CHARACTERISATION OF FOAMED BITUMEN STABILISATION

J.M.RAMANUJAM
Principal Engineer (Pavement Rehabilitation)
Road System & Engineering
Queensland Department of Main Roads

&
J.D.JONES
Engineer (Pavement Rehabilitation)
Road System & Engineering
Queensland Department of Main Roads

August, 2000

Synopsis

Since 1997 Main Roads has been developing the foamed bitumen stabilisation technique to provide a more flexible and fatigue resistant stabilisation treatment suitable for Queensland conditions. Several projects have been completed using this technique. Supplementary specifications have been also developed based on the experience to date. These project sites are currently being monitored to assess the performance of this treatment. This monitoring includes site inspections, fatigue and rut resistance testing, deflection testing, back analysis of deflection and coring of samples from the field to assess its performance properties.

This paper summarises the experience and knowledge of this treatment currently in the Queensland Main Roads Department. As the process becomes more accepted and greater volumes of material are recycled, the design, construction and maintenance techniques will be further developed in the light of the increased data available. Further testing and performance monitoring will also be required to determine whether superior performance and lower maintenance is possible using the foamed bitumen stabilisation method compared to other more conventional stabilisation treatments.

1.0 INTRODUCTION

Since 1997 Queensland Main Roads Department has been trialing foamed bitumen stabilisation as a potential structural rehabilitation treatment for roads in Queensland. Foamed bitumen stabilisation is considered to be more flexible than other stabilisation treatments. The aim of this treatment is to achieve a flexible but strong and impermeable road pavement.

This paper addresses the following topics:

- The basic principles and properties of foamed bitumen stabilisation.
- The construction process of foamed bitumen stabilisation.
- The design process and testing for foamed bitumen stabilised material.
- Performance monitoring and research into foamed bitumen stabilisation.

2.0 SHORTCOMINGS WITH CEMENT STABILISATION

Traditional pavement stabilisation has typically involved using high cement additive contents resulting in the development of a fully bound Cement Treated Base (CTB) layer. Due to the high stiffness of the layer, transverse shrinkage cracks develop along the length of the pavement. Currently deep lift stabilisation (depths up to 350mm) is generally a common technique in most State Road Authorities (SRA's). Although, these SRA's have changed from cement to slow setting cementitious additives, they aim at obtaining higher Unconfined Compressive Strengths (UCS). This leads to higher stiffness and associated cracking problems. Due to the relatively thin nature of granular pavements in Queensland, Pavement Rehabilitation has been developing several treatments of modifying rather than stabilising the base layer. This involves using treatments that increase the material strength and reduce the permeability in order to produce a layer with improved material properties compared to the original granular materials. The intention is to avoid fatigue cracking that is a result of the stiff pavement layer. This type of stabilisation typically uses additives such as Lime/Flyash, Emulsion/Cement, and Foamed Bitumen. Several foamed bitumen stabilisation trials have been carried out and are performing satisfactorily. Long term monitoring will be required to confirm this observation.

3.0 DESCRIPTION OF TREATMENT

Foamed bitumen is a mixture of air, water and bitumen. Injecting a small quantity of cold water into hot bitumen produces an instantaneous expansion of the bitumen to about 15 times its original volume and forms a fine mist or foam. In this foamed state, the bitumen is ideal for mixing with fine aggregates. The foam dissipates very quickly and therefore vigorous mixing is required to adequately disperse the bitumen throughout the material. During the mixing process foamed bitumen coats the finer particles forming a mortar that will effectively bind the mixture together. Typically the foamed bitumen contains 97% bitumen, 2.5% water and 0.5% additive.

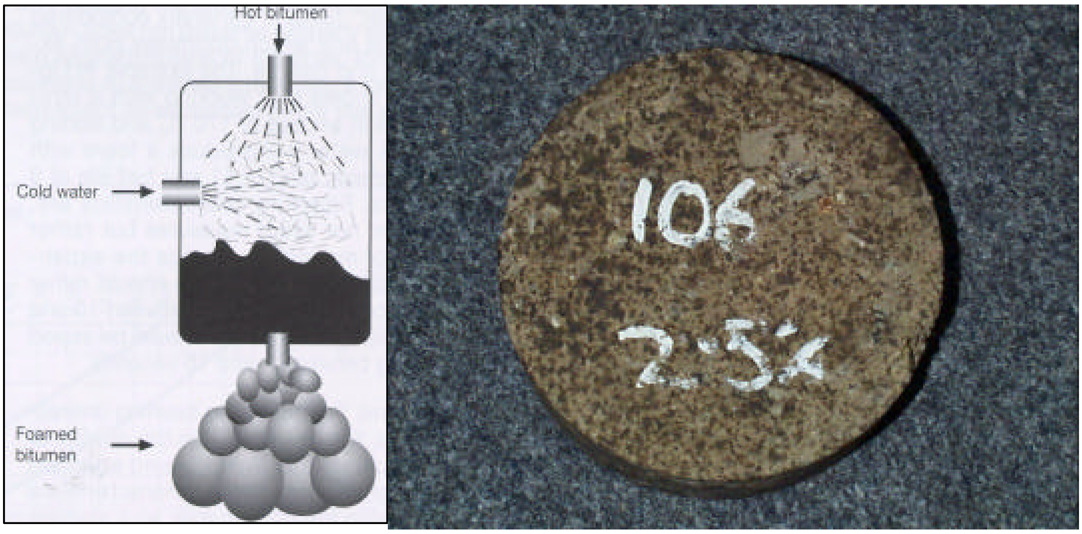

Figure 1 – Bitumen foaming concept (left) and foamed bitumen stabilised sample (right).

This type of stabilisation can be undertaken using one of two methods.

