AAPA 14th INTERNATIONAL FLEXIBLE PAVEMENTS CONFERENCE

"SUSTAINABLE ROADS"

PREVENTION OF CRACK PROPAGATION SIXTH AVE TRIAL

By:

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1. INTRODUCTION

The Sixth Avenue pavement trial grew from the need for conclusive knowledge on what pavement engineering technology, products and construction methods are available to prevent or retard a road pavement from reflective cracking when overlaid with a new asphalt surface wearing course. The crack propagation prevention consideration is mostly for block cracking that is usually caused by environmental expansion and contraction movement due to daily temperature cycles and the semi-cementitious nature of the underlaying unbound granular pavement. In Western Australia (WA) block cracking is mostly caused in pavements with a base course that generally comprises of either natural gravel (laterite), high Plasticity Index (PI) fine crushed rock base or low percentage bitumen stabilised crushed limestone. Whilst the trial was carried out on a very low traffic volume residential road pavement, many of the findings would also apply to much more heavily trafficked pavements.

Most pavement maintenance engineers are well aware of some of the products and methods available to prevent or retard reflective cracking. A great number of products and methods have in the past been tried with varying degrees of success. Unfortunately, in past trials, quite often, the degree of success is measured over only a very short period of time in relation to the total length of life of the pavement or at least the surfacing. Most trials in WA in the past were carried out without following a process, nor were they documented. Inevitably, once a pavement rehabilitation practitioner left a particular organization or the discipline of pavement maintenance, so too did the information and knowledge of any trials carried out. This rendered the ongoing ability to draw useful knowledge from the trial non-existent and therefore the effectiveness of the trial, almost useless.

The Sixth Avenue trial incorporates as many different alternatives that were possible at the time, bearing also in mind that they had to be economically viable when considering whole of life cycle cost.

The Sixth Avenue trial has been reasonably well documented so as future generation engineers will be able to glean useful information from it.

This paper presents up-to-date information after 10 years of service from some thirty different pavement rehabilitation scenarios.

2. BACKGROUND

An asphalt overlay is the most common method of rehabilitating a pavement to restore it to as-new condition. This might be in the form of a structural overlay which involves asphalt layers greater than 30mm in depth and can easily be assessed and designed from non destructive deflection testing or it might be a thin asphalt overlay to correct other anomalies including, ride quality, skid resistance, texture depth, cracking, noise levels, potholes, patches and the overall continued water proofing and durability of the whole pavement.

In Western Australia there are four main types of asphalt mixes used for overlays as follows: -

(a) Dense-graded – 35, 50, and 75 Marshall blows.

(b) Gap-graded – 35 and 50 Marshall blows.

(c) Open-graded, and more recently,

(d) Stone mastic asphalt (SMA).

All of these asphalt types have varying properties and, where they may be good in one application may not be so good in another.

Table 1 summarises the properties of the asphalt types into strengths and weaknesses in relation to some key pavement performance parameters. (The more * the better) (Cost is estimated for a 25mm thick overlay/m^2)

	DURABILITY	RUT REST	SKID	TEXTURE	SPRAY	NOISE	COST
DENSE-GRADE	* * *	* * *	* * *	* * *	*	* * *	8.40
GAP-GRADE	* * * * *	*	* * * *	*	*	* * *	8.70
OPEN-GRADE	*	* *	* * *	* * * * *	* * * * *	* * * * *	8.40
SMA	* * * *	* * * * *	* * *	* * * * *	* * * *	* * * *	9.90

TABLE 1 – ASPHALT MIX PROPERTIES

At the City of Stirling it was found that asphalt overlays over block cracked pavement host surfaces were re cracking within a very short period after the overlay. Whilst the cracking had generally not ever caused a structural problem in residential, low traffic volume roads, the cracks were aesthetically unacceptable and even more unacceptable when crack sealed with a hot applied modified bitumen filler or band.

In May 1998, after very careful consideration of all of the products available for the prevention or reduction of reflective cracking in asphalt overlays, it was decided that there was possibly no easy or cheap fix. It was also felt that in situ recycling using bitumen emulsion stabilisation may produce a road material which would be flexible enough to be able to “give” within its make-up or matrix during volumetric change due to temperature cycles.

It is believed that, other than shrinkage during construction as a result of poor conditioning of the pavement, gravel, high PI and bitumen stabilised limestone base course pavements crack in a block crack pattern as they react to temperature differentials somewhat like a cementitious pavement in that the pavement is very stiff and as the daily temperature changes occur, the pavement structure must “give”. Rather than “giving” or expanding and contracting within the matrix of the pavement material structure, the contracting and consequently the expansion occurs along defined paths or cracks. These cracks develop into wider cracks with ongoing expansion and contraction and as silt is trapped in the cracks over subsequent seasons.

It was believed that the introduction of bitumen in the stabilised pavement material (provided that it was sufficient in volume), would act as a lubricating glue, allowing micro movement all over the pavement matrix rather than defined weak spots, thereby preventing reflective cracking from the base course and the sub base.

3. INSITU RECYCLING

The areas earmarked for in situ recycling at the City of Stirling were the roads where the pavement materials were gravel or where the pavement material had been constructed with high PI crushed rock base from hard rock quarries.

The first full-scale trial of in situ recycling was carried out at Stuart Street, Inglewood in May 1998.

After some two years of evaluation it was found that the in situ recycled pavement: -

(a) Eliminated reflective cracking and it could be considered to be a long-term solution to the problem.

(b) Increased pavement strength. In fact, FWD testing revealed that the design traffic capacity of the pavement after two years of curing went from 2 E5 to 7 E6 ESA’s.

(c) Allowed longitudinal and transverse grade improvement.

(d) Was a very fast construction process with minimal disruption to residents. In fact the pavement could be trafficked virtually throughout the entire construction period.

(e) Conserved resources - economical.

(f) Stops the unnecessary filling of refuge sites – environmentally friendly.

On the strength of the above findings, it was decided that all block cracked pavements at the City of Stirling would be recycled to a depth of 100mm to 120mm (including the existing asphalt surface) with the addition of 5% (60/40) emulsion (i.e. 3% residual bitumen).

The first full scale contract for recycling work commenced in November 2000. The work was valued at some $1.5M and included two passes of the stabilising machine, supply and addition of the emulsion, grading, compacting and final trimming to level. The unit cost of this work in 2000 was estimated to be $13.00/m^2.

