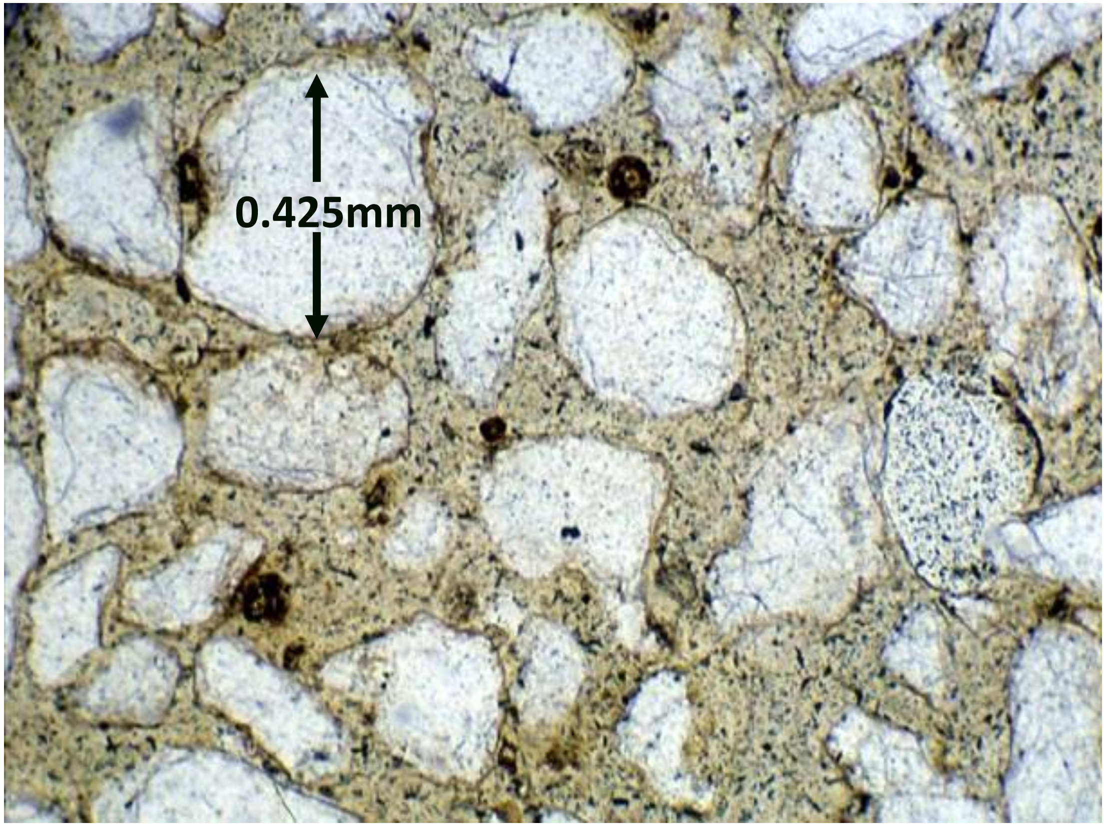


Foamed Bitumen & Cement can be added to the material in one pass

Foamed Bitumen

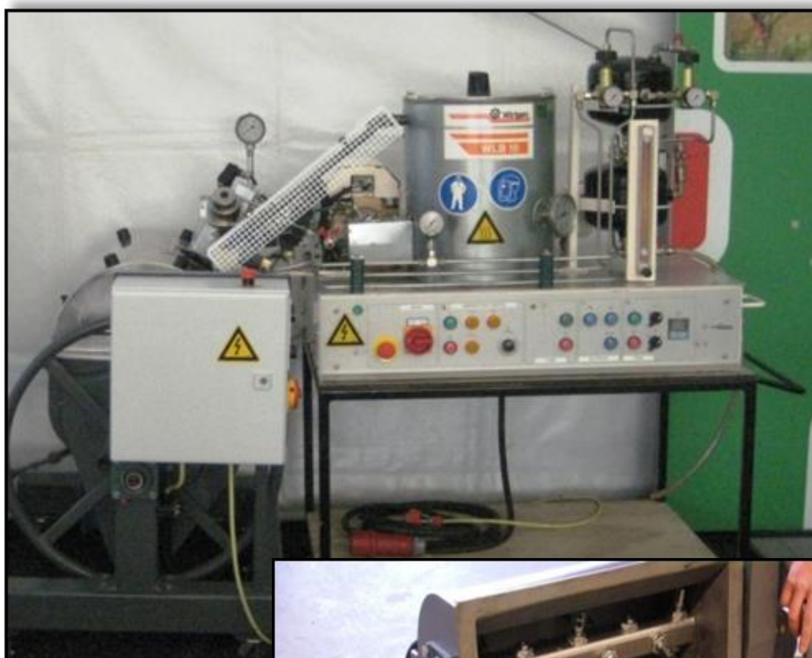
Foamed bitumen preferentially targets microfines. “Squeeze test” is a means of determining adequate bitumen dispersion

