GEOTEXTILE REINFORCED SEALS – THE WESTERN AUSTRALIAN COMING OF AGE

GARNET GREGORY, MAIN ROADS WESTERN AUSTRALIA, AUSTRALIA

ABSTRACT

A number of major highways and freeways in Western Australia are showing significant pavement defects and failures associated with cracking and ingress of moisture post cracking. Significant works have been undertaken over the last two summer seasons to resurface these roads by applying Geotextile Reinforced Seals (GRS) as a Strain Alleviating Membrane Interlayer (SAMI) under asphalt and as a Strain Alleviating Membrane (SAM) with a double double seal as the running course.

This paper describes the experience of Main Roads Western Australia of implementing a technology (GRS) commonly used on the east coast but previously used only sporadically in WA. The usage of GRS has grown from close to zero to be in excess of 300,000m^2 per year which will continue for some years to come. This paper includes how Main Roads WA managed the rapid expansion in the use of GRS, improvements to the finish of cold planed surfaces, issues with applying GRS in a very hot climate and overlapping of geotextile fabric to provide continuous protection across the width of a carriageway.

SCOPE

This paper describes the experience of Main Roads Western Australia of implementing a technology (GRS) commonly used on the east coast but previously used sporadically in WA. The paper includes how WA managed the rapid expansion in the use of GRS, improvements to the finish of cold planed surfaces, issues with applying GRS in a very hot climate and overlapping of geotextile fabric to provide continuous protection across the width of a carriageway.

Western Australia (WA) is the largest Australian state by size and has a population of 2.3 million people of which 1.7 million people reside within Perth the Capital City. In 2010 WA had growth rate of 2.1% which is the highest rate of population growth of any Australian state or territory.

The Perth metropolitan area spans approximately 120 kilometres along a north / south axis and approximately 40 kilometres along an East / West axis. The city is sprawled over a large area with the population heavily reliant on motor vehicle transportation. Perth is the major service centre for a state which is approximately one third of the Australian land mass. Throughout WA are contained some of the largest mineral and energy resource projects of the nation earning billions of dollars in export income for the nation. All these projects and rural population centres are connected with a road network comprising of 18000 kilometres of state controlled roads.

Within the Perth metropolitan area over the last twenty years in particular the road network has expanded to cope not only with the growing population but also the size of trucks and associated loading that the road network is expected to cope with in a burgeoning economy.

A number of Perth metropolitan major roads are experiencing shrinkage cracking and fatigue cracking which allows moisture to penetrate the pavement and cause in some circumstances premature failure of the pavement.

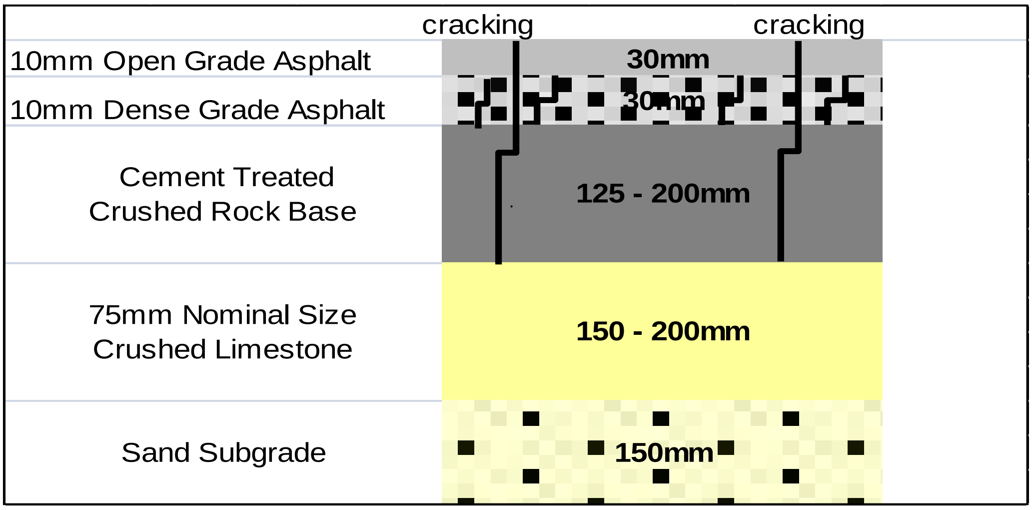
In order to address this situation Main Roads WA has adopted the use of Geotextile Reinforced Seals (GRS) to mitigate the effects of the cracking pavement reflecting through overlying seals and asphalt courses and therefore preventing moisture ingress into the pavement layer.

GRS USED AS A SAMI

GRS used as a SAMI is the predominant use of this technology in WA at the moment as most of the recent focus has been on metropolitan roads which have asphalt as the wearing course. The GRS is used to prevent the reflection of pavement cracks into the overlying asphalt and thus reducing the potential of moisture ingress into the pavement.

Pavement Structure

The typical pavement design model with failure mode looks like:



Mode of Failure

Cracking is not usually immediately apparent in this pavement design as the open grade asphalt resists crack reflection for a longer period than the underlying dense grade. However once cracking is noticed within the open grade running surface the underlying basecourse and pavement is usually severely cracked. The time taken for the formation of cracks to appear within a pavement is variable but in some circumstances cracking can appear within a very short period after the pavement has been constructed in particular where cement treated crushed rock base has been used within the pavement.