- **Insitu** – The existing pavement material is milled and the additive injected into the material without removal from site.
- **Pugmill/paver** – The existing material can be milled and hauled to a central batch plant, additive injected and hauled back to site for layering with a paver and compacted.

The insitu stabilisation process is generally cheaper and quicker than the pugmill/paver operation. This is because the material does not need to be hauled between the pugmill and construction site. The subgrade is never exposed to the weather with insitu stabilisation (as occurs with the pugmill/paver operation). This is therefore a lower risk option during period of rainfall. In contrast, removal of the base material allows inspection of the subgrade material and any defects/weaknesses can be rectified prior to relaying of the stabilised material. The pugmill/paver operation also allows the removal of any unsuitable material, or allows the use of an external source of material in the stabilised layer. Therefore it is considered that a more consistent product can be achieved using the pugmill/paver operation.

4.0 CONSTRUCTION PROCESS

Currently only insitu stabilisation has been used for Queensland Main Roads projects, and will be discussed here. The field process generally used for foamed bitumen stabilisation is discussed within this section.

4.1 Pre-milling and pulverising prior to stabilisation

A road recycler is used to break up the wearing course and any patches prior to stabilisation. This is shown in figure 2. The depth of pre-milling is generally less than that of the final stabilisation depth.

4.2 Shape correction

A grader is used to correct any irregularities in the surface before stabilisation and compaction. This is shown in figure 2.

Figure 2 – Pre-milling existing pavement (left) and shape correction (right)

4.3 Spread and slake lime

Quicklime is spread over the road (generally 1.5% by weight) prior to slaking with water. The quicklime must be fully slaked prior to stabilisation with bitumen. This is shown in figure 3.

Figure 3 – Spreading (left) and slaking (right) of quicklime

4.4 Foamed bitumen injection and mixing

For the projects undertaken so far, a Wirtgen WR2500 recycler has been used with a purpose built foaming chamber with 15 nozzles arranged along the length of the spray bar inside the mixing chamber. The foaming chamber is connected with two pipes, one of which carries cold water from an on board water tank and the other hot bitumen from an external bitumen tanker. As cold water is sprayed into the hot bitumen through the foaming chamber, bitumen expands to form foamed bitumen. This foamed bitumen is then injected through the nozzles onto the recycled pavement material. During the mixing process foam bitumen coats the finer particles forming a mastic that will effectively disperse and bind the mixture together. The

PRINT Back to TOC Return to Page 1

loose material is churned up and the bitumen and hydrated lime is thoroughly mixed through the material.

4.5 Compaction and Trimming

The material is generally compacted using several compaction rollers. Initial compaction is generally completed using a pad foot vibrating roller to ensure the full depth of material is adequately compacted. Initial compaction should be completed within 2 hours after the lime has been spread on the pavement material to ensure the lime does not begin to stiffen the material. Compaction is completed using a vibrating steel wheel roller and multi-tyred roller. Grading and trimming is carried out to level the surface and achieve the designed desired cross-falls. Initial compaction is shown in figure 4.

Figure 4 – Foamed bitumen mixing using the road recycler with foaming apparatus (left) and initial compaction using a pad foot roller (right).

4.6 Sealing

A primer seal should be preferably applied as soon as possible. The maximum time delay accepted would be 2 weeks after construction. However, adequate time should be allowed for the pavement material to dry out prior to sealing. If sealing is delayed, the stabilised layer may begin to deteriorate or develop a slick surface during wet weather. A full seal (preferably PMB) should follow to provide a suitable skid resistant watertight surface.

5.0 ADVANTAGES AND DISADVANTAGES OF FOAMED BITUMEN

After the initial Gladfield trial was completed in 1997, several observations were made about the advantages/disadvantages of using foamed bitumen. These observations were discuss by Ramanujam et al (1997) and are repeated here in full.

5.1 Advantages

- Easy application – The foamed bitumen is sprayed directly into the recycler's mixing chamber.
- Rapid Strength Gain – The road was trafficked immediately after compaction was complete. The deflection results taken the day after the first lot indicated values less than 0.75mm confirming adequate structural strength is available for immediate trafficking.
- Additive Content – The trial showed that it required only a small percentage of cement to improve the early strength significantly.

5.2 Disadvantages

- Cost – Relatively more expensive as compared to other forms of stabilisation.
- Sealing Work – The trial indicated that the seal design requires special attention. There were stripping problems with a polymer-modified seal (no primer seal) sprayed after two weeks of completion. A slurry seal is commonly used on foam stabilised pavements in South Africa.
- Bitumen Temperature – The process requires hot bitumen (180^{o}C) for the foaming action to be successful.
- Grading – The success of this technique (based on literature survey) appears to be very sensitive to the grading of the host material. The preferred should be closer to a standard 'C' grading. An additional requirement is the percentage passing the 0.075mm sieve should be 5 to 15%. This may force the user to obtain imported material to mix with the existing material to achieve the grading requirements.
- Purpose Built Equipment – The recycling equipment requires expansion chambers etc., to carry out the foaming and associated work. Most other additives could be used with an ordinary high production recycler.

6.0 MATERIAL PROPERTIES

6.1 Bitumen

Typically both bitumen and lime are used in foamed bitumen stabilisation. Usually 3.0 – 4% bitumen and 1.5% quicklime is adopted for most projects. Class 170 bitumen is the preferred bitumen for foamed bitumen stabilisation. A batch of Class 320 bitumen (most common for asphalt in Queensland) was tested during 1999 for a project in the Northern Territory and it was found that the foaming properties were inadequate for effective stabilisation. A foaming agent must also be added to the bitumen to counteract the anti-foaming agent (silicone) that is used in the refining process of bitumen. Without this additive the desired foaming characteristics could not be achieved. Typically 0.5% foaming additive is required to achieve the desired foaming properties.