4. SIXTH AVENUE TRIAL

Whilst the in situ recycling work carried out at the City of Stirling was proving to be very successful, there were some concerns as to whether in situ recycling was the most cost effective treatment for the prevention of reflective cracking and whether there might be other lower cost methods. It was also unknown if the long term effect of the bitumen addition would in fact cause more severe cracking as a result of hardening of the binder. At Council pavement maintenance Engineering management level there was a great deal of discussion on the matter and there were plenty of people advising that they had tried many options during their career. However, not one person was sure of the long-term success or in fact, could even remember in which location the trials had been carried out. Accordingly, it was decided to conduct a full-scale trial incorporating as many alternatives as possible.

Sixth Avenue, Inglewood was chosen for the trial section as Sixth Avenue was in the then current budget to be rehabilitated. The City of Stirling had requested that the trial be carried out within the budgeted rehabilitation value allowed. This was possible at Sixth Avenue as this road was earmarked for recycling which allowed enough funds to carry out all of the alternatives, as, even though some of the treatments were more expensive, others, such as a straight overlay without host surface preparation were cheaper making the task of completing the work within budget very easy.

The trial was concluded on the 28th June 2001. The trial section is some 900m in length, consisting of 7 sections of some 100m in length between Beaufort Street and Hamer Parade, having different types of pavement preparation prior to asphalt overlay. There is also a 200m section East of Beaufort Street where there is no host surface preparation. However this section has four different asphalt mix types used in the overlay.

The total different scenarios in the trial are 13 base preparations, including no preparation and 2 to 3 different asphalt surfaces or some thirty different scenarios.

The pavement was also structurally tested with a FWD prior to commencing the construction work and re tested on 22.05.02, 7.05.05, 22.04.05 and most recently on 21.06.11.

Appendix A contains drawings showing the various sections with various treatments on the sections.

The costs of the various treatments at the time of construction are summarised as follows: -

(a)	Dense-graded asphalt (25mm thick inc. prep. & gully)	$7.10/m^2$
(b)	Gap-graded asphalt (25mm thick inc. prep & gully)	$7.50/m^2$
(c)	SMA (25mm thick inc. prep and gully)	$9.50/m^2$
(d)	Gravel Asphalt (inc. prep. & gully)	$9.50/m^2$
(e)	Asphalt 37mm thick - add	$2.50/m^2$
(f)	5% SBS PMB SAMI with 7mm blind	$3.10/m^2$
(g)	Geotextile	$4.30/m^2$
(h)	Dense-graded asphalt base course (35mm thick)	$7.00/m^2$
(i)	Dense-graded asphalt base course (50mm thick)	$10.10/m^2$.
(j)	Dense-graded asphalt base course (75mm thick)	$14.70/m^2$
(k)	Mill out 35mm thick	$2.00/m^2$
(l)	Mill out 50mm thick	$2.50/m^2$
(m)	Mill out 75mm thick	$3.00/m^2$
(n)	In situ recycle 100mm thick with 5% emulsion	$13.00/m^2$
(o)	In situ recycle 100mm thick with 3.3% emulsion	$11.00/m^2$
(p)	In situ recycle 100mm thick with no addition	$7.00/m^2$
(q)	Bitumen prime and blind	$1.80/m^2$
(r)	Box out 100mm and place100mm of FCR	$10.00/m^2$
(s)	Box out 100mm and place 100mm of ESL	$13.00/m^2$
(t)	Dump waste pavement material	$15.00/t

Therefore the cost of the various trial sections is as follows: -

SECTION 1 – No host surface preparation and 25mm of: -

i)	Dense-graded AC surface	$7.10/m^2$
ii)	Gap-graded AC surface	$7.50/m^2$
iii)	SMA surface	$9.50/m^2$

SECTION 2 – Apply 5% SBS PMB SAMI with 7mm blind and 25mm of: -

i)	Dense-graded AC surface	$10.20/m^2$
ii)	Gap-graded AC surface	$10.60/m^2$
iii)	SMA surface	$12.60/m^2$

SECTION 3 – Mill 20mm and apply geotextile and 37mm of: -

i)	Dense-graded AC surface	$14.60/m^2$
ii)	Gap-graded AC surface	$15.00/m^2$
iii)	SMA surface	$17.00/m^2$

SECTION 4 (North side) – Mill 35mm and place 35mm of 50 blow, 2% air voids AC and 25mm of: -

i)	Gap-graded AC surface	$17.75/m^2$

ii) SMA surface with a SAMI over the milled Base course $22.85/m²

SECTION 5 (South side) – Mill 50mm and place 50mm of 50 blow, 2% air voids and 25mm of: -

i) SMA surface $23.90/m²
ii) Dense-graded AC surface with a SAMI over the milled Base course $24.60/m²

SECTION 6 (North side) – Mill 75mm and place 75mm of 50 blow, 4% air voids AC and 25mm of: -

i) SMA surface with a SAMI over the milled Base course $32.80/m²
ii) Gap-graded AC surface $27.70/m²

SECTION 7 (South side) – Mill 50mm and place 50mm of 50 blow, 4% air voids AC and 25mm of: -

i) Dense-graded AC surface with a SAMI over the milled Base course $24.60/m²
ii) SMA surface $23.90/m²

SECTION 8 (North side) – In situ recycle 100mm with the addition of 3.3% (2% resid. bit) emulsion and 25mm of: -

i) Gap-graded AC surface $18.50/m²

SECTION 9 (South side) – In situ recycle 100mm with the addition of 5.0% (3% resid. bit) emulsion and 25mm of: -

i) SMA surface $22.50/m²
ii) Dense-graded AC surface $20.10/m²

SECTION 10 (North side) – In situ recycle 100mm with no addition of emulsion, SAMI prime and 25mm of: -

i) Gap-graded AC surface $17.60/m²

SECTION 11 (South side) – In situ recycle 100mm with no addition of emulsion normal prime and 25mm of: -
i) Dense-graded AC surface $15.90/m²
ii) SMA surface $18.30/m²

SECTION 12 (North side) – Mill 100mm, place 100mm of emulsion stabilised limestone and 25mm of: -

i) Gap-graded AC surface, with SAMI over the ESL $30.35/m²
ii) Gap-graded AC surface $27.25/m²

SECTION 13 (South side) – Mill 100mm, place 100mm of crushed rock base, normal prime and 25mm of: -

i) SMA surface $28.05/m²

ii) Dense-graded AC surface $25.65/m²

5. PEFORMANCE EVALUATION

5.1 CRACKING

The photograph below shows the original cracking on Sixth Ave prior to construction.