Foamed Bitumen



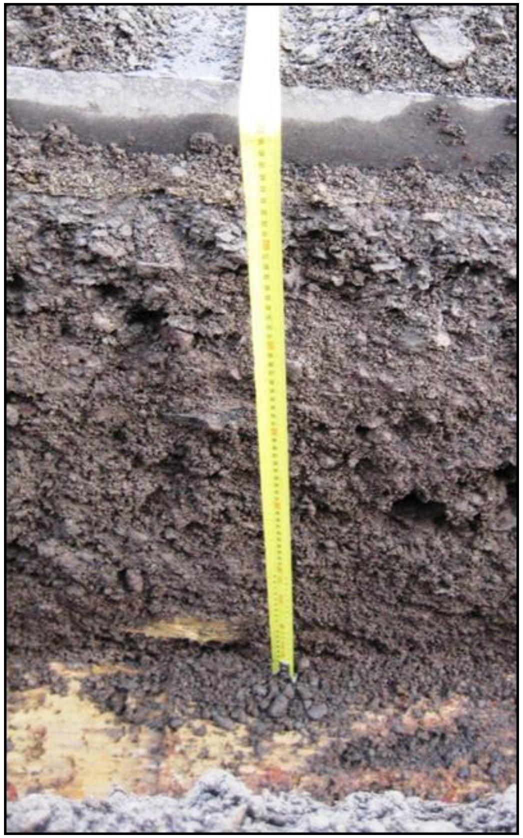
Bitumen dispersion – foamed bitumen is "dispersed" into millions of tiny specks, which only have energy to attach themselves to moisture on fines fraction of aggregate

Foamed Bitumen – Mix Design



Foamed bitumen stabilisation

- Appropriate number of test pits / FWD / Site evaluation ?
- Any geometric changes captured in dependable granular cover ?
- Consistency through site - or variations understood ?
- Prehoe considerations ?
- Adequate modular ratio (FBR layer not overlying weak substrate) ?
- Adequate drainage ?
- Design constructible within site constraints ?



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.

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

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

Foamed bitumen

- Concept is to derive modified basecourse that is too stiff to rut, yet not so stiff that is can develop cracking.
- Design to mix design 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 modulus values extremely high).

Foamed bitumen

- May need to manage plasticity – here the pre-treatment with lime or KOBM integral.
- ITS testing is conservative for FB as non-continuously bound. Particularly for South Island aggregates with reduced broken faces. Difficult to core initially.
- *In situ* modulus as demonstrated by FWD testing is superior but need to consider time for curing.
- Representative sampling (and proportioning) for obtaining mix design aggregates is critical

Foamed bitumen

- Consider differentiating between large scale Greenfields / Capital works projects
  - Consistent quarried virgin aggregates
- and smaller scale TLA / SH rehabilitations
  - more variability with aged aggregates, variable surfacing thickness, variable geology etc.
  - Manage proportions of surfacing/ layers, plasticity, localised structural problems

Design of asphalt overlays

Where an asphaltic cement overlay or inlay is to be designed, use methodology from

- *Austroads Guide to Pavement Technology Part 2* (Austroads 2012) and
- *Austroads Guide to Pavement Technology Part 5* (Austroads 2011)

Modelling of thin asphaltic surfacing

- Mechanistic pavement design modelling shall not rely on the stiffness of the thin asphaltic surfacing being any greater than the stiffness of the underlying materials.
- Should the underlying materials be stiffer than the TAS then the TAS stiffness is to be used in the modelling.

