Bitumen Stabilisation – An Australian Perspective

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ABSTRACT

This paper provides an overview in the design of foamed bitumen stabilised materials in Australia. Some aspects of construction practices and specification compliance of insitu foamed bitumen works is included.

CONTENTS

1. INTRODUCTION

Bitumen stabilisation in Australia is a viable pavement rehabilitation option with more than 95% of the work done by the insitu process using foamed bitumen rather than bitumen emulsions. Bitumen emulsions are not common due to the higher construction costs, problems with the development of early strength and the lack of a suitable design methodology.

Both bitumen emulsion and foamed bitumen products use Class 170 bitumen with a foaming agent. Class 320 bitumen for use in hot climates has been trialled in the laboratory with limited success. The supplementary binders for foamed bitumen and bitumen emulsions are lime and cement respectively.

The high-impact process detailed in the Austroads stabilisation guide (Austroads, 1998) has not been used in Australia for some time.

Foamed bitumen was introduced into Australia in the 1960s but never really gained acceptance until the late 1990s, with the introduction of better reclaimers and the use of more experienced contractors (AustStab, 2004). A pavement design model for foamed bitumen stabilisation for Australian roads now appears to be closer and short of an ALF test program, the use of foamed bitumen will continue to be used for medium to heavy trafficked roads.

Mobil Bitumen funded an accelerated loading trial using ALF[1] on a foamed bitumen stabilised material at the Dandenong ALF site (Victoria) in 1997. However the results have never been published despite many requests from industry and to date, there have been no other known ALF or CAPTIF trials of foamed bitumen materials in Australia or NZ.

The use of foamed bitumen stabilisation can only succeed if the laboratory mix design procedure matches with the design models to provide certainty with the predictions of trafficked life. This paper will outline how laboratory testing with core test results has made it possible to get an interim design model to determine binder content and pavement thickness.

According to overseas literature and experience, the type of supplementary used in foamed bitumen varies according to the actual application and overall pavement design parameters. For example, in some parts of South Africa foamed bitumen stabilisation is used to upgrade poor pavement materials and therefore cement is the preferred supplementary binder (Smith, 2004, CSIR, 2002). In other parts of South Africa though, foamed bitumen is used with good quality pavement materials in the basecourse. In these situations lime is the preferred supplementary binder (Smith, 2004).

In the United Kingdom, as with some other European countries, foamed bitumen is incorporated into good quality pavement materials with the stabilised material used as a subbase material with a minimum asphalt base thickness of 100 mm. In these situations, cement is usually the preferred supplementary binder (Smith, 2004).

In Australia, most of the work is basecourse work and the granular material that has been foamed bitumen stabilised has been of good quality. In these circumstances lime works well as the supplementary binder [AustStab 2002].

In 2003, the RTA produced a best practice guide (RTA, 2003) covering insitu foamed bitumen stabilisation. The guide covers the following topics:

- Brief history
- Characteristics of foamed bitumen

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[1] ALF refers to the Accelerated Loading Facility owned by ARRB Transport Research

- Mechanism of foamed bitumen
- Initial suitability of material for stabilisation
- Mix design
- Pavement design
- Construction Process

Subsequent to this guide, a trial was conducted and monitored to assess the recommendations in the guide. The trial was conducted on the Pacific Highway north of Port Macquarie (see Figure 1) and details of the trial are listed below (Butcher, 2004 & Ng, 2003):

- 20 year design traffic life of 5.5×10^7 ESAs
- Constructed in July 2003
- Length of trial – 500 m and 8,240 m^2
- Pavement depth stabilised was 280 mm on a design subgrade CBR of 7%
- Laboratory testing with 3% bitumen and 2% hydrated lime.
- MATTA test results needed were M_{dry} = 6,718 MPa and M_{wet} = 1,876 MPa (M_{wet}/M_{dry} = 0.28)
- The structural design was based on the asphalt fatigue equation in the Austroads guide (Austroads, 1992) with 50% of the wet modulus (ie 938 MPa)

Figure 1 Insitu foamed bitumen stabilisation trial at Cooperabung, NSW prior to stabilisation (LHS) and the road after construction in January 2004 (RHS).

No problems were experienced during the trial and apart from an incorrect bitumen application rate on the seal resulting in flushing in the wheel paths along some stretches of the work, the pavement is performing very well.

Foamed bitumen stabilisation may be considered in most situations, such as:

- A pavement which has been repeatedly patched to the extent that pavement repairs are no longer cost effective
- A weak granular base which overlies a reasonably strong subgrade
- A granular base too thin to consider using cementitious binders
- Conventional reseals or thin asphalt overlays which no longer correct flushing problems
- An alternative to full-depth asphalt in moderate to high trafficked roads
- Unfavourable wet cyclic conditions unsuitable for granular construction
- Situations where an overlay is not possible due to site constraints eg entries to adjacent properties & flood prone areas
- A requirement to complete the rehabilitation quickly to prevent disruption to business or residents

Over the last five years there has been very little development in bitumen emulsions and this form of stabilisation has declined to several small regions for maintenance patching. Due to the low usage of bitumen emulsion stabilisation in Australia, this paper has focused only on foamed bitumen stabilisation. This paper also covers the following topics from an Australian perspective:

- Laboratory mix design
- Structural design
- Construction practices
- Current compliance measures

2. SUITABLE PAVEMENT MATERIAL

In the recent Austroads mix design guide (Austroads, 2002a), the only major requirement for the pavement material was the grading curve and PI (see Figure 2). In the guide to stabilisation (Austroads, 1998a), the following information is provided to establish the suitability of bitumen stabilisation:

- Less than 25% passing the 75 µm
- PI ≤ 10

Experience to date has shown that a wide range of PI values may be applicable (ie up to 20) for foamed bitumen stabilisation as the addition of lime to the process will reduce the PI to an appropriate value for compaction and final material properties.