Typical block cracking

5.1.1 After 6 months

The visual inspection after 6 months revealed two cracks on the overlay only in Section 1. One of the cracks was a transverse crack through the dense-graded and gap-graded mix that appeared to be a reflection of previous trenching cracks. The other crack was through the gap-graded asphalt only and did not extend into the neighbouring SMA on the Southern half of the road. No other sections of the trial had any signs of cracking.

5.1.2 After 1 year

The visual inspection revealed that the gap-graded asphalt in Section 1 had hairline cracks that extended over approximately 30% of the surface. The dense-graded asphalt in Section 1 was also showing some hair line cracks (5% extent). The SMA showed no signs of cracking.

There was a longitudinal crack in the gap-graded asphalt in Section 2 that had reflected from a previously widened section of the pavement.

There was some evidence of flushing in the gap-graded asphalt that had been placed in Section 2 that has the SAMI under the asphalt.

5.1.3 After 2 years

A summary of the visual assessment findings is provided as follows: -

(i) SECTION 1 – No host surface preparation

The cracking in the gap-graded asphalt had reflected to some 60% of the cracking of the host surface cracking prior to the overlay. The severity was slight, i.e. approximately 1 to 2 mm whereas the cracking prior to the overlay was 5mm in width.

Cracking in Section 1, gap-graded AC (after 2 years)

The cracking in the dense-graded asphalt had reflected to some 15% of the extent of the host surface cracking and severity was slight, i.e. approximately 1 to 2 mm.

Cracking in section 1, dense-graded AC (after 2 years)

There was no cracking in the SMA. The photograph below shows a crack in the gap-graded asphalt extending to and stopping at the SMA.

Cracking in Section 1 GG but not in SMA (after 2 years)

(ii) SECTION 2 – SAMI seal prior to overlay

Cracking was evident in both the gap-grade and dense-graded asphalt and was estimated to have an extent of some 10% of the host surface cracks prior to overlay. The severity of the cracks was slight.

Cracking Section 2, dense graded AC (after 2 years)

The gap-graded asphalt had quite heavy flushing in the wheel paths. The flushing is believed to be as a result of migration of binder from the SAMI to the surface. Photograph No 7 shows the flushing.

There was no cracking in the SMA.

Flushing in Section 2, GG AC (after 2 years)

(iii) SECTION 3 – Mill out 20mm of host asphalt apply a geotextile membrane and lay 37mm of asphalt.

Cracking was evident in both the gap-graded and dense-graded asphalt and was estimated to have an extent of some 10% to 15% of the host surface cracks prior to overlay. The severity of the cracks is slight.

There was no cracking in the SMA.

Cracking in Section 3, DG AC (after 2 years)

5.1.4 After 4 years

A summary of the visual assessment findings is provided as follows: -

(i) SECTION 1 – No host surface preparation

The cracking in the gap-graded asphalt has reflected to some 75% of the cracking of the host surface cracking prior to the overlay. The severity is slight, i.e. approximately 2 to 3 mm whereas the cracking prior to the overlay was 5mm in width. The photographs below show the cracking in the gap-graded asphalt.

Cracking in Section 1, gap-graded AC (severity after 4 years)

The cracking in the dense-graded asphalt had also reflected to some 35% of the extent of the host surface cracking and severity is slight, i.e. approximately 2 to 3 mm.

There is no cracking in the SMA. The photograph below shows cracks in the gap-graded asphalt extending to and stopping at the SMA.

Cracking in Section 1 GG but not in SMA (after 4 years)

(ii) SECTION 2 – SAMI seal prior to overlay

Cracking was evident in both the gap-grade and dense-graded asphalt and was estimated to have an extent of some 10% of the host surface cracks prior to overlay. The severity of the cracks was slight. The severity and extent do not seem to have changed a great deal in the last two years.

Cracking Section 2, GG AC (after 4 years)

(iii) SECTION 3 – Mill out 20mm of host asphalt apply a geotextile membrane and lay 37mm of asphalt.

Cracking was evident in both the gap-graded and dense-graded asphalt and was estimated to have an extent of some 10% to 15% of the host surface cracks prior to overlay. The severity of the cracks was slight. There was not a great deal of change in severity and extent from 2 years ago.

There was no cracking in the SMA.

(iv) SECTION 12 – Mill out 100mm, place 100mm of emulsion stabilised limestone and 25mm of gap graded asphalt.

After 4 years and somewhat surprisingly, this section is now showing cracking. The cracking is evident to some 10% of the pavement and the severity is slight.

Cracking in Section 12, GG AC on new ESL base (after 4 years)

No other sections showed any signs of cracking.

5.1.4 After 10 years

The Trial sections were visually assessed and photographs taken in August 2011.

After 10 years it can clearly be concluded that

- The cracking in Section 1 which does not have any host surface preparation is at an extent and severity of 100% of the original cracking in the gap graded asphalt and 70% in the dense graded asphalt. The crack widths are 3mm to 6mm in the gap grade and 2mm to 4mm in the dense grade. There is absolutely no cracking in the SMA.

- There is cracking in most of the other sections where there is gap grade or dense graded asphalt and the extent and severity are shown in Table 2 below.

- The photographs below Table 2 show typical examples of some of the cracking in various sections.

- There is no cracking in the SMA on any of the section alternatives.

