Thin bituminous surfacings for stabilised pavements

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An Important Note For The Reader

The research detailed in this report was commissioned by Transfund New Zealand.

Transfund New Zealand is a Crown entity established under the Transit New Zealand Act 1989. Its principal objective is to allocate resources to achieve a safe and efficient roading system. Each year Transfund New Zealand invests a portion of its funds on research that contributes to this objective.

Contents

Executive Summary

This report was prepared for Transfund New Zealand's 1999/2000 research program. The objectives of this project are to:

- conduct a state-of-the-art review of the use of thin surfacings over bound (cementitiously-stabilised) pavement layers, and
- develop proposals for future research, based on field evaluations of in-service trial pavements.

The major output of the project is the preparation of guidelines for the most effective and efficient use, and management, of thin bituminous surfacings over bound pavement layers. Initially, draft guidelines will be prepared which would be confirmed/revised following field trials.

This report documents current information and research on the use of thin surfacing techniques to reduce or substantially eliminate reflection cracking from cementitiously bound or heavily modified granular pavement bases. Over recent years, a range of thin surfacing treatments have been developed which claim to inhibit the reflection of cracking in base layers through to the surface. However, these surfacings have yet to be widely introduced into New Zealand. Substantial cost savings are possible if practitioners feel confident enough to specify stabilisation techniques, knowing that surfacing treatments are available which can provide effective long-term waterproofing of a surface which may otherwise allow moisture entry into the pavement.

The vast majority of stabilisation undertaken in Australasia involves the use of cementitious binders. The cost of the binding agent typically comprises 50% of the total stabilisation works cost and, where the cost per tonne of cementitious binder is approximately one-third to one-quarter of the cost of bituminous binders; this binder type has become dominant in Australasia.

Cementation is the formation of cementitious hydrates, which bind the soil particles. During the hydration process moisture is consumed by chemical reaction and lost to the atmosphere by evaporation. This results in the shrinkage of the material matrix as cementitious bonds develop and as free moisture is lost.

Classical cracking of cemented base materials comprises transverse and block type cracking associated with material shrinkage during the hydration of the cementing process and also to evaporative losses. The focus of this project is to consider the subsequent traffic-induced cracking of the base material.

Traffic induced cracking also occurs in cemented pavements where the stiffness of the pavement structure allows excessive flexure of the bound layer, i.e. the bound thickness is of insufficient thickness to support the load, or the underlying layers provide insufficient support to the bound layer, resulting in fatigue cracking of this bound layer.

Cracking of pavements is a problem due to the occurrence of rapid moisture ingress to the base, and sub-base layers. Control of moisture content in flexible pavements is critical to their continued performance at a desirable level.

Treatments for reflection crack control include:

- Polymer Modified Binders (PMBs),
- Scrap rubber,
- Geosynthetics,
- Glass fibre reinforced bituminous treatment,
- High mastic type asphalt, and

Strain alleviating membrane interlayer (SAMI) and strain alleviating membrane (SAM) treatments.

Some treatments which reportedly performed well in one trial did not so in another. The fact that the use of SAMIs comprising aggregate covered membranes has been largely discontinued in France due to their poor performance is at odds with current practice in Victoria where geotextile reinforced chip seals are routinely placed over cracked surfaces. OGA[1] performed poorly over jointed concrete pavements at test sites in Belgium, whereas in the VicRoads surfacing trial constructed on new jointed concrete pavement, OGA and SAMI performed very well.

Factors that affect the performance of crack reflection suppression treatments are shown below, with a brief comment relating to the efficacy or chance of preventing cracking reflecting through an overlying surfacing.

Surface factors

- Crack size (width): the narrower the better.
- Crack activity: the less movement the better.
- Crack type.

Key non-surfacing factors

- Drainage: the better drained the pavement, the better.
- Traffic Loading: the lower masses and numbers of vehicles, the better.
- Environmental Loading: the lower the loading (thermal and moisture), the better.
- Base Strength: the stronger the better.

Factors Common to Consistent Performance

- Treatments involving higher bitumen contents performed better than those with lower bitumen contents did.
- Treatments comprising modified binder in asphalts were considered to perform better than those with nil modification.
- Of interest is the good performance of scrap rubber as a modifying agent in bitumen, used in both seal and in asphalt applications.
- Treatments using localised SAMIs such as 'bandage' type treatments did not perform well in the one trial where these were reported.

The table shown over provides performance trends for the factors influencing reflective crack treatments.

[1] Open graded asphalt

Performance Trends for Factors Influencing Reflective Crack Treatments

Treatment Characteristics	Trend	
Bitumen content	The greater, the better performing the treatment.	
Binder modification	By use of polymers and additives, such as scrap rubber, improve the efficacy of these treatments.	
Geofabric	Inclusion provides greater reservoir for bitumen and ability to alleviate strain within surfacing.	
Mastic type asphalts	Higher mastic content (than conventional DGA) assists in proving additional elasticity to the mat.	
Pavement Characteristics	**Trend**	**Related to**
Sound; structurally adequate	Very difficult to mask reflection cracking if pavement is structurally inadequate.	Drainage, traffic loading and inadequate thickness
Active cracks	The greater the movement, the more aggressive the wear on the treatment.	Loading and soundness of pavement
Crack widths	Wider cracking is more difficult to effectively treat.	Base material characteristics
Drainage	Good drainage is generally essential to providing the best performance for any treatment.	
Loading	**Trend**	**Related to**
Environmental; thermal and moisture	The lower the loading, the lower the crack activity.	Drainage and base material characteristics
Traffic; heavy vehicle axle masses and number	The lower the loading (in axle mass and numbers), the lower the activity.	

Trial to Evaluate Proposed Treatments

It is recommended that:

- Reflective crack suppressing techniques should apply to cracks caused by initial environmental loading and to subsequent traffic loadings where the distress mode is primarily cemented-material related.
- Existing flexible pavement sites showing ideally classical shrinkage or block cracking be selected for comparison of crack reflection suppression techniques. Where the ideal crack types can not be located in sufficient extent within a reasonable length site, consideration may be given to the inclusion of other crack types such as crocodile and general cracking for inclusion into the trial sites.
- Sites be selected having cracks, reasonably uniform in severity and activity within the one site (so that individual treatment sections have an equal chance of performance), but differing between the sites to provide for the potential to discriminate between treatments if one site does not provide such indication.
- An estimate be made of crack severity at least for the initial survey, for possible use in discriminating between surface treatment performance.
- Timing for the collection of this data should correspond with the period of maximum crack width.

- Cognisance should be made for any dynamic seasonal behaviour of the cracks.
- Cognisance needs to be made of the contribution of pavement moisture to longitudinal crack dynamics.
- Climatic data for each candidate site should be considered as part of the selection process.
- As it is difficult to quantify the consequence of using two independent teams for assessments, the best test scheme would use the same staff for each of the assessments since the differences are considered most important for the performance indicator, rather than the absolute levels of crack length.
- The best method for this study, is that of physically mapping the cracking in Sections based on discrete chainages, annotated with a general indication of crack severity (width and activity).
- Crack lengths should be normalised for ease of comparison of treatment efficacy.
- Given the level of uncertainty associated with this crack assessment approach, implying too much precision into the treatment ranking based on absolute length of cracks re-appearing may be unproductive. Grouping the treatment performance together may help identify a broad property/performance relationship.

Based on the evidence gathered for this report strong consideration should be given to selection of the following treatments:

- Scrap rubber SAM,
- PMB SAM,
- Geosynthetic reinforced seal, and
- Glass fibre reinforced bituminous treatment.

ABSTRACT

This report presents a state-of-the-art review of the use of thin surfacings over bound (cementitiously-stabilised) pavement layers and develops a test protocol for future research, based on field evaluations of in-service trial pavements. Current information and research primarily from Australasia on the use of thin surfacing techniques to reduce or substantially eliminate reflection cracking from cementitiously bound or heavily modified granular pavement bases is presented. Over recent years, a range of thin surfacing treatments have been developed which claim to inhibit the reflection of cracking in base layers through to the surface. Treatments for reflection crack control included polymer modified binders, scrap rubber, geosynthetics, glass fibre reinforced bituminous treatment, high mastic type asphalt, and SAMI and SAM treatments. Factors that affect the performance of crack reflection suppression treatments are given, with a brief comment relating to the efficacy or chance of preventing cracking reflecting through an overlying surfacing.

1 Introduction

This report was prepared for Transfund New Zealand's 1999/2000 Research Program, Project 0403. The objectives of the project were to:

- conduct a state-of-the-art review of the use of thin surfacings over bound (cementitiously-stabilised) pavement layers, and
- develop proposals for future research, based on field evaluations of in-service trial pavements.

The major output of the project has been the preparation of guidelines for the most effective and efficient use and management of thin bituminous surfacings over bound pavement layers. Initially, draft guidelines were prepared which would then be confirmed/revised following field trials.

This report documents current information and research on the use of thin surfacing techniques to reduce or substantially eliminate reflection cracking from cementitiously bound or heavily modified granular pavement bases. This information comprises published data, data associated with work in progress or yet to be published and information obtained through discussions with surfacing and pavement practitioners and industry personnel.

2 Background

The release of the Austroads (1992) 'Pavement Design Guide' and the Austroads (1998) 'Guide to Stabilisation in Roadworks' has resulted in an increased interest in New Zealand in the use of stabilised materials for both new construction and for rehabilitation. The benefits of the use of stabilised pavement layers include the savings associated with the use of locally available materials rather than higher quality aggregates and the improved performance that can be expected in terms of increased design life.

However, these benefits are not being realised in New Zealand because of the conservative approach being taken by some designers who still recommend that a minimum cover of unbound M/4 basecourse is required which cannot be replaced by a stabilised material of equivalent strength and durability.

One of the major reasons for this conservative approach is the expectation that cement-stabilised materials will crack under traffic and that this cracking will reflect through to the pavement surface, which is generally a thin bituminous seal. The concern is that, if cracking does occur, then the surface will disintegrate under loading and the associated entry of water into the sub-layers of the pavement will lead to inevitable failure requiring costly rehabilitation works or, at worst, total reconstruction.

Over recent years, a range of thin surfacing treatments have been developed which the manufacturers/suppliers claim inhibit the reflection of cracking in base layers through to the surface. However, these surfacings have yet to be widely introduced into New Zealand. Substantial cost savings are possible if practitioners feel confident enough to specify, and implement, the use of these types of thin surfacings into New Zealand practice. The cost savings will be derived from:

- the use of cheaper, locally-available materials which do not meet specification requirements in their unbound form but would be suitable for use in a stabilised or modified form;
- the lack of the need for the inclusion of an unbound base layer over the top of the stabilised sub-base;
- associated environmental and community benefits through reduced quarrying and haulage operations;
- increases in pavement life resulting from the use of stabilised layers within the pavement structure; and
- savings in rehabilitation costs through the use of thin surfacings rather than expensive structural asphalt or granular overlays.

In addition, increased confidence in the use of thin surfacings over cement-stabilised layers, will result in an increased level of confidence in the use of alternative cementitious binders, such as bitumen/cement, especially in rehabilitation treatments involving the recycling of existing unbound materials using *in-situ* stabilisation.

3 Definition and Types of Stabilisation

Stabilisation of a pavement material is a process by which the material's properties are modified to perform a desired function. The physical material parameters to be modified can be varied, ranging from permeability, plasticity, shear strength, stiffness and particle size distribution amongst others.

Typically, stabilisation as it pertains to pavement construction and rehabilitation, refers to improving the stiffness or strength of a material such that:

- loads placed upon the pavement material may be better distributed to lower layers in the pavement, resulting in a reduction in stress and hence a delay in the onset of rutting, and

- the stabilised material is able to withstand the imposed traffic loading and sustain an acceptable amount of deformation, i.e. it has sufficient shear strength to resist rutting or shoving.

3.1 Methods of Stabilisation

The major methods of stabilisation of pavement materials, in decreasing order of usage, are as follows:

- chemical - by cementing action via cementitious binding agents;
- physical – by the gluing together of material particles, typically by use of bitumen; and
- mechanical - by the blending of materials, which each have different but generally complementary properties, to form a hybrid material that has the desired properties.

Of the above methods the vast majority of stabilisation undertaken in Australasia, either in square metres of pavement treated or by monetary value, involves the use of cementitious binders. As the cost of the binding agent typically comprises 50% of the total cost of the stabilisation works, it is not surprising that this binder type is dominant in Australasia because the cost per tonne of cementitious binder is approximately one third to one quarter of the cost of bituminous binders

3.1.1 Cementitious Stabilisation

Cementitious stabilisation involves mixing a small percentage of either a Portland cement and/or blended cement with other cementitious additives into a variety of materials, ranging from cohesionless sands and gravels, to more plastic clays and silts, to reduce the moisture susceptibility and to increase the materials strength. Cementation is the formation of cementitious hydrates, which bind the soil particles. During the hydration process moisture is consumed by chemical reaction and lost to the atmosphere by evaporation. This results in the shrinkage of the material matrix as cementitious bonds develop and as free moisture is lost.