Recent experience in Western Australia has indicated that rounded coarse aggregates may result in early rutting of the material. Whilst no immediate guidelines have been set, it would be preferable for the coarse aggregates to have at least two broken faces.

In addition, recent experience in Sydney with the use of crushed concrete using both the insitu and plant mix approach, indicates that the material may not be suitable for foamed bitumen stabilisation.

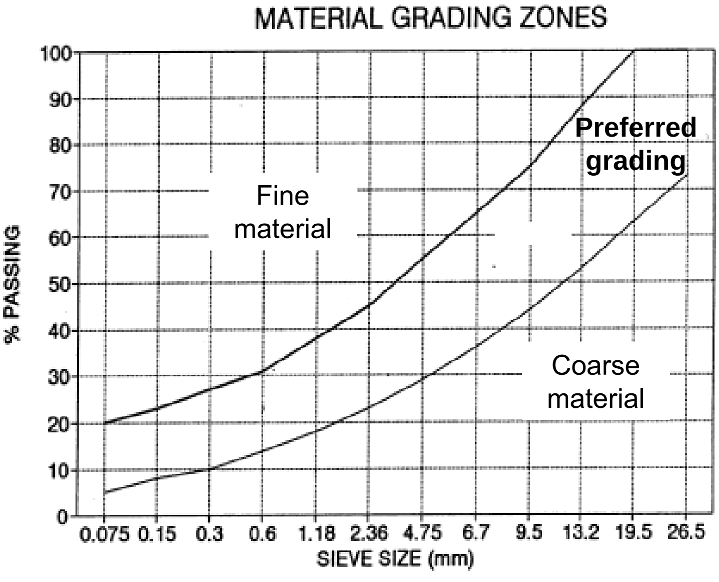

Figure 2 The preferred particle size distribution for pavement materials to be stabilised with foamed bitumen (Austroads, 2002).

Quicklime is used in Australia as a supplementary binder and it is used to:

- reduce PI
- assist with early and long-term strengthening of the pavement material
- assist with the adhesion of bitumen to aggregates
- reduce stripping

Research work carried out by the QDMR[2] indicated that the addition of lime in the mix will increase the modulus of the material (Ramanujam, 2000). Figure 3 shows that by adding 2% lime, the dry (M_d) and wet (M_w) modulus increased by 1.6 and 4.9 times respectively. This also indicates that with the addition of 1% lime, the sample will have early strength for the pavement to be trafficked at the end of the days work. In Figure 3, M_i and M_2 refers to initial material properties after compaction and 3 hours air curing after compaction respectively.

There are no other known requirements for the pavement material to be stabilised at this stage.

3. FIELD CORING OF FOAMED BITUMEN MATERIALS

AustStab and its contracting and bitumen supplier members have recently been coring foamed bitumen pavements to assess the stiffness of these pavements and compare this stiffness with laboratory mix values. The test protocols were developed by AustStab[3] and consist of:

- Determining the moisture content
- Measuring the resilient modulus of the upper and lower half of the core.
- None of the cores are corrected for temperature effects.

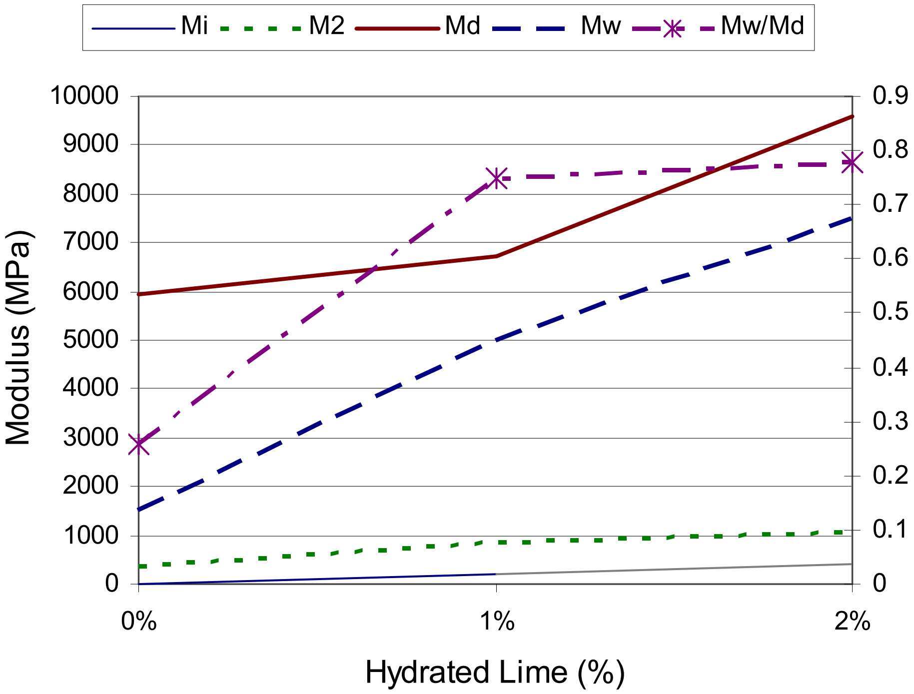

Figure 3 Increasing the lime content will also increase the modulus of the foamed bitumen sample (Ramanujam, 2000) Refer to previous page for definition of symbols.

