ROADING NEW ZEALAND

TECHNICAL NOTE No 001

FOAMED BITUMEN TREATED MATERIALS

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1. Introduction

In this process, a flexible bound pavement layer is produced by adding foamed bitumen during the recycling of in situ pavement materials. It can be used on basecourse or sub-base layers, new or old pavements and a wide variety of geological materials, provided some simple gradation and plasticity parameters are met.

The technique of using foamed bitumen as a binder was first developed in 1956 by Dr Ladi Csanyi at Iowa State University, USA. Dr Csanyi injected steam into hot bitumen and used the resulting foamed bitumen to produce a warm hot mix in a stationary asphalt plant. The technique was modified in the late 1960s to use cold water instead of steam. This change was more practical for use in in-situ recycling operations.

The modern version of in-situ recycling using foamed bitumen as a binder has been available in New Zealand since 2004.

2. What is foamed bitumen?

As shown in figure 1 below, foamed bitumen is a mixture of air, water and hot penetration grade bitumen. Introduction of water and pressurised air (which are at ambient temperature) into the hot bitumen (between 175° and 185°C) in the right conditions produces a mixture that expands as much as 5 to 25 times its original volume (typically 8 to 15 times for bitumen grades used in New Zealand). The resulting foamed bitumen temporarily has lower apparent viscosity, higher volume and lower surface tension characteristics than the original bitumen. These properties enable it to preferentially attach itself to the moist fine (<75 µm) fraction of aggregates.

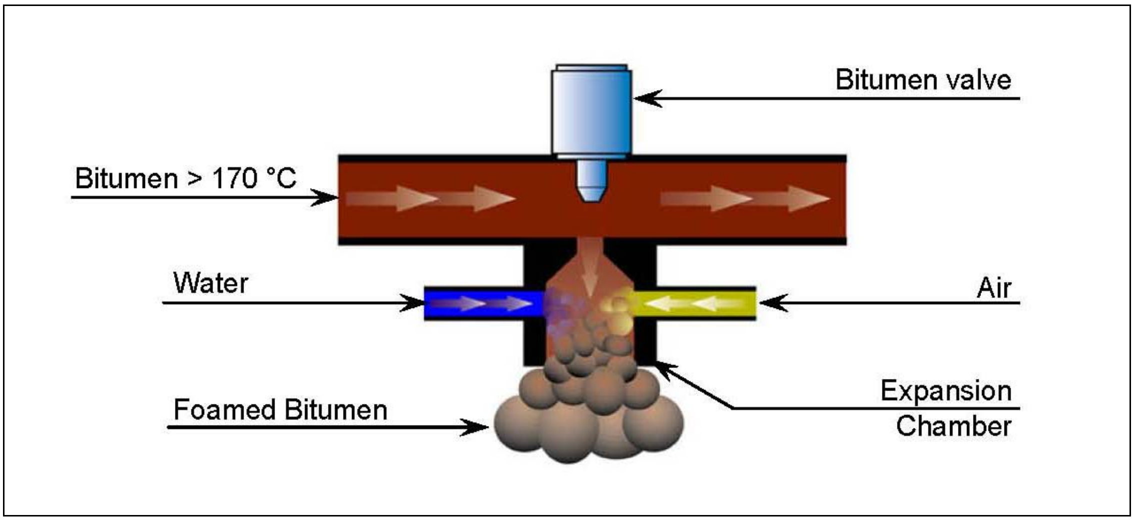

Figure 1: Schematic of foamed bitumen production

3. Foaming Characteristics – Half Life and Expansion

A simple and accepted method of quantifying the quality and suitability of the bitumen for the foaming process is to measure expansion and half-life during the foaming process. Expansion is defined as the maximum increase in volume relative to the original bitumen volume. Half-life is defined as the time in seconds that the foamed bitumen takes to collapse from the maximum expansion to half of the maximum expansion. These terms are represented in figure 2 below.