SIXTH AVENUE TRIAL CRACKING EVALUATION-10 YEARS								
Section		Cracking - % of host surface						
		GG		DG		SMA		
		Ext.	Sev.	Ext.	Sev.	Ext.	Sev.
1	No host surface preparation	100	100	70	70	0	0
2	Apply SAMI	25	50	12	40	0	0
3	Mill 20mm, Apply geotextile	20	50	25	50	0	0
4	Mill 35mm, place 35mm 50 blow	3	20	1	10	0	0
5	Mill 50mm, place 50mm 50 blow	0	0	0	0	0	0
6	Mill 75mm, place 75mm 50 blow	0	0	0	0	0	0
7	Mill 50mm, place 50mm 50 blow	0	0	0	0	0	0
8	In situ recycle 100mm with 2% bit	5	30	5	30	0	0
9	In situ recycle 100mm with 3% bit	0	0	0	0	0	0
10	In situ recycle 100mm no addition	12	35	8	30	0	0
11	In situ recycle 100mm no addition	12	35	8	30	0	0
12	Mill 100mm, place 100mm ESL	14	35	10	30	0	0
13	Mill 100mm, place 100mm FCR	2	20	2	20	0	0

TABLE 2 – CURVATURE FROM FWD TESTING

GG on right & DG on left
(No host surface preparation)

GG on right & SMA on left cored 05
(No host surface preparation)

Pumping from base course
(No host surface preparation)

Crack at same width as host - 6mm
(No host surface preparation)

In situ recycle–2% added bitumen **In situ recycle – No added bitumen**

5.2 STRUCTURAL

OVERLAY DESIGN

Design life	20 years
Commercial vehicles	2% (assumed)
Growth rate	2% (assumed)
AADT	2000 (assumed)
ESAs	200,000

Tolerable deflection	1.47mm
Tolerable curvature	0.26mm
Deflection prior to rehabilitation	0.96mm (ave)
Curvature prior to rehabilitation	0.26mm (ave)

According to the simple overlay design above, the pavement did not require a structural overlay. However the existing asphalt surface was worn out. It was estimated that the existing asphalt was in excess of 30 years of age.

The curvature results of FWD testing carried out in 2002, 2004, 2005 and 2011 are recorded below in Table 3. The results are also plotted in Figure 1. Deflection has not been considered as the deflections prior to construction of treatments was very low and is generally never an issue in the Perth sand sub grades.

SIXTH AVENUE TRIAL – STRUCTURAL EVALUATION					
Section		Curvature (mm)			
		2002	2004	2005	2011
1	No host surface preparation				0.158
2	Apply SAMI	0.193	0.208	0.183	0.138
3	Mill 20mm, Apply geotextile	0.208	0.248	0.198	0.164
4	Mill 35mm, place 35mm 50 blow	0.150	0.155	0.185	0.121
5	Mill 50mm, place 50mm 50 blow	0.150	0.175	0.115	0.087
6	Mill 75mm, place 75mm 50 blow	0.150	0.130	0.117	0.055
7	Mill 50mm, place 50mm 50 blow	0.145	0.120	0.110	0.083
8	In situ recycle 100mm with 2% residual bitumen	0.165	0.125	0.130	0.086
9	In situ recycle 100mm with 3% residual bitumen	0.130	0.105	0.100	0.047
10	In situ recycle 100mm no addition, SAMI prime	0.200	0.155	0.160	0.131
11	In situ recycle 100mm no addition, normal prime	0.175	0.170	0.205	0.140
12	Mill 100mm, place 100mm ESL	0.227	0.210	0.150	0.095
13	Mill 100mm, place 100mm road base	0.255	0.210	0.265	0.166

TABLE 3 – CURVATURE FROM FWD TESTING

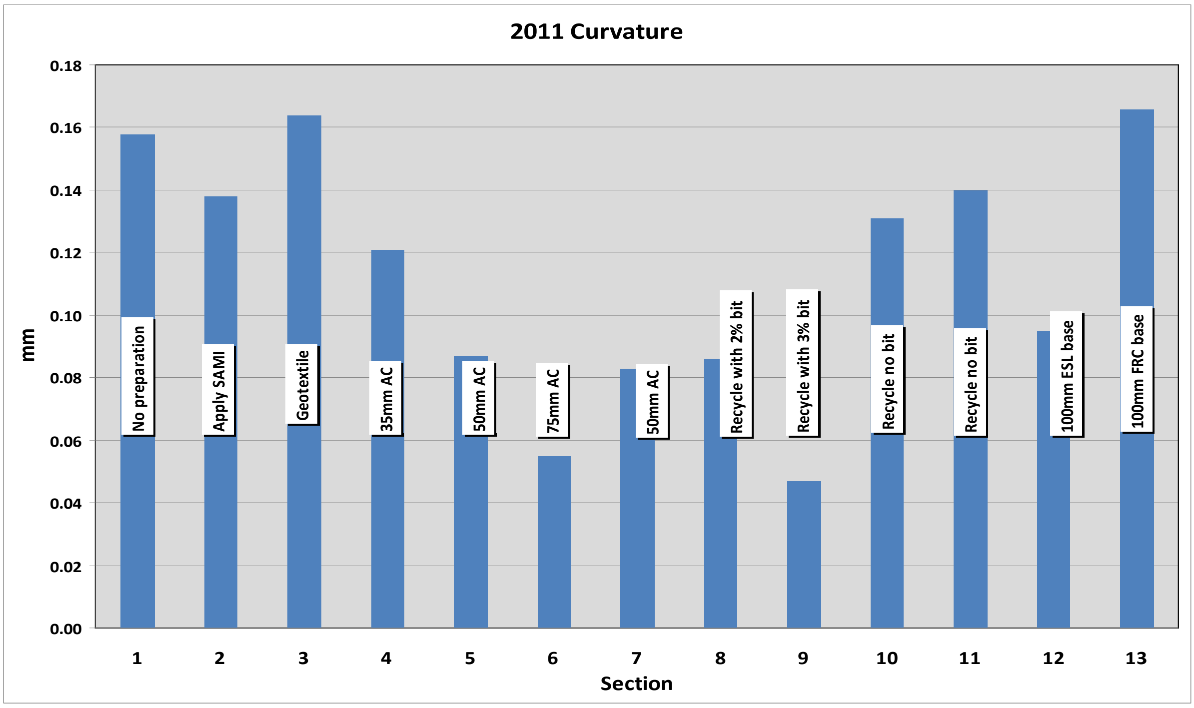


FIGURE 1 – CURVATURE AS TESTED IN JUNE 2011

5.2.1 Structural testing after 12 months

The results of the FWD structural testing carried out prior to construction showed an overall characteristic deflection for the entire road of 0.96mm with the worst case being 1.17mm. A tolerable deflection of 0.96mm has a design life of 4 E6 ESAs and 1.17mm, about 9 E5 ESAs. The results of FWD carried out on 22nd May 2002 generally showed an improvement in deflection of about 17%. However, clearly the sections 12 and 13 that had been milled to a depth of 100mm and filled with new base course material (emulsion stabilised limestone and crushed road base) showed a reduction in deflection resistance, (i.e. higher characteristic deflection).