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[2] QDMR refers to Queensland Department of Main Roads.

[3] For more details on the test protocol refer to www.auststsab.com.au/foamedbitumen/FBSCores.pdf.

Table 1 shows the results of core testing carried out on a local road in Sydney (Southey, 2004). In this project, the base material was stabilised with 3.5% bitumen and 2% hydrated lime[4] to a depth of 175 mm. A laboratory test program indicated that the particle size distribution of the base material met the Austroads requirements, and the wet and dry resilient modulus was 1,760 and 2,980 MPa respectively. The road was stabilised in October 1998.

Upon examination of the cores and results, the material was bound and the modulus in the lower half was about half that in the upper half of the core. The samples also indicated that the lower layer modulus was typically greater than the wet modulus from the laboratory mix design.

Colin Leek of the City of Canning has engaged researchers to extract samples from the road after 5 months of age to assess density, UCS and resilient modulus of the extracted cores of three roads (Leek, 2001). Tables 2 and 3 lists the resilient modulus results of cores taken from existing roads separated where appropriate into three sub-cores. These smaller cores were tested for indirect modulus to assess the change in modulus with depth. The laboratory design modulus for all three roads was in the order of 1,300 to 1,800 MPa, and these results showed that on many occasions the modulus exceeded the design value by a factor of 2. These high modulus values after 5 months also confirms that the material becomes well and truly bound using the appropriate mix design protocols and construction procedures.

The lower modulus values in the bottom area of the core indicate that greater voids or less density is achieved during compaction. Table 5 shows work reported by Leek (Leek, 2001) and confirms the lower compacted densities in the lower half of the stabilised pavement layer.

One of the challenges of this coring project is to capture and monitor modulus over a sufficient period taking into consideration the environmental factors for the pavement. AustStab members intend to pursue more data collection of the pavement performance over time.

Leek also looked at flexural modulus values from slabs extracted from the pavement and tried to compare those with resilient modulus values. Based on the samples taken from various roads in Canning Vale, he prepared a table of typical flexural modulus values for the two types of base materials used in their region (see Table 6). The values from the study indicated that the flexural modulus and resilient modulus were in the same order of magnitude and that further work on a correlation between flexural and resilient modulus for foamed bitumen stabilised materials was probably unwarranted.

4. LABORATORY MIX DESIGN

The two key elements in the laboratory mix design process are to:

- ensure the hot bitumen foams to the desired range of parameters
- mix sufficient bitumen and lime to meet the target design modulus.

This paper will not discuss the bitumen foaming process as it is well covered by other documents (AustStab, 2002, Ramanujam, 2000 and RTA, 2003). Nevertheless, the bitumen must foam sufficiently to coat the fine particles and provide adequate bonding of the matrix. A lack of fines, cold material or too wet or dry a material may effect the foaming process and cause a weak matrix to be formed during curing. Use of appropriate laboratory equipment, such as the Wirtgen WLB10 (see Figure 4), is essential to ensure similar foaming to field conditions and adequate foaming volume to mix sufficient material to produce the samples.

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[4] The method of converting the appropriate application rate for quicklime is documented in AustStab Lime Stabilisation Practice (www.auststab.com.au/technotes/TN01.pdf)

Table 1 Cores taken from stabilised base after 4.5 years. (Southey, 2004)

Core Location	Core layer	Resilient modulus[1] (MPa)	Moisture content (%)
1 - Between Wheel Path (Centre)	Top	7,313	3.8
2 - Wheel Path (Centre)	Top	4,717	3.8
	Bottom	374[2]	
3 - Between Wheel Path (North)	Top	3,117	4.0
	Bottom	1,353	
4 - Wheel Path (North)	Top	3,540	4.2
	Middle	4,331	
	Bottom	1,747	
5 - Wheel Path (South)	Top	3,256	3.7
	Bottom	1,834	
6 - Between Wheel Path (South)	Top	4,304	4.2
	Bottom	1,632	
Note: 1. Testing carried out at 25°C and 40 ms 2. Core was cracked on extraction.			