The foaming properties are characterised by two terms: expansion ratio and half-life.

Expansion Ratio: The ratio of the maximum volume of the foamed bitumen compared to the volume of the unfoamed bitumen.

Half-Life: The time taken for the volume of the foamed bitumen to settle to half of the maximum volume achieved.

It is important that sufficient expansion ratio and half-life characteristics are present to ensure adequate coating of the fine particles by bitumen. An inferior stabilised product will result due to the lack of bitumen dispersion within the material.

Several factors affect the foaming properties of bitumen. These include:

- Foaming temperature (typically 175^{o}C).
- Anti-foaming agents.
- Foaming water content.
- Foaming agent used.
- Bitumen chemical composition.

Only the foaming water content can be changed readily to improve the foaming characteristics. The influence of this property on the bitumen foaming properties is shown in Figure 5. Testing indicates the “best” foaming properties are usually achieved with a water content of 2.5%. The minimum foaming limits recommended are 10 times expansion and 30seconds half-life.

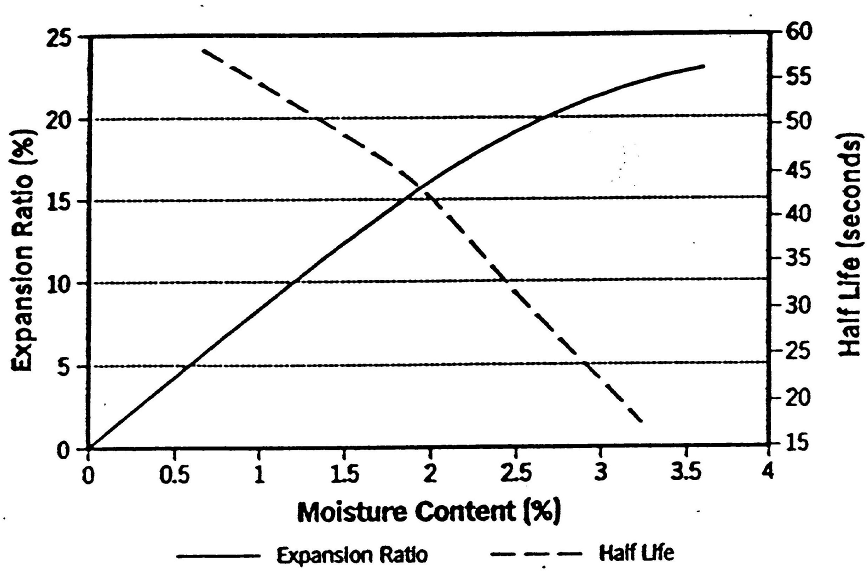

Figure 5 – Influence of the foaming water content on the expansion ratio and half-life of foamed bitumen (Kendall et al, 2000).

6.2 Lime

Lime is also used in the stabilisation process for the following purposes:

- To flocculate and agglomerate the clay fines in the material.
- Stiffens the bitumen binder.
- Acts as an anti-stripping agent to help disperse the foamed bitumen throughout the material.
- Improves the initial stiffness of the material and increases the early rut resistance of the stabilised material.

Quicklime rather than hydrated lime is used because:

- It is more economical per tonne.
- It is denser and less likely to be blown away during construction.

Quicklime does have some disadvantages. These include:

- It must be fully slaked prior to the injection of foamed bitumen into the material.
- It is relatively volatile in this state and will cause significant burning if it comes in contact with human skin. People working with quicklime are required to wear appropriate protective clothing and masks.

6.3 Material Grading

It is generally considered that materials that conform to the "C" grading curve as per MRS11.05 are usually suitable for stabilisation. The success of the treatment (based on literature) appears to be sensitive to grading of the material. Main Roads experience tends to indicate that "C" graded materials are usually stronger than those that fall outside this grading curve. With foamed bitumen stabilisation it is essential that adequate fines are available for the bitumen to bind with. It is recommended that the percentage passing the 0.075mm sieve should be between 5 to 20%. Imported material may be used to achieve the desired grading. The material must also have some plasticity or foamed bitumen stabilisation will not be suitable treatment.

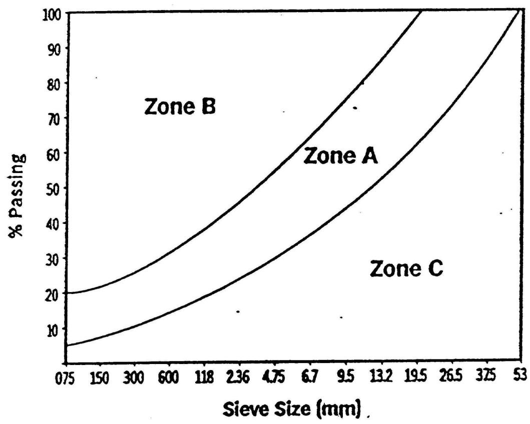

Figure 6 – Material grading suitable for foamed bitumen (Kendall et al, 2000).

7.0 COST

The cost of foamed bitumen stabilisation is considered to be higher than other stabilisation treatments. Kendall et al (2000) discussed the costing of various stabilisation treatments along the New England Highway between Toowoomba and Warwick (including foamed bitumen). These costs are shown in Table 1.

Table 1 - Relative Costs of Stabilisation (Kendall et al, 2000)

Treatment	Cost ($/m^2)
2-3% lime/flyash (200mm)	$6 - $9
Bitumen (2%) emulsion/cement (2%) (200mm)	$12 - $14
Ad-Base 4/cement (175mm)	$12 - $14
Foamed bitumen (250mm OWP, 200mm IWP)	$13- $15

8.0 DESIGN

Pavement design of foamed bitumen material consists of 3 components. These are:

- Trench investigation.
- Material testing.
- Mechanistic pavement design.

