ACTIVE FILLER TRIALS FOR *IN SITU* FOAMED BITUMEN STABILISED PAVEMENTS

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SUMMARY

This report reviews the results of research undertaken into the performance of a road section stabilised with foamed bitumen incorporating different percentages of quick lime as active filler and compares with two other sections using Portland cement and another without active filler. An adjacent section with higher bitumen content is also compared.

1 INTRODUCTION

The City of Canning has some experience with the *in situ* foamed bitumen stabilisation process. In January 1999, four pavement sections were rehabilitated using this process and following the success of these projects; this process has become the major method for the rehabilitation of moderate to heavy trafficked roads throughout the City. Main Roads Western Australia was at the time interested in taking up the process for its own road network as a rehabilitation option, but was interested in the early strength performance of the material. It was decided that a trial would be undertaken in Nicholson Road Canning Vale to assess the effects of different active binders.

2 TRANSVERSE CRACKING

In the early works undertaken at City of Canning, some significant transverse cracking developed in the pavement as shown in Figure 2.1. In order to address this cracking, the original hydrated lime content of 2% was reduced to 1% hydrated equivalent, but quicklime was to be used in lieu of hydrated lime. Subsequent to that change, no further cracking occurred. It was decided to test if the lime content was an issue leading to the cracking by trialling a section with 2% hydrated lime equivalent, or 1.5% quicklime.

Figure 2.1: Transverse cracking in High Road.

3 TRIAL DETAILS

Five trial sections were constructed in Nicholson Road as detailed in Table 3.1. Falling Weight Deflectometer (FWD) testing was undertaken after 24 hours curing on each section, and then repeated daily for at least 10 days, and then at increasing time periods thereafter. As construction extended over several days, and the FWD was on site, some sections received more testing than others. In order to ensure reasonable statistical analysis, 10 FWD tests were undertaken on each section.

When lime is used as the active filler, the usual practice adopted by the City of Canning is to lime a section one day whilst another section is bitumen stabilised. Thus it is usual for 24 hours curing to apply. In the case of cement, the cement was added in the same pass as the bitumen stabilisation, as any significant delays will result in premature stiffening by hydration of the cement making working of the surface difficult.

Table 3.1: Nicholson Road trial sections.

Construction chainage (m)	% bitumen	Active filler
300 - 540	4	0.8% quicklime
540 - 780	3.5	1% cement (OPC)
780 - 1000	3.5	0.8% quicklime
1000 - 1230	3.5	1.5% quicklime
1230 - 1460	3.5	No active filler

During the construction, asphalt surfacing was constructed at different times, and thus some testing was undertaken on the base and some on the asphalt surfacing. Asphalt surfacing was 30 mm of 10 mm 75 blow Marshall dense grade asphalt. The depth of stabilisation was 300 mm and the existing pavement was a mixture of limestone, crushed granite roadbase, old spray seal and in some areas, additional recycled pavement, comprised of profiling from past works, was added to correct surface shape prior to stabilisation. The City of Canning originally applied a primer seal to foamed bitumen projects, but ceased this practice in 2002 and has observed no indication that performance has suffered as a result of this decision.

In order to provide additional data, a lesser trial was undertaken in Vahland Avenue between High Road and Collins Road where a higher percentage of bitumen was used. Owing to less traffic loading, the stabilised thickness of Vahland Avenue was 270 mm.

During the previous construction process, the issue of adding lime to the pavement had been questioned on many occasions. Active filler, generally lime in Australia but cement has also been used, is added to the pavement. The lime, or active filler, is said to serve the following purposes: (Jenkins, 2008)

- stabilising agent for early strengths and cementitious bonds
- modifier to reduce plasticity
- dispersive agent for foamed bitumen
- anti-stripping agent.

Traffic counts undertaken in 2010 give the annual average daily traffic (AADT) as 6500 vehicles/day south bound (the trial carriageway) with 5.3% heavy vehicles.

4 RESULTS OF TESTING

The results of FWD testing prior to surfacing and post surfacing are shown in Figure 4.1 and Figure 4.2 are summarised in Table 4.1. Only deflection and curvature were analysed and in this research deflection is taken as the deflection immediately under the applied load and curvature is the difference in deflection immediately under the load and 200 mm from the centre of the applied load when the load is normalised to 700 kPa. The testing was unfortunately affected by heavy rain over several days of the works. In excess of 70 mm of rain was received during the course of construction over 17 days, the heaviest daily fall being 21 mm. The rain did not stop works, but higher than usual moisture contents will have some effect on the results.