Table 2 Indirect tensile modulus values at 30°C at 5 months age for High Road, City of Canning. (Leek, 2001)

Pavement Section	Chainage	Rise Time (ms)	Indirect Tensile Modulus (MPa)				
			0 - 100mm	100 - 200mm		200 - 300mm	
			Value	Value	% Top	Value	% Top
High Road West Bound	174	75	9769	6179	63.3		
		37	10585	7606	71.9		
		25	10826	8281	76.5		
		19	10941	8657	79.1		
	473	75	8558				
		37	10358				
		25	11164				
		19	11605				
High Road East Bound	200	75	9776				
		37	11573				
		25	12353				
		19	12777				
	587	75	6488				
		37	7675				
		25	8240				
		19	8555				
	787	75	7235	4450	61.5		
		37	8549	5000	58.5		
		25	9154	5276	57.6		
		19	9488	5431	57.2		
	816	75	3676	3104	84.5		
		37	4485	3629	80.9		
		25	4848	3862	79.7		
		19	5047	3989	79.0		
	1083	75	7544	4873	64.6	3578	47.4
		37	9008	5854	65.0	4010	44.5
		25	9658	6331	65.6	4200	43.5
		19	10014	6598	65.9	4304	43.0

Table 3 Indirect tensile modulus values at 30°C at 5 months age for Nicholson Road and John Street, City of Canning. (Leek, 2001)

Pavement Section	**Chainage**	**Rise Time (ms)**	**Indirect Tensile Modulus (MPa)**				
			0 - 100mm	**100 - 200mm**		**200 - 300mm**	
			Value	**Value**	**% Top**	**Value**	**% Top**
Nicholson Road	180	75	10020	5420	54.1	3518	35.1
		37	12090	6545	54.1	4543	37.6
		25	12928	7087	54.8	5068	39.2
		19	13375	7389	55.2	5365	40.1
	277	75	9113	8401	92.2	2095	23.0
		37	10424	9562	91.7	2461	23.6
		25	11021	10069	91.4	2589	23.5
		19	11349	10345	91.2	2654	23.4
	310	75	5355	4182	78.1		
		37	6277	4820	76.8		
		25	6707	5114	76.2		
		19	6945	5275	76.0		
	340	75	5893	5505	93.4	4286	72.7
		37	6823	6622	97.0	5043	73.9
		25	7228	7150	98.9	5383	74.5
		19	7448	7443	99.9	5569	74.8
John Street	40	75	2936				
		37	3261				
		25	3407				
		19	3486				
	113	75	2802				
		37	3179				
		25	3324				
		19	3401				

Table 5 Density measurement results from testing cores at various pavement depths. (Leek, 2001)

Pavement Section	**Chainage**	**Core Depth**	**Density (t/m^3)**				
			0-100mm	**100-200mm**		**>200mm**	
			Value	**Value**	**% Top**	**Value**	**% Top**
High Road West Bound	174	250	2.10	2.03	96.6		
	473	170	2.10				
High Road East Bound	200	180	2.10				
	587	100	2.07				
	787	180	2.07	1.97	95.2		
	816	220	2.02	1.92	95.1		
	1083	270	2.12	2.08	98.1	1.98	93.4
Nicholson Road	180	330	2.03	1.94	95.6	1.92	94.6
	277	330	2.13	2.05	96.2	2.01	94.4
	310	220	2.09	1.95	93.3		
	340	320	2.08	2.05	98.6	2.04	98.1
John Street	40	150	2.18				
	113	120	2.24				

Table 6 Typical flexural modulus values from road stabilised in the City of Canning. (Leek, 2001)

Material Type	Typical Flexural Modulus (at 20^{0}C)[1]		
	Depth from Surface (mm)		
	0 – 100	100 – 200	200 – 300
Crushed angular materials stabilised	5,800	4,100	2,800
Natural rounded materials stabilised	3,400	2,400	1,600
NOTE: 1. For 30 ^{0}C these values should be reduced by 8%			

In terms of the laboratory protocols, Austroads published a robust design method in 2002 covering the preparation of the sample and testing for modulus as shown in Figure 5. Using this approach over two decades has been found to give good representation of field performance.

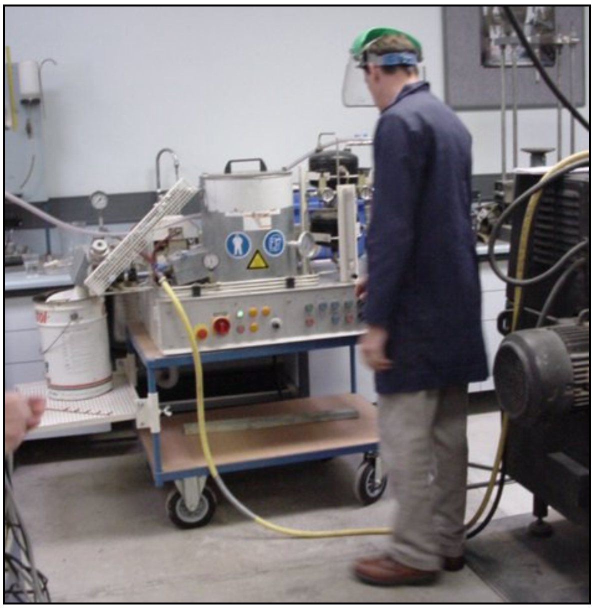

Figure 4 The Wirtgen WLB10 foamed bitumen laboratory equipment.

The QDMR has carried out very limited testing comparing the use of the Marshall and Gyropac compaction methods (Ramanujam, 2000), and QDMR continues to recommend the Marshall compaction method. The use of Marshall compaction has not been adopted by other regions of Australia due to a lack of evidence supporting the need to shift from the Gyropac compaction method.