This is the dilemma of Main Roads WA in that there is a lot of fairly young pavements constructed in a similar fashion to the above model which are either in failure mode or are showing the typical signs of cracking and moisture ingress.

The Remedy

The remedy for the dilemma from an engineering point of view was reconstruction of the defective pavements. However this remedy was considered to be financially unacceptable, disruption to the motoring public meant that it was impractical and such a decision would be politically unacceptable.

This was the catalyst for Main Roads WA to adopt the use of GRS to provide an effective water proof barrier to prolong the life of the existing pavement.
A number of trials were established to ascertain the most effective use of this technology as a SAMI:

1. Cold plane off 40mm of asphalt and apply GRS then re-instate open grade asphalt.
2. Cold plane off 50mm of asphalt and apply GRS then re-instate dense grade and open grade asphalt layers.
3. Cold plane off 50mm of asphalt then re-instate the dense grade asphalt then apply GRS then re-instate the open grade asphalt.

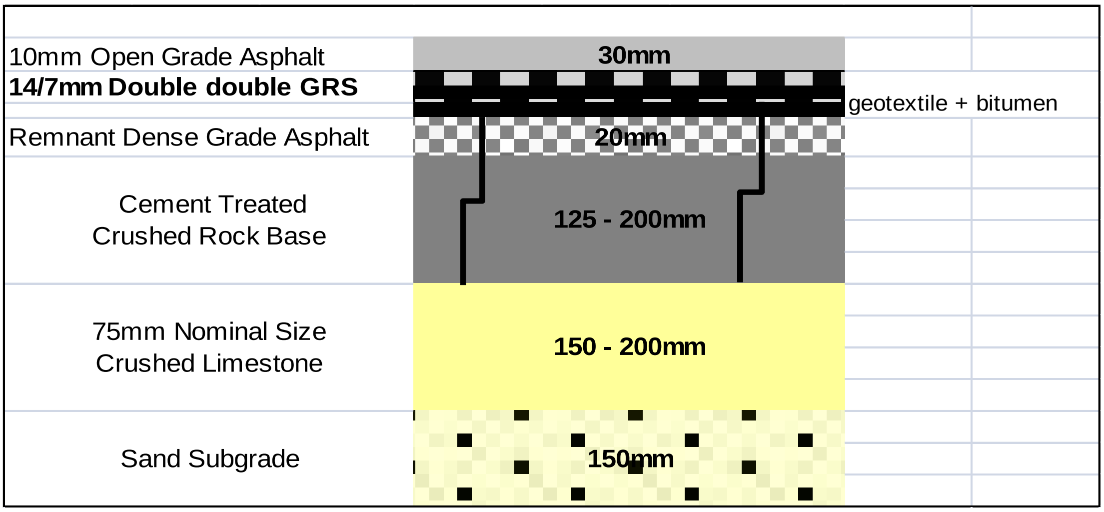
Due to economic and pavement design considerations the process used in Trial 1 was adopted as the treatment for the cracked pavements.
Open Grade asphalt placed in a typical layer thickness of 30mm is relatively fatigue resistant and able to handle pavement stress better than dense grade.
The open grade asphalt is designed as a drainage layer to mitigate spray and noise generation. Armed with this knowledge the GRS will need to be an extremely robust, water proof membrane as the overlying open grade will be at times a vast reservoir of water ready to flow down any apparent cracks into the pavement.
Main Roads WA specifies a non-woven needle punch fabric manufactured from polyester that conforms to the properties in Table 1 taken from the Main Roads WA Specification 503.

TABLE 1: **PROPERTIES OF GEOTEXTILE FABRIC**

Test Property	**Test Method**	**Limits**	
		Light Grade Fabric	**Heavy Grade Fabric**
Wide strip tensile strength (kN/m)	AS 3706.2	≥ 6.0	≥ 9.0
Mass per unit area (g/m^2)	AS 3706.1	130 - 160	170 - 200
Maximum Elongation (%)	AS 3706.2	40 – 60	40 - 60
UV Stabilisation - Retained Strength	AS 3706.11	At least 50% after 672 hours of exposure	At least 50% after 672 hours of exposure
Melting Point (°C)	ASTM D276	≥ 200	≥ 200
Bitumen Retention (loaded) Note 1 (L/m^2)	ASTM D6140	≥ 0.9	≥ 1.1
Thickness (mm)	AS 3706.1	1.2 – 1.6	1.6 – 2.0

Note 1 – test shall be completed using Class 170 bitumen as per AS 2008

The heavy grade of fabric (170 – 200 g/m^2) was chosen which can take up to 1.1L/m^2 of bitumen to saturate the cloth in accordance with the Austroads Technical Report AP-T37/05 Geotextile Reinforced Seals. In addition to this amount of binder absorbed into the cloth by adding a 14/7mm double double seal on top of the cloth can give a total bitumen content of up to 3.5L/m^2. With this level of binder within the SAMI one can be reasonably confident that if the processes of applying the GRS is conducted correctly then a robust water proof layer can be installed which will maintain its integrity for many years to come. Therefore the model for the repaired pavement now looks something more like the following:



The Process of Applying the GRS

Profiling

To provide a good platform for the GRS all the open grade asphalt and approximately 10mm of the dense grade asphalt are profiled off leaving 20mm of the dense grade asphalt as the platform for the GRS.
Specification 508 (Cold Planing) was amended in recognition that more and more GRS was to be placed as a SAMI on the road network and clear guidance was required to ensure the best outcome.
Main Roads WA stipulated that the "fine" milling drum be used so that the grooves left on the profiled surface are not too deep. Deep grooves would be problematic as the geotextile would have to bridge the apex of these grooves which may create air voids under the GRS which is not desirable. Table 2 is taken out of Specification 508 and classifies work into three types and clearly states that GRS work is Type 1 and requires a maximum tool spacing on the profiling drum of 8mm.

Table 2 Selection of Profile Drum

Type of Drum	Tool Spacing on Drum	Type of Work
Fine	Maximum 8 mm	**TYPE 1** • Where a SAMI or GRS seal is to be applied to the cold planed surface • Bridge Deck resurfacing
Fine	Maximum 8 mm	**TYPE 2** • Milling to retexture a road surface • Removal of surface defects such as shoving
Standard	15 mm	**TYPE 3** • Asphalt without an underlying seal • Other applications not requiring a fine drum

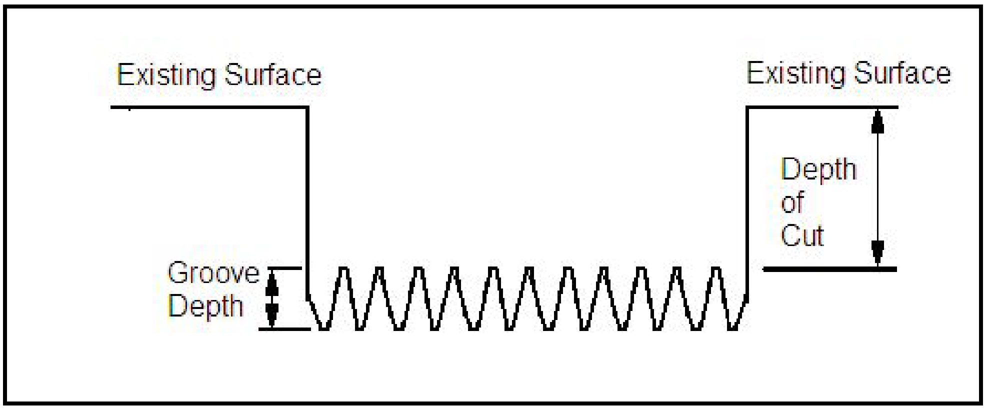
To give the contractor a guide to what is required with the milled surface Main Roads WA specified that the Sand Patch test be used as a quick check to verify that the grooves in the profiled surface are not too deep. By performing the Sand Patch test and measuring the diameter of the sand circle the contractor can quickly verify that the surface texture is within specification. Table 3 is used as the quick reference for profile texture.

TABLE 3 SURFACE TEXTURE – TYPE 1 WORKS

Location within Cold Planed Surface	Texture Depth	Sand Patch Diameter (where 50cc of sand is used)
Average	< 2.0 mm	> 180 mm
Any location	≤ 2.3 mm	> 170 mm

Specification 508 states that the depth of grooves at any point on the planed surface after sweeping shall be no more than 5mm, as defined in Figure 1.

FIGURE 1 GROOVE DEPTH – TYPE 1 WORKS



The essential point is that the profiling process should present a uniform surface with groove depths not more than a few millimetres in depth. However, a good platform is not one that is devoid of any surface texture as a slick surface may also present problems with potential slip of the GRS. Some texture is required for a successful long term outcome. Figure 3 depicts the current milling drums available of which Main Roads WA specify up to an 8mm spacing.

FIGURE 3

DRUM SELECTION FOR COLD PLANING

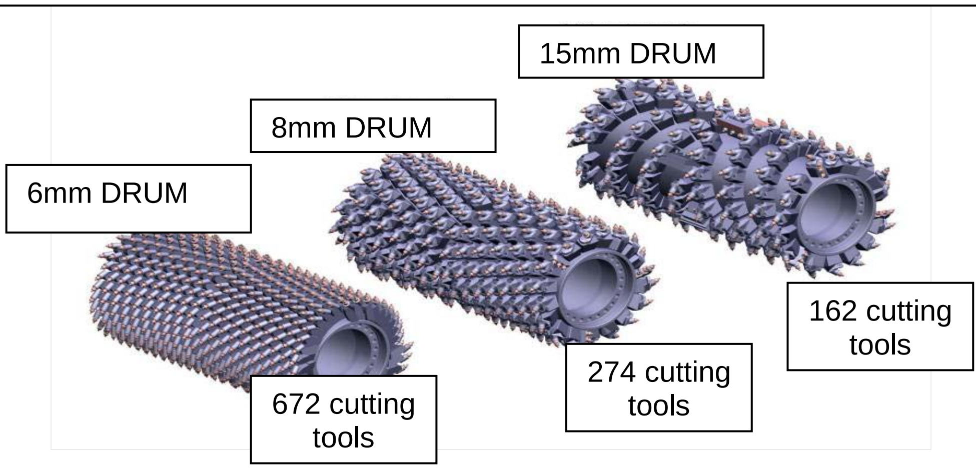


Photo 1 depicts a typical profiled surface using a fine milling drum with 8mm spacing. The surface is generally uniform in appearance and texture. However as individual cutting tools wear or become loose they can cause deeper grooves to appear such as is highlighted in the yellow oval shape in Photo 1. When this appears it is time to schedule the drum to undergo a service to replace or repair the errant cutting tool/s.