The Nicholson Road results do indicate that cement does give higher earlier stiffness than lime. There is some variability in the results as can be seen from Table 4.1 and all that may be concluded is that the addition of some lime does seem to give increased initial pavement stiffness over a pavement where no lime is added at all, but in the longer term, may have little effect.

To compare deflections and curvature values over time, consideration to the pavement temperature at the time of testing is required. In this particular road, the subgrade is well-drained sand, and variations of subgrade support with climate conditions are considered negligible. As there was no published data on the variability of deflection and curvature with temperature found for foamed bitumen materials, and the data collected by City of Canning was insufficient to give an insight, the Austroads charts for variation of deflection and curvature based on FWD test conditions were adopted to estimate the deflection and curvature values at the weighted mean annual pavement temperature for Perth (30°C) were adopted. These charts, shown in Figure 4.3 are specifically for asphalt, but in the absence of better data, were used for the correction of deflection and curvature. The pavement thickness is approximately 300 mm and using the 300 mm pavement thickness curve, the following equations were derived for corrections:

Correction for deflection: $y = 0.0539x^3 - 0.4565x^2 + 1.3552x + 0.0331$ ($R^2 = 1.0$) Equation 1

Correction for curvature: $y = -0.2421x^3 + 0.7646x^2 + 0.6424x - 0.1964$ $R^2 = 1.0)$ Equation 2

However when corrections were applied, the resulting data made no logical sense, and it was concluded that whilst some degree of temperature correction for deflection and curvature may be necessary, current knowledge does not allow for a reliable conclusion.

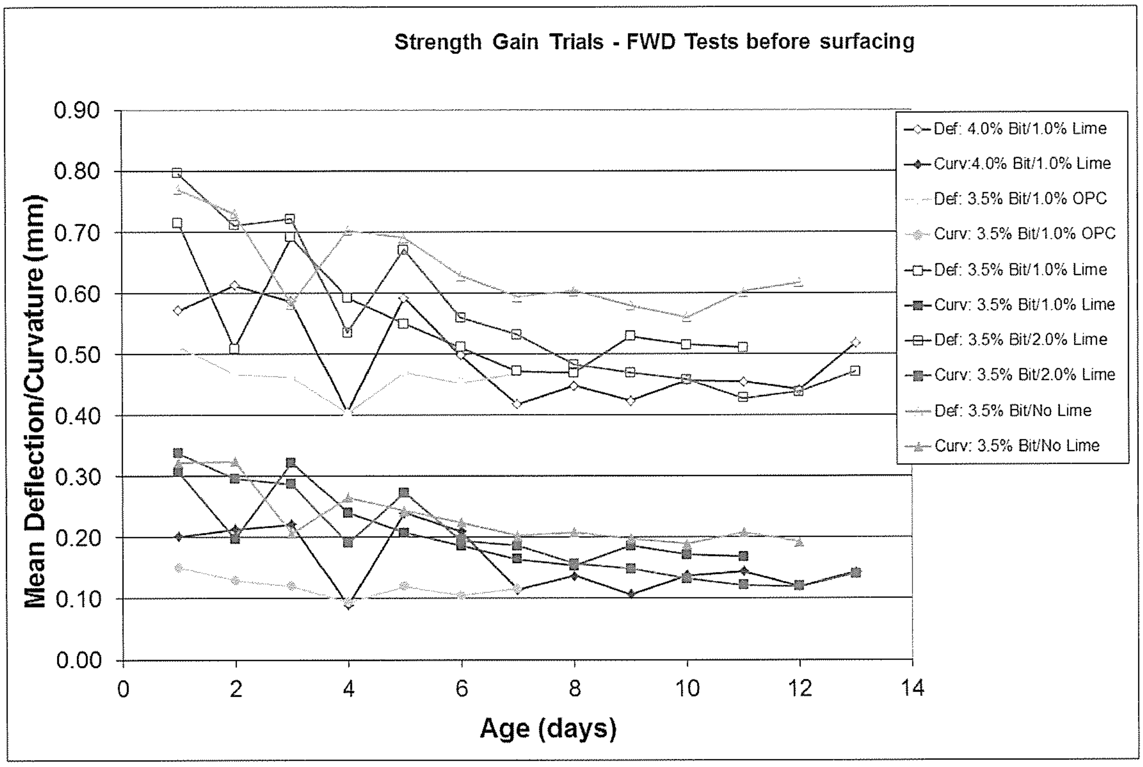

Figure 4.1: FWD Deflection & Curvature prior to surfacing (normalised to 700 kPa).