The interim material design criterion is as follows:

- The initial modulus[5] of the compacted sample prior to curing should be a minimum of 500 MPa for light traffic (typically less than 10^6 ESAs) and 700 MPa for heavier design traffic levels
- The target wet modulus (M_w) after curing is between 1,500 to 2,500 MPa
- The minimum wet to dry modulus (M_d) ratio is 0.5

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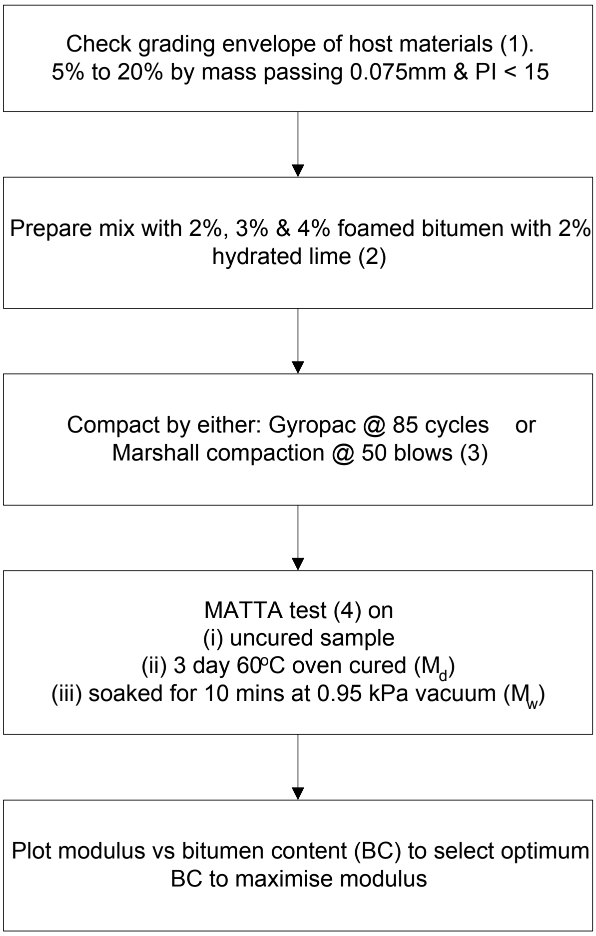
[5] In this paper modulus is referred to as the resilient modulus determined from the MATTA test to AS 2890.13.1

Modulus values should be determined from a minimum of 3 samples with the mean value taken as representing the material provided such that the upper and lower values remain within 30% of the mean value. Whilst pavement designers have been known to accept lower values of M_w for light trafficked roads, further work is required to assess the impact this lower value may have on performance.



Notes:
1. Refer to Figure 2 for best particle size distribution.

2. Typically the best results are when the expansion ratio is at least 10 and the half-life is at least 30 seconds.

3. The preferred compaction option is the Gyropac.

4. MATTA testing is carried out to AS 1289.13.1.

Figure 5 Material design for foamed bitumen stabilisation (Austroads, 2002a).

It is also suggested that pavement designers review test results if the wet modulus exceeds 3,000 MPa as this indicates that the pavement will end up being very stiff and possibly act as a cemented layer. A reduction in the use of hydrated lime in the test sample may reduce the modulus laboratory value.

Whilst the addition of lime may increase the wet modulus of the sample, it is suggested that no more than 2% of hydrated lime be used to improve laboratory samples which do not reach a wet modulus of 1,500 MPa. GP cement has sometimes been used in Australia as the supplementary binder, but observations by the authors indicate that cement tends to cause shrinkage cracking in the material at an early date. Additional aggregates are recommended to improve stiffness rather than substituting cement for lime as the supplementary binder for stabilisation of base course materials.

The minimum value of wet to dry modulus ratio of 0.5 was recommended by Maccarrone based on ensuring the stiffness of material would not be unduly affect by moisture during seasonal changes (Maccarrone, 2002). Work by Jones and Ramanujam indicates that this ratio could be as low as

0.4 for light trafficked routes (Jones, 2003). The laboratory data from the Cooperabung trial presented in this paper indicated that the ratio was 0.28, and at this stage there is little evidence of poor structural performance.

There does not appear to be a current method to establish presumptive values for modulus similar to the use of Shell nomographs for asphalt. Whilst an initial trial design may be carried out using a target design modulus of between 1,500 and 2,500 MPa, the design modulus must be tested with the materials selected for the project. Even more critical, is that if existing materials are to be blended with quarried or recycled materials to increase the stabilised depth, the blended product should be tested with an upper and lower bound of approximately 20% of the blend.

5. STRUCTURAL DESIGN

5.1 OVERVIEW

The structural design of pavement materials using a layered elastic analysis model typically requires a design modulus and fatigue equation. It makes sense that the design modulus is derived from the laboratory MATTA test (AS 2890.13.1) with some shift factor. A damage equation using ESAs and resulting tensile strain should provide an estimate of the number of repetitions to failure. This section discusses recent trends in the development of a reliable approach to estimating the thickness and traffic life of foamed bitumen stabilised materials.

5.2 DESIGN MODULUS

The current Austroads approach for the determination of the resilient modulus is based on testing the sample in a dry and wet (or soaked) state. Whilst a layered elastic analysis requires the elastic modulus, modelling of pavement materials indicates that the wet modulus is a sufficient input for the design modulus provided the M_w/M_d exceeds 0.5 and the minimum value for M_w is 1,500 with an appropriate upper limit of about 2,500 MPa. It is currently suggested that the shift factor be set at 1.0 for rehabilitation projects with a 20-year design life.