8.1 Trench Investigation

The trench investigation and materials testing should be completed in accordance with standard materials sampling procedures. This should include the following components:

- Material classification.
- Assessment of moisture conditions.
- Assessment of failure mechanism (subgrade strength, ingress of water, pavement material properties, and drainage).
- Pavement profile and layer thicknesses.
- Dynamic Cone Penetrometer (DCP) subgrade strength profile.
- Material sampling for foamed bitumen testing (using milling equipment).

8.2 Materials testing

The following testing should be completed as an initial assessment of the suitability of foamed bitumen stabilisation.

- Particle size distribution.
- Atterberg limits.
- Maximum Dry Density / Optimum Moisture Content testing.

If initial testing and findings from the trench investigation indicate foamed bitumen stabilisation is a suitable option, foamed bitumen testing should be undertaken.

A full design consists of the following:

- Preparation of three 10kg samples for each location of varying material properties.
- Samples are mixed with 70% OMC water content, 2% hydrated lime and bitumen (2%, 3%, and 4%) using the foamed bitumen apparatus (figure 7) at the Herston laboratory.
- From each bag of material three samples are compacted using 50 blows Marshall compaction.

Samples are tested in three conditions using the MATTA apparatus (figure 7) for indirect tensile resilient modulus.

- Initially after compaction (to simulate early strength).
- After 3 days oven curing at 60°C.
- After soaking the cured samples in water under vacuum.

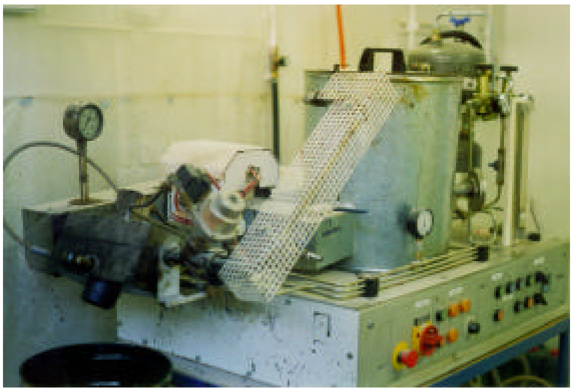
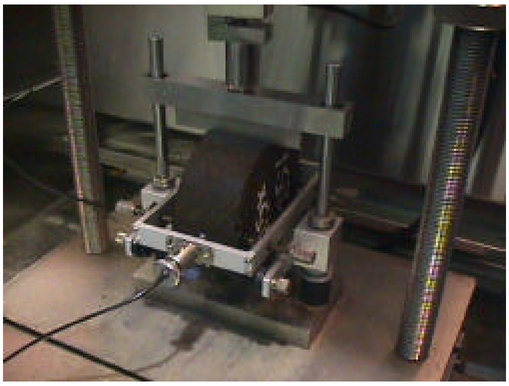

Figure 7 - Laboratory bitumen foaming machine (left) and MATTA apparatus (right).

The optimum bitumen content determined through testing is usually recommended as the minimum specified bitumen content for field construction. Minimum MATTA modulus limits test limits for foamed bitumen stabilisation suitability assessment are listed in table 2.

Table 2 – Minimum MATTA test results for foamed bitumen stabilisation.

	Minimum Requirements
Initial Modulus	700MPa
Soaked Modulus	1500MPa
Retained Modulus	0.50

Pavement design calculation for foamed bitumen stabilised layers should be carried out using a computer package based on mechanistic design principles such as Circly.

For pavement design using this methodology, the following parameters must be known, estimated or assumed:

- Flexural modulus.
- Failure criterion.

Back analysis and preliminary fatigue beam testing indicate that the flexural modulus of the foam-stabilised material is between 500 and 2000MPa. As yet a fatigue criterion is not available for foamed bitumen stabilised material so therefore its fatigue properties can not be accurately determined. Presently the foamed bitumen layer is modelled as an 800MPa - 1200MPa granular layer and as a 1200MPa or 1500MPa asphalt layer. An average of the two models is assumed to be the design life. The modulus used for the pavement design is selected through experience and materials testing results. Although this model is not the correct representation of the material's performance, it is the best estimate currently available. Further performance monitoring of field trials, back analysis of deflection data and fatigue beam tests are required to refine the model.

9.0 CONSTRUCTION CONSIDERATIONS

- Field construction must be completed in the order outlined in section 4.
- Lime must not be mixed into the material prior to foamed bitumen injection as it will work on the fines and change the surface area.
- The lime must be added at the time of bitumen injection.
- The time between the spreading of quicklime and the compaction of material should be limited to 2 hours to ensure adequate compaction is achieved.
- Even and adequate bitumen and lime content across the pavement needs to be achieved.
- The pulverising pass should be less than the final stabilisation depth. This is to ensure "lenses" of unstabilised and uncompacted material is not present below the stabilised layer.
- Although the control of moisture content is of a prime importance for optimum compaction conditions, there is currently no automated process available that can ensure the provision of moisture at a uniform and optimum level during the recycling process. It is therefore vital that an experienced operator controls the stabilisation process and acceptable moisture conditions are maintained.

9.1 Quality Control Measures

- Checking of stabilisation depth
- Slaking of lime – slaking temperature test
- Lime content – tray test
- Bitumen content – bitumen tank dipping, spray bar check, bitumen pressure flow check, bitumen content test
- Foaming properties – test jet check for expansion and half-life requirements are met.
- Adequate compaction – MDR test

Reference should be made to the foamed bitumen supplementary specification for details of the above testing.

10.0 QUEENSLAND TRIALS OF FOAMED BITUMEN STABILISATION

RS&E (Pavement Rehabilitation) have been involved with design; materials testing, construction involvement and performance monitoring of foamed bitumen stabilised pavements for several districts and local road authorities within Queensland. A list of the projects already completed is shown below.