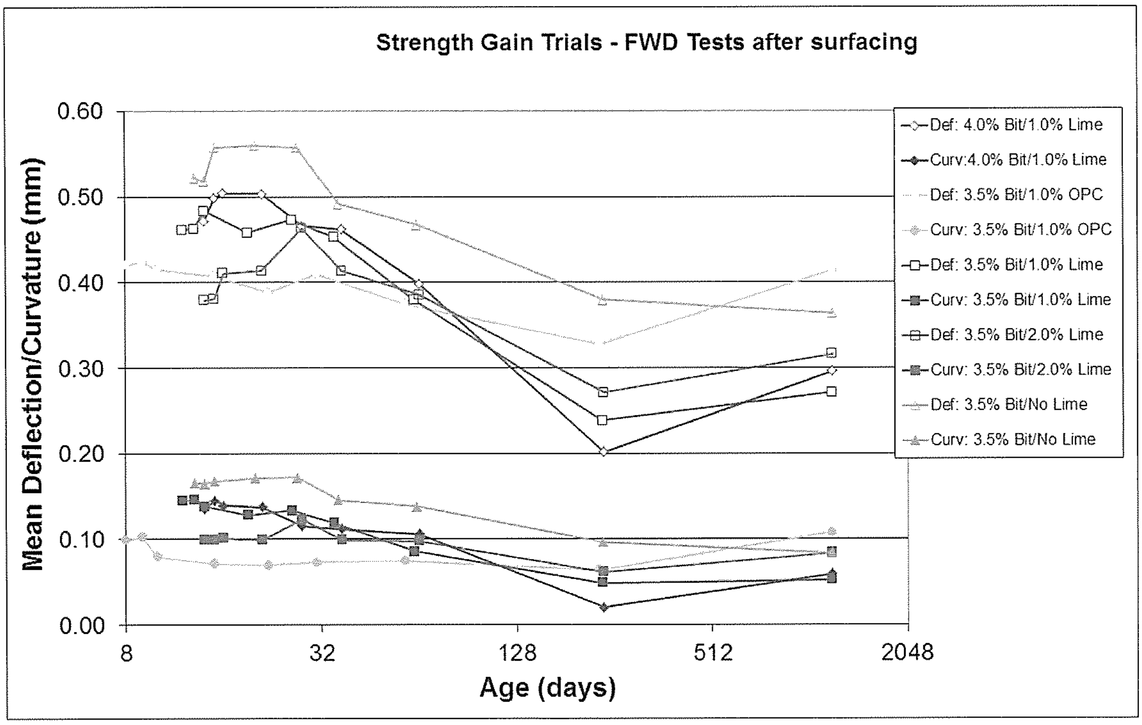

Figure 4.2: FWD Deflection and Curvature after to surfacing (normalised to 700 kPa).