The greater the cement content added, the greater the demand for moisture to complete the hydration process and thus the greater the net shrinkage.

4 Cracking of a Cemented Layer

When sufficient cementitious binding agent is used in a granular material to create a bound material, the pavement material shrinks and cracks, initially in a transverse pattern at a spacing of about 40 times the stabilised layer thickness for high quality host material. The initial spacing of transverse cracking will be less for poorer-quality host materials, such as those with higher plasticity or excess of fines. At this stage this phenomenon is termed 'environmental cracking' and if not loaded by traffic, additional transverse cracking may eventually appear which may double the number of transverse cracks per unit length of pavement.

Depending upon the layer thickness, composition and strength of the base material, traffic loading may then accelerate this process, resulting in additional transverse and longitudinal cracking of the stabilised layer. Such cracking can become relatively closely spaced in both directions, sometimes to the point that it appears to be more like fatigue (crocodile) cracking.

The design philosophy adopted in New Zealand for low quality base materials permits the improvement of these materials by stabilisation such that the total thickness of cover (base and subbase) to subgrade satisfies the design requirement. The stabilised base layer is not considered to have any 'first life', i.e. in the uncracked cemented mode, and is considered to commence it's service life as 'fully cracked'. Where the cemented material cracks further under the action of traffic loading, additional (block then fatigue) cracking occurs. It is this cracking which reflects through the applied thin surfacing and which desirably should be controlled.

When a cemented base layer is trafficked prior to the strong bonds being developed within the stabilised soil matrix it is widely believed that the process of micro-cracking may occur. This occurs when the cementitious bonds are broken at the micro-level within the soil matrix whilst the tensile strength of the bonds are still low. This action is similar to that occurring in transverse contraction joints in a concrete footpath or highway pavement, i.e. many cracks or physical discontinuities form within a given length of cemented material, rather than one wide crack or joint forming at a much wider spacing. Micro-cracking can reduce or largely eliminate transverse cracks caused by shrinkage.

Crack movement and the build up of stresses in cementitious materials result from thermal loading (Wright and Guild 1996). Cemented materials containing aggregates having a large thermal coefficient, combined with extreme diurnal temperature variations (typically inland desert situation), will exacerbate the occurrence of this mode of cracking.

Cracking of pavements is a problem because they allow rapid moisture ingress to the base and subbase layers. Control of moisture content in flexible pavements is generally critical to their continued performance at a desirable level. Severe changes in moisture content (generally an increase for granular layers) may lead to a range of deleterious changes in the physical properties of the pavement and subgrade materials. In addition, the presence of free moisture and cracking or fissures within the pavement structure, typically permits the phenomenon of material erosion and pumping whereby key material elements (binder and or fines components; typically < 0.075 mm size particles) of the pavement are ejected.

Cracks in a stabilised pavement largely control the durability of the pavement, these forming the 'weak link' in much the same way that joints in a rigid pavement require careful design and attention to detail if their load-transfer ability is to be maintained.

Therefore one of the key reasons cited for crack control treatments, including reflection cracking, is that of waterproofing the pavement (Edser 1990).

5 Treatment of Cracked Layers

5.1 Polymer Modified Binders (PMBs)

5.1.1 Performance of PMBs

One of the pavements tested during the Callington (South Australia) ALF[2] Trial (Statton and Kadar 1990) consisted of a thin layer of open-graded asphalt (OGA) over a SAMI[3] with and without a modified binder in the OGA. Testing was conducted during cold conditions and Statton and Kadar concluded that:

> *Comparative overlay experiments clearly demonstrate a significant extension in treatment life [reflection cracking] through the use of a modified binder in asphalt overlays.*

Guozheng (1996) concluded that ['rubber'] modified bituminous asphalts [PMB asphalts] had enhanced stability in high temperatures, and an increased ductility at

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[2] Accelerated Loading Facility

[3] Strain Alleviating Membrane Interlayer

low temperatures resulting in an increase in the shear fracture and fatigue life of bituminous mixes.

Austroads (1997) provides a specification framework for sealing and asphalt grade PMBs, which was developed for use by Member Authorities as a basis for their model and standard specification documents. Part 2 of this document is the *Companion PMB Selection Criteria* where a decision tree to assist in the selection of the appropriate PMB class is presented as part of the guidelines. Three tables are extracted from this document and are presented in Appendix A (note the nomenclature of Class types used in this document are Australian):

- PMB selection Criteria for Sprayed Sealing Applications - A. Strain Alleviating Membrane Interlayer (SAMI).
- PMB Selection Criteria for Sprayed sealing Applications - B. Strain Alleviating Membrane (SAM).
- PMB Selection Criteria for Asphalt Applications - B. Fatigue Resistance.

Supporting notes are provided at the foot of each table to assist in the selection of the appropriate generic product.

Suggested PMB materials for placing a SAM onto cement-treated base are those given in the tabulation in Appendix A, Section B, column headed 'slow movement (environmental)' crack type.

5.1.2 Use of PMBs in New Zealand

Asphalts and bitumens comprising PMBs have had mixed success in New Zealand (Patrick 2000) as they have in Australia. Monitored trials of modified binders for use in high-stress chip seal application have not shown the PMBs to have a clear advantage over non-modified binders.

Where binder application rates are higher, as used for retardation of reflection cracking, the PMBs have had variable success.

5.2 Scrap Rubber

5.2.1 General

Scrap rubber is only one of a range of (polymer) modified bitumens which are used in road surfacing applications. Modified bitumens are generally used on defective or highly stressed pavement surfaces where a conventional bitumen binder would not be expected to perform well (RTA 1995).

Scrap rubber comprises fine particles, generally vehicle tyre buffings from retreading works or conveyor belts etc. made from either natural or synthetic rubber.

In Australia the scrap rubber has generally undergone vulcanisation (or cross-linking) which introduces chemical bonds and improves mechanical properties. Conventional bitumen is a ductile material with a limited elastic recovery. Scrap rubber bitumen has increased elastic recovery providing improved performance as a crack treatment. Generally higher application rates are used for scrap rubber bitumen binders, including a higher binder content in scrap rubber asphalt to provide a longer fatigue life (RTA 1995).

5.2.2 Use in Sealing Cracked Surfaces

Seals with a moderate proportion of scrap rubber in the binder (15 to 20% by mass) are considered suitable for use as SAM seals over a cracked surface, to waterproof the pavement and extend the pavement's service life prior to further treatment (RTA 1995).

Seals with high a proportion of scrap rubber (20 to 25% by mass) in the binder are suitable for SAMIs on badly cracked, but structurally sound pavements, prior to asphalt overlay. Major cracks should be filled and major patching be undertaken prior to the SAMI treatment (RTA 1995).

5.2.3 Use of Scrap Rubber Seals in New Zealand

This technique of using granulated scrap rubber appears to have gained only limited use in New Zealand, due possibly to the comparative ease of using other modifiers with bitumen, other than scrap rubber (Patrick 2000).

5.3 Geosynthetics

The term geosynthetic has become the widely used generic term for the terms geotextile geogrids and geofabric materials. Geosynthetics, in conjunction with bituminous materials, are selected in interlayer and strain alleviating treatments to either:

- reinforce by offering tensile strength to [overlying] asphalt (eg. geogrids), or
- relieve stress by transferring movement stresses into a bitumen-impregnated fabric (e.g. geotextiles) (Wright and Guild 1996).

5.3.1 Reinforcement

The geosynthetic material to be used in a reflective crack control system is required to have a tensile strength greater that the enveloping material and a low elongation, such that the strength of the geosynthetic may be mobilised to offer a reinforcing role for the crack control overlay. Kirschner (1990) has determined that the tensile strength of such reinforcement should not be less than 35 kN/m in both material directions and that, at a strain of 3%, a tensile strength of at least 10 kN/m be developed to absorb stress within the overlying pavement layer. *Geogrids* provide this reinforcement function.

5.3.2 Stress Relief

Most geosynthetic materials used for stress relief are non-woven *geotextiles* that exhibit a minimum tensile strength of 1.2 kN/m and a minimum elongation of 50% at break. The material of low tensile strength and high extension bridges the crack. Bitumen is impregnated into the geotextile and finished with a surface dressing which would usually be stone chippings. By bridging the cracks with this layer, lateral movements within the pavement surface are transmitted laterally into the body of the interlayer and absorbed. Therefore the aim of this system is not to prevent movement as in the 'reinforcing' concept, but rather to permit movement, dissipate its effect over a greater area than that of the immediate crack-zone, and prevent cracking from progressing through this interlayer and any applied overlying surfacing.

This method has the secondary but very important function of waterproofing the pavement surface by the reduction of severity or the elimination of cracks reflecting through the SAM or to the new surface if used as a SAMI.

5.3.3 Surface Treatments Overlying the Geosynthetics

Of the above two mechanisms, the reinforcing method is typically used in conjunction with asphalt overlays, such that the asphalt physically envelops the 'geogrid' to realise the reinforcing potential of the grid. The stress relief method (of a low tensile strength geosynthetic) employs overlying surfacing treatments of both chip seals and asphalt.

5.3.4 Disadvantages of Reinforcing and Stress Relief Systems

- Stress relief geosynthetics do not contribute structurally to the pavement, as is sometimes claimed by producers of reinforcing type geosynthetics. In the author's experience, 'geogrids' similarly do not provide additional structural capacity to a pavement when applied in a thin surfacing layer.
- Stress relief geosynthetic structures allows the ready absorption of bitumen, which also means free water may also be absorbed. This is be considered to be only of concern in cool and very wet temperate climates where delamination of the layer from its substrate may occur.
- Stress relief geosynthetic systems do not perform well at locations of high shear loading from traffic.
- Reinforcement geosynthetics have an inherent rigidity and inelasticity that is non-compatible with asphalt material that may expand and contract greatly with seasonal and diurnal temperature changes. This, however, can be considered to be a strength of the 'geogrid' reinforcing system.
- Reinforcement geosynthetics do not adhere well to the underlying substrate and do not bond well together, such that when overlayed at joint zones, they form a zone of separation and weakness in the reinforcing system.
- Reinforcing geosynthetics cannot develop a reinforcing tensile strength at their joints, unless care is taken to ensure that adjoining rolls of reinforcing geosynthetic are mechanically joined, or that the roll of material is securely anchored to the pavement. In the latter case (at the edge of the roll of geosynthetic) any movement of the pavement may then reduce the tension in, and hence the efficacy of, the geosynthetic.
- Reinforcing geosynthetics can be difficult to attach securely to the pavement, especially on curved pavements, and may present difficulties in being paved with asphalt because any looseness of geosynthetic will cause a 'bow wave' of geogrid to form in front of the paver, which will require cutting and tamping into the asphalt mat, thereby destroying the localised efficacy of the reinforcing system.
- Reinforcing geosynthetics installation costs are typically two to three times those of stress relief geosynthetics, based on UK data from the mid 1990s (Wright and Guild 1996).

5.3.5 Composite Reinforcement/Stress Relief Geosynthetics

Products are available which aim to combine properties of both the reinforcing and the stress relief systems, albeit compromising the key properties of each of the separate material systems. The aim of these materials is to provide tensile strength to resist intermediate strains, as well as offering an impermeable stress relieving function to provide waterproofing to the pavement. One such material is a woven polypropylene (Loktrak Pavelay, a product of Don and Low Ltd. UK, Wright and Guild 1996). To-date, trials undertaken and reported in Wright and Guild (1996) over concrete slabs on a test track in England have not yet showed any difference in performance to the control section without the Pavelay.

Glassgrid (Australia) and Glasphalt (Europe) are glass fibre bitumen impregnated (or bitumen backed) materials which provide stress relieving and reinforcing properties to overlay systems. In Glasphalt, a non-woven polypropylene fabric backs the glass grid. Netlon (UK) have produced Tensar AR-G which comprises a polypropylene geogrid (Tensar AR-1) thermally bonded to a thin non-woven polypropylene geosynthetic. These composite geosynthetics are generally used in conjunction with asphalt overlays.

5.3.6 Current Usage in New Zealand

Geofabric seals have been in use in New Zealand for at least ten years (Patrick 2000). Local authorities have been the main user of this type of treatment, where crack sealing has been the prime function of the geofabric seal. It is believed that this treatment has been used to rectify flushed seals as well.

5.4 Strain Alleviating Membrane Interlayer (SAMI) and Strain Alleviating Membrane (SAM) Treatments

5.4.1 SAMI

SAMI is an acronym in generic use for the term Strain Alleviating Membrane Interlayer (Austroads 1992). Other variations noted in overseas literature for 'SAMI' are Stress and Absorbing for the terms Strain and Alleviating. Whatever the term in the literature, SAMI refers to a material, or system of materials, that have low tensile strength and good elongation properties at the point of breaking. In this way the SAMI does not act as a reinforcing medium, but as a medium which can bridge cracks and absorb the lateral movement directly into the body of the SAMI, thereby dissipating the effect of the movement in the lower layer and preventing its transmission into the upper layer.

SAMIs are generally used:

- on cracked pavements, and
- to waterproof pavements and bridge decks.