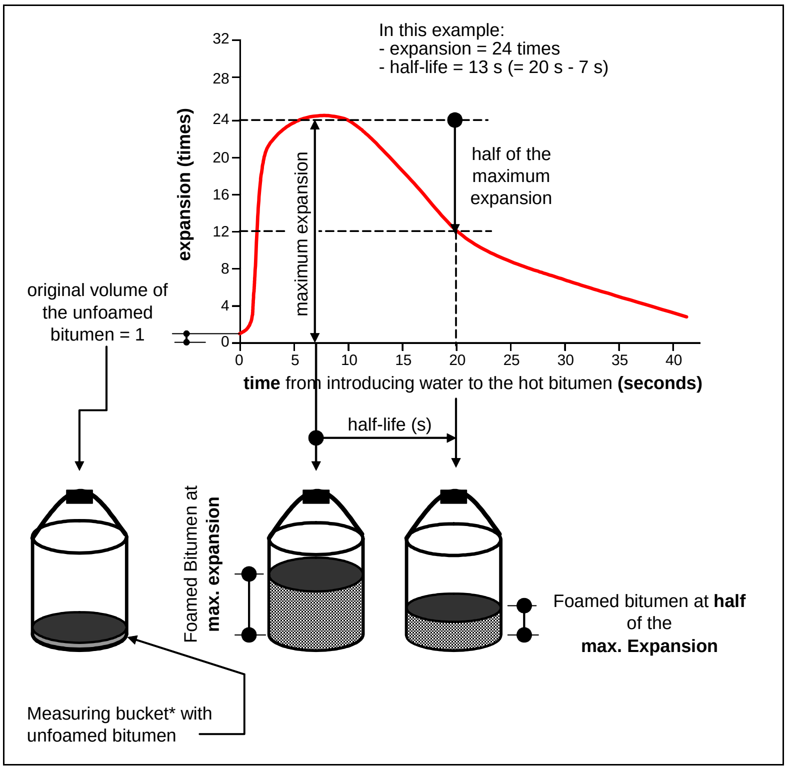

Figure 2: Volume change of the foamed bitumen vs. time of injecting water with the hot bitumen

The expansion of the foamed bitumen is increased by increasing the water content, which however decreases the half-life, because the "bubbles' are more unstable. The aim is to get a balance between achieving a large expansion, which improves the degree of dispersion, and a long half-life, which allows enough time for the foamed bitumen to reach and mix with the aggregates. In addition, the foaming characteristics are affected by the temperature of the bitumen before the water is introduced, so there is an optimum foaming temperature for each bitumen type and grade. For instance, the optimum temperature range for 80/100 penetration grade bitumen currently used in New Zealand is 175 ºC to 185 ºC. These principles, shown graphically in figure 3, are determined by means of laboratory scale foamed bitumen plant, depicted in figure 4.

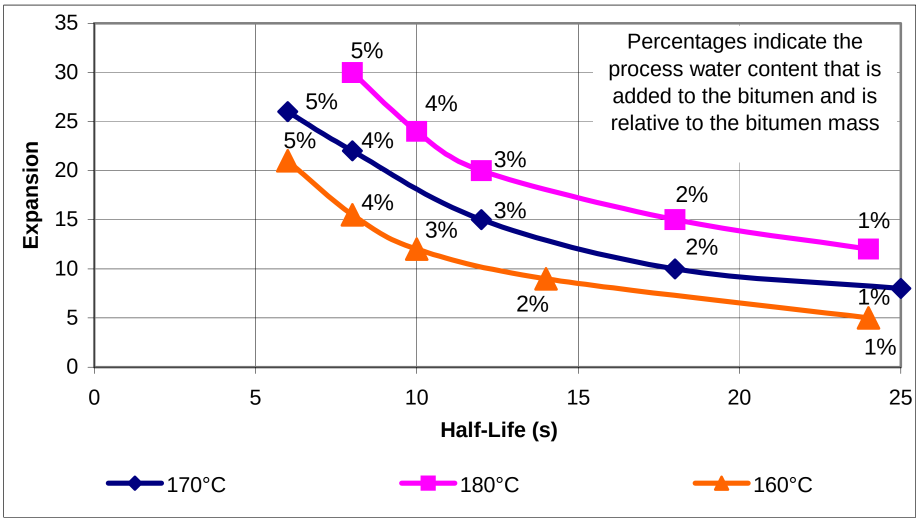

Figure 3: Relationship between Expansion, Half-life and Bitumen temperature

Figure 4: Example of a laboratory scale foamed bitumen unit

4. The materials

A combination of components are used to produce foamed bitumen treated materials:

- The aggregate(s)
- Penetration grade Bitumen
- Foaming agents (if required)
- Inactive fillers such as PAP 5, crusher dust, etc. (if required)
- Active fillers such as lime, cement and fly-ash
- Water (including compaction water if required)
- Pressurised air

Characteristics of aggregates

Foamed bitumen can be used in aggregates ranging from premium quarried materials to marginal aggregates. Plasticity in marginal materials must be treated before mixing with foamed bitumen. A small amount of plasticity can be tolerated. Where the material has a clay index > 3 and/or a plasticity index > 10, it should be pre-treated with lime, cement or suitable active fillers to modify the plasticity.

One of the key elements to a successful application is utilising an aggregate that has a suitable grading curve. Figure 5 shows broad guidelines for deciding if an aggregate has a suitable grading. Additional aggregate and/or non-active fines can be added to the pavement prior to application of the foamed bitumen to produce a more suitable material; however the impact on overall grading needs to be considered. The two key elements for appraising grading suitability are the provision of a uniform curve (i.e. not gap graded) and an appropriate percentage of fines passing the 75 micron test sieve (ideally between 5% and 20%).

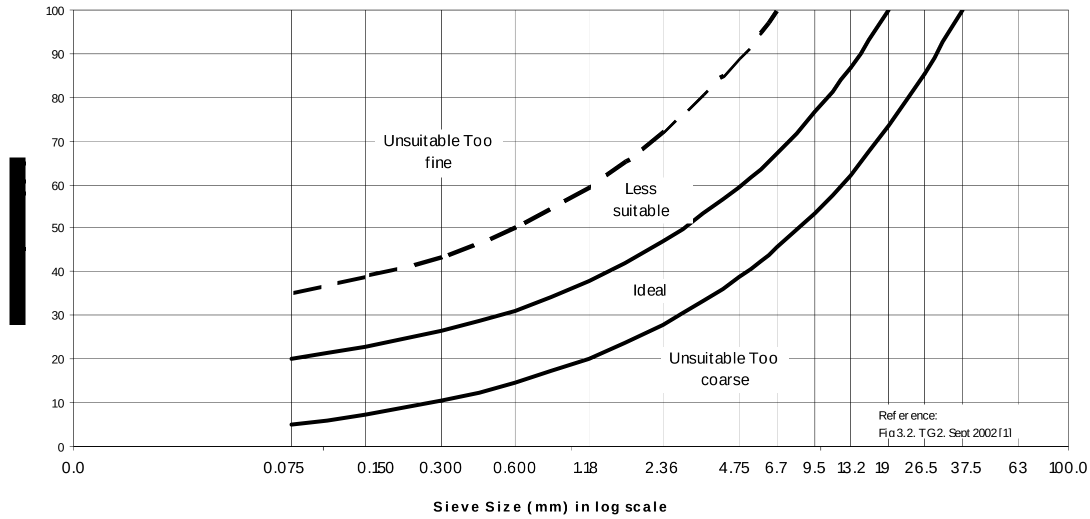

Figure 5: Ideal particle size distribution of aggregate to be treated with foamed bitumen

5. Characteristics of a foamed bitumen treated material

Minute ‘specks’ of bitumen attach themselves to the moist and fine aggregate particles, generally those smaller than 75 μm. The coated fines form a mortar that provides a matrix of ‘spot welds’ for the coarse aggregate. This is depicted in figure 6, which is a microscopic slice through a sample of foamed bitumen treated sand. The largest ‘white’ particle passed the 0.425 mm sieve.