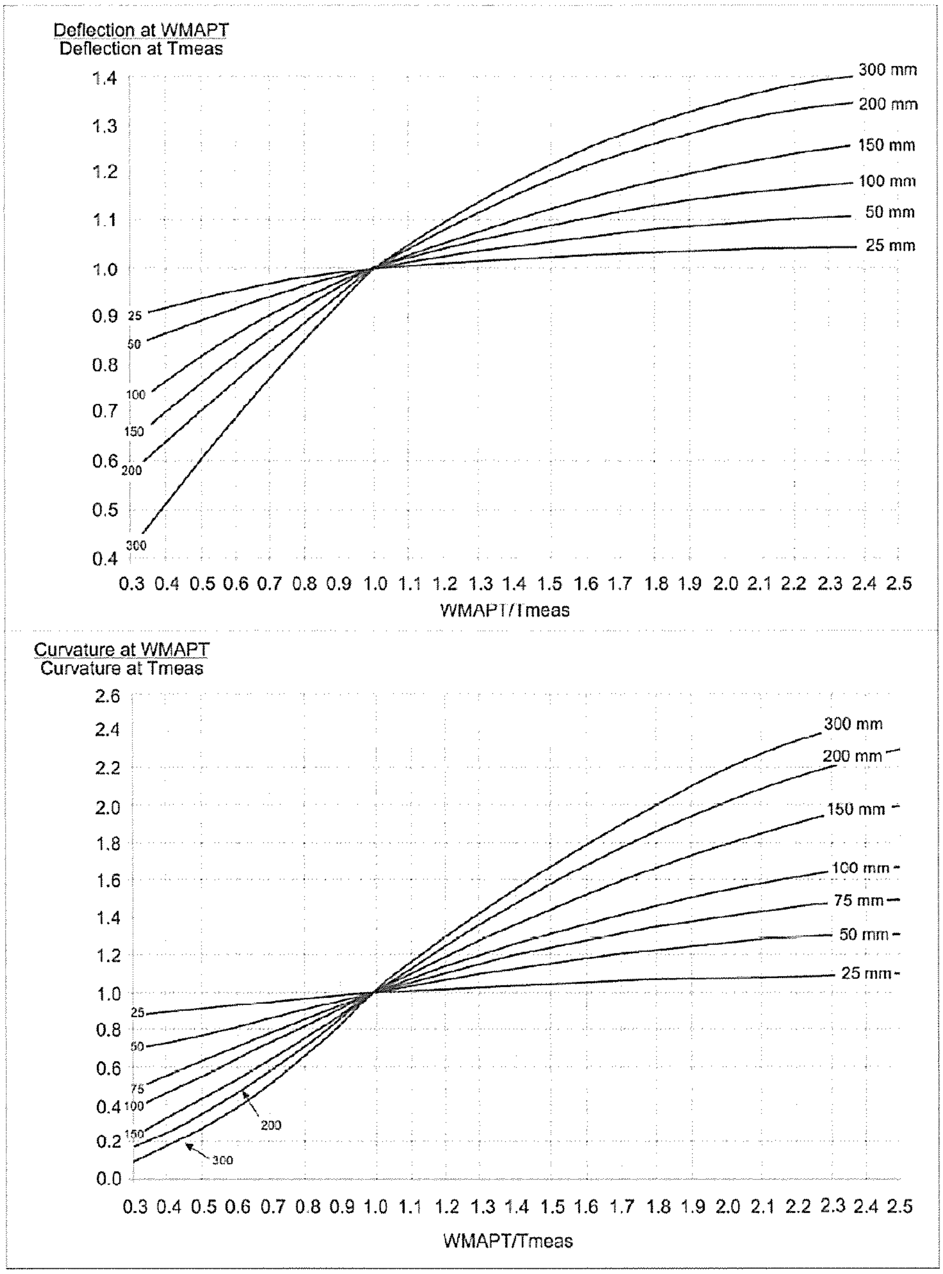

Figure E.2: Temperature correction of FWD deflections and curvatures for various asphalt thicknesses

Figure 4.3: Austroads charts for correction of deflection and curvature values to weighted mean annual pavement temperature.

Irrespective of the surface temperature, and the application of temperature corrections, data from a Curtin University test site in Great Eastern Highway, Belmont where three sites are monitored at 5 minute intervals at various depths in a full depth asphalt pavement 290 mm thick, temperatures are not constant throughout the layers as shown in Figure 4.4. Thus without understanding the full temperature profile, direct comparisons between the days of testing where variations in temperature with depth are not reliable, only variations between sections on any one day may be made.