5.4.2 SAM

Where no overlay or surface or wearing course is placed above the Strain Alleviating Membrane the treatment is simply known by this name, abbreviated to SAM, i.e. it does not form an interlayer. Typically SAMs comprise a thick layer of bitumen which may or may not be modified (by scrap rubber or polymers) and a protective coating of either aggregate chippings or a geosynthetic material with an additional coating of bitumen and aggregate chippings.

An additional and often important function of a SAM or SAMI is that of waterproofing the pavement to reduce the amount of water that may reach the base and subgrade layers, to maintain the strength of the pavement system under traffic load.

Perez-Jimenz *et al.* (1996) concluded *inter alia* that the important physical properties of a SAMI for resisting reflective cracking are, to be a tenacious material with a high fracture energy by area unit, to exhibit ductile fracture, and to have a low modulus of elasticity and high flexibility. Perez-Jimenz's laboratory research clearly indicated that the inclusion of acrylic fibres to asphalt improved these key physical parameters over non-modified asphalt. This finding lends support to the practise of introducing fibres into very thin SAMIs and SAMs such as sprayed bituminous layers reinforced with glass fibres. (refer to Section 5.5)

The monitoring of the performance of SAM and SAMI treatments in the field indicates the following (Austroads 1998):

- The performance of the treatment is dependent on the degree and rate of crack movement and on crack width.
- Pre treatment of cracked pavements is essential.
- The treatments are effective in minimising the reflection of fine to medium cracks from the underlying surface/underlying layer when the cracking results from fatigue failure of the original surface/underlying layer and minimal environmental crack activity is present.
- With medium to coarse cracks, and where environmental activity if present, the treatment merely delays reflection cracking. However, the resultant reflection cracking could be less severe than the cracking in the original underlying surface.
- The treatment cannot be expected to prevent the reflection of wide active cracks from the underlying surface without other remedial action.
- PMB treatments are more effective in dealing with cracking caused by surface deterioration and binder hardening, and are less effective for treating severe structural and environmental cracking.
- These treatments can arrest degradation of distressed pavements by preventing further ingress of water.
- Selected PMBs will reduce shearing on winding roads and high stress areas.
- These treatments are considered to be methods of strategic control of surface distress, and not necessarily its elimination.
- SAMI treatments can prevent water ingress despite some reflective cracking in the asphalt.
- SAM and SAMI treatments have limited effect in the treatment of pavements with pumping problems.

5.4 3 Current Use in New Zealand of SAM/SAMI treatments

These techniques have been in use in New Zealand for about 20 years (Patrick 2000).

5.5 Glass Fibre Reinforced Bituminous Treatment

5.5.1 General

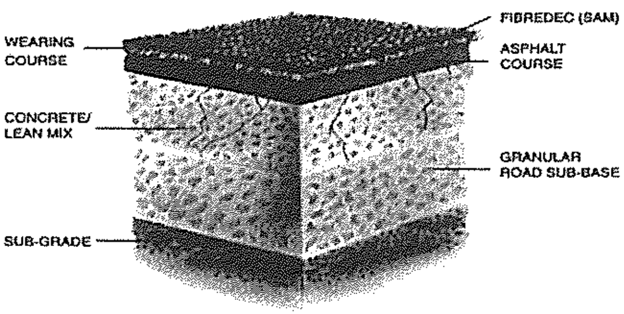
This treatment is known in Australia as the Fibredec system and is promoted in Australia by Pioneer Road Services. Fibredec is a sprayed sealing system comprising two coats of polymer modified bitumen emulsion, between which is applied a layer of glass fibre strands (60 mm in length, added to achieve typically 80 g/m^2). Fibres are blown onto the initial bitumen coat in a random arrangement that is claimed to resist reflection cracking. A layer of sealing aggregate is then spread and rolled to complete the Fibredec surfacing process.

5.5.2 RTA (NSW) Technical Guide

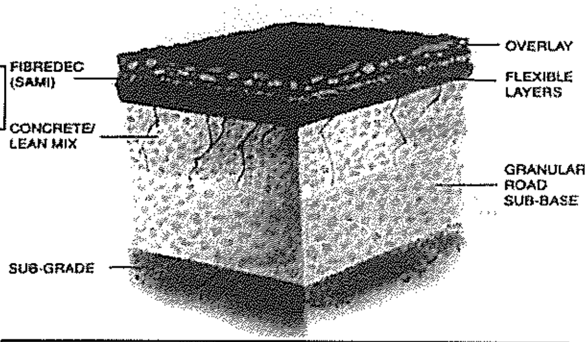
RTA NSW (1994) has produced a technical guide for the use of the Fibredec system of reinforced bituminous-sprayed sealing. This guide comprises sections detailing with their selection and use, materials, surface preparation, plant used and field operations.

- Fibredec's key applications include:
- surfacing of cracked pavement (SAM), and
- as a SAMI between asphalt layers of a pavement.

These applications are illustrated in Figure 1.



Fibredec SAM surfacing on cracked pavement



Fibredec SAMI for overlay

Figure 1: Various Fibredec Applications (RTA NSW 1994)

The main benefits of the Fibredec system include (RTA NSW 1994):

- cost-effective treatment for cracked pavements (cheaper than geotextiles and has potential to outlast traditional maintenance without strain alleviation);

- may be laid at near ambient[4] temperature, providing operational and environmental benefits; and
- the use of emulsion means that the treatment may be laid throughout the year, even under cool and damp conditions.

The application of the Fibredec system is relatively simple, through a purpose-built machine. Benefits of its application (RTA NSW 1994) are:

- treatment is completed in one pass, minimising disruption to traffic,
- traffic may use the new surface immediately after rolling, and
- the use of emulsion leads to minimal splashing and over-spray (than of less viscous binders).

The Fibredec system has the advantage over traditional geosynthetic reinforced overlays in that:

- it is approximately twice as fast in its application,
- it can be placed in windy conditions, which may cause difficulties with geosynthetics,
- no jointing is required,
- typically the residual binder application rate is 1.8 L/m^2 (for a 14 mm size aggregate) compared to 2.6 L/m^2 for a geosynthetic seal, and
- curved alignments require no additional effort.

Lysenko and Scott (1999) report that:
"The tensile strength developed by the Fibredec system is considerably lower than that of many other geosynthetics, however, it is adequate for the purpose of inhibiting crack propagation. Tensile strength, while important, is not considered to be a controlling factor in the reduction of reflection cracking."

5.5.3 Performance of Fibre-Reinforced Seals

The overall performance of the fibre-reinforced membrane is determined by a combination of fibre type, length and concentration as well as the binder quality. Glass fibre reinforced seals are designed in accordance with conventional methods. However, an additional 0.5 L/m^2 of binder is required to allow for fibre absorption, and an additional 10 to 12% of the emulsion binder is allowed to provide satisfactory initial stone retention. As the emulsion is polymer modified, the seal is less temperature sensitive than conventional seals at a given binder level.

As with most surfacing treatments, the level of crack retardation is a function of the initial pavement condition and that of the loading regime, primarily traffic-induced loads. Summarised results of RTA NSW trials undertaken on heavily-trafficked roads are reported in Lysenko and Scott (1999) which indicate very good performance in the prevention of fatigue cracking after three to four years of monitoring.

5.5.4 Use of Fibre-Reinforced seals in New Zealand

At the time of preparation of this report the system of insitu fibre-reinforced seals is not being used in New Zealand (Patrick 2000).

[4] When pavement is very hot, it is required to be cooled via a water spray.

5.6 High Mastic Type Asphalt

Mastic asphalt comprises a gap-graded mineral content such that a proportionately larger mass of fine mineral particles and bitumen binder are present in the mix. When combined with the bituminous binder these smaller particles combine to form a mastic which envelopes the coarse sized aggregate. In Australia, where fibres are added to the mix which provide improved toughness and tenacity of the mastic, this is known as stone mastic asphalt.

Vanelstraete and Decoene (1996) reported on 13 test sites within Belgium where cracked and jointed (rigid) pavements were overlaid with a combination of types of geosynthetics and types of PMBs to impregnate the materials. As with most literature on the control of reflective cracking, the cracked or jointed pavements were typically fully bound (Portland cement concrete) or heavily bound cement-treated granular bases.

From the evaluation of the 13 projects, it was concluded *inter alia* that high mastic type asphalts are advantageous in the prevention of reflection cracking. This was in contrast to porous asphalt, which although placed at the same site one year earlier, has fully cracked after 4 years. The observation that high mastic asphalt had good potential for reducing crack reflection supports a VicRoads trial (refer to Section 5.1) where the stone mastic asphalt performed the best of five bituminous treatments over a jointed concrete substrate. However the poor performance of the open-graded asphalt is in contrast to the same VicRoads trial, where this material performed almost as well as the mastic asphalt.

Another point from Vanelstraete and Decoene's paper (1996) pertinent to this project, and to pavement rehabilitation in general, was the recognition of the importance of proper drainage, the authors noting some distress observed at the sites had been due to a lack of adequate drainage.

5.7 Ultra-Thin Asphalt

In keeping with the aim of this project, which is specifically targeting thin (bituminous) surfacing layers, asphalt as a surfacing has not been considered in detail, apart from being reported as part of trials. However, the process of ultra-thin asphalt is worthy of consideration due to, as the name suggests, its ability to be laid thinly. In many urban areas where a smooth and quiet surface is desirable, ultra-thin asphalts have been placed as part of rehabilitation treatments for surfaces that have been previously cracked.

An ultra-thin asphalt friction course comprises a layer of open-graded hot mix placed over a heavy polymer-modified asphalt tack coat. The course thickness ranges from 10 to 20 mm, with the layer thickness being typically 1.5 times the diameter of the largest stone. A single pass of a proprietary designed, multi-purpose paving machine applies the thin layer of asphalt and warm binder. This treatment is also referred to as 'paver laid seal'.

This process was devised by the French in the mid 1980s, with the aim being to produce a very thin asphalt surface course with similar textural appearance to that of a seal but without the problem of loose aggregate (Austroads 1994). Boral Asphalt introduced this process into Australia in 1993 and to 1997 approximately 500,000 m^2 of this surfacing had been placed (Wonson 1997).

Ultra-thin asphalt can be placed as a final wearing course on new construction.

Specific trials designed to test the efficacy of ultra-thin asphalt to resist reflection cracking are not known, but rather instances where the process has been used, as stated above, in rehabilitating sound but cracked heavily-trafficked surfaces. To date, anecdotal evidence is that where it is used on sound pavements, the performance in resisting reflection cracking due to underlying shrinkage and fatigue cracking has been very good.

Austroads (1994) reports that the cost per square metre of ultra-thin asphalt is approximately AUD $ 5.00, a 10 mm reseal AUD$1.50 and, for 25 mm of open-graded asphalt with modified binder, AUD$ 9.00.

5.8 Placement of Treatments onto Stabilised Surfacings

Where pavements are stabilised with cementitious binding agents, particular care is required to ensure good bond between the 'cemented' substrate and any bituminous surface. Typically a thorough brooming followed by application of a surfactant or primer is required to suppress any dust, and/or to soak into the surface to reduce any chalkiness and provide a compatible bonding medium such as that provided by a prime coat prior to a seal coat.

The treatments presented in this report as 'reflection crack suppressants' would be typically placed over an existing surfacing where cracking is evident. For this project, however, it has been suggested that the stabilised pavement may be initially surfaced with the special treatment, such that cracking (typically shrinkage cracking) that occurs under trafficking does not penetrate this initially applied surfacing.

Very little information pertains to this use of the treatments, i.e. being placed at the time of stabilisation, *and monitoring the performance thereof.* This is not to say that many of these treatments are placed at the time of stabilisation, as clearly they would be.

The following advice was obtained from Pioneer Road Services regarding the Fibredec treatment (Lysenko 2000):

> *"Fibredec has been successfully used on stabilised pavements as SAM and SAMI treatments. Generally all that is required is to dampen the pavement if dusty. Clearly the pavement must be well compacted and free of loose material for best result. Under very hot conditions it may be necessary to spray water on the seal to cool the surface and eliminate stone roll over under traffic as the fresh hot binder may remain lively for several hours".*

SAM seals are routinely placed as initial treatments, including on to stabilised surfaces (Brisbane City Council, *refer* to Section 6).

Geotextile seals are also routinely applied directly onto paved (and unsealed/unsurfaced) surfaces as well as to previously surfaced pavements, however placing a geofabric seal on an unsealed surfacing would generally only occur given the certainty of shrinkage cracking occurring in the base layer.

Thin asphalt layers generally should be placed onto a SAMI. Where used as a treatment to suppress reflective cracks, it is essential that a SAMI be placed prior to the thin asphalt.

6 Trials of Crack Reflection Treatments

6.1 VicRoads' Surfacing Trial (Yeo and Foley 1997)

In 1994 VicRoads, the State road authority of Victoria, commenced a long-term surfacings trial comprising two concrete and five bituminous surfacing types. Monitoring has been undertaken at regular intervals for a range of surface characteristics including reflection cracking. As all surfaces were either part of, or placed on, a plain jointed concrete base, the opportunity arose to monitor the development of reflection cracking of the bituminous surfacings at each transverse contraction joint, spaced at 4.2 m intervals along each 80 m length of dual lane width surfacing type.