Photo 1

GRS Placement

The design of the GRS when used as a SAMI seal is as follows:

Bitumen Application Rate (BAR) for Class 170 Bitumen calculated at 15°C.

Bond Coat	1.1L/m^2
1st Coat (14mm)	1.7L/m^2
2nd Coat (7mm)	0.7L/m^2
Total binder	**3.5L/m^2**

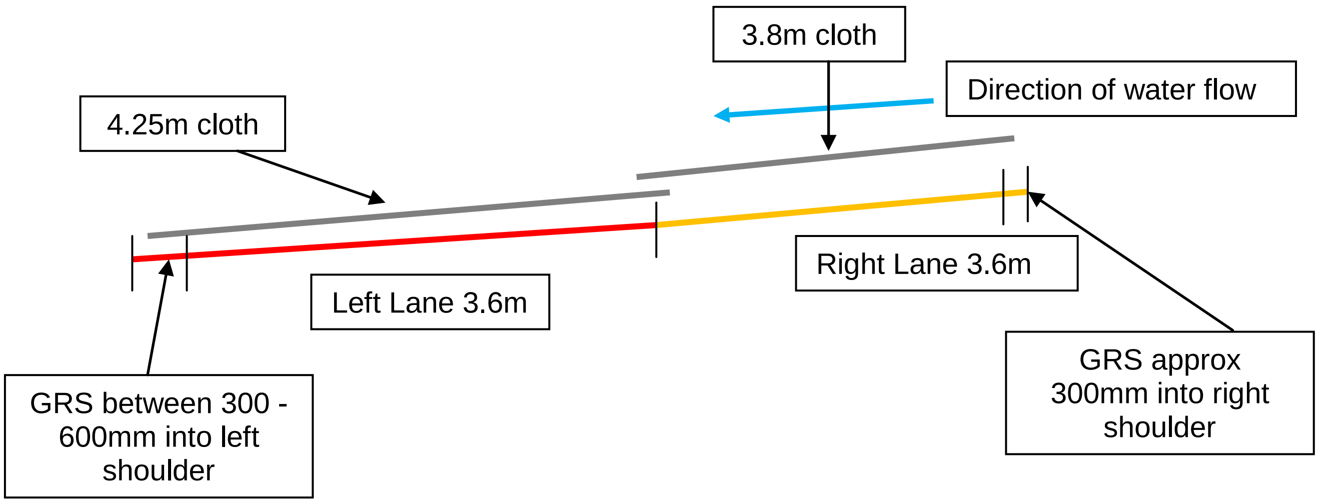
Aggregate spread rates

14mm – 100m^2/m^3
7mm - 250 m^2/m^3

The direction of crossfall of the carriageway is determined as this dictates which lane receives geotextile first. In most circumstances carriageway crossfall is to the left which means that the left hand cloth is placed first. Main Roads WA elected to overlap geotextile along longitudinal joins to ensure maximum coverage of the pavement is achieved. Experience has taught that on a good day an operator placing the geotextile will position the cloth ± 50mm of where it should be on a longitudinal plane. Therefore if

the design specified that one geotextile cloth is to butt against the other along a longitudinal join then one can expect that there will be areas where there will be gaps of up to 100mm in width where there is no Geotextile.
By specifying a 150mm overlap at the centre takes into account the natural wander of the operator placing the cloth.
Placing the left cloth first will cause the water on top of the GRS to flow over the overlapped join and not into the join and thus avoiding any possibility of moisture build up at the overlap. Figure 4 gives a typical view of a GRS placement onto a carriageway.