5.3 FATIGUE EQUATION

The current fatigue relationship for cemented materials and asphalt in Australian design models are (Austroads, 2004):

$$N = RF\left[\frac{\left(113{,}000/E^{0.804} + 191\right)}{\mu\varepsilon}\right]^{12} \quad \text{for cemented materials}$$

$$N = \mathrm{RF}\left[\frac{6918(0.856\,\mathrm{V_B} + 1.08)}{S_{mix}^{\ 0.36}\ \mu\varepsilon}\right]^{5} \quad \text{for asphalt}$$

where
N = allowable number of repetitions of the load
$\mu\varepsilon$ = tensile strain produced by the load (microstrain)
E = modulus of cemented material modulus (MPa)
V_B = percentage by volume of bitumen in the asphalt (%)
S_{mix} = asphalt modulus (MPa), and
RF = reliability factor.

In the above equations the:

- strain is based on the static loading of an equivalent axle load of 80 kN using a dual tyre configuration with 750 kPa tyre pressure
- modulus is either a presumptive value or from laboratory measurements
- reliability factors for new pavements are based on the importance of the road

As noted earlier in this paper, cores extracted from the existing foamed bitumen stabilised materials indicate that the material is ‘fully’ bound and not modified or granular as may have been considered about 5 years ago.

Research work carried out by Mobil Bitumen (Maccarrone, 1994), by ARRB Transport Research (Alderson, 2001) and QDMR (Jones, 2003) indicates that the asphalt fatigue equation with appropriate modulus and volume of bitumen should provide reasonable estimates of fatigue life for foamed bitumen stabilised material with bitumen and hydrated lime contents in the range of 2 to 4% and 1 to 2% respectively. In addition, the material being stabilised would be of a granular material meeting the particle size distribution in Figure 2.

Table 7 shows the difference between asphalt and foamed bitumen for three parameters. The high air void content is indicative of the lower modulus of foamed bitumen materials compared to asphalt.

Table 7 Property differences between dense graded asphalt and foamed bitumen stabilised materials.

Property	Dense graded asphalt	Foamed bitumen stabilised
Volume of bitumen	11%	7%
Air voids	4 to 10%	10 to 15%
Resilient modulus (25°C, 4ms)	3,000 to 8,000 MPa	1,000 to 3,000 MPa

Since 1992, the Austroads pavement design guide has always allowed for reliability factors. These factors in the 2004 guide are now applied to the fatigue equation and for new pavements. For rehabilitation, the reliability factor is taken as 1 (Austroads, 2002b).

5.4 RUT RESISTANCE

The laboratory rut resistance properties of foamed bitumen stabilised materials has been tested by QDMR, who noted excellent rut resistance properties within 24 hours of compaction and laboratory performance approaching that of many high strength asphalt mixes (Ramanujam, 2000). Figure 6 shows the deflection results from the wheel rutting test[6] using 3.5% bitumen and 2% hydrated lime for the initial uncured state (ie immediately after compaction) and after 24 hours of sample preparation.

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[6] QDMR Test Q320-1998

Figure 6 Deflection results from wheel rutting test of foamed bitumen stabilised material (Ramanujam, 2000).

Similar to asphalt (Austroads, 1998b), there has been little guidance to set specific levels of rut resistance for foamed bitumen materials. However the limits set must take into consideration whether the foamed bitumen material is to be used as a subbase or base layer, even though the material may be exposed to traffic during rehabilitation. Current thinking indicates that should the initial modulus of the uncured sample not exceed 700 MPa, rutting is unlikely to occur if the material is trafficked as a subbase layer.

5.5 INTERIM DESIGN MODEL

The proposed interim design model is outlined in Table 8 and limited for the following uses:

- Class 170 bitumen with foaming characteristics as described in this paper
- The particle size distribution limits shown in Figure 2
- Laboratory sample preparation and curing as described in this paper
- Normal road traffic loading conditions
- Foamed bitumen material constructed to AustStab model specifications.

There is insufficient data at this stage to apply this design approach for heavy wheel loads likely at container hardstands and major airports taking commercial jet aircraft. It is also important to ensure that the construction temperature limits specified in the AustStab model specifications are met. For instance, experience has shown that the foaming mechanism diminishes when the pavement material temperature is below 10°C. In addition, poor construction equipment will also lead to inefficient bitumen foaming resulting in less than desirable bitumen distribution.

6. CONSTRUCTION PRACTICES

In 2002, AustStab released an addendum to the 2nd edition of the Austroads bitumen seal safety guide (Austroads, 2002c) titled *Foamed bitumen stabilisation*. This addendum is an interim measure to:

- provide safe working practices in foamed bitumen stabilisation using either insitu or plant mix equipment
- be read in conjunction with the Austroads Bitumen Sealing Safety Guide[7].

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[7] This addendum contains amendments to Sections 1 to 11 of the guide.

Table 8 Interim design method for foamed bitumen stabilisation.