10.1 Cunningham Highway, Gladfield

Location:	21km east of Warwick
Project length:	1.6km
Traffic loading:	AADT = 4000, %CV = 24%
Material type:	Clayey Gravel
Treatment:	3.5% foamed bitumen, 2% cement
Construction date:	May, 1997.

10.2 Rainbow Beach Road, Rainbow Beach

Purpose:	To trial several alternative treatments for low volume roads by north coast hinterland district.
Location:	4km west of Rainbow Beach
Section lengths:	200m
Material type:	IWP = sand, OWP = low quality crushed rock.
Treatment:	3%, 4% and 5% foamed bitumen with 2% hydrated lime. 1% and 3% residual bitumen from emulsion with 1% and 2% cement. A control section of granular construction.
Construction date:	June 1998

10.3 Cunningham Highway, Inglewood

Location:	Just east of Inglewood
Project length:	1.6km
Treatment:	4% bitumen, 2% hydrated lime
Construction date:	May 1999

10.4 New England Highway, Allora

Location:	South of the Nobby turnoff.
Project length:	17km
Traffic loading:	AADT = 2500, %CV = 10%
Material type:	Well graded clayey gravel.
Treatment:	3.5% bitumen, 2% lime
Construction date:	May 1999

10.5 Barron Road & Shore Street, Redland Shore

Location:	Cleveland
Project length:	550m and 400m
Treatment:	3% bitumen, 2% lime
Construction date:	February 2000

11.0 PERFORMANCE ASSESSMENT

11.1 Cunningham Highway (Gladfield)

The first trial conducted by Main Roads was undertaken along a short section of the Cunningham Highway between Cunningham's Gap and the 8-mile interchange. This section of pavement is very heavily trafficked considering the existing pavement and weak subgrade materials present. Due to the high volume of heavy vehicles which use this route (including B-Doubles), the stabilised layer was given a design life of only 5 years using a conservative F1 (ESA/CV) factor of 2.1. Weigh-In Motion data along this section indicates that the F1 factor has increased considerably since construction and in 1999 this figure had increased to 5.0 in the eastbound direction. This trial was conducted using cement instead of lime due to its lower cost and ease of use compared to quicklime. Early performance was relatively good, however some isolated cracking had occurred within two years of service. Kendall et al (2000) reported that "After two years of service, the pavement is exhibiting distress in approximately 10% of the pavement due to block cracking which coincides with the original cement treated patches and the lack of subgrade support and overloading, but is otherwise performing well".

11.2 Rainbow Beach Road

The material at rainbow beach was considered to be less than ideal for stabilisation. The section stabilised was originally a widened granular pavement. The material in the inner wheel path was a beach sand and the material in the outer wheel path was a low strength granular material. It was considered that during construction considerable breakdown of the stone in the outer wheel path (OWP) during the milling process as it significantly affected the grading.

The foamed bitumen section held up to early traffic much better than the other sections. Some rain also occurred during construction and prior to sealing. During this time the emulsion section had become very slick and rutted significantly. Screenings were spread over the surface to make it trafficable again. The foamed bitumen section had no such ill effects and as a consequence foamed bitumen became the preferred bitumen stabilisation treatment. Both treatments are now performing well and have required minimal maintenance since construction with fatigue cracks having not developed as yet.

11.3 Cunningham Highway, Inglewood

From the lessons learned from the Gladfield trial, the treatment was changed to 4% bitumen and 1.5% quicklime for the Inglewood trial. During early trafficking the stabilised layer performed remarkably well considering that during the first 6 weeks 142mm of rainfall was recorded prior to sealing. The general pavement moisture conditions within the trial site were also relatively poor. This is due to the following reasons:

- Poor Drainage – the road reserve is basically flat and water therefore remains stagnant at the edge of the pavement saturating the pavement materials.
- Flood Irrigation - it appeared that farms on property adjoining the trial site use flood irrigation regularly. Therefore the surrounding material and subgrade would be saturated.

During March 2000 a performance assessment of the site was conducted. It was considered that the stabilised layer was performing relatively well considering the moisture and subgrade conditions that were present. Some of the defects recorded are listed below:

- Bleeding and flushing of the seal over the entire length of the trial. This is possibly a result of the bitumen in the seal not being able to penetrate into the stabilised layer.
- No obvious signs of cracking was apparent over the length of the pavement and appears to be currently acting as a relatively “flexible” layer rather than a stiff, fatigue prone layer.
- Areas where additional lime was used to dry out a “wet spot” during construction, some crocodile cracking had developed.
- The depth of rutting over the length of the trial was in the order of 5mm with some areas showing greater rut depths.

11.4 New England Highway, Allora.

The stabilised section of the New England highway has performed very well since construction. No significant structural defects were recorded prior to May 2000 when a PMB seal was applied. An initial primer seal was applied shortly after construction to provide a suitable fulling surface and seal the stabilised layer. The primer seal was showing signs of ravelling and stripping of stone at intersections and farm entrances where the forces of turning vehicles are highest prior to PMB sealing. Some minor stripping and flushing had also occurred in areas where these turning forces were not present. It was considered that the bitumen used in the primer seal was not able to sufficiently penetrate the surface of the stabilised layer. A PMB seal was applied in order to reduce the possible affects of fatigue cracking.

11.5 Deflection Testing

Deflection testing and back-analysis has also been carried out for several of the trial sections since construction. The deflection testing was carried out using an FWD test device. Back analysis results of these deflection data for the Gladfield and Rainbow Beach trials are shown in Table 3.

Table 3 - Back analysis results of foamed bitumen trials.