Similarly, the characteristic curvature prior to construction was an average of 0.26mm that is tolerable for about 2 E5 ESAs and after construction an average of 0.19mm that is tolerable for about 8 E5 ESAs, representing a 400% increase in design traffic. However the section where 100mm of the top of the pavement had been removed and replaced with new base course, in general showed higher curvatures than those prior to construction.

From this it can be concluded that the reconstruction or partial reconstruction of the pavement does not add any structural strength to the pavement.

5.2.2 Structural testing after 4 years

The results after 4 years clearly show that most of the sections had an improved upper base course layer strength; the strongest or most improved strength is the section that had been in situ recycled with the addition of bitumen by way of emulsion. The section that was milled 100mm and replaced with 100mm of new fine crushed road base does not show any strength improvement at all. However this did not show any signs of cracking.

After 4 years the section that had been milled 100mm and replaced with emulsion stabilised limestone had cracked. However the curvature showed a marked improvement in strength. This would indicate that the bitumen in the ESL had broken and cured and the pavement strength had increased. Unfortunately the pavement strength may have reached a stage that it was as strong as the gravel base course that it replaced and that thermal movement was causing the pavement to crack.

The question that arises from this is; why is the ESL section cracking but the emulsion stabilised in situ recycled gravel section not cracking? Moreover, the very first emulsion stabilised in situ recycled pavement at Stuart St Inglewood, after 7 years and in fact now, after 12 years, is still not showing any sign of cracking. The hypothesis to this is that; either the binder content in the gravel is greater and thereby allowing greater lubrication or that the binder in the gravel being from cationic emulsion provided “braking” during the construction period and is now acting as an elastic glue. Whereas, the emulsion in the ESL being anionic “Brock” at a much slower rate and due to the fact that the limestone is more porous than gravel, the available effective binder on the surface of the stone is a lot less thereby providing enough glue to strengthen the material but not enough to provide lubrication or "give" between the stone.

5.2.3 Structural testing after 10 years

The last round of FWD testing after 10 years clearly shows that even though the objective of the trial was not to achieve a pavement that had greater strength, some of the rehabilitation methods clearly show substantial pavement strength improvement.

Figure 1 clearly shows that in sections 6, 7, 8 & 9 the pavement structural capacity as at a level more depicting expectation of pavement strength of a distributor road with 35,000 vehicles per day (VPD) than a residential street with less than 2000 VPD.

The strongest of the pavements is the in situ recycled with 3% residual bitumen. However the visual assessment reveals that some cracking has occurred in the gap graded and dense graded but not in the SMA mix.

At about the same structural capacity of the in situ recycled with 3% binder is the 75mm + 25mm of asphalt Section 6 which has not cracked, followed by the 50mm + 25mm of asphalt Sections 5&7, together with the in situ recycled with 2% binder.

Whilst sections 1, 3 & 13 show a greater strength than prior to construction, the improvement is minimal.

The most surprising finding is the lack of strength improvement in Section 3 with geotextile.

All other sections show good structural capacity well within tolerable limits for the roads class.

5.3 SKID RESISTANCE

Skid resistance and texture depth testing was carried out on the pavement using a British Pendulum (BP) on the 12th July 2003 (after 2 years). The pavement was also tested with a ROAR and results reported in equivalent SCRIM in August 2003. The results of the testing are as follows: -

Gap-graded asphalt (7mm):	Corrected Skid - BP	69
	- SCRIM	0.55
	Texture depth	0.2mm
Dense-graded asphalt (7mm):	Corrected Skid - BP	63
	- SCRIM	0.51
	Texture depth	0.3mm
SMA (7mm):	Corrected Skid - BP	65
	- SCRIM	0.54

Texture depth	0.7mm

This clearly shows that the fine, smooth, dense surface of the gap-graded asphalt has a higher frictional resistance. However, the texture depth is very low and its use should be restricted to low speed roads. The texture depth of the SMA is far superior to the other two surfaces.

5.4 BINDER HARDENING

From the visual assessment it can easily be concluded that SMA far out performs the other asphalt types in being able to prevent or retard reflective block cracking.

It has been suggested by European practitioners that SMA also has superior durability or life.

The oldest SMA in WA is now some 13 years old and it is understood that Vic Roads trialled SMA some 17 or 18 years ago and carried out the first full scale freeway job in the mid nineteen nineties.

In an effort to try and predict the potential life expectancy of SMA in comparison to other asphalt mixes some 6 cores were taken from the three trial mixes being gap graded, dense graded and SMA. The cores were prepared by cutting off the top and bottom and combined so as to provide an average and reasonable sample size. The binder was then extracted and viscosity tested by ARRB by “Sliding Plate Microviscometer. The results are plotted in Figure 2 below.