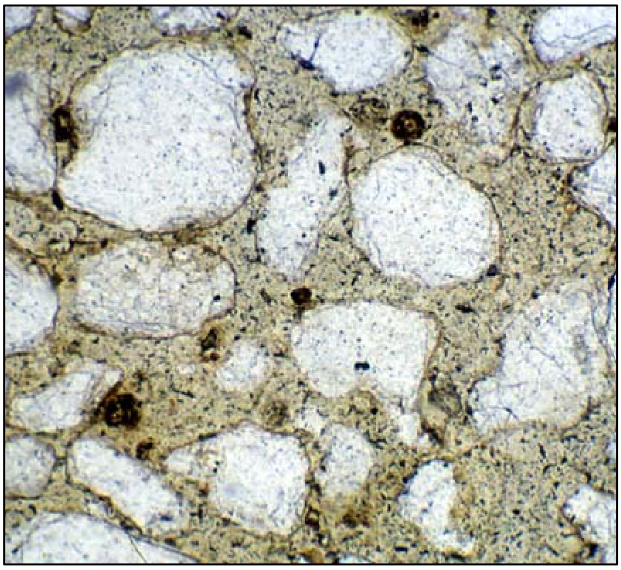

Figure 6: Microscopic slice of a foamed bitumen treated sand

Figure 7: A 150 mm diameter foamed bitumen treated basecourse core cut in half. The stones at the top represent the chipseal

The fresh material does not look black as one would expect with a bituminous material, but retains the colour of the parent aggregate. Observers may occasionally think that no bitumen is present, but squeezing a handful of the fresh material will leave small specks of bitumen adhering to your skin. The degree of dispersion can be assessed by the size of these bitumen specks, so that the specks become smaller so as the degree of dispersion improves. To date, this is the only reliable form of determining the degree of dispersion of the foamed bitumen. This squeeze test also provides a rapid indication of moisture condition of the foamed bitumen treated aggregate.

For any given aggregate, the two ingredients that will influence the performance characteristics of the foamed bitumen recycled pavement are:

- Bitumen
- Active filler(s)

Figure 8 shows how different proportions of bitumen and active filler can be combined to produce pavements with behaviour that will approach that of cemented materials or hot mix asphalt. The performance of the foamed bitumen treated material tends to depend on the ratio of active filler causing cementation and the foamed bitumen. The magnitude and relative proportion of binder type broadly determines its characteristics and performance.

As an indication, cemented materials can be produced by the use of a moderate amount (>1.5%) of active filler and a small amount (<3.0%) of foamed bitumen. Pavements constructed with this material will tend to be rut resistant but may be brittle with little flexibility.

The addition of a moderate to high amount (>3.0%) of foamed bitumen with a small amount (<1.5%) or no active filler will produce materials with visco-elastic tendencies. This type of mix will avoid the brittleness of cemented materials but provide a more flexible pavement.

The optimum blend of active filler and foamed bitumen as indicated by experience with foamed bitumen stabilisation work in New Zealand is from 3.0 to 3.5% bitumen and 1.0% cement. These percentages are by dry mass of aggregate to be treated.

Active fillers are often added to increase the rut resistance and the moist shear strength of the material. The amount of these active fillers should however be kept below 1.5% in order to take advantage of the flexibility provided by the foamed bitumen treatment.