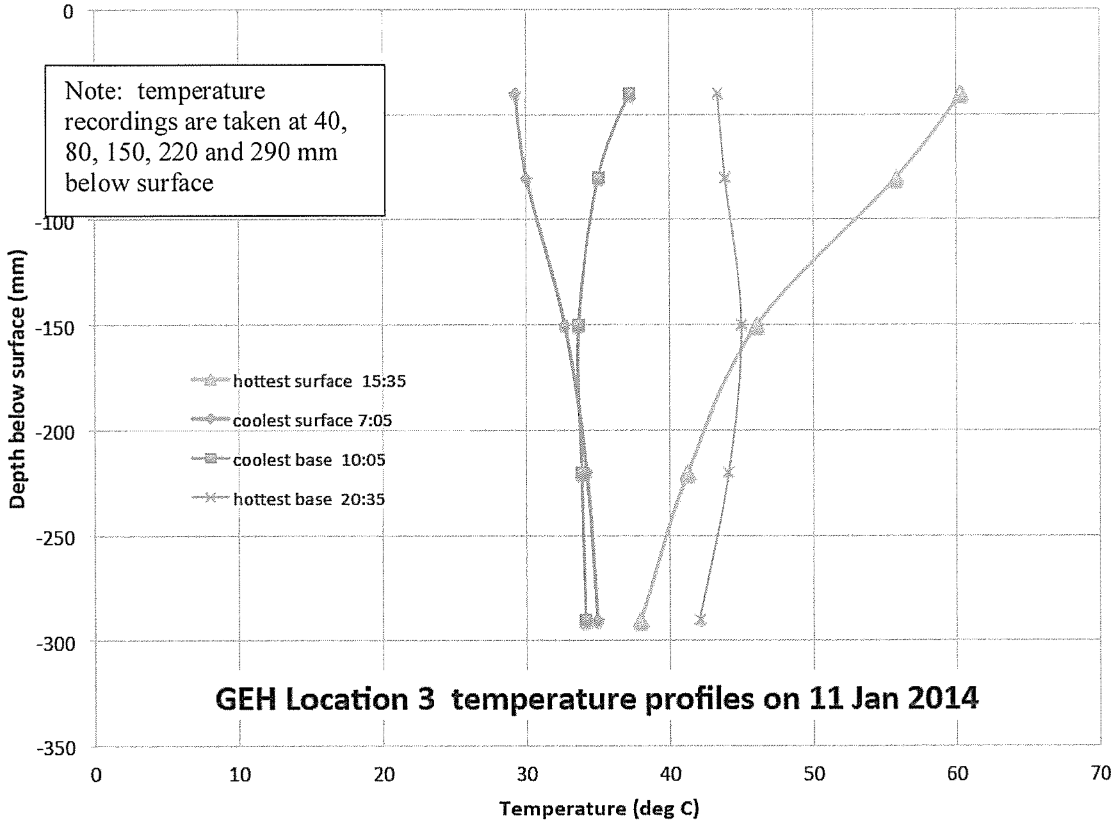

Figure 4.4: Temperature data from Great Eastern Highway, Belmont

The Vahland Avenue results as detailed in Table 4.2, whilst limited, do seem to confirm the conclusions reached from Nicholson Road. Vahland Avenue was constructed in dry weather, and comparing the results, it is apparent that the process is fairly tolerant of inclement weather conditions.

The data shown in Table 4.1 was subject to an ANOVA analysis, and the analysis showed that between the sections on any one test day, the probability of a difference in curvature between sections was 99.9%. This was not followed by a paired T-Test to determine if the difference between each pair was statistically significant, as a visual analysis of data was sufficient to show the similarity of some sections. The main reasons for undertaking these trials were to determine if any of the active filler concentrations would induce shrinkage cracking; no cracking has been observed, but the recent upward trend in the deflection and curvature of the OPC section will be of significant interest in the next round of testing.

Table 4.1: Mean FWD deflection and curvature values on trial sections of Nicholson Road at increments in time.