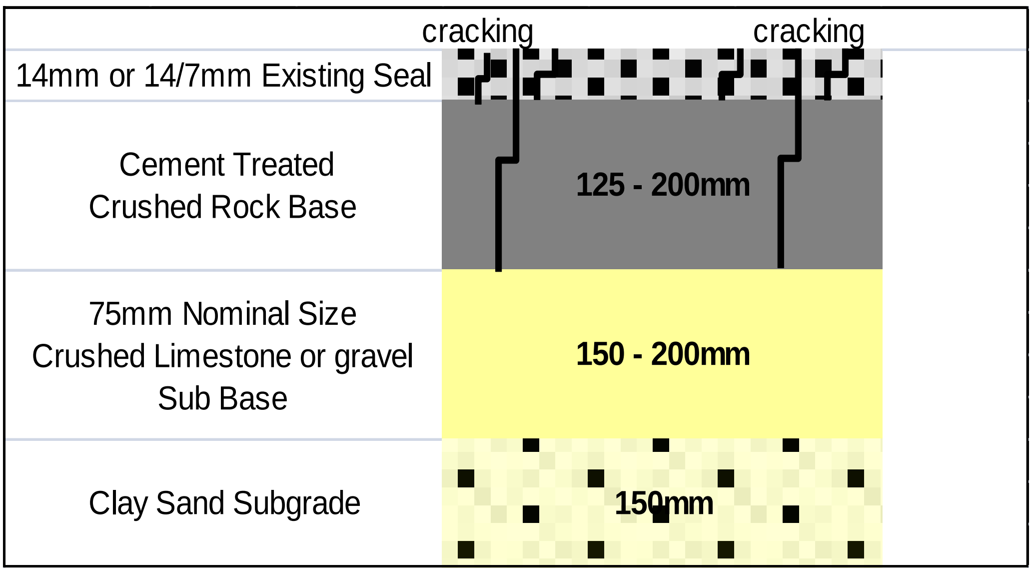
FIGURE 4: GEOTEXTILE PLACEMENT



GRS USED AS A STRAIN ALLEVIATING MEMBRANE (SAM)

Some of Perth's semi rural highways have sprayed seal as the wearing course. Of these some have also been constructed using cement treated crushed rock base which is displaying signs of cracking. In these situations the GRS is applied to the existing running surface and the new 14/7mm double double seal becomes the new wearing course. However in this situation the design of the GRS is subject to all the variables and constraints that are typically encountered with designing a sprayed seal.

The current pavement structure is similar to:

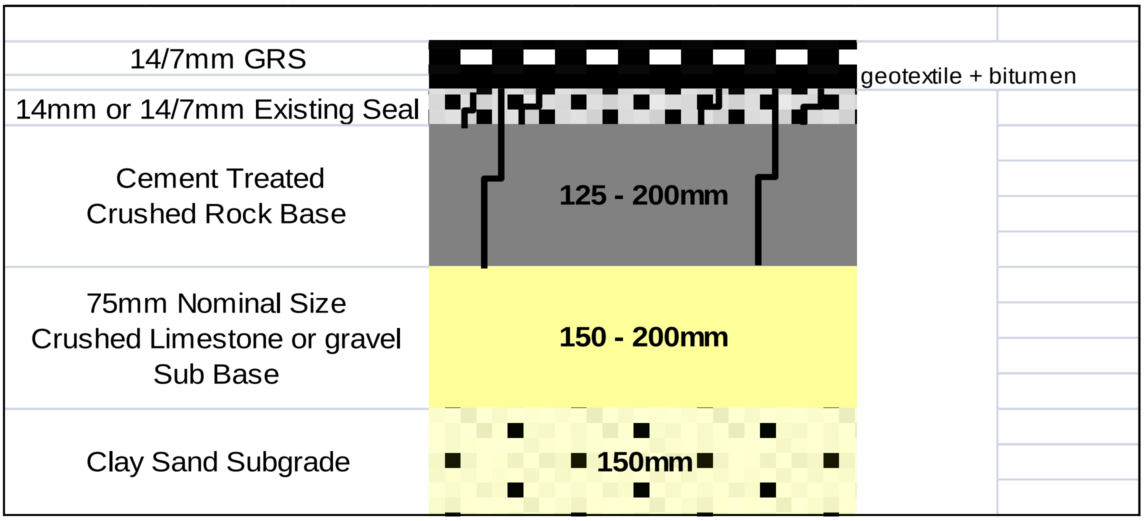


The Remedy

Applying a 14/7mm GRS in theory will prevent the underlying cracks (Photo 2) from seeing the light of day for many years.

Photo 2

Again Main Roads WA elected to use the heavy grade of geotextile fabric as specified in Table 1 to maximise the volume of bitumen contained within the 14/7mm double double GRS that can be applied within the constraints of the seal design.
Class 170 bitumen is the binder of choice and has very good visco-elastic properties which enable the bitumen membrane to remain flexible and relatively "self healing".
What I mean when I use the term "self healing" is that in warmer weather the Class 170 binder will flow and seal over any cracks trying to penetrate the seal. The binder will maintain this ability for many years before steric hardening and oxidation stiffen the binder to the point that it loses its visco-elastic qualities.
Once the GRS is applied to the wearing course of the road the pavement structure looks more like:



GRS Placement

The orientation of the geotextile cloth is as detailed in Figure 4 and the design of the bitumen application rates (BAR) must include all the known variables that will impact on the total amount of binder. Variables such as surface texture, surface embedment, traffic load and distribution, road geometry are quantified and included in the BAR determination. Main Roads WA uses the Austroads Sprayed Seal Design Method in conjunction with the Austroads Technical Report for Geotextile Reinforced Seals.

Typical GRS BAR Design used as a SAM are:

Class 170 Bitumen calculated at 15°C.

SLOW LANE		**FAST LANE**	
Bond Coat	0.9L/m^2	Bond Coat	0.9L/m^2
1st Coat (14mm)	1.2L/m^2	1st Coat (14mm)	1.4L/m^2
2nd Coat (7mm)	0.7L/m^2	2nd Coat (7mm)	0.7L/m^2
Total Binder	**2.8L/m^2**	**Total Binder**	**3.0L/m^2**

These BAR designs are desktop designs and need to be verified as appropriate and adjusted when onsite.