	Gladfield	Rainbow Beach
Subgrade	40 MPa (CBR 3)	90 MPa (CBR *)
Subbase	200 MPa (CBR 40)	-
Stabilised Base	1250 MPa	1100MPa

Deflection testing has also been carried out twice along the 1.5km trial section of the New England Highway project. These were conducted 6 weeks and 10 months after construction. The maximum deflection and deflection ratio results of this testing is shown in Figure 8. It can be seen that there has been a reduction in deflection and an increase in deflection ratio. This means that during the past year the pavement has stiffened noticeably since construction. The deflection over the length of the trial site has also become more consistent. It is considered that the pavement has not become fully bound but any further increase in the deflection ratio is likely to result in the pavement becoming fatigue susceptible. Back-analysis has not yet been carried out on the New England Highway deflection data.

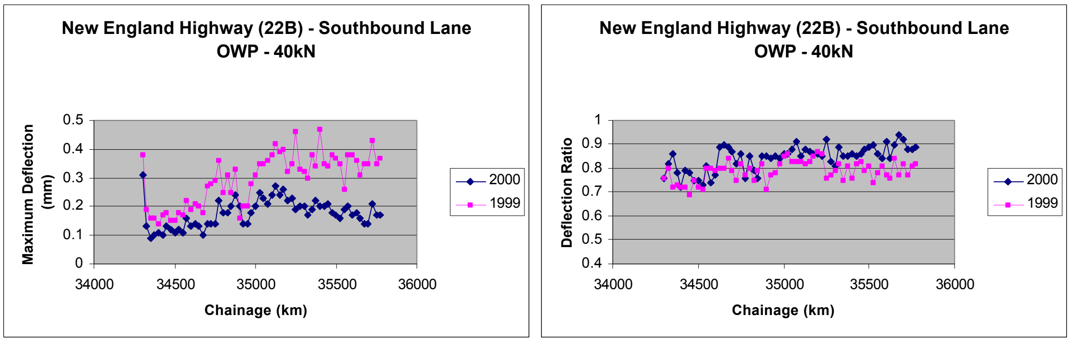

Figure 8 - Maximum deflection (left) and deflection ration (right) of the New England Highway trial section during 1999 and 2000 using the FWD deflection devise.

11.6 Cored Samples

Samples were also cored from the New England Highway pavement in April 2000 as a comparison with the design modulus samples and samples tested during the construction phase of the project. Two samples were cored in both the IWP and OWP. There were cored in a staggered pattern 250m apart. They were cored to the full depth of the stabilised layer (200mm IWP and 250mm OWP). The cores were cut into 3 or 4 samples of similar size to the laboratory samples (60mm - 70mm high). Therefore the modulus of material at the top surface could be compared with material at the bottom of the stabilised layer. The results of this investigation are shown in Table 4.

From these tests results the following observations were made:

- The MATTA modulus achieved from these samples decreased with depth.
- The density of the stabilised layer decreased with depth.

- The MATTA modulus of the samples at the top of the stabilised layer approached that of samples compacted in the laboratory.
- The MATTA modulus decreased with density/air voids content.
- The bitumen content of some of the samples was less than that specified in the design of 3.5% (although 3% was specified for the first section of the job).
- The bitumen content increased along the length of the trial section.
- Air void content varied significantly between 5.8% and 21.5%.

Table 4 – Results of New England Highway cores.

Core	Sample	Dry Modulus (MPa)	Soaked Modulus (MPa)	Bitumen Content (%)	Compacted Density (t/m^3)	Air Voids (%)
OWP	Top	6725	4139	2.05	2.265	14.0
	Middle 1	5761	3749	2.10	2.234	15.2
	Middle 2	3180	3406	2.10	2.137	19.9
	Bottom	2533	1290	2.40	2.076	21.5
IWP	Top	10907	9329	2.55	2.326	6.8
	Middle	8468	11270	2.50	2.303	7.1
	Bottom	7330	5852	2.85	2.225	11.1
OWP	Top	7200	6275	3.20	2.173	7.2
	Middle	5743	5220	2.55	2.174	9.2
	Bottom	2428	2072	3.20	2.107	13.4
IWP	Top	6000	5308	4.10	2.232	8.5
	Middle	7831	5911	3.40	2.295	5.8
	Bottom	2744	1842	3.75	2.213	10.8

12.0 LABORATORY PERFORMANCE TESTING

12.1 Fatigue Performance

Most stabilisation treatments tend to be very prone to fatigue due to the bound nature of these materials. One of the anticipated advantages of using bitumen in the stabilising process is the reduction in stiffness and an increase the flexibility of the bound layer. Fatigue resistance is one of the most important properties of any stabilisation treatment. If this treatment is more fatigue resistant than other stabilisation treatments, it will have a distinct advantage compared to conventional stabilisation treatments.

The method used to assess the fatigue resistance of bound pavement materials is the fatigue beam test. This test applies a cyclic load (at 3rd points along a simply supported beam) to determine the flexural stiffness and fatigue performance of the material. This test has typically been used to assess the fatigue properties of asphalt mixes. The fatigue beam test apparatus is shown in figure 9.

Some preliminary fatigue beam testing has already been carried-out on foamed bitumen stabilised material. Samples have been prepared using materials taken from Mt Bilewilam and Image Flats Quarries (shown in figure 10) to assess the fatigue performance of two materials bound with foamed bitumen.