Pavement layer tested	Days since stabilisation	4% bitumen / 0.8% quicklime			3.5% bitumen / 1% cement			3.5% bitumen / 0.8% quicklime			3.5% bitumen / 1.5% quicklime			3.5% bitumen / 0% lime		
		Mean Temp (°C)	Mean (mm)	St Dev (mm)	Mean Temp (°C)	Mean (mm)	St Dev (mm)	Mean Temp (°C)	Mean (mm)	St Dev (mm)	Mean Temp (°C)	Mean (mm)	St Dev (mm)	Mean Temp (°C)	Mean (mm)	St Dev (mm)
Pavement curvature (D_0 - D_{200})																
Base	1	19	0.20	0.06	22	0.15	0.05	19.46	0.31	0.04	18	0.34	0.09	19	0.32	0.10
	2	18	0.21	0.06	17	0.13	0.04	22.25	0.20	0.03	19	0.30	0.06	19	0.32	0.15
	3	20	0.22	0.05	15	0.12	0.05	15.78	0.32	0.05	20	0.29	0.09	21	0.21	0.05
	4	22	0.09	0.05	16	0.09	0.03	18.85	0.24	0.06	21	0.19	0.05	20	0.27	0.06
	5	19	0.24	0.16	26	0.12	0.05	22.28	0.21	0.05	17	0.27	0.09	19	0.24	0.07
	6	19	0.21	0.10	20	0.10	0.04	16.55	0.19	0.03	19	0.20	0.04	23	0.22	0.04
	7	22	0.11	0.04	20	0.12	0.03	15.47	0.16	0.02	23	0.19	0.04	19	0.20	0.05
Asphalt	14	20	0.07	0.05	23	0.07	0.03	20.94	0.14	0.02	20	0.10	0.02	21	0.17	0.02
	28	18	0.12	0.02	20	0.07	0.04	19.26	0.13	0.02	16	0.12	0.02	21	0.17	0.03
	37	22	0.11	0.03	20	0.07	0.04	22.08	0.12	0.02	24	0.10	0.02	25	0.15	0.02
	60	48	0.11	0.03	20	0.07	0.05	51.16	0.09	0.02	48	0.10	0.04	48	0.14	0.01
	237	15	0.02	0.02	15	0.06	0.05	15.12	0.05	0.02	15	0.06	0.02	15	0.10	0.04
	1201	40	0.06	0.05	41	0.11	0.04	40.72	0.05	0.03	41	0.08	0.03	41	0.08	0.03
Pavement deflection (D_0)																
Base	1	19	0.57	0.08	22	0.51	0.09	19	0.71	0.09	18	0.80	0.18	19	0.77	0.27
	2	18	0.61	0.16	17	0.47	0.08	22	0.51	0.05	19	0.71	0.09	19	0.73	0.18
	3	20	0.59	0.08	15	0.46	0.10	16	0.69	0.06	20	0.72	0.13	21	0.58	0.07
	4	22	0.40	0.09	16	0.40	0.06	19	0.59	0.09	21	0.53	0.08	20	0.70	0.17
	5	19	0.59	0.15	26	0.47	0.11	22	0.55	0.07	17	0.67	0.12	19	0.69	0.19
	6	19	0.50	0.04	20	0.45	0.08	17	0.51	0.06	19	0.56	0.07	23	0.63	0.13
	7	22	0.42	0.08	20	0.47	0.08	15	0.47	0.06	23	0.53	0.06	19	0.59	0.15
Asphalt	14	20	0.37	0.09	23	0.41	0.08	21	0.46	0.05	20	0.38	0.06	21	0.52	0.07
	28	18	0.47	0.06	20	0.41	0.10	19	0.47	0.05	16	0.46	0.04	21	0.56	0.09
	37	22	0.46	0.09	20	0.41	0.10	22	0.45	0.05	24	0.41	0.06	25	0.49	0.04
	60	48	0.40	0.05	20	0.37	0.09	51	0.38	0.05	48	0.39	0.06	48	0.47	0.04
	237	15	0.20	0.03	15	0.33	0.11	15	0.24	0.03	15	0.27	0.06	15	0.38	0.09
	1201	40	0.30	0.07	41	0.41	0.09	41	0.27	0.04	41	0.32	0.05	41	0.36	0.06

Note: Mean temperatures are pavement temperatures at approximately 40mm below surface.

Table 4.2: Mean FWD deflection and curvature values on trial sections of Vahland Avenue at increments in time.

Pavement Details			4% bitumen / 0.8% quicklime	4% bitumen / 1% cement
Testing on base	Day 1	Ave defl (mm)		0.42
		Ave curv (mm)		0.13
Testing on asphalt	Day 2	Ave defl (mm)	0.50	0.47
		Ave curv (mm)	0.15	0.13
	Day 7	Ave defl (mm)	0.40	0.29
		Ave curv (mm)	0.09	0.05
	Day 14	Ave defl (mm)	0.38	0.25
		Ave curv (mm)	0.09	0.05

5 DISCUSSION

The testing on the Nicholson Road trial section is showing some unexpected and unusual trends. In considering the results, it is accepted that curvature is the indicator for base stiffness and deflection is indicative of total pavement performance.

As expected, the section with 1% cement and 3.5% bitumen showed the highest early strength, indicated by a curvature value of 0.15 mm at 1 day age. The 0%, 1% and 2% lime blended with 3.5% cement all showed similar stiffness, but with considerably higher curvature values of around 0.32 mm at 1 day age. The section with 4% bitumen and 1% lime returned a 0.2 mm curvature at 1 day age.