Aggregate spread rates

14mm – 100m^2/m^3
7mm - 250 m^2/m^3

Placing GRS as a SAM successfully is also greatly impacted by the weather at the time of application. The climate around Perth is Mediterranean which means that it has cool wet winters followed by dry and very hot summers. Based on the climate, sealing works are predominantly done during the summer months where a seal designer has less variable weather conditions.
Furthermore the hot summer months are essential for "bedding" the seal down.
The pavement temperature in summer on a Perth metro highway can be as much as 40 - 45°C at approximately 9:00am reaching upwards of 55 - 65°C by 2:00pm. Class 170 bitumen starts flowing freely in temperatures approaching the high 50's which can cause some serious problems on the day.
Main Roads WA does specify cutting the Class 170 bitumen of a final seal however but this is not done during hot weather. However we do specify that the aggregate is to be precoated with distillate containing adhesion agent to promote adhesion of the bitumen to the predominantly granite aggregates. During very hot weather the amount of precoat needs to be controlled as any free precoat fluid will slightly cut the viscosity of the binder which on a hot day can cause the binder to become too thin and begin to flow at lower temperatures. Ideally the precoated aggregate should be what is called "surface saturated dry". That is, the surface of the stone has been completely covered with the precoat fluid however there is no excess or free fluid so the stone feels dry to the touch. To achieve this surface saturated dry state the aggregate may need to sit and drain for a number of days in a stockpile which can be mixed regularly with a loader to expose the aggregate to the air and thus aid in drying the aggregate of excess fluid.

During periods of very hot weather the various bitumen coats applied during the application of the GRS can be varied to control the amount of binder at each stage. However the total quantity of binder applied should remain as per the BAR design for the seal. The bond coat should provide enough binder to adequately bond the geotextile to the existing surface as can be seen in Photo 3.

Photo 3

With adequate binder and rolling the geotextile surface should indicate a slightly mottled appearance where the bitumen is beginning to draw up through the geotextile as in Photo 4. However there should be very little or no free binder drawn to the upper surface of the geotextile.

Photo 4

When pavement temperatures approach 55°C it is prudent to drop the Bond Coat BAR down to prevent flooding the geotextile cloth with bitumen as can be seen in Photo 5. Depending on the expected maximum pavement temperature of the day the Bond Coat can be dropped to as low as $0.4L/m^2$ and still achieve a satisfactory outcome as in Photo 4. However the amount the Bond Coat is reduced should then be added to the 1^{st} Coat so that the total amount of binder remains as per the design.

Photo 5

Furthermore the sprayer operator should be proficient in particular during very hot weather so as to avoid the sprayer sitting on the geotextile for lengthy periods. The sprayer operator needs to determine the pump revs and forward speed required to deliver the design BAR before moving onto the fabric.

The longer the machinery sits on the cloth the more binder is drawn through the cloth and is picked up by the tyres which can lead eventually to the pick up of the geotextile as in Photo 6. This pick up of the geotextile occurred despite dropping the bond coat down to 0.4L/m^2.

Photo 6

The essential practice in hot weather is not to traffic the geotextile by keeping all construction traffic off the cloth as much as possible. This can be facilitated by having all construction traffic such as spreader trucks arrive and leave always on the finished seal. When rolling the geotextile with a multi tyred roller it may take only one pass on a hot day to achieve the outcome as in Photo 2 whereas on a cool day it may take two or three passes to achieve the same outcome.

A second problem associated with applying GRS in very hot weather is that the binder in the second coat may also cause the 7mm stone to pickup under traffic very quickly

subsequently exposing the 14mm aggregate to traffic which in turn can be picked up by tyres. To mitigate this problem the BAR of the 2nd Coat can be dropped down to 0.5L/m^2. However the decision to do this needs to be made in advanced so that the balance of the binder is added to the 1st coat in order to keep the total binder as per the design.
Photo 7 is showing a section of freshly placed GRS with a 14/7mm double double seal when pavement temperature reached 60°C.
With only construction traffic moving over the seal this was enough to pick up both the 7mm and 14mm stones off the geotextile. Within an hour of the photo being taken the whole 1.1km section of GRS applied on this day turned black as the bitumen began to flow coating all aggregate particles and causing aggregate pick up. To control the pickup, 7mm aggregate was re-applied at a rate of 200m^2/m^3 which is overspread to prevent the tyres from coming into contact with the binder.

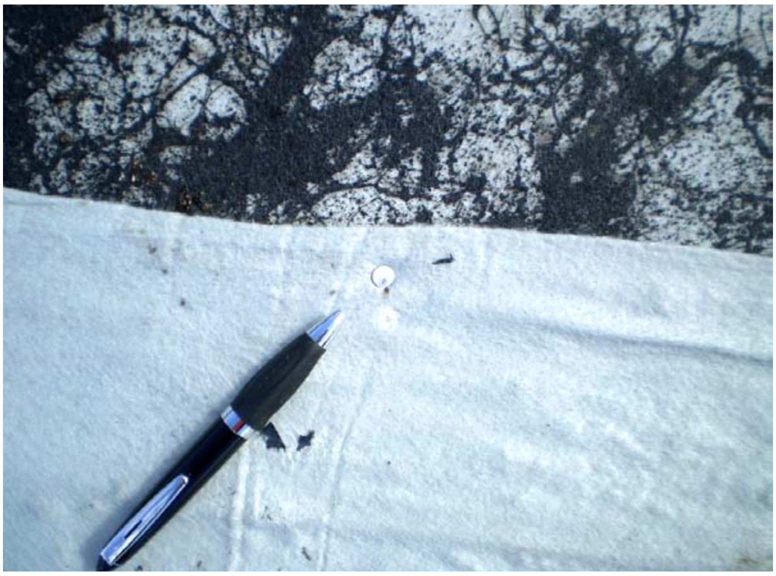
Photo 7

Thirdly a series of issues associated with the overlap at the centre line have been detected:

- During summer, Perth can experience some strong and at times very hot winds coming off the hinterland. These winds can lift the geotextile cloth at the overlap causing it to fold over and double up in thickness. This must be avoided as there will not be enough bitumen at this point to successfully hold the aggregate.
- In addition to this it has been witnessed that at times when the bitumen sprayer is applying the 1st Coat of bitumen on top of the geotextile that a pocket of super heated air can form under the geotextile and cause the cloth to lift off the Bond Coat briefly. This can cause the cloth to crease longitudinally especially at the overlap.
- Furthermore it has been noted that when the geotextile is placed under tension onto the bond coat the longitudinal edges may curl upwards when the 1st coat of bitumen is added on top of the cloth through the effect of the heat. In most circumstances the cloth will relax, uncurl and return to its original position as the bitumen cools. However there are times when the curl remains in a vertical position and can protrude through the overlying seal.

To prevent these issues at the overlap from causing problems a flat head nail is hammered into the overlapping geotextile at the centreline (Photo 8) at a frequency of approximately 5 – 10 metre intervals.

Photo 8



One issue not associated with hot weather that occurs frequently is creasing of the geotextile when being applied. This usually occurs due to uneven tension applied to the geotextile coming off the roll through the applicator. Usually the applicator has not been properly adjusted for elevation or the correct crossfall causing one half of the roll being under tension and the other half being tension free. Creasing can occur more often when negotiating a curve but with the correct tension and crossfall the cloth can be placed crease free.

Photo 9

Creasing as in Photo 9 can cause problems with the geotextile's ability to hold the aggregate in place at this spot due to a lack of binder.
All creases above 20mm of height are hand cut out of the geotextile in a manner that will not overlap the cloth at this point. To achieve this a cut either side of the fold is made then the centre of the fold can then be removed leaving two edges butting together and not overlapping. Failure to remove creases in the geotextile will lead to localised stone loss as can be seen in Photo 10.

Photo 10

Areas to Avoid Placement of GRS

As Main Roads WA is new to the GRS technology numerous enquires were made to more experienced and knowledgeable colleagues in the eastern states regarding their practices.
A couple of experiences worthy of note and worth recognising in this document is that GRS at times can be seen by maintenance Manager's as the saviour of all pavement cracking issues. Unfortunately this is not the case as there are occasions when a pavement is so far gone that even GRS will be of no help.
Materials Engineering Branch staff from Main Roads WA visited a site in Geelong in Victoria where we were shown a failed pavement that had received a GRS SAMI some 18 months earlier.

Photo 11 shows a severely cracked pavement with signs of pumping fines on the surface. This pavement is on a road leading to the Geelong Port and has subsequently failed very soon after remedial works involving the placement of GRS as a SAMI and new dense grade asphalt applied over the top.
What can be determined from this failure is that where the cracked pavement is very mobile and the individual plates of the cracked surface move independent of each other as a load is applied then a GRS would not be able to cope with the stress of this situation very long. Due to the mobility of the platelets of failed asphalt under the GRS the asphalt applied on top of the GRS is subject to high stress which in turn causes fatigue in this asphalt layer. Eventually due to the mobility of the pavement the GRS is also put under stress by the axle loading and eventually the binder within the GRS is stripped away which then allows water to ingress into the pavement.

Photo 11

A second experience from our eastern states counterparts is from South Australia where GRS was applied to a rural road on a bend. Photo 12 is of a GRS SAM applied in 1999 that has suffered slippage under the horizontal shear forces of the traffic negotiating the bend.