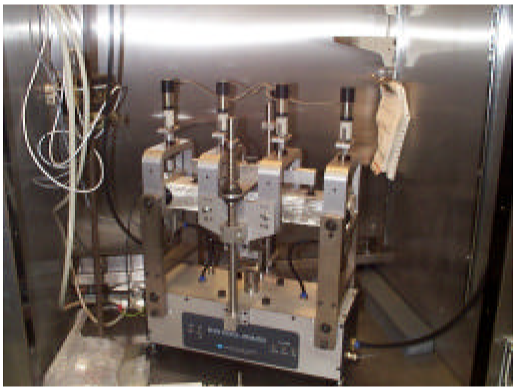

Figure 9 - Fatigue beam testing of a foamed bitumen specimen (left) a foamed bitumen slab (right).

The method used to manufacture these specimens is listed below:

- Material mixed with foamed bitumen using the laboratory foamed bitumen machine at Herston. Samples were mixed with 3.5% bitumen, 2% lime and 70% of OMC (unstabilised material) water.
- Marshall samples are compacted and tested for compacted density.
- Additional material is mixed for compacting a foamed bitumen slab using the BP slab compactor at the Herston Laboratory. The slab is compacted to 100% of the compacted Marshall samples.
- The slab of stabilised material is then oven cured for 3 days at 60^{o}C.
- The slab is then cut using a thin blade circular saw into beams of suitable dimensions.
- The “loading points” of the beams are filled with plaster (if necessary) to ensure adequate contact with the beam occurs at the load points and supports.
- The beams were then tested using the Fatigue beam test machine at the Brisbane City Council laboratory.

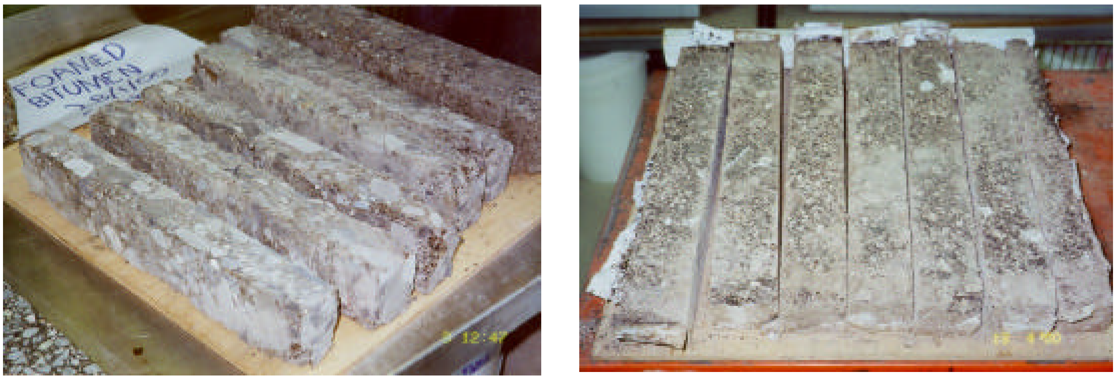

Figure 10 - Fatigue beams cut from slabs from Mt Bilewilam (left), and Image Flats material (right).

Table 5 - MATTA test results for Mt Bilewilam Beach and Image Flats Material.

Material	Initial Modulus (MPa)	Cured Modulus – Dry (MPa)	Cured Modulus - Soaked (MPa)
Mt Bilewilam	548	5387	1798
	811	4189	1684
	953	3829	1705
Average	**770**	**4470**	**1730**
Image Flats	249	10189	7883
	209	9723	8617
	236	10498	7328
Average	**230**	**10140**	**7940**

Table 6 - Fatigue beam test results of foamed bitumen stabilised material.

Material	Strain me	Initial Stiffness (MPa)	Cycle Count (MPa)	Cumulative Dissipated Energy (MPa)	Initial Phase Angle (MPa)
MB1	450	664	98860	3.06	30.7
MB2	450	477	>1000000	16.71	9.8
IF1	450	2228	25830	2.62	20.8
IF2	450	1770	5990	0.52	10.8
IF3	450	1575	45050	3.26	20.0
IF4	200	2073	227180	3.25	2.6
IF5	200	3202	28030	0.50	7.9
IF6	200	1960	261030	3.48	9.2

From the tests completed so far (using 60^{o}C curing for 3 days) the fatigue potential of foamed bitumen appears somewhat greater than asphalt. It was also found that the Image Flats

material produced both a higher MATTA modulus (table 5) and flexural modulus (table 6) value than the Mt Bilewilam material. The variability of test results is very high using this test method.
This variation is possibly due to:

- The large size of the aggregate compared to the overall dimensions of the beam sample (65mm x 50mm).
- The partial binding (fines only) provided by the stabilisation process.
- Cracking and aggregate break out of the beams due to saw cutting.

The fatigue life appears to be relatively short at high strain levels. Therefore the fatigue performance on low strength subgrades would therefore be relatively low (like most stabilising treatments). The curing condition has a significant influence on the properties of the stabilised material. The samples may have excessively stiffened as a result of the curing process resulting in an artificially short fatigue life. It is intended to test several samples under more natural curing conditions to determine whether this is true. To provide the most accurate test results, a slab could be cut and beams tested from the New England Highway pavement. This could be used as a comparison between field performance with material tested in the laboratory.

13.0 RUT RESISTANCE OF FOAMED BITUMEN STABILISED MATERIAL

One of the problems with some stabilisation treatments is the poor rut resistance of the material immediately after stabilisation. It is usually desirable for the road to be open to traffic as soon as possible. In order to assess the rut performance of foamed bitumen stabilised material; the asphalt wheel tracker test was to perform this task. This device applies a wheel load across a compacted slab at a uniform speed to assess the rut performance of asphalt material.

Figure 11 - Wheel tracker test apparatus (left) and foamed bitumen stabs after immediate curing (right) and 24 hours curing (middle).