Transverse contraction joints were cut at a width of 3 mm prior to the concrete gaining a critical tensile strength, so that all longitudinal contraction of the concrete base slab would occur at the sawn transverse joints. Some of these joints were widened (erroneously) to a width of 7 mm prior to overlaying the trial surfacings. Records do not exist of the locations of the widened joints. Monitoring has shown that nil unplanned cracking (cracking through slabs, between the joints) has occurred at all within the whole construction works (much longer than the trial surfacing sections) and thus all contraction will be occurring at the joint locations. Inspection of the transverse contraction joints by the author revealed that almost nil induced cracking failures occurred, i.e. no induced transverse contraction joints along the main job failed to open. This is important to note, as reflection cracking will not occur above a closed joint in the underlying substrate. It was not possible to monitor the success of the induced cracking beneath the five (bituminous) overlaid sections of the trial site, due to the presence of the overlay itself.

Although not a stabilised pavement, the rigid pavement with transverse contraction joints provides a benchmark for a comparative assessment of bituminous materials bridging severe 'cracking' of a minimum of 3 mm width under urban, semi-arterial traffic loading. The subbase of this pavement comprises lean-mix concrete and thus good supporting conditions exist for the base slab providing relatively good load transfer across the joints. In this case the majority of movement is lateral, rather than vertical which better replicates the behaviour of a cracked cemented base where these treatments would be utilised. The good support across the joints would tend to also mitigate against the 'severity' of the wide 'cracking' at the minimum 3 mm joint width (others were 7 mm).

It is considered that the results of a trial such as this - where all loadings (environmental and traffic) are equal, and the substrate is very uniform with respect to drainage provision, type, thickness and strength, can be considered with some confidence.

Surface Types Monitored for Reflection Cracking

Dense -Graded Asphalt (DGA)

An asphalt mix comprising aggregates (densely graded), mineral filler and bitumen, having a low air void content, mixed, placed and compacted while hot. Approximately 30 mm thick.

Open - Graded Friction Course (OGFC) Asphalt

An asphalt mix comprising only small amounts of fine aggregates and having a marginally higher bitumen content resulting in a high percentage of air voids. Approximately 25 mm thick.

Stone Mastic Asphalt (SMA)

A gap-graded asphalt mix with added mineral fibres and a high proportion of course aggregate to form greater stone-on-stone contact than dense-graded asphalt. Approximately 30 mm thick.

Bituminous Slurry (Slurry Seal)

A road surface treatment comprising a mixture of bitumen emulsion, water and fine aggregate applied in the form of a cold slurry. Approximately 15 mm thick.

Strain Alleviating Membrane Sprayed Seal (SAM Seal)

A sprayed film of modified bituminous binder covered with aggregate. Approximately 10 mm thick.

Note that all surfacing types with the exception of the SAM had a SAMI comprising 2.0 L/m^2 of an AB5 type PMB with a size 10 aggregate over a 0.3 L/m^2 prime coat. The SAM seal had the prime coat only applied to it.

Results

Figure 2 shows the time progression of cracking reflecting through the thin bituminous surfacings. All transverse contraction joint locations were established and the presence or otherwise of a commensurate joint line in the thin bituminous surfacing was noted. Reflected crack lengths were measured over both lanes of each 80 m long trial surface section to calculate the percentage of the total possible length of reflection cracking.

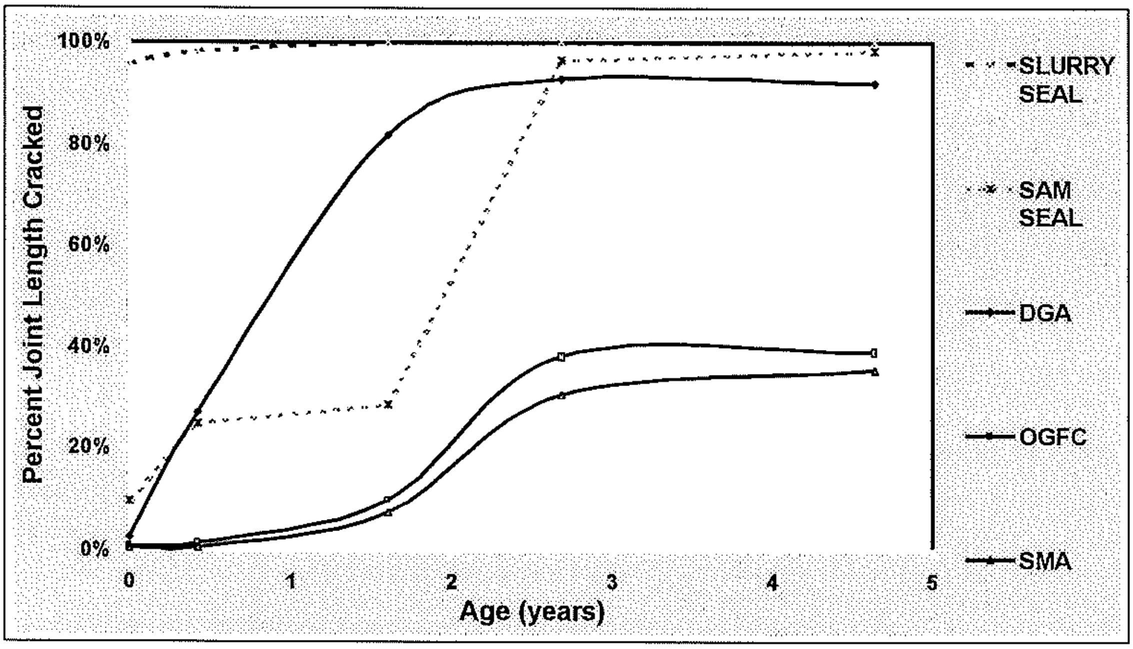


Figure 2: Reflection Crack Progression at VicRoads' Surfacings Trial Site (Yeo 1999)

The slurry seal reflected cracking from the concrete substrate almost immediately (and prior to trafficking). The SAM seal and dense-graded asphalt's propensity to crack occurred over a two to three year period with cracking being exhibited over most joints. The open-graded and stone mastic asphalts have performed the best of the five applied bituminous surfacing types with approximately 40% of the potential length of reflection cracking occurring in these surface types over the initial 4.7 year period. Crack length has not increased substantially over the last two years (to March 1999) of monitoring at this site.

6.2 VicRoads' SAMI over Cracked Concrete Trial

As with the above trial, the performance of a range of treatments incorporating thin bituminous layers placed over the transverse contraction joints of a jointed Portland cement concrete pavement was monitored (VicRoads 1997). Although this pavement type has different materials and performance characteristics to that of a cemented or modified and cracked flexible pavement, an understanding of the performance of thin treatments in a severe situation (7+ mm wide joints leading to wide reflection cracking of the overlying asphalt surface) may be transferable to the other less rigid pavements, in which reflection cracking occurs. This study is also one of the few that have been monitored and documented for up to 10 years, most other trials being less than 5 years in duration.

The Western Highway in Melbourne carries substantial volumes of heavy traffic with between 10 to 14% commercial vehicles. An old jointed concrete pavement had been overlaid with asphalt to improve its ride quality and all underlying contraction and longitudinal joints had reflected through to the pavement surface. Deflectograph testing showed generally good load transfer across the joints.

After cleaning of all joints and inserting a PMB as individual crack sealants, the following treatments were undertaken, as shown in Table 1.

Table 1: VicRoads SAMI over Concrete Trial Results

<table>
<tr><th colspan="2">Treatment No. and Description</th><th>Life at Transverse Joints</th><th>Rank</th></tr>
<tr><td>1</td><td>No further treatment, then 30 mm of size 14 DGA[5]</td><td>14% after 5 yrs; 30% after 10 yrs</td><td>Control</td></tr>
<tr><td>2</td><td>High tensile strength woven-fibre glass fabric bandage, then 30 mm of size 14 DGA</td><td rowspan="3">↑
3% to 10% after 5 yrs
10% to 29% after 10 yrs
↓</td><td rowspan="3">3rd about equal & better than control</td></tr>
<tr><td>3</td><td>PMB bandage (SAMI with no reinforcing fibres), then 30 mm of size 14 DGA</td></tr>
<tr><td>4</td><td>PMB bandage (SAMI with some reinforcing fibres), then 30 mm of size 14 DGA</td></tr>
<tr><td>5</td><td>Saw cutting and sealing a 30 mm layer of size 14 DGA overlay</td><td>3% cracking after 5 yrs; same at 10 yrs</td><td>Clear 2nd</td></tr>
<tr><td>6</td><td>Bituminous Scrap Rubber Asphalt (BSRA, crumbed rubber) placed 30 mm thick</td><td>nil cracking after 10 yrs</td><td>Best</td></tr>
</table>

Results

Virtually nil reflection cracking was observed for the BSRA[6] overlay, Treatment No. 6. This was the best performing treatment.

Of the other five treatments, all provided some control of reflection cracking, even the control treatment section of 30 mm of DGA with nil specific joint bandaging. Of these five treatments, the saw cut and seal provided joints which remained almost intact over the ten year period, performing substantially better than the remaining three bandage Treatments (Nos. 2, 3 and 4) which performed relatively similarly.

Thus the order of performance over the ten-year period is reflected in the above order of treatments given in the tabulation, in order of increasing performance for controlling reflection cracking from the concrete base substrate. The Technical Note (VicRoads 1997) cautions the reader by acknowledging that the performance observed in this trial, due to the good load transfer between the underlying slabs, may not necessarily be replicated on other concrete or flexible pavements.

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[5] Dense-graded asphalt

[6] Bituminous Scrap Rubber Asphalt

6.3 VicRoads' Experience with Geosynthetic Reinforced Bituminous Surfacing

Vans Deuren and Esnouf (1996) reported that a minimum of 100 lane km of geosynthetic reinforced chip seals are placed in Victoria each year. These seals are placed over heavily- cracked and (structurally) sound pavements comprising a wide range of materials from old concrete slabs, macadam and cemented granular bases.

Van Deuren and Esnouf also reported that PMB and BSR modified seals by themselves had only limited success, with cracks reappearing after 2 to 3 years on heavily-trafficked pavements.

VicRoads typically have used non-woven needle-punched geosynthetics of 140 g/m^2 in these applications. Polyester geosynthetics are considered particularly suitable due to their high melting point of 250°C, which is suitable for application of relatively high-temperature PMBs; Campbell and Kleimeier (1996) support the use of polyesters for high temperature applications. Polyesters are not sensitive to sunlight, and being porous they absorbs sufficient bitumen to assist in the waterproofing function and only absorb small amounts of water (Van Deuren and Esnouf 1996).

Polypropylene can also be used provided bitumen temperatures do not approach 175°C, the melting point of this fabric. It is more sensitive to ultra-violet light than are polyester geosynthetics.

Van Deuren and Esnouf provided the following advice for the placement of geosynthetic seals:

1. Single application stone chip seals should not be placed where there is:
   - high volumes of turning traffic,
   - high percentage[7] of heavy commercial vehicles, especially on climbing lanes,
   - stop/start traffic, such as at approaches to signalised intersections.
2. Double application stone chip seals have a distinct advantage over the single application geosynthetic seals because they are able to absorb the additional stresses introduced by turning cars and commercial vehicles.
3. Geosynthetic seals perform best on straight sections of roads but can also be laid on large radius curves. This may result in the formation of minor creases in the geosynthetic, which do not diminish the effectiveness of this treatment. they can be placed on tight bends/curves if the geosynthetic is cut and wedges removed.
4. Cold planing can do removal of the geosynthetic as part of future rehabilitation or reconstruction work. Paving fabrics are recyclable in both hot and cold stabilisation processes with the geotextile providing some [residual] tensile reinforcement. Van Deuren and Esnouf (1996)

6.4 QDoT Crack Control Trial – Beerburrum Deviation (1987-1991)

During the 1980s many cement treated base (CTB) pavements in Queensland showed early signs of high distress in the form of either transverse or longitudinal cracking

[7] Although no figures are presented in van Deuren and Esnouf's paper for heavy vehicle volumes for climbing lanes, this value (for rural highways) would be typically be in excess of 20%.

and associated pumping of fines once water entered the pavement layers. A crack control trial was established at Beerburrum, near Brisbane to test a range of treatments intended to prevent or reduce the cracking occurring in a cement treated pavement from reflecting through a 45 mm asphaltic overlay (QDoT June 1992). By preventing or reducing this cracking and/or providing a waterproof barrier between the surfacing and the underlying CTB, the infiltration of moisture into the pavement is reduced, thereby minimising further deterioration.