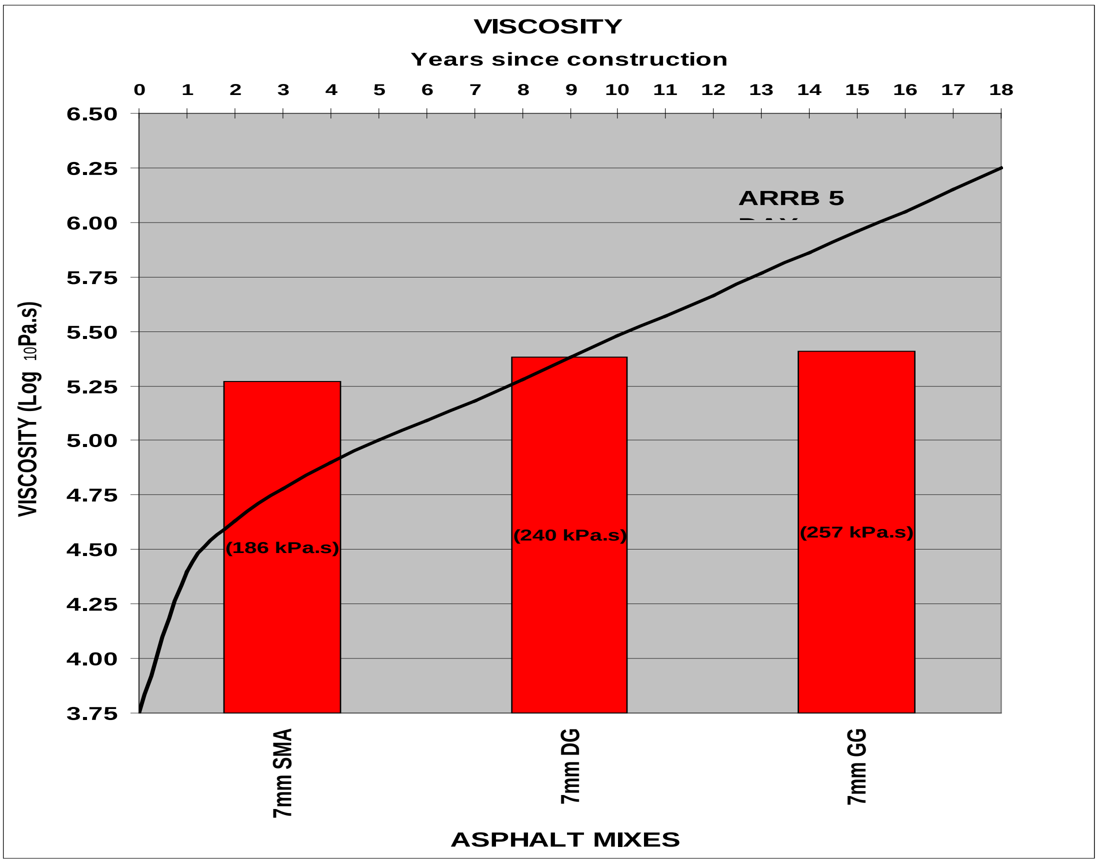


FIGURE 2 – BINDER VISCOSITY AFTER 10 YEARS OF SERVICE

Figure 2 above also shows an overlay plot of the ARRB 5 day bitumen hardening curve for Melbourne that has been lifted from ARRB Research Report ARR 326 – “The performance of Sprayed Seals” by John Oliver 1999. This figure shows that the hardening of binder in the SMA is less than or slower than the other two mix types. It was surprising, in fact somewhat disappointing to see that the hardening in the gap graded asphalt was no better than that in the dense graded asphalt. However after checking the original test reports of the gap graded mix for this Section, it was found that the air voids were excessively high and accordingly it can be accepted that the binder hardening performance would not be any better. For the same reasoning, it is also somewhat surprising that the SMA binder hardening is less than the other two mixes as the in situ air voids in this mix are around the 8% mark, whereas current European specifications are asking for in situ voids of less than 6%. It is hypothesised that the reason for the superior performance is purely the fact that the SMA has a higher binder and or mastic film thickness.

From the ARRB 5 day durability overlay it is reasonable to deduce that the SMA that has now been in service for 10 years has binder hardening equivalent to some 8 years and the dense grade and gap grade equivalent to some 9 years.

6. FUTURE MONITORING

The pavement at Sixth Avenue will continue to be monitored every year and reported as and when significant changes occur.

It is highly likely that it will take a further 10 years before the trial can be drawn to conclusion. However, it is also now realised that, apart from the knowledge that this trial will bring to the understanding of reflective crack prevention, it should also add significant knowledge to the durability of various surfaces as they are basically placed alongside each other on a road which has the same host surface, traffic conditions and environmental conditions.

This paper also shows very clearly the effect of various treatments on the structural capacity of the pavement. Furthermore the surfaces have been and should continue to be tested for skid resistance and a level of understanding deduced from the results. However the results can only be applied to roads with low traffic volumes and should not be assumed to be the same in high traffic volume roads as it is highly unlikely that any significant degree of stone polishing will occur on Sixth Avenue.

7. CONCLUSION

After ten years, it can be concluded that: -

(a) The gap-graded asphalt and the dense-graded asphalt on Section No 1 which does not have any host surface preparation, has reflective cracked within a very short period of time. The cracking on the gap-graded asphalt is more extensive and severe than the dense-graded asphalt. There is no cracking in the SMA. Accordingly it can be said that SMA is the least cost resurfacing alternative for prevention of crack propagation of environmental block cracking.