Thin asphaltic surfacing

Traffic volume	Heavy trafficked pavements (ADT > 5000)		Medium Trafficked pavements (ADT: 500 – 5000)		Lightly Trafficked pavements (ADT < 500)	
Deflection criteria / Surfacing mix type	Maximum 95 Percentile Beam Reading (d_0)	Maximum 95 percentile curvature $(d_0 - d_{200})$	Maximum 95 Percentile Beam Reading (d_0)	Maximum 95 percentile curvature $(d_0 - d_{200})$	Maximum 95 Percentile Beam Reading (d_0)	Maximum 95 percentile curvature $(d_0 - d_{200})$
AC	0.70 mm	0.15 mm	1.00 mm	0.17 mm	1.60 mm	0.2 mm
OGPA	1.10 mm	0.17 mm	1.60 mm	0.19 mm	2.40 mm	0.22 mm
Slurry	0.70 mm	0.15 mm	1.00 mm	0.17 mm	1.60 mm	0.2 mm

Asphalt mix design

Design according to NZ Transport Agency M10:2014

- Binder Selection
- Aggregate Selection
- Compaction Methods
- Performance Testing
- Design Reports

Basecourse and subbase granular strain criteria

- The life of the basecourse aggregate in terms of rutting and when a smoothing treatment is required can be calculated either through a laboratory approach (RLT) or *in situ* testing (FWD) as appropriate.
- The methodology described shows promise in predicting performance.
- However, at this stage it should only be used to support an experienced Pavement Engineer's estimate of material performance, rather than as a pass/fail tool.

Sand Grading Exponent

Requirements:

SGE ≥ 0.4 (for 5 million DESA over 25 years)

OR: RLT Test

Approval from NZ Transport Agency's Pavement Group < 0.4

M4 Basecourse Changes – Accredited Quarries

- This system is based on the Asphalt Plant Accreditation Scheme (APAS) system.Quarries that run a recognised QA system and can show a good statistical history of 30 tests will remain accredited quarries. All M/4 bought for NZTA work will need to come from an accredited quarry from July 2018.
- AQA will be maintaining the register of accredited quarries – the list will be available on website aqa.org.nz

Existing:

Lot Size		Number of Samples
From	To	
1 m^3	400m^3	2
400m^3	1500m^3	3
1500m^3	4000m^3	4

M4 Basecourse Changes – Accredited Quarries

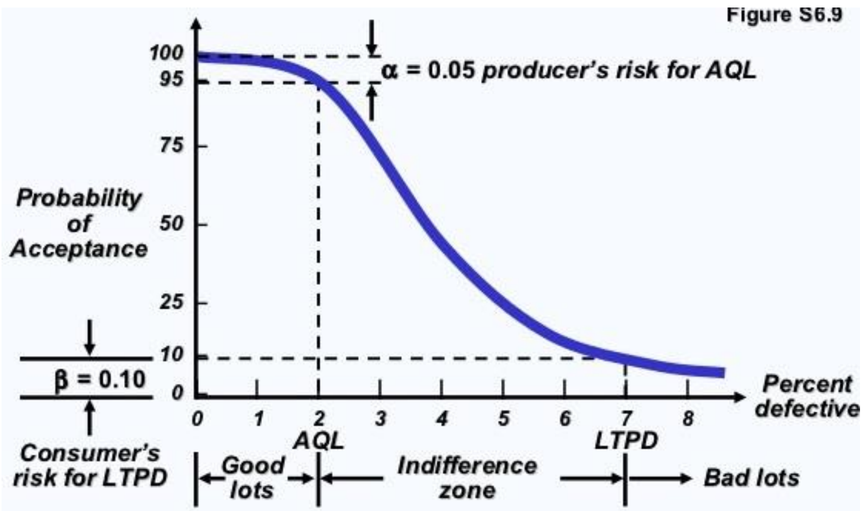
- As part of the scheme, 85% of individual samples and 100% of moving average of 5 samples must pass the M/4 criteria, with 100% of individuals inside the extreme limits (1.5x limits)
- Testing requirements are slightly changed:
    - 1 per 200m³, first 1000m³ production
    - 1 per 1000m³, production lots > 1000m³
    - 1 per 1000m³, stockpile is > 12 months old
- If an outlier is reported, 3 samples are required.