The trial commenced in September 1987 and visual inspections and accurate crack mapping occurred on a regular basis. It was established on a 5600 metre section of the two northbound lanes of the Beerburrum Deviation comprising 19 tested sections. The installation of 17 No. 300 metre-long crack control test sections, including two control sections without treatments, included the following treatments systems:

- Polymer modified binder interlayers with asphalt overlay
- Adhesive backed strip treatments with asphalt overlay
- Geotextile interlayers with asphalt overlay
- Polymer modified asphalt
- Two coat polymer modified binder reseal

The trial pavement was subjected to a variety of naturally occurring extremes of climatic conditions ranging from extremely dry to extremely wet and from winter to summer. The findings of the Crack Control trial after the first 4.5 years service showed:

- Two full width treatments reduced cracking reflecting through the applied surfacing for the first 12 months, these were:
  - Polymer modified asphalt
  - Polymer modified binder interlayer full width with asphalt overlay
- After 4.5 years only one treatment would appear to have a reduced number of cracks reflected through when compared to the control sections. This treatment is:
  - Polymer modified binder interlayer full width with asphalt overlay
- No pumping and relatively little cracking was also observed on the polymer modified binder reseal treatments, however, this can be attributed to the extensive fattiness of the treatment that disguises any meaningful results.
- Strip treatments in general are the worst performing in both the areas of crack retardation and the prevention of pumping.
- After 4.5 years all treatments had significant propagation of pre-existing cracks. Previous assessments did show that some initial delay was experienced through the use of crack control treatments.
- Two full width treatments had limited the pumping to minor occurrences up to 4.5 years, these were:
  - Polymer modified binder interlayer with asphalt overlay
  - Geotextile interlayer with asphalt overlay.

Relative performance of the treatments over the initial 4.5 year period is summarised in Figure 3.

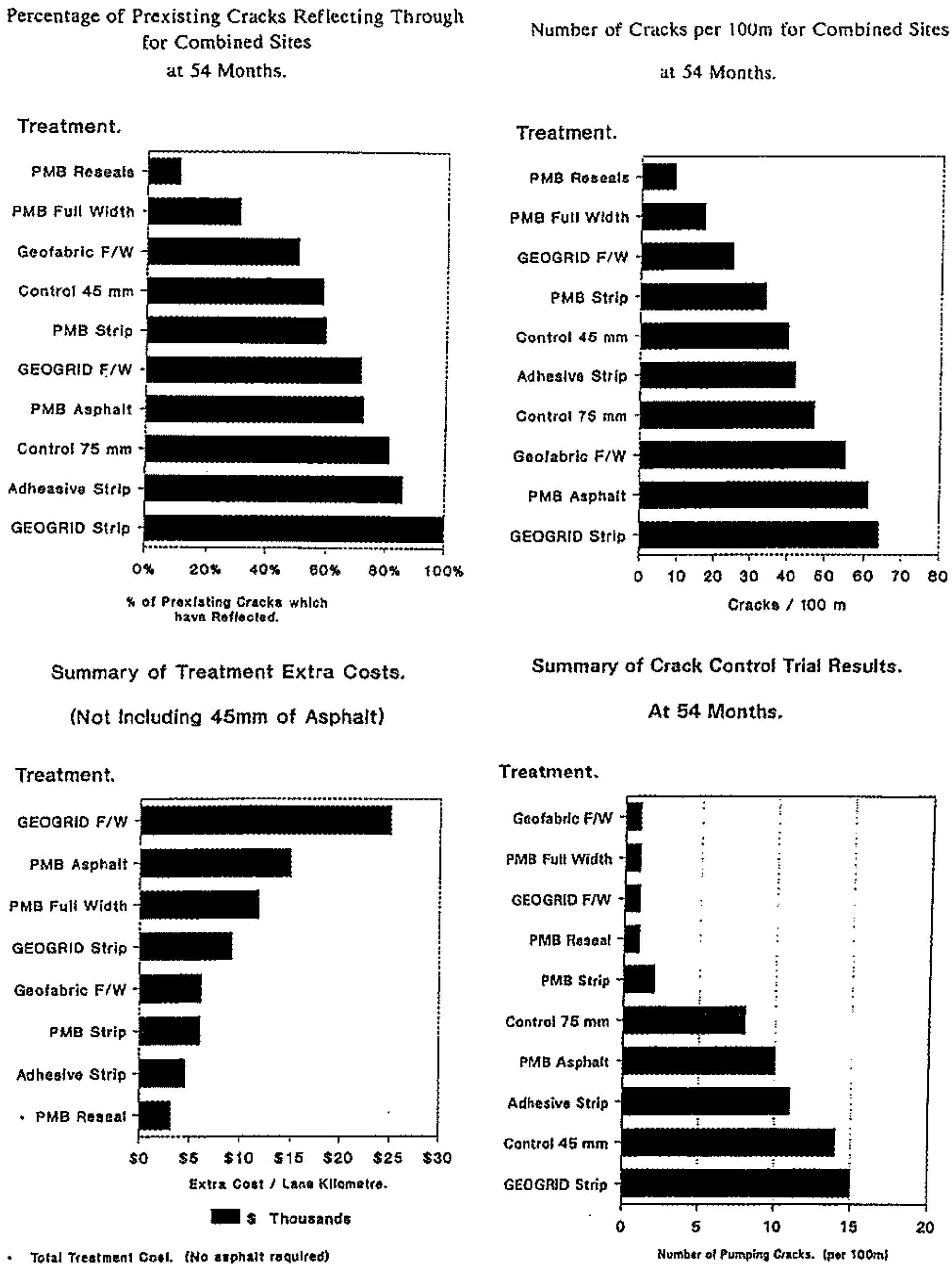


Figure 3: Summary of Crack Control Trial Results (QDoT 1992)

6.5 QDoT Paving Fabric Sealing Trial: Cunningham Hwy (1990 – 1992)

As indicated in Section 6.4, many pavements in Queensland, which incorporated cement-treated bases (CTB) were showing early signs of distress during the 1980s (QDoT Aug. 1992). This distress was usually in the form of either transverse or longitudinal cracking and associated pumping of fines once water had ingressed into the pavement layers.

A full scale trial was established on the Cunningham Highway in March 1990 to identify paving fabric treatments which in conjunction with a spray seal would prove effective in the prevention of reflective cracking and the pumping of fines from CTB pavements (QDoT Aug. 1992). The CTB pavements that had been constructed in stages from 1984 to 1986 were in an extreme state of distress and by late 1989 the pavement required rehabilitation. Three sites on the Cunningham Highway were divided into 4/300 metre and 4/100 metre research sections with the following paving fabric treatments:

- A Class 170 Binder and 16 mm Aggregate over "POLYFELT PGM 13" Over Class 170 Binder.
- A1 Class 170 Binder and 16 mm Aggregate over (100 m roll of "TYPAR" for trial of new product as gift).
- B Class 170 Binder and 16 mm Aggregate over "POLYFELT PGM 13" over "EVABOND" Polymer Binder (5% Residual Polymer).
- C Class 170 Binder and 16 mm Aggregate over "BIDIM PF1" over Class 170 Binder.
- D Class 170 Binder and 16 mm Aggregate over "BIDIM PF1" over "EVABOND" Polymer Binder (5% Residual Polymer).

The QDoT report (QDoT Aug 1992) presented findings from the assessments since the installation of the paving fabric treatments with respect to:

- Long and short term performance of the paving fabric
- Effectiveness of paving fabrics treatments on CTB pavements
- Costs associated with paving fabrics treatment.

Performance trends of the research sections were derived from the first five assessments including the pre-installation assessments with respect to: reflective cracking (i.e. longitudinal, crocodile, transverse); pumping of fines; roughness; surface texture and rut measurements.

6.5.1 Analysis and discussion of field data

- Since the installation of the paving fabric treatments, transverse cracking reflecting through to the surface was non existent. The results of the five assessments undertaken in both the southbound and northbound lanes are shown in Figures 4 and 5 respectively.
- Longitudinal cracking reappeared in late 1991 some 23 months after treatment and increased in some sections of the southbound lane from early 1992 onwards. Longitudinal cracking in the northbound lane was not evident even though the total length of longitudinal cracking in the northbound lane was much higher than that of the southbound lane. The results of the five assessments (pre and post installation) are presented in Figures 4 and 5.
- Block cracking has only started to reappear in section 4 in the northbound lane 26 months following treatment and in section 3 in the southbound lane at 20 months following treatment and increasing when assessed at 26 months.
- The southbound lane had very little patching as of May 1992 since installation in March 90 (about 1 m^2) where as the northbound lane had a steadily increasing amount of patching applied.

- The number of pumping positions on the southbound lane was much lower that the northbound lane.
- Road roughness levels have tended to remain constant at least since the installation of the paving fabric, indicating that the rate of deterioration of the CTB pavement is very low.
- Rut Depths have on the whole remained unchanged since the installation of the paving fabric. Rutting in general was about 5 mm in both the southbound and northbound lanes. Ruts in some localised failure points were in the range of 20 – 40 mm in depth.
- The results so far show that the surface texture depth since the paving fabric reseal had remained constant. If site 1 is ignored, the average surface texture depth was approximately 1.6 mm which was greater than the 1.0 mm minimum recommended for sprayed seal so that aquaplaning was not a problem to road users. Pre-installation Sections 4, 6 and 7 exhibited bleeding problems in the wheelpaths where the surface texture was < 1.5 mm. Since installation, bleeding problems appeared in Sections 1, 2 and 4. The texture depth in these sections was not much greater than 1.5 mm.
- Potholes in the southbound lane have been re-occurring at isolated points in Sections 5, 6 and 8 since the installation of the paving fabric treatments. Potholing in the northbound lane had been more wide spread with potholes reappearing 8 months following treatment. The number of potholes however had remained fairly constant for the following 18 months.
- Beam testing had been limited to research section 3 since it had a large number of longitudinal, transverse and some areas of block cracking. The deflection bowl data indicated that subgrade CBR values were much lower in embankment areas and those deflections were high in these areas. This may have been due to moisture movements in the embankment.

6.5.2 Costs associated with treatments [AU$ 1992]

Prior to the installation of the paving fabric treatments in March '90 the maintenance cost on the sites treated were high due to the poor condition of the CTB pavement.

No actual maintenance costs were recorded prior to treatment however some costs have been collected since installation of the paving fabric treatment. An indication of costs before installation however may be gained by considering the cost of similar aged pavements next to the treatments. The annual maintenance cost of a 5½ year old pavement immediately preceding the trial area was approximately $9,000 per kilometre.

- Since installation the annual maintenance costs on the paving fabric sites have been in the range of $200 to $300 per kilometre.
- The cost of installing the paving fabrics at the Cunningham Highway sites varied between $35,000 to $42,000 per kilometre.

Limited life cycle costing was performed to determine equivalent annual cash flow (EACF) for various discount rates for options with different lives. The 16 mm paving fabric seal EACF @ 7% was $7,158/km whereas for the no treatment option the EACF @ 7% was $9,629/km.

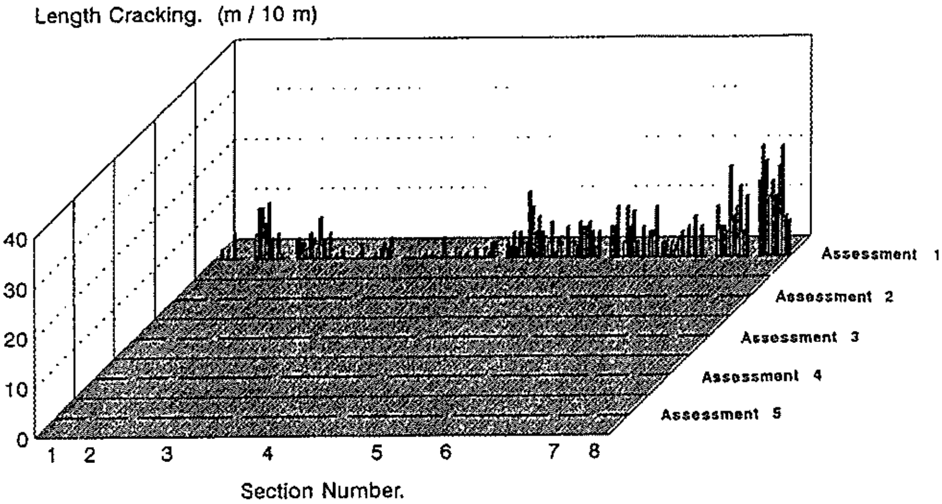
6.5.3 *Major findings*

- Paving fabric treatments have effectively controlled the reappearance of cracking in the surfacing. Existing transverse cracking has not reappeared at all to date.
- Prevention of the ingress of water into the pavement was the most important factor in preventing deterioration of CTB pavement under design traffic loading. This was evidenced by:
  - pre-treatment defects were much higher in sections with large numbers of cracks
- high embankments which experience moisture variations were likely to exhibit longitudinal cracking which in turn leads to further deterioration
- High embankments have the potential for the appearance or reappearance of defects due to moisture movement causing lowering of subgrade support and greater movement in the embankment.
- Paving fabric treatments have to date provided an effective waterproofing membrane because of the following:
  - no increase in rutting
  - no increase in road roughness
  - low level of surface defects recorded
  - reduction in number of pumping locations
- Total binder applications rates much higher or lower than those calculated using Technical Note 8 (QDoT 1994) [Appendix B] would cause either bleeding or stripping problems.
- Surface texture has remained unchanged since the installation of the paving fabric treatments.
- 'Fatty' areas can be corrected with application rates at the lower design limit suggested in Technical Note 8.
- Surface defects such as potholes and rutted premix patches should be repaired before the installation of paving fabric seals.
- One year after installation of the paving fabric reseal the annual maintenance costs per kilometre of 2 lane carriageway were in the range of $200 - $300.[AU$ 1992].
- Lower equivalent annual cash flows over the life of the reseal.