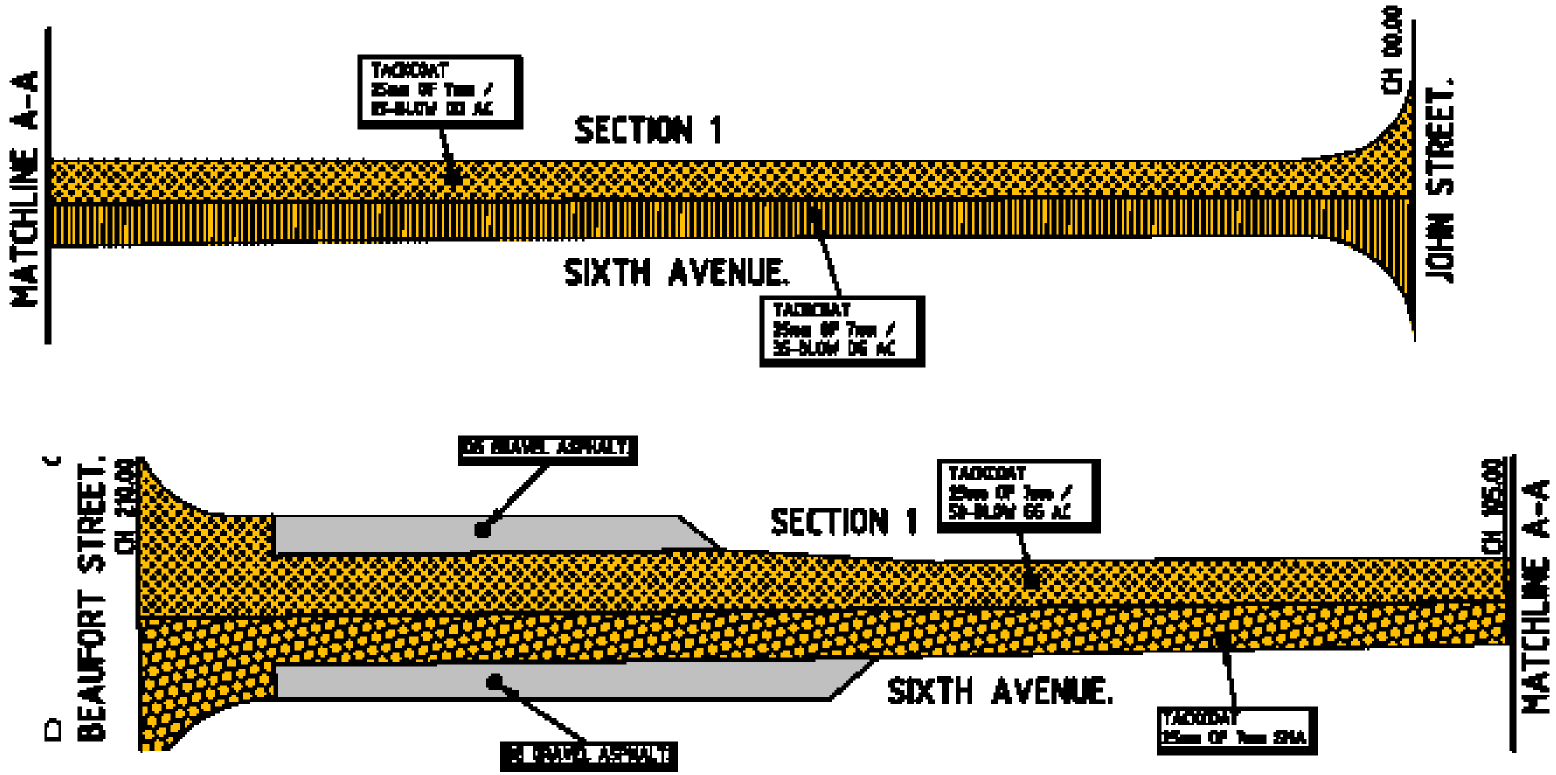
(b) The structural capacity of the road has improved with all of the treatments except where the base course has been reconstructed with virgin material and in situ recycled with no addition of bitumen emulsion. The structural capacity of the in situ recycled with the addition of 3% residual binder is so impressive that it might be considered to be equivalent to asphalt and deserves further investigation.

(c) The friction resistance of the gap graded asphalt is superior to dense grade and SMA. However the texture depth of the SMA is far better than the others. This would result in a calculated IFI that would be far superior to any of the other surfaces.

(d) The viscosity of the SMA is lower than the dense grade and gap grade indicating that the durability of the SMA is highly likely to be better.

Appendix A

DRAWINGS OF SIXTH AVENUE TRIAL SECTIONS



LEGEND

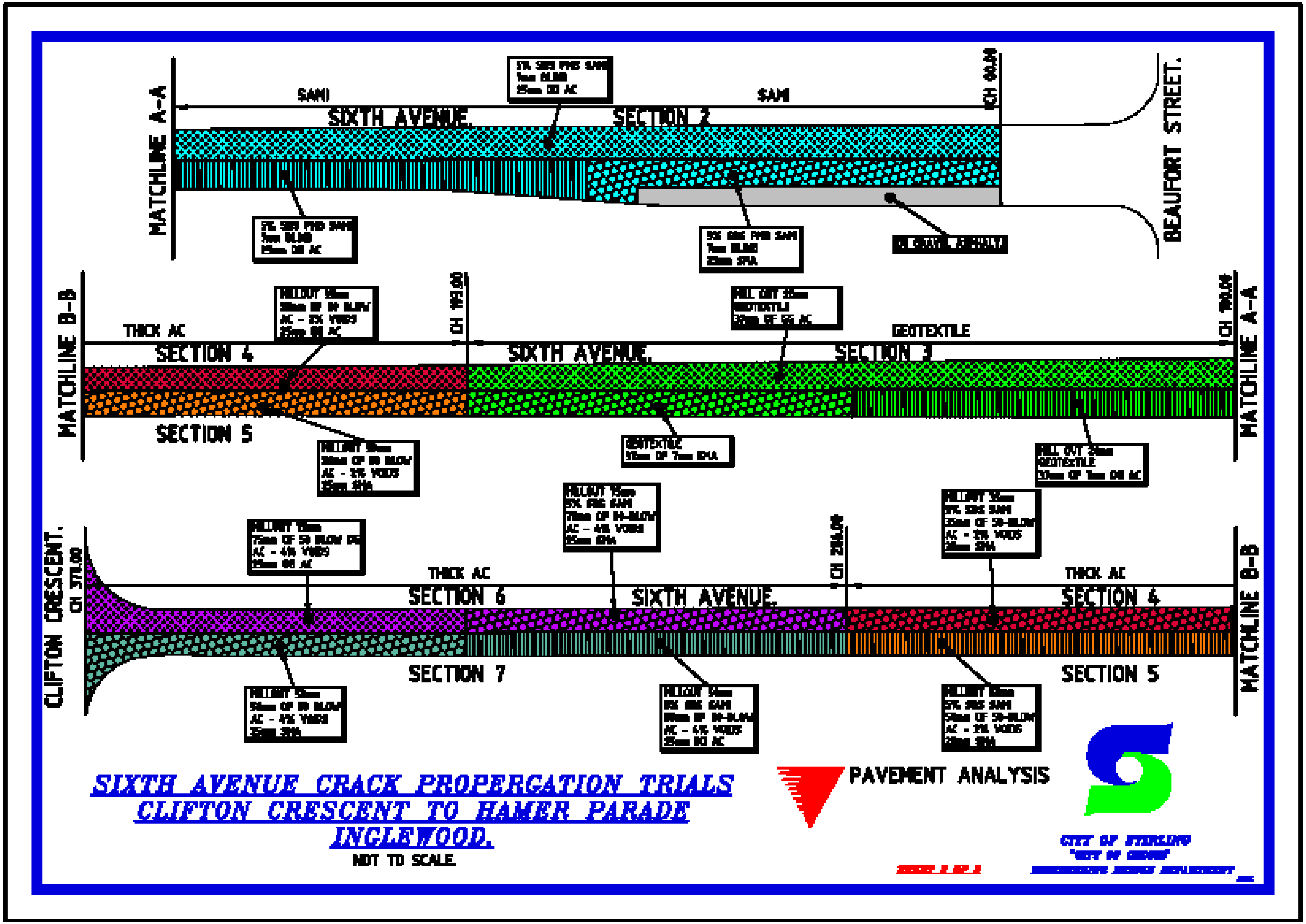
- DG AC – DENSE GRADED ASPHALTIC CONCRETE.
- GG AC – GAP GRADED ASPHALTIC CONCRETE.
- SMA – STONE MASTIC ASPHALT.