Initial testing has been carried out using Image Flats type 2.1 and ‘C’ grading quarry material. In order to assess the properties of the stabilised material, samples were prepared at 70%

OMC (in accordance with the standard test procedure) with 3.5% bitumen and 2% hydrated lime. The stabilised slabs were compacted to 100% Marshall density (at 70% OMC) using the BP slab compactor. A standard 300 x 300mm square mould was used. The test procedure was completed in accordance with Q320-1998 except that the samples were tested at room temperature. The test apparatus is shown in figure 11. The slabs were tested in 2 conditions:

- Immediately after compaction
- 24 hours after compaction

The test results indicate that the immediate rut performance of the stabilised material is relatively low. However, within 24 hours the stabilised material was very stiff and minimal rutting occurred. This is illustrated in figure 12. Therefore the stabilised material exhibits excellent rut resistant properties within 24 hours of compaction (approaching the rut performance of many high strength asphalt mixes at 60°C). This indicates care must be taken after construction to ensure that excessive moisture is not present prior to trafficking of the stabilised layer. Restricting traffic movements within the first 24 hours should minimise early rutting significantly. Further rut resistance characterisation will be carried out during 2000/01. It is hoped to eventually incorporate this test into the standard test method for foamed bitumen stabilisation.

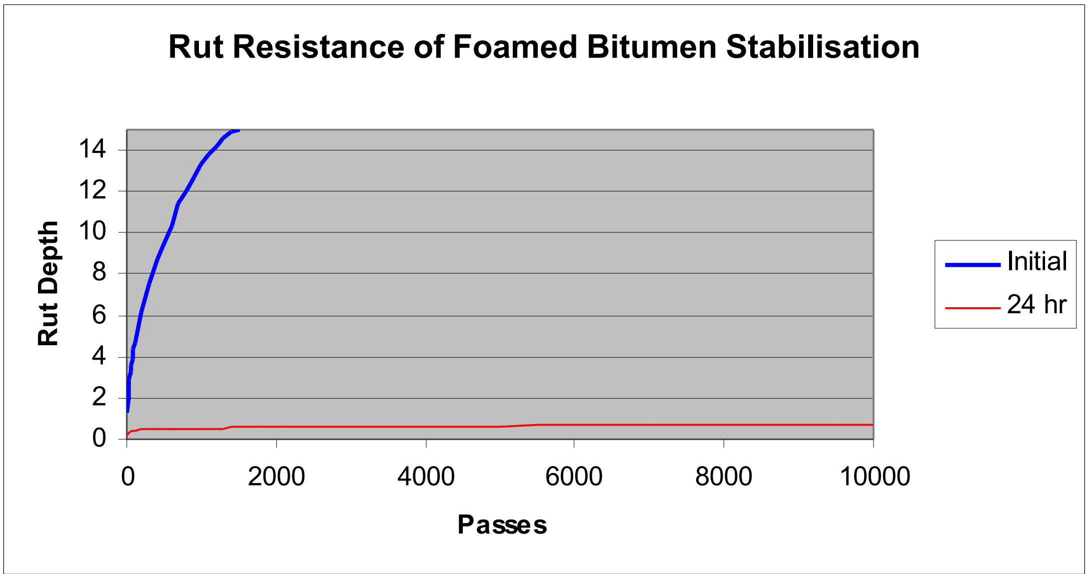

Figure 12 - Rut Performance of foamed bitumen stabilised materials.

14.0 FUTURE RESEARCH

Main Roads is still learning about the performance properties and the types of material suitable for use with foamed bitumen stabilisation. Some of the issues involved include:

- The fatigue performance and rut resistance of foamed bitumen stabilised material.
- Development of selection tools for foamed bitumen based on grading, plasticity and linear shrinkage.
- Improvements in the current test method.
- Ability of the foam bitumen stabilised material to resist moisture infiltration using Capillary Rise, Permeability and/or dielectric testing.

15.0 CONCLUSION

Main Roads has invested considerable time and effort in developing the foamed bitumen stabilisation technique to provide a more flexible and fatigue resistant stabilisation treatment suitable for Queensland conditions. Supplementary specifications have been developed based on the experience to date. The foamed bitumen stabilisation treatment appears to be mainly suitable for "C" graded material that has some plasticity. Generally the material is treated with 3.5% to 4% bitumen and 1.5% quicklime (or equivalent). Standard class 170 bitumen is suitable as long as the desired expansion and half-life are achieved.

Performance assessments of the various trial sites using this treatment have been carried out. These assessments include:

- Site inspections of trial sites.
- Laboratory tests of samples taken during construction.
- Deflection testing and back analysis to determine the flexural modulus of the stabilised material.
- Laboratory performance testing to indicate the fatigue and rut performance.
- Coring of samples from the field to compare with mix design results.

Further testing and performance monitoring will be required to determine whether superior performance and lower maintenance is possible using the foamed bitumen stabilisation method compared to other more conventional stabilisation treatments.

The information contained in this paper offers to summarise the experience and knowledge currently in the Main Roads Department. As the process becomes more accepted and greater volumes of material are recycled, the design, construction and maintenance techniques will be further developed in the light of the increased data available.

REFERENCES

1. Kendall, M & Baker, B & Evans, P & Ramanujam, J (2000). *Foamed Bitumen Stabilisation*. Washington, DC: Transportation Research Board Conference.
2. Ramanujam, J & Fernando, D (1997). *Foamed Bitumen Stabilisation*. Main Roads Transport Technology Forum July 1997.
3. Ramanujam, J & Fernando, D (1997). *Foamed Bitumen Recycling – Initial Findings*.
4. Ramanujam, J & Fernando, D (1997). *Foam Bitumen Trial at Gladfield-Cunningham Highway*. Proceedings of the Southern Region Symposium, Australia, 1997.
5. *Supplementary Specification for Foam Bitumen Stabilisation*. 1999 Queensland Main Roads Department, Construction Services, Transport Technology Division.