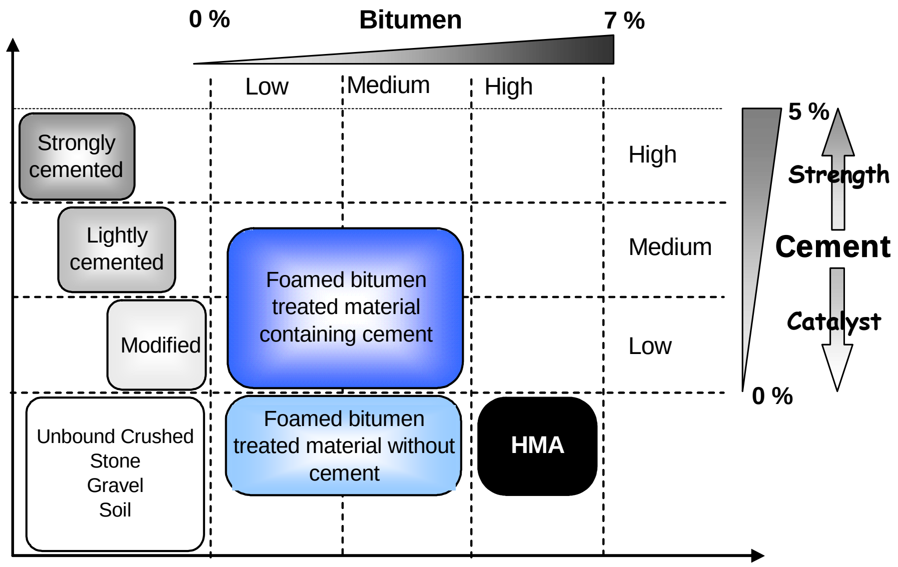

Figure 8: Indicative spectrum of binder contents used in various road construction materials

A good indication of the foamed bitumen treated material's performance under saturated conditions is the amount of retained strength, which is the ratio between the soaked and dry indirect tensile strengths (ITS). Commonly a retained strength ratio of greater than 70% should be achieved.

6. Site mixing of foamed bitumen treated materials

The foamed bitumen is sprayed from an electrically heated spray-bar through a series of foaming nozzles located in the upper region of the mixing chamber of the stabilising machine. The width of application can be reduced to cater for overlaps and tapering areas. The water that is added to get the material close to its optimum moisture content, for the purposes of compaction, is added by a second spraybar located below the foamed bitumen spraybar, thereby moistening the aggregates before treatment with foamed bitumen. Modern machines are equipped with variable adjustable (pressurised) exit gates, thereby controlling, to a certain extent, the mixing time of the treated material. In addition, the forward speed of the machine can be altered to adjust the particle size distribution of the treated material.

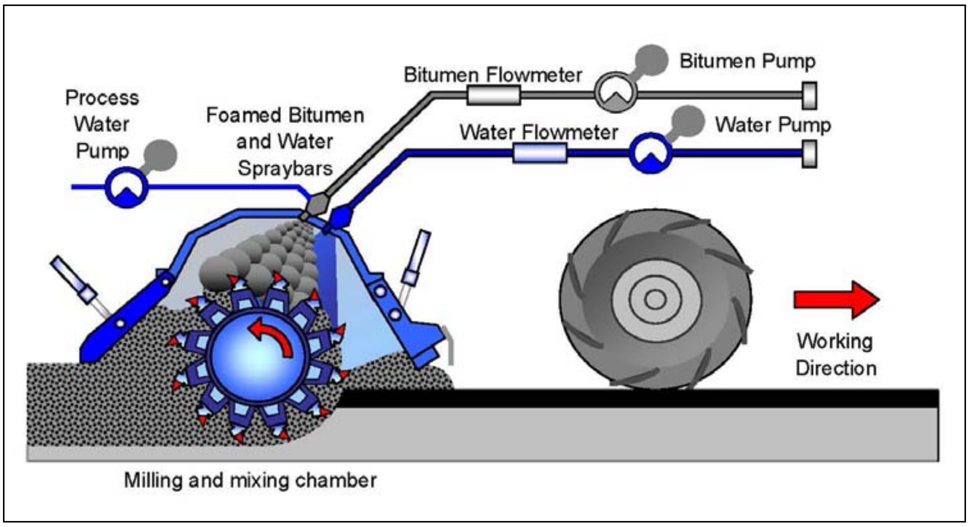

Figure 9: Mixing chamber of an in-situ stabilising machine injecting foamed bitumen and water for optimum compaction

7. Construction

Once the pavement design and foamed bitumen mix design are complete and clearly documented, the construction process needs to be closely monitored and managed to ensure that the design parameters are recognised and achieved.

Before commencing the foamed bitumen recycling operation, the supply of all plant and materials needs to be planned, comprising adequate supply and delivery of water, bitumen (at the correct temperature), active filler, in addition to appropriate foaming, compaction, shaping and finishing plant.