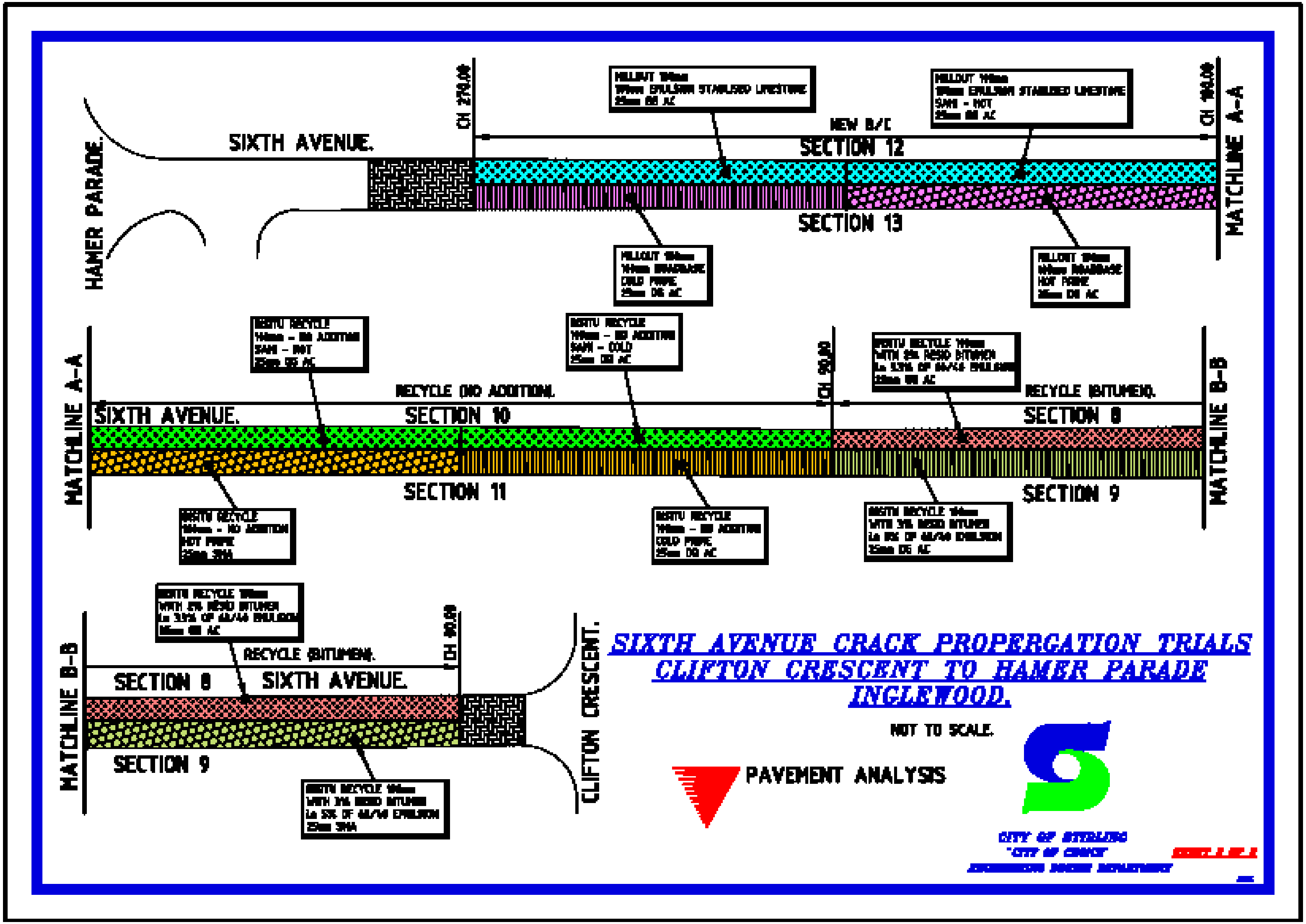
SIXTH AVENUE CRACK PROPERGATION TRIALS
CLIFTON CRESCENT TO HAMER PARADE
INGLEWOOD.

NOT TO SCALE.

PAVEMENT ANALYSIS

CITY OF STIRLING


MATCHLINE A-A
SAMI
SIXTH AVENUE.
SECTION 2
SAMI
CH 00.00
BEAUFORT STREET.
MATCHLINE B-B
THICK AC
SECTION 4
CH 193.00
SIXTH AVENUE.
GEOTEXTILE
SECTION 3
CH 100.00
MATCHLINE A-A
SECTION 5
CLIFTON CRESCENT.
CH 378.00
THICK AC
SECTION 6
SIXTH AVENUE.
CH 286.00
THICK AC
SECTION 4
MATCHLINE B-B
SECTION 7
SECTION 5
SIXTH AVENUE CRACK PROPERGATION TRIALS
CLIFTON CRESCENT TO HAMER PARADE
INGLEWOOD.
NOT TO SCALE.
PAVEMENT ANALYSIS
CITY OF STIRLING


HAMER PARADE.
SIXTH AVENUE.
CH 270.00
NEW B/C
SECTION 12
SECTION 13
CH 180.00
MATCHLINE A-A
MATCHLINE A-A
SIXTH AVENUE.
RECYCLE (NO ADDITION).
SECTION 10
SECTION 11
CH 90.00
RECYCLE (BITUMEN).
SECTION 8
SECTION 9
MATCHLINE B-B
MATCHLINE B-B
RECYCLE (BITUMEN).
SECTION 8
SIXTH AVENUE.
SECTION 9
CH 00.00
CLIFTON CRESCENT.
SIXTH AVENUE CRACK PROPERGATION TRIALS
CLIFTON CRESCENT TO HAMER PARADE
INGLEWOOD.
NOT TO SCALE.
PAVEMENT ANALYSIS
CITY OF STIRLING