6.5.4 *Limitations (QDoT Aug. 1992)*

- Roughness levels were maintained but not reduced by paving fabric reseals.
- Rut depths were not corrected by the paving fabric treatments.
- In areas where there are large variations in surface texture across the pavement surface, uniform spray rates across the cross section may cause bleeding or stripping problems.

- Large movements in subgrade/pavement cause localised rupturing of the paving fabric membrane thereby reducing the waterproofing function of the membrane.
- Excessive rutting was observed in areas of premix patching. The paving fabric has not prevented rutting of premix patches in wheelpath positions.



North Bound Lane.

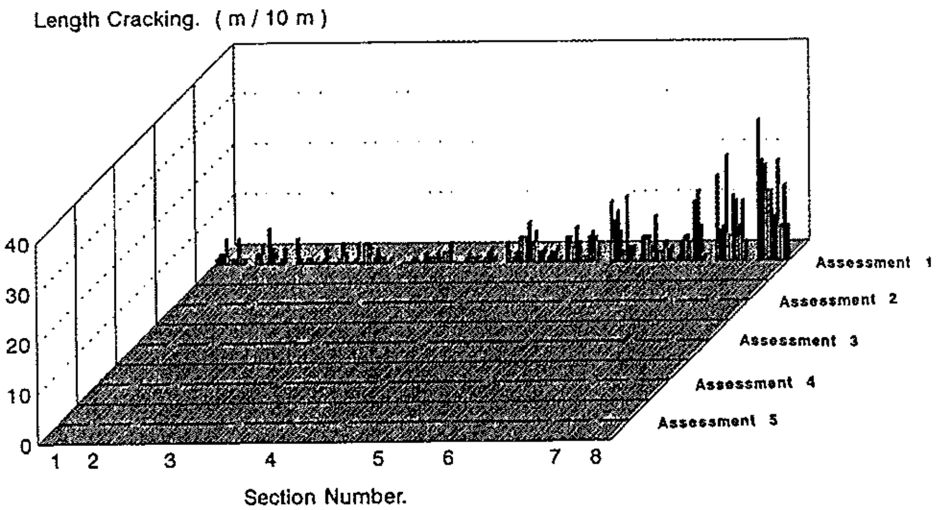


Figure 4: Transverse Cracking, South Bound Lane (QDoT Aug. 1992)

6.6 QDoT Geosynthetic Interlayer Treatment Field Trial

Queensland Department of Transport (QDoT 1993) undertook a trial of SAMI [composition still being sought] and geosynthetic interlayer treatments beneath a thin (25 to 30 mm) open-graded asphalt over a 30 month period on an urban arterial pavement in Brisbane. Substantial reflective cracking was present along the Western

Arterial Road, which was caused by cracking of the cement-treated base (CTB) layer. The cracked dense-graded asphalt surfacing of the CTB was nominally 60 mm thick. The cracking allowed the infiltration of water leading to the pumping of fines.

Two sections were chosen for the trial; one area performing well, given the pattern of closely spaced cracks with minor pumping of fines, the other being described as in a severe state of distress with closely spaced cracking and more widespread pumping.

During the 30 month monitoring period, 4.3% of SAMI interlayer treatment had transverse cracking reappear, with 10.5% of the same defect re-appearing in the geofabric treatment site. No longitudinal cracking re-appeared over the monitoring period. Pumping of fines from both sites was virtually eliminated.

The site lengths are relatively short being 100 m and 150 m for SAMI and geofabric treatments respectively.

6.7 Queensland SAM Trial

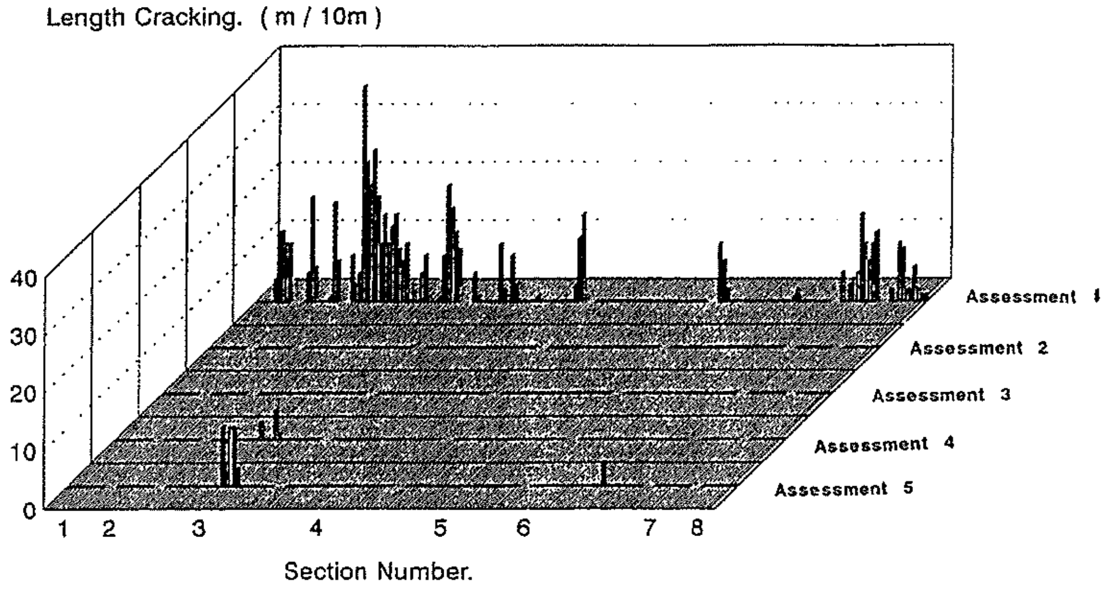
As part of an Austroads program, the Queensland SAM Trial Working Group was established to monitor the performance of a range of SAM treatments applied to cracked flexible and semi-rigid (cement-treated bases - CTB) pavements in that State (Treadrea 1999). Data relevant to this Project has been selected from two 1 km-long sites where the length of cracks pre-SAM treatment (Dec. 1994 to May 1995) were measured and again in September 1997.

Seven binder types, including a Class 170 (80/100 grade) binder as a control, were tested and the sites were monitored in both the fast and slow lanes for both transverse and longitudinal cracking. Cracking was categorised due to the expectation that the transverse cracking originated, and would behave differently, under traffic and environmental loadings to that of the longitudinal cracking. The binder types used in the study are given in Table 3.

Table 2 refers to Figures 4 and 5.

Table 2: Cunningham Highway Fabric Sealing Trial Details

Assessment No	1 (Pre-treatment)	2	3	4	5
Date	9/89	11/90	5/91	11/91	5/92
Section No.	1	2	3	4	5
Length	100	100	300	300	300
Treatment (Nth Bnd / Sth Bnd)	B/D	C/A	C/A	D/B	C/A
Treatment type	A Polyfelt PGM 13 over Class 170 binder	B Polyfelt PGM 13 over EVABOND binder	C Bidim PF1 over Class 170 binder	D Bidim PF1 over EVABOND binder	



North Bound Lane.

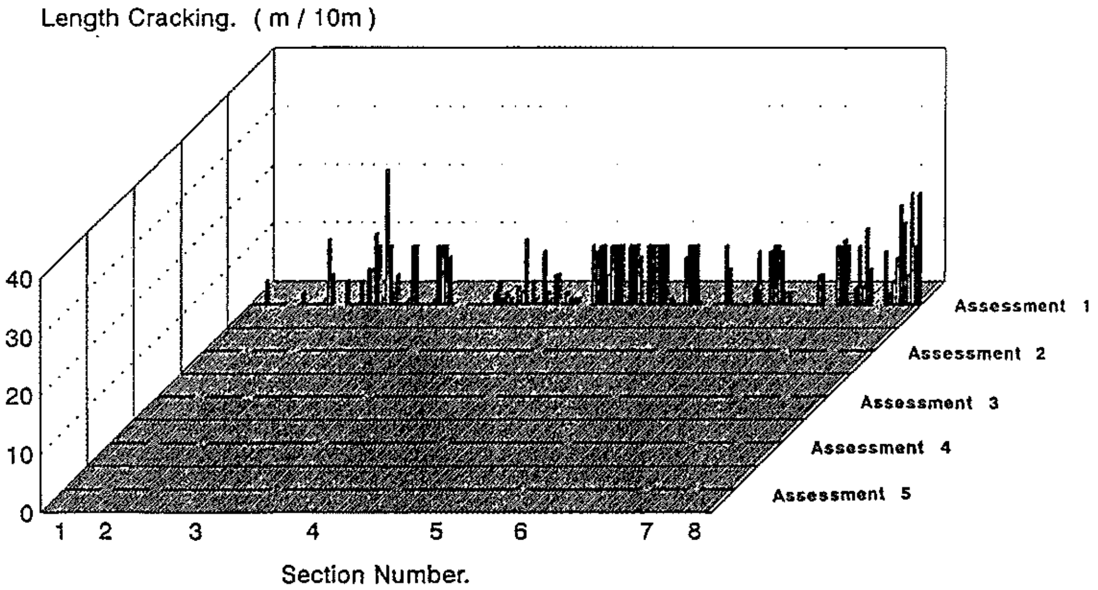


Figure 5: Longitudinal Cracking, South Bound Lane (QDoT Aug. 1992)

Ranking Group in Table 3 refers to the percentage of cracking which had reappeared over the three-year period with Group 1 being the best performing binder with less than 25% of cracks reappearing. Group 2 has 25-50% of cracking reappearing etc. From Table 3 the best performing binder at Sites 17 and 18 were SR15 and SB5. Further evaluation of the performance for longitudinal and transverse cracking may be made by inspection of Figures 6 to 9.

Table 3: Binder Performance Ranking for CTB Sites after 3.2 Years of Trafficking

Binder type	Description	Ranking Group	
		Site 17[1]	Site 18[1]
SR15	Scrap Rubber at a concentration of 15 pph	1	1
SB5	Styrene Butadiene Styrene at concentration of 5%	1	1
SR20	Scrap Rubber at a concentration of 20 pph	2	1
SB3	Styrene Butadiene Styrene at concentration of 3%	3	1
PBD	Polybutadiene	3	2
AB3	Asphalt grade (EMA)	4	2
Class 170	Control binder; neat binder (80/100 grade)	4	4