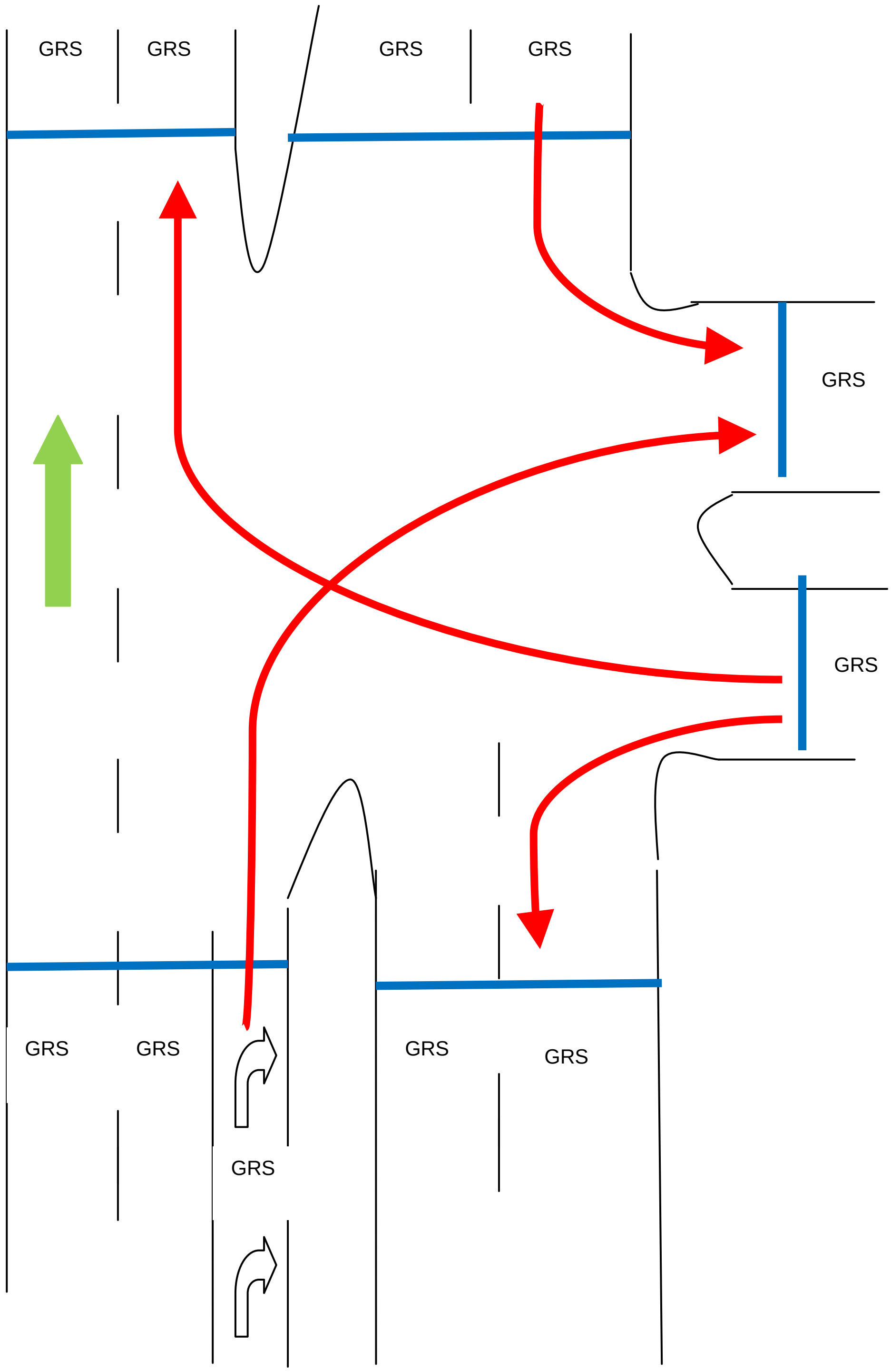
The GRS was comprised of the light weight geotextile with a 14/5mm double double seal on top. The traffic loading now has an Average Annual Daily Traffic (AADT) of 2700 vehicles of which 5% are heavy vehicles.

The binders used were Class 170 bitumen for the Bond coat and 2nd coat and S35E for the 1st coat.

Photo 12

Based on this information and advice from other practioners who use GRS Main Roads WA specify that GRS is not to be applied to areas where horizontal shear forces may cause slippage of the GRS. Figure 5 is a typical scenario of an intersection where the red arrows highlight the turning arcs of the traffic. It is in this area that GRS would not be recommended as the horizontal shear forces may have an impact on the GRS with the potential to cause slippage. Therefore the GRS would be terminated and re-started where it is determined that no vehicle turning occurs as shown by the blue lines. The green arrow suggests that GRS could be placed in this lane if after studying traffic movements it was determined that no turning occurs in this lane.

Figure 5



CONCLUDING REMARKS

Main Roads WA has adopted a technology in GRS to treat areas where pavement cracking has been identified in particular where cement treated crushed rock base has been used as the base course material. Main Roads WA in the past two years has successfully placed hundreds of thousands of square metres of GRS with double double seals on metropolitan major roads in particular to those that have recently been constructed to mitigate problems of moisture ingress through cracking. It is anticipated that this technology will become a routine pavement preservation tool where conditions are favourable for its use. Main Roads WA “Coming of Age” with the use of GRS has been a very steep learning curve. The spray seal and asphalt industry within Western Australia are becoming quite proficient in the application of GRS technology and it will not be too long before they become expert practitioners.

ACKNOWLEDGEMENT

This paper presents the findings of Main Roads WA in the use of GRS technology over the past two years. The author wishes to thank the Managing Director of Main Roads WA, Menno Henneveld.
The author wishes to thank the Technical Support Manager of Sprayline of Victoria, Barry Mulholland and the Senior Surfacings Engineer, Robert Busuttil of DTEI South Australia for their knowledge transfer.

AUTHOR BIOGRAPHIES

Garnet Gregory is the Project Officer Surfacings in the Materials Engineering Branch of Main Roads WA. He has expertise in the design and application of sprayed seals including GRS. Mr Gregory also has experience in the design and selection of asphaltic concrete, the specification and calibration of bitumen sprayers and bituminous binders and additives.