Upon commencing the foamed bitumen recycling the quality and consistency of the mixed and granulated material is evaluated. If the granulation or breakdown of aggregate is excessive, then the mixing chamber gate can be opened or the machine's forward speed can be increased to reduce the mixing time. The moisture content is vital, and a target of between 70% and 80% of optimum moisture content of the parent material is ideal. If the material is too wet it is very difficult to remedy, while a mix that is too dry can have compaction water added during the foaming process through the water spraybar, i.e. it is better to have the mix too dry than too wet.

It is recommended that the freshly treated material is checked regularly for material and moisture variability, and this can be undertaken by visual appraisal combined with the 'squeeze test'. Process control should include regular checks and monitoring of depth and independent checks (via loads cells, dips, mat tests or loading dockets) of bitumen, water and active filler application rates relative to design requirements and instrumentation settings.

The interval between stabilising and completion of compaction should comply with the time limitations as set out in TNZ Specification for in-situ stabilisation of modified pavement layers [4] when considering all binders and active fillers that are used.

Compaction and trimming should be undertaken so as to avoid laminations. It should be noted that the density of the treated material is one of the most important contributing factors to the layer's long-term performance.

8. Benefits and limitations

The benefits of foamed bitumen stabilisation are:

- Lower overall costs than full reconstruction.
- Environmental benefits in terms of recycling the existing material.
- The optional use of marginal materials.
- Enhanced physical properties compared to unbound granular pavement materials.
- Fewer time delays because the construction method offered by the in-situ addition and mixing of binders is quick, and compaction follows immediately.
- The treated layers can be trafficked as soon as compaction is complete, thereby limiting traffic disruption.
- The bitumen improves durability and waterproofing to the pavement material.
- Significant improvement in moisture sensitivity and freeze/thaw resistance.

The limitations are:

- The mix design and manufacturing process requires an advanced level of experience and specialised equipment to produce a product of satisfactory quality.
- Mix design procedures are not as well formulated for cold mixes as for HMA because of the inherent variability in recycling in-situ materials.
- A suitable grading of fines in the pavement material is required, especially in the fines to sand sized fractions (although the grading can be corrected with the addition of inert fillers and/or supplementary aggregate).
- Without reliable long-term pavement performance data for New Zealand roads, the life cycle cost vs benefit calculations have a degree of uncertainty.

9. Typical applications

Foamed bitumen stabilisation is a suitable treatment where an increase in shear strength and / or layer modulus is required in a granular pavement layer.

Typical applications are:

- Highly trafficked areas, e.g. > 1 million standard axle repetitions.
- Where early trafficking is required in high use corridors or where traffic controls restrictions exist.
- A sensible alternative to dig-out and reconstruction, especially if the reconstruction is structural asphalt or concrete.
- For pavements that are exposed to numerous freeze and thaw cycles.

10. Design considerations

Two designs are required: one for the mix, and one for the pavement.

Mix design involves carrying out laboratory work on the aggregate proposed for treatment, which can be either retrieved from the existing pavement or sourced from the quarry. This work will optimise the use of ingredients to produce a material that will achieve the pavement design requirements. The *Wirtgen Cold Recycling Manual [2]* provides a high level of detail regarding mix design, pavement design and construction considerations.

The Pavement design should also incorporate the requirements of the current *New Zealand Supplement to the Austroads Pavement Design Guide [3].*

The pavement design needs to be verified with the physical properties achieved by the actual treated material to be used.

References

[1] South Africa, Transportek. 2002. *The design and use of foamed bitumen treated materials.*

[2] Germany, Wirtgen. 2nd edition November 2004. *Cold Recycling Manual.* www.wirtgen.de

[3] Transit New Zealand. 2007. *Supplement to the Austroads Pavement Design Guide.* www.transit.govt.nz/technical/manuals

[4] Transit New Zealand. 2007. TNZ B/05 – *Specification for in situ stabilisation of pavement layers.* www.transit.govt.nz/technical/specifications

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