During the first 14 days, all materials continued to stiffen as they gained strength, but after that time, the bitumen cement blend stabilised, so that after 250 days, the stiffness of the bitumen cement blend based on curvature values had been exceeded by all of the lime blends, and only the section without lime showed a lower stiffness. The stiffest material was the blend with 4% bitumen and 1% lime.

After 3 years, a major shift had occurred, the bitumen cement blend had reduced in stiffness to be the least stiff of all of the blends and the 3.5% bitumen 1% lime showed the highest stiffness, again based on curvature. It was noted that the pavement temperature was 40°C, higher than most previous tests.

The curvature values have all been corrected for pavement temperature, but based on Austroads 2008 adjustments for asphalt. The comparison of testing undertaken at City of Canning on both samples of asphalt and foamed bitumen is shown in Figure 5.1 and shows that whilst foamed bitumen is temperature sensitive, it is so to a lesser degree than asphalt. This implies that the temperature correction would be less severe than calculated and that the variation in results over the past two years is not related solely to pavement test temperature.

Thus it is apparent that some significant changes have occurred over the three years since construction, but that there is some inconsistency. Both the 3.5% bitumen 1% cement blend and the 4% bitumen and 1% lime blends have apparently lost considerable stiffness in the last two years since reaching a maximum value, where the 3.5% bitumen 2% lime has lost some stiffness, the 3.5% bitumen 1% lime remained relatively stable and the straight 3.5% bitumen without lime has continued to gain strength over the same period.

Where the bitumen cement blend showed the greatest stiffness immediately after construction, after 14 days the strength gain apparently stabilised for around 12 months, but has reduced in stiffness since reaching a peak. The higher bitumen content section reached a maximum stiffness of all of the test sections, but again reduced stiffness in the latest test.

If all test sections had shown the same trend, then calibration differences between FWD's may explain the differences, but given that one test section continues to decrease in curvature, indicating increasing stiffness, and a second remains relatively stable over a two year period, then these results indicate that the pavement may be subject to fatigue, as in the process of fatigue or bituminous materials, the modulus decreases with an increasing number of cycles.

There is no surface indication that the pavement is distressed, nor is the pavement rutted. It should be noted the 4% bitumen 2% lime performance is not typical with other cases constructed in Canning where curvature values have remained at a constant value around 0.03 mm for up to 5 years.

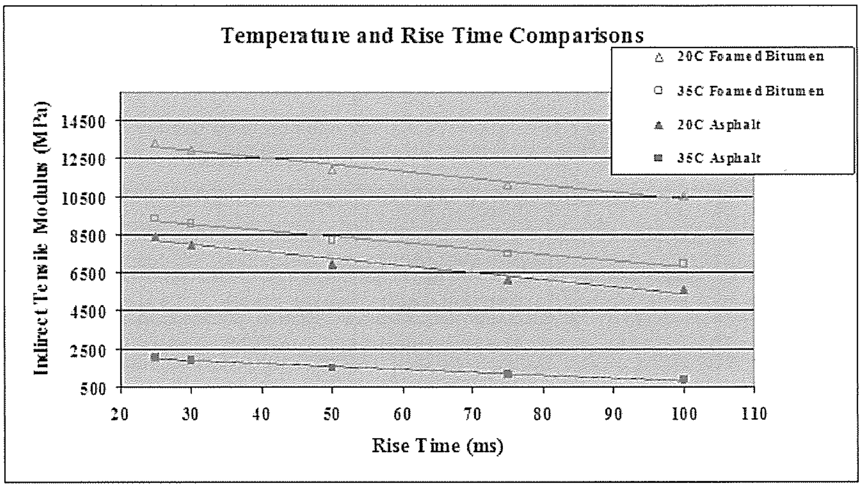

Figure 5.1: Temperature and rise time effects on modulus for asphalt and foamed bitumen.

6 CONCLUSIONS

Based on the results of the active binder trials in Nicholson Road, it is apparent that 1% cement does give much higher early strength than lime blends, and that some lime does give moderate early strength benefits, but not to the same extent as cement. It is also suggested that there is little difference in performance between 1% and 2% lime, but it is cautioned that this pavement is granular crushed materials of very low plasticity.

The testing also shows that, in the longer term, the lime or cement content may make little difference to the ultimate stiffness as that achieved with bitumen alone.

If further testing shows a continuation in the trends observed, then this would indicate that the material in this pavement has suffered fatigue in some sections.

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