1. Predominantly comprised transverse cracking at both Sites

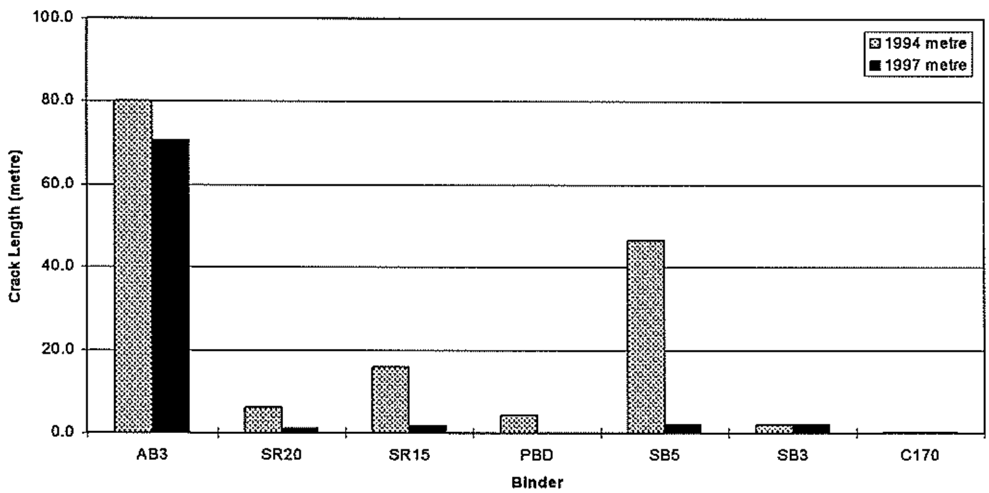


Figure 6: Longitudinal Crack Record Site 17

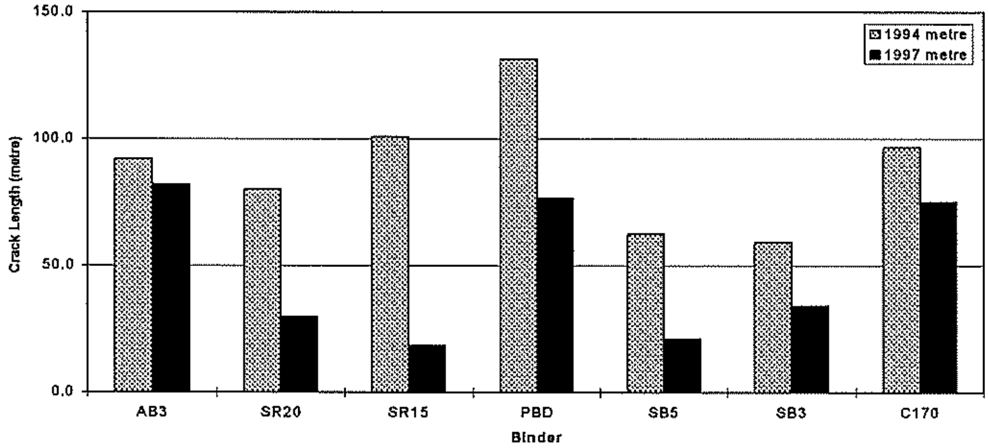


Figure 7: Transverse Crack Record Site 17

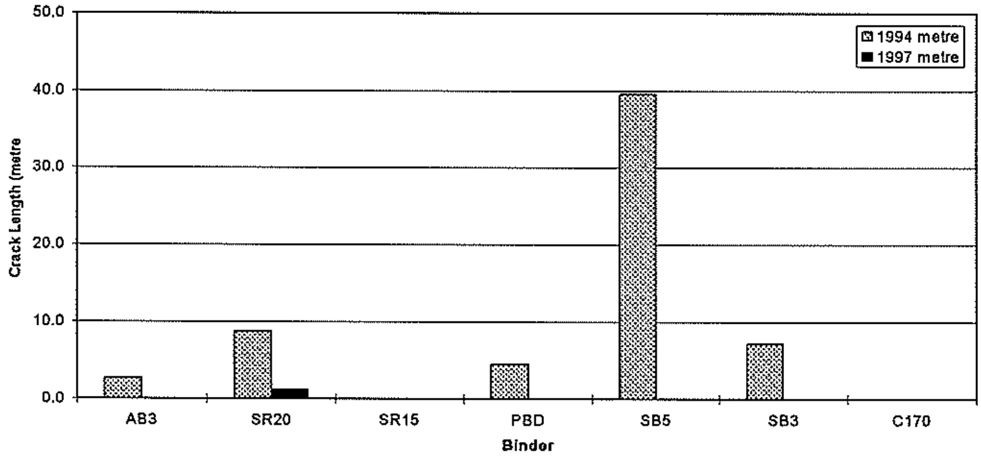


Figure 8: Longitudinal Crack Record Site 18

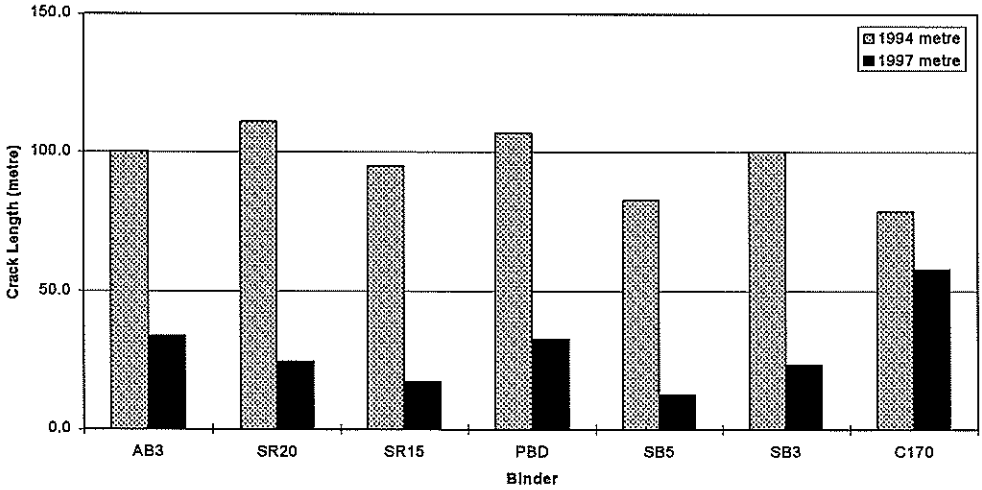


Figure 9: Transverse Crack Record Site 18

Measurements at Sites 17 and 18 of the Queensland SAM trials were undertaken in December 1994, and again in September 1997.

With the exception of binder AB3 at Site 17, all binders effectively reduced cracking over the three-year period. Transverse cracking consistently reappeared at all sites (uniformly across wheelpath and non-wheelpath locations) indicating the relative activity of these cracks, due largely to environmental loading; the final crack monitoring being taken in January 1998, which coincides with heavy rainfall and high temperatures at these sites. It was considered that these environmental conditions tended to close cracking with a degree of healing of the bituminous surfacing in the warmer weather and higher moisture contents in the shoulders swelling the subgrade and keeping closed most longitudinal cracking present.

Tredrea (1999) reported that:

- better SAM performance is likely to be linked to the higher binder film thickness (application rates), and
- complementary laboratory testing of binder fatigue (South African method) was undertaken with these seven binders who also supported the field trials. Preliminary data clearly indicates binders SR20, SR15 and SB5 have superior fatigue performance.

6.8 French National Roads Monitoring

Laurent *et al.* (1996) presented the results of monitoring undertaken on a nation-wide survey of some 100 pavement sections comprising hydraulically-bound base layers during the winter months throughout France. The crack prevention systems are divided into six categories as shown in Table 4. All systems except one routinely employ a thin asphalt wearing course of 40 mm thickness over the treatment, this one exception treatment comprising the only "asphalt" treatment which is 30 mm in thickness.

Table 4: Summary of French National Monitoring. (Laurent *et al.* 1996)

Method	Covering layer	Time for 50% Crack Reappearance	Time to Fully Crack	Cost in FF (1995)
Control; 40 mm non-modified bitumen asphalt	Nil	4 to 5 winters	6 winters	na[1]
Sand Asphalt Interlayer; 20 mm	40 mm asphalt	5 to 6 winters	7 to 8 winters	20 – 30
SAMI (largely discontinued)	40 mm asphalt	5 winters	7 winters	25 – 40
Membrane with cold asphalt; 10 mm	poss. 40 mm AC	>7 winters on AC base. 4 to 5 winters on chip seal base.	Not enough data	25 – 35
Modified binder and geotextile	40 mm asphalt	6 winters	7 to 8 winters	10 – 20
Geotextile chopped strand; 10 mm (with chip seal)	poss. 40 mm AC	5 to 6 winters	> 7 winters	na.
Fibre modified asphalt; 30 mm	nil	"promising performance" reported to 4th winter.		na.

1. not available

These results as presented in Laurent *et al.*'s paper can only provide a general view of the efficacy of the various systems in use in France due to the wide range of substrate pavement thicknesses and environmental conditions and traffic loadings. Results of crack reappearance are primarily mean values, with various degrees of spread around the mean value. Sample sizes varied greatly due to the newness of some techniques and the abandonment of one technique. Some newer treatments can, by virtue of their newness, provide only indicative results.

Laurent *et al.*'s conclusions regarding the various treatments were as follows:

Sand Asphalt Layers:

- Sensitive to rut development and have only a marginal effect on slowing crack progression (compared to the control treatment).
- Incorporation of fibres into the mix improves rut and crack resistance.
- Aggregate covered membranes (SAMIs)
- Poor performance (not described) has led to this technique being largely abandoned in France.

Membrane covered with cold asphalt

- The one site with this technique is performing well; only five years of observations at the time of reporting.

Modified binder and geotextile

- Comparable performance to sand asphalt treatments but at a lower price.
- The quality of installation was critical to their performance.
- Geotextile chopped strand
- The one site observed had similar performance to other applications using geotextiles, but with much easier application.

Fibre modified asphalt

- Promising performance to-date, but further time was required to evaluate.
- Good rut resistance.

Inspection of the summarised data in Table 4 suggests that while, in general, all treatments appeared to retard the occurrence of reflection cracking from cement-treated bases, none at the time of reporting showed outstanding success. This may in part be due to the large spread of performance for each type of system whereby the mean values for the delay of reflection cracking show not dissimilar results to that of the control section. However, if the system type was selected judiciously for the particular location or if sound preparation of the cracked substrate were undertaken (not clear from the paper) then these treatments may show better performance.

6.8.1 Suggested guide for dressing course treatment

Observations were that the rate of reflection cracking was related to the load transfer capability of shrinkage cracking and to the volume of heavy traffic. Laurent *et al.* suggested that, if differential vertical crack movement is limited to less than 300 μm and traffic volumes are less than 300 HGV[8]/day/direction, then a surface dressing (i.e. deletion of the asphalt wearing course) would suffice in providing a watertight (non-reflective cracking) surface.

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[8] Heavy goods vehicle (per direction)

7 Discussions with Australian Practitioners

Mr. John Lysenko (Technical Manager Road Binders and Surfacings, Pioneer Road Services) considered that the use of glass fibre reinforced seals to be an effective treatment for crack-prone and cracked surfaces. He presented a paper on fibre reinforced seals (Lysenko and Scott 1999) at the 16th Annual IMEA (Institute of Municipal Engineers, Australia) State Conference in Perth.

Mr. Bruce Hansen (Principal Research and Development Officer Brisbane City Council) advised the Brisbane City Council (BCC) to undertake 100,000 to 200,000 m^2 of cement-treatment on a wide range of base-course types each year. These are primarily in residential streets with low heavy-vehicle volumes. Typically, 4.5% of a 70/30 cement/fly ash binder is used per dry mass of pavement material to a depth of 150 to 200 mm. BCC cure the stabilised base with a single coat Class 170 sprayed seal. Assurance testing is undertaken with a Benkelman Beam prior to placing a 25 mm layer of densely-graded asphalt. No special additives or binders are used in either the spray seal or the asphalt overlay. This treatment type has performed well where heavy vehicle volumes are low.

Where this stabilisation technique has been tried on heavier trafficked pavements, typically unacceptable block cracking has reflected through to the surface, resulting in the BCC ceasing this treatment.

Where stabilised pavements have need to be recycled, this has been undertaken by milling and pulverising the cement-treated base and thin asphalt surfacing and re-dosing with cement. This stabilisation procedure is routinely employed with generally little further site specific laboratory investigations.

Mr John Figueroa (Roads and Traffic Authority, NSW) is researching the minimum depth of asphalt required to inhibit reflection cracking from cement-treated bases without the need for tensile interlayers. Laboratory and field testing will be undertaken over the next two years, with an initial report due in about late 2000. Crack propagation is to be modelled using finite element analysis. Although this research is not utilising a thin layer treatment, some relevant data could be generated if John introduces thin tensile interlayers at the pavement asphalt overlay interface.

Mr. John Lancaster (Pioneer Road Services, Victoria) believes it is essential to provide excellent adhesion of thin bituminous surfacings on cement-treated bases to have an effective treatment for inhibiting reflection cracking. This would be achieved by the introduction of a bituminous emulsion into the surface of the stabilised layer prior to final compaction. This impregnated layer would then act similar to a prime coat for normal spray sealing of water-bound aggregates, improving adhesion to the surface layer of the substrate. He fully recognises the practical implications of his suggestion.

Mr. Lancaster also considers that:

- the use of PMB asphalts by themselves show little evidence of controlling the crack propagation from cement-treated bases, and
- where possible, the cementitious content be limited to between 2 to 3% by mass of dry material, to substantially reduce the occurrence of shrinkage cracking in treated base layers.

Mr Walter Holtrop (Manager, Training and Advisory Centre, Australian Asphalt Pavement Association) suggested that the following generic treatments and products would provide some measure of crack-reflection treatment:

- Sprayed bituminous seal, designed as a SAMI or incorporating a PMB, and
- Reinforced seals as per Austroads specification incorporating a PF1 (130-140 gm/m^2) geosynthetic, or a glass fibre such as Pioneer Fibredec.

8 Other Techniques to Limit Cracking in Bound Pavements

Although not formally requested as part of this Project, the opportunity was taken to document various techniques that became available during the literature searches. Some of these techniques are somewhat specialist and would pertain to more heavily-bound base materials, whilst others are routinely adopted in pavement design and maintenance activities. These techniques primarily control environmental or shrinkage cracking, rather than cracking due to the continued trafficking of the pavement.

8.1 Pre-Cracking

Vautrin *et al.* (1991) describe CRAFT (French acronym for automated creation of transverse cracks) a technique practised in France for controlling cracking in hydraulically bound pavement bases, both new and rehabilitated pavements. This method comprises physically slicing the partially-compacted stabilised layer during the 'working time' of the stabilising agent. The slice is transverse to the pavement at approximately 3 m intervals to create a discontinuity to induce a crack or joint at that location. The slicing is typically achieved by the use of a blade mounted on an articulated arm on a back-hoe. Bitumen is simultaneously incorporated into the 'slice zone' to act as another physical separation between adjoining sections of bound pavement, and also to act as an insitu sealant at the induced joint zone.

Shahid and Thom (1996) described a method used in the UK of using a vibrating plate with a vertical cutting blade attached to its base to form a 10 mm wide groove transversely across the pavement at 3 m intervals to approximately 50% of the depth of the cement bound layer. A bitumen emulsion would be introduced into the slot prior to final compaction of the base layer. This process would be completed within 2 hours after mixing the cemented material. The bitumen impregnated zone thus provided a zone of weakness so to as control the transverse contraction cracking of the cemented base.