Step	Description
1	Design a laboratory mix program and report M_i, M_w and M_d.
2	Meet requirements for laboratory mix M_i and M_w/M_d for traffic volumes (this may include wheel tracking test)
3	Estimate the design traffic and damage factors
4	Select trial pavement thickness
5	Determine tensile strain at underside of foamed bitumen layer using CIRCLY
6	Using the asphalt equation with appropriate input, determine allowable repetitions to failure
7	Compare allowable axle repetitions to design traffic for layer
8	Check against allowable life for other layers in the pavement configuration
9	Revise layer thickness or modulus to optimise all material layers
10	Take into consideration details of joints, drainage and interlayer

It is envisaged that this document will become Section 14 (ie Foamed Bitumen Stabilisation) of the safety guide document at the next major revision.

Foamed bitumen stabilisation of pavement materials is a specialist process that allows the addition of small amounts of water into hot bitumen to form a foamed bitumen product under controlled conditions.

AustStab has developed the following model specifications:

- Insitu stabilisation of local government roads with bituminous binders
- Insitu stabilisation of main roads with bituminous binders
- Plant-mix stabilisation of main roads with bituminous binders

These model specifications take into consideration the supply of bitumen and supplementary binder, minimum equipment requirements, mixing, compliance measures and payment items.

The contractors preferred choice for mobile plant used for foamed bitumen tends to be the Wirtgen WR2500 with a specialist foamed bar and water spray bar within the mixing chamber (see Figure 7). This plant has bitumen lines that can be heated to minimise cleaning at the end of the day's operation. Stabilised Pavements of Australia has the only WR2500K[8] with a foamed bitumen bar in the world. One contractor has also had success with a CMI RS425 with a special foamed bitumen bar.

The minimum power requirement to ensure excellent mixing quality and production is now set at 300 kW. Smaller machines may be acceptable for very small patches.

Other essential equipment features are:

- a centrally mounted mixing chamber
- the bitumen injection system must be linked to the ground speed (preferably by computer) to ensure an accurate application throughout runs, irrespective of the speed of the plant
- an inspection or test jet must be fitted to ensure the flow of bitumen and that the required expansion and half life qualities of the bitumen are being achieved

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[8] Special model with integrated powder binder spreader in front of the mixing chamber.

- bitumen jets must be self cleansing
- a bitumen pressure gauge should be located downstream of a filter system and on the bitumen spray bar to ensure constant bitumen flow and foaming activity easily read bitumen temperature gauges
- correct coupling fittings for the bitumen lines
- a foaming unit to confirm foaming characteristics (see Figure 8)
- fire extinguishers

Figure 7 The Wirtgen WR2500 reclaimer coupled with a bitumen tanker providing hot bitumen to the reclaimer.

Figure 8 Operator assessing foaming nozzle operation from special inspection system on the reclaimer.

The timing of the addition of lime in the process has been a vexed question for many years. Road authority engineers and contractors have looked at mixing the lime prior to mixing foamed bitumen (ie 2 mixing passes) and mixing the lime at the same time as the foamed bitumen is incorporated. For some time it was considered that mixing the lime prior to incorporating the bitumen reduced the fines and hence changed the effectiveness of the foamed bitumen material. There is no evidence of this in the cores recovered and visual examination of the mixed material directly behind the reclaimer.

The current practice adopted by Australian contractors is to pulverise and incorporate the lime in the first pass and follow with a separate foamed bitumen pass. This procedure also allows the contractor to incorporate water into the pavement material to assist with compaction and eliminates the need to have both the bitumen[9] and water tanker coupled during the second pass.

7. CURRENT COMPLIANCE MEASURES

Compliance measures for foamed bitumen are similar to those for cement stabilisation in that the following site measurements are taken:

- Bitumen application rate
- Application rate of lime
- Grading and moisture content for plant mix materials
- Depth of stabilised layer
- Relative density
- Surface levels
- Ride quality (where applicable)

The minimum frequency of testing is outlined in Table 9, and serves as a guide. For instance, in the plant mix, the stockpiles may be certified to one source of material and the frequency of testing required will therefore be based on these stockpiles.

Table 9 The minimum frequency of testing.

Test	Minimum frequency of testing
Uniformity of bitumen application rate	One test for each separate continuous run. The Contractor shall have a current certificate of calibration for the bitumen tanker and shall produce evidence of the actual running bitumen application rate when requested by the Superintendent.
Uniformity of spreading of supplementary binder	At the start for each separate continuous spreading run except where calibrated load cell computerised spreading devices are fitted with a system to monitor the spread rate every 100 m.
Density ratio	Every lot.

The application of bitumen into the pavement material is best carried out by the tanker method as outlined in the AustStab guidelines (AustStab, 2000) rather than testing the residual bitumen after mixing due to the uncertainty of the bitumen content in the parent material when seals and asphalt patches may be incorporated into the works. Experience from various projects has indicated that the highly variable results obtained from residual bitumen testing exceed compliance tolerances and are unworkable in contract administration.

For insitu works either quicklime or hydrated lime[10] is used for the supplementary binder, and the application or spread rate is verified by the use of trays or mats. The application rate when quicklime is used can be as low as 1% and conventional spreaders with load cells must be used to ensure uniformity of spreading.

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[9] A low capacity water tanker is present on the WR2500 to supply water to the bitumen foam bar.