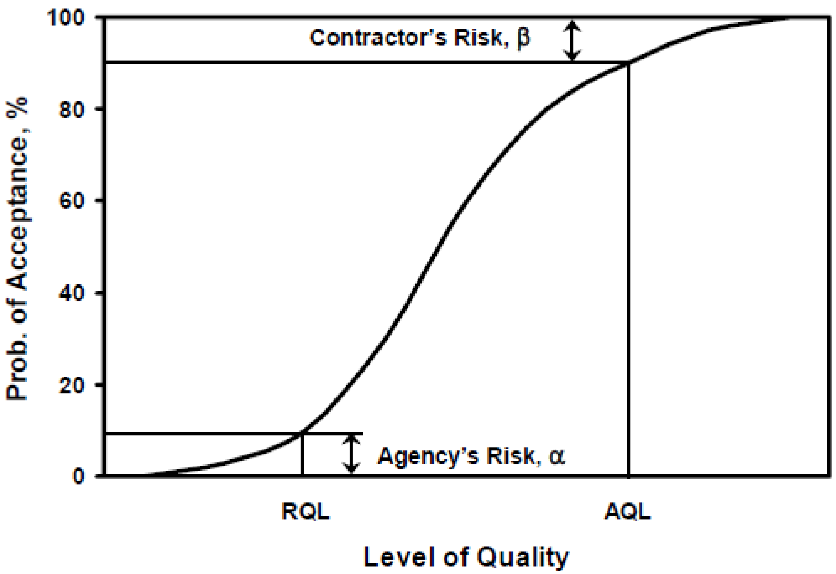
Existing:

Lot Size		Number of Samples
From	To	
1 m³	400m³	2
400m³	1500m³	3
1500m³	4000m³	4

M4 Basecourse Changes – Statistical Acceptance

- Operating Characteristic Curve allocates risk to producer and consumer.
- A 95/10 curve for example means there is a 5% chance a good product will not be accepted (Producer Risk) and a 10% chance a bad product will be accepted (Consumer Risk)



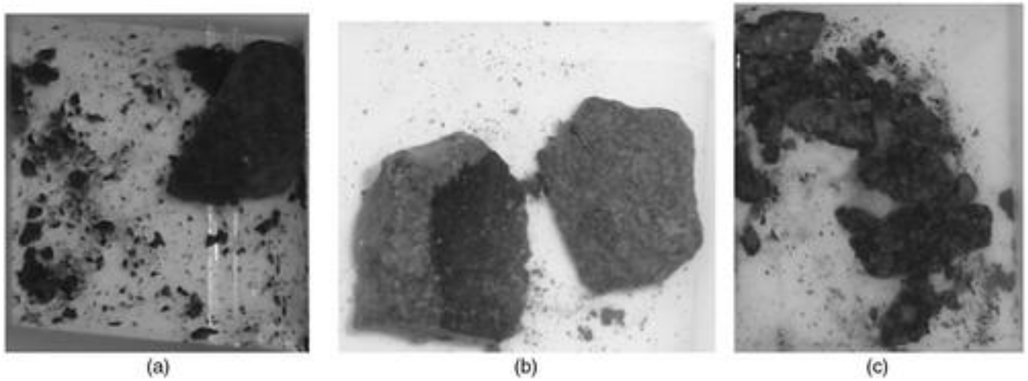


Potential for Ethylene Glycol Test

- The Agency has flagged aggregates susceptible to premature weathering as responsible for several significant recent pavement failures
- Gerhard van Blerk, NZTA National Technical Adviser (Pavement) has proposed an ethylene glycol (antifreeze) testing regime based on experience in South Africa.

Potential for Ethylene Glycol Test

- Ethylene Glycol is used to swell any swelling clays (smectites) and weaken the aggregate = Accelerated Weathering Test.
- Aggregate is soaked for 21 days in Ethylene Glycol and then put through a crushing resistance test. Results compared to the crushing resistance of a non-soaked sample.



a. Spalling
b. Split
c. Disintegration

Repeated load triaxial testing

The guide provides a number of ways in which testing with the RLT allows for interpretation of material qualities

- Warnings on sample preparation
- Guidance for use where material does not meet M4
- Requirement to supplement M4 testing for higher trafficked sites.

Not to be used in isolation

Base layer quality

- Rut resistance can be estimated using the RLT results
- Design estimates can be made using RLT modified by an ITS improvement factor