Transport South Australia plan to use a technique similar to this for construction of a trial cement treated base (CTB) (TSA 1998).

Coring through the induced transverse joint zones in the UK paper showed that 40% to 90% of joints had cracked full depth (at two separate sites), with a joint width of less than 0.5 mm. This contrasted with the control section where uncontrolled transverse cracking had crack widths greater than 1.0 mm at a spacing of 12 to 40 m.

Falling weight deflectometer (FWD) testing across the transverse contraction cracks and induced joints showed greater load transfer across the discontinuity for the induced jointing, commensurate with the closer spacing and narrower joint in this joint type.

Back-calculated material stiffness derived from FWD test data shows that the stiffness of the CTB is slightly affected by the controlled jointing at a 3 m spacing, such that it does not influence the structural performance of the CTB base.

8.2 Sawing

Sawing to provide transverse contraction joints is undertaken in the same manner as that for Portland cement concrete pavements. This technique is applicable to materials where sufficient binding agent permits sufficient strength gain to develop such that sawing of the hardening material can be undertaken with minimal erosion and plucking of aggregate from the surface. As such, its application to lightly to moderately bound granular materials, whether this degree of binding is due to the quality of the host material or the quantity of binding agent added, would be very limited.

8.3 Two-Layer Coating Mixes

Vautrin *et al.* (1991) described an unusual double layer technique. Sand comprising a grading from 0 to 4 mm with 9 to 10% of bitumen (may be modified) is placed 15 to 20 mm thick, upon which is placed 40 to 60 mm of conventional bituminous concrete [dense-graded asphalt].

This is not a thin bituminous dressing in an Australasian sense, and performance data is not readily available. This technique is listed for information only. It is recognised by Vautrin *et al.* that thicker treatments such as this incur the risk of rutting.

8.4 Stabicol

Stabicol is a propriety name for a composite bitumen and hydraulic binder in a homogenous and stabilised water suspension developed by Colas (France). The binder is used cold and according to Colas (Godard 1991) can be incorporated using traditional construction and stabilisation techniques.

This product imparts the stiffness of an hydraulic binder and the flexibility associated with a bituminous binder to produce a semi-rigid material in which macro-cracking is eliminated (Godard 1991). Typically this binder is applied at 6% of the dry mass of the host material, resulting in a 4% cementitious and bituminous residual binder content. Three grades of Stabicol comprise different ratios of cement, bitumen and water, ranging from a 2:1 ratio to a 5:6 ratio of cement to bitumen. A cure coat or process must be applied to the compacted material to ensure full hydration of its hydraulic component.

The *in situ* material is claimed (Godard 1991) to be:

- non-rutting,
- not susceptible to shrinkage cracking, and
- can be mixed in a range of thicknesses, unlike a cemented layer which, depending upon the traffic volume, generally must be constructed to a minimum layer thickness.

The inclusion of bitumen into the binding agent makes the stabilised material's physical characteristics dependent on temperature with a decrease in UCS and resilient modulus with an increase in temperature. Based on data given in Godard (1991) the range of UCS over temperatures from 0°C to 30°C were 3 to 9 MPa, values that infer a moderately to highly bound material. The 'stiffness modulus'[resilient modulus] over the same temperature range was between 15,000 to 20,000 MPa. At temperatures greater than say 20°C, this material is substantially stiffer (approximately twice at 20°C) than that of a typical dense-graded asphalt. As the temperature increases above 20°C, the difference in resilient modulus is even more pronounced with the modulus of the Stabicol treated material tending to plateau near the 15,000 MPa value. No information was available of the dose rate and the host material's physical properties for the UCS and moduli values.

Stabicol was introduced into Australia by Pioneer Road Services earlier this decade. However, its use in its initial proprietary form (and name) currently no longer exists within the road construction industry.

Stabicol is similar in concept to 'black and white' stabilisation where similar quantities of cementitious and bituminous binders are added successively in *in situ* pavement stabilisation.

8.5 Stabilised Material Design

Laboratory testing is undertaken to assess the likely strength gain of the host material and binding agent(s). Typically UCS testing is undertaken to determine the state of binding of the pavement material with stabilising agent. Different quantities of binder are assessed to produce a stabilised material having the desired strength, either a minimum or a maximum value, depending upon the required modification or stabilisation. Thus if shrinkage cracking is to be minimised, an upper limit would be placed on the strength gain of the stabilised material. Typically a UCS value at 7 days for general purpose cement of 1 MPa would be such an upper limit, to restrict the occurrence of shrinkage cracking (Austroads 2000).

8.6 Monolithic Construction

The ALF Trial at Beerburrum in Queensland (ARRB TR 1987) demonstrated the mechanism of moisture being able to penetrate along the interface of two cementitiously-bound pavement layers leading to rapid failure of the pavement base. The inability of the two bound layers to adequately bond proved to be critical for the performance of this pavement system. The high strains developed at the base of the upper bound layer lead to rapid fatigue cracking of this layer leading to moisture penetration and accelerated erosion of bound material at the interface, and from the crack faces.

A pavement system in this trial, whereby a bitumen interlayer was provided to ensure separation of the two bound layers, provided the best performance of any of the pavements. This was due to a combination of provision of some bond of the two bound layers (providing some of the original design, composite action of both cemented layers) and the resultant sealing ability in reducing the flow of free moisture between the layers, which in the non-bituminous interlayer pavement system, lead to rapid erosion and deterioration.

Given the inability in this controlled experiment to achieve a full composite action of the two cemented pavement layers, it is unlikely that full bonding would be readily and consistently achieved in the field. Therefore design of a stabilised pavement should take construction practicalities and limitations into consideration. If a pavement containing binding agent can not be constructed in a single lift at its design depth, due perhaps to inappropriate sized equipment or proximity to sensitive structures (where compactive energy levels need to be restricted), then the rehabilitation design should be reconsidered.

9 Summary Of Trial Data

Based on the trials summarised in this report an attempt has been made to rank the 'as-reported' results in terms of efficacy in the prevention of primarily transverse cracking from reflecting through the new surface dressing. Table 5 provides this summary.

Table 5: Summary of Field Trials Reported

SAM/SAMIs on new jointed concrete base (transverse jointing)

VicRoads Surfacing Trial (1994-99) refer to Section 6.1 (Yeo and Foley 1997)		
Treatment	Performance	Ranking
DGA with SAMI	90% cracked at 2 yrs	4
Slurry seal with SAMI	100% cracked at 1 yr	4
SAM Seal	100% cracked at 3 yrs	4
OGA with SAMI	35% cracked at 4.7yrs	2
SMA with SAMI	30% cracked at 4.7 yrs	2

cont.

Table 5: Summary of Field Trials Reported *(cont.)*

SAM/SAMIs over old jointed concrete base (transverse jointing)

VicRoads SAMI Trial (1986-96) refer to Section 6.2 (VicRoads 1997)		
Treatment	Performance	Ranking
No further treatment, then 30 mm of size 14 DGA	14% after 5 yrs; 30% after 10 yrs	4
High tensile strength woven-fibre glass fabric bandage, then 30 mm of size 14 DGA	↑ 3% to 10% after 5 yrs; 10% to 29% after 10 yrs ↓	3
PMB bandage (SAMI with no reinforcing fibres), then 30 mm of size 14 DGA		3
PMB bandage (SAMI with some reinforcing fibres), then 30 mm of size 14 DGA		3
Saw cutting and sealing a 30 mm layer of size 14 DGA overlay	3% cracking after 5 yrs; same at 10 yrs	**2**
Bituminous Scrap Rubber Asphalt (BSRA, crumbed rubber) placed 30 mm thick	nil cracking after 10 yrs	**1**

SAM seal (Chip seal) treatments over cracked CTB (longitudinal and transverse cracking)

Queensland SAM Trial (1995-98) refer to Section 6.7 (Treadrea 1999) Treatment	% of original Cracking Re-appearing	Observation period	Ranking
SR15 Scrap Rubber at a concentration of 15 pph	18	3.2 years	**1**
SB5 Styrene Butadiene Styrene at concentration of 5%	18-34	3.2 years	**1**
SR20 Scrap Rubber at a concentration of 20 pph	22-37	3.2 years	**2**
SB3 Styrene Butadiene Styrene at concentration of 3%	23-58	3.2 years	3
PBD Polybutadiene	30-58	3.2 years	3
AB3 Asphalt grade (EMA)	34-89	3.2 years	4
Class 170 Control binder; neat binder (80/100 grade)	74-77	3.2 years	4

Table 5: Summary of Field Trials Reported *(cont.)*

SAMIs with 40 mm asphalt surfacing over cracked CTB

French Monitoring (1988-95) refer to Section 6.8 (Laurent *et al.* 1996) Treatment	No. of winters To 50% crack appearance	Observation period	Ranking
Control; 40 mm non-modified bitumen asphalt	4-5	6 years	4
Sand Asphalt Interlayer; 20 mm	5-6	8 years	3
SAMI (largely discontinued)	5	5 years	3
Membrane with cold asphalt; 10 mm	4-5[3]	5 years[1]	3
Modified binder and geotextile	6	8 years	3
Geotextile chopped strand; 10 mm (with chip seal)	5-6	6 years	3
Fibre modified asphalt; 30 mm (no other asphalt)	'promising'	4 years	Na[2].

1. On chip seal base 2. Not applicable 3. >7 years when on AC base

Ranking is based upon a scale of 1 to 4 with a low score providing an indication of very good performance in preventing reflection cracking. A score of 4 would indicate either the 'control' section performance, which performed at the lower end of each trial's results, or almost nil improvement at the time of measurement. Scores of 2 or 3 represent performance between these extremes. Treatments ranked either 1 or 2 in Table 5 are highlighted with a box and bold rank number.

10 Discussion

10.1 Cement Treated Base (CTB) versus *in situ* Stabilised Base

Most trial data reported in the literature and around Australia typically comprises either rigid or semi-rigid (i.e. cement treated base layers and treatments comprising a composite SAM and SAMI, i.e. a SAMI with a thin asphalt overlay). The one thin SAM treatment (not SAM and SAMI) trial is the Queensland SAM trial reported in Section 6.6 of this report. Even this trial utilises a cracked CTB which is typically constructed from a quality granular material stabilised at a batch plant and placed by paving machine to produce a highly bound material.

In situ stabilised pavement materials would typically be 'designed' to produce UCS values of between 1 and 3 MPa at 7 days cure, and typically lower values at 7 days for slower setting cementitious binders. In many cases this design component is replaced by contractors 'experience' which may then produce a wider range of material strengths. QDoT (Queensland Transport 1990) specified, for their two weaker categories of CTB, only minima UCS values of 2 and 3 MPa, with no upper limit. Typically 3 to 4 per cent (by dry mass of host material) of cementitious binder would be used in quality crushed materials to achieve these minima values.

Therefore the CTB pavements reported in these trials are typically stiffer with greater quantities of binding agents, than those typical of *in situ* stabilisation. Cracking at these sites tends to be more pronounced (wider) and therefore harder to prevent reflecting through any overlying treatment. Hence the reason why these type bases are usually selected for trials. Where pavement stiffnesses are lower than those of the CTBs reported in this report the efficacy of the same treatments would be expected to improve.

10.2 Interpretation of Trial Results

Some treatments which reportedly perform well in one trial do not so in another. The French (Laurent *et al.* 1996) report - that SAMIs comprising aggregate covered membranes have been largely discontinued in France due to their poor performance - is at odds with current practice in Victoria (van Deuren and Esnouf 1996) where geotextile reinforced chip seals are routinely placed over cracked surfaces. OGA performed poorly over jointed concrete pavements at test sites in Belgium (Vanelstraete and Decoene 1996), whereas in the VicRoads surfacing trial constructed on new jointed concrete pavement, OGA and SAMI performed very well.

Inspection of the data in Table 5 shows a range of treatments with the potential to perform well relative to a control section. Treatments involving higher bitumen contents performed better than those with lower bitumen contents did. For example, the OGA and SMA over SAMI treatments in the VicRoads surfacing trial performed markedly better than the DGA over SAMI treatment, the DGA having less binder (and different grading). Tredrea (1999) also reported that the better performance of SAM seals in the Queensland SAM trial was related to the application rate of binder for the SAM seals.

Treatments comprising modified binder in asphalts, were considered to perform better than those without modification: Statton and Kadar 1990 Callington ALF Trial, SA; VicRoads SAMI Trial and monitoring on the French network. Of particular interest was the good performance of scrap rubber as a modifying agent in bitumen, used in both seal and asphalt applications: Queensland SAM trial and VicRoads SAMI trial.

All three treatments using localised SAMIs such as 'bandage' type treatments did not perform well in the one trial where these were reported (VicRoads SAMI trial).

10.3 Key Surface Factors Affecting Reflection Crack Control Treatment Performance

10.3.1 Crack Size (width)

Wide cracks are more difficult to effectively treat