[10] Hydrated lime is only used for plant-mix operations.

In general there are no problems with obtaining density (100% standard compaction) in foamed bitumen stabilisation. Typically, non-compliance is the result of areas of weak subgrades, plant breakdowns or rainfall during construction and with timely testing, foamed bitumen stabilisation allows the contractor to rework the material without the addition of bitumen or lime, and to recompact the material. This reworking usually occurs the day after initial mixing.

The AustStab model specification for foamed bitumen stabilisation allows reworking within 7 days of initial mixing. After this period, the contractor should present a design solution for the design traffic specified by the Superintendent.

In terms of insitu density, the two test options are either the sand replacement method or use of the nuclear density meter. In both cases, the insitu density can only be practically measured up to 300 mm in depth.

The Northern Region of Queensland Department of Main Roads test method requires six sand replacement tests versus six readings from a Nuclear Meter. The results have to lie within specified error tolerances followed up with three versus three tests after one week of continuous production. Hamilton (ARRB, 2003) notes that this is seen as a real challenge due to the extreme variability of insitu stabilised gravels in north Queensland.

Specialist stabilisation contractors carrying out insitu works will generally tend to mix on the drier side of OMC to allow the pavement to be open to traffic that evening without the use of dry-back. This will invariably require greater compactive effort and this may in turn lead to more variable density results as shown in Figure 9. However the bitumen in the material appears to aid compaction to its optimum level.

The use of the nuclear gauge for foamed bitumen stabilisation is still widely used in Australia, and until better test procedures are in place, it will remain part of the compliance test procedure.

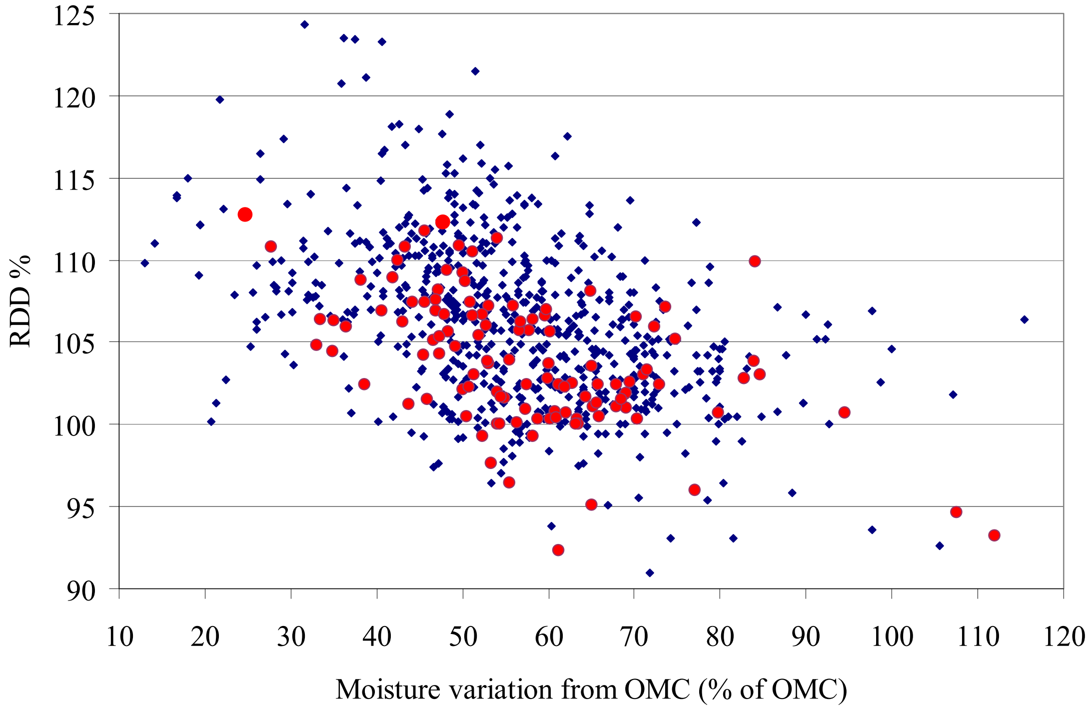

Figure 9 Variation in relative dry density compared to OMC for a project in North Queensland (ARRB, 2003).

8. CONCLUSIONS

This paper has provided an overview of the current design and construction practices for foamed bitumen stabilisation in Australia. There is no doubt that foamed bitumen rather than bitumen emulsion is a better recycled pavement material for road rehabilitation projects.

The use of foamed bitumen is restricted to heavy trafficked local and main road routes at this stage due to the cost of the treatment.

The interim design model detailed in this paper is now being used by various road designers in Australia. The current limitations to the design model are important and with time there is likely to be additional fine tuning to the input parameters and laboratory values used to improve the prediction of performance.

Specialist contractors, such as Highway Stabilisers, Pavement Technology and Stabilised Pavements of Australia, are working with local and state road authorities to apply foamed bitumen stabilisation as a viable rehabilitation treatment to the aging rural and urban network in Australia.

Further work is required in the following areas:

- Improvement of working time
- Refinement of the fatigue design model using resilient modulus
- Analysis of post-fatigue life of material
- Laboratory testing of foamed bitumen with crushed building materials.
- Establishment of spray sealing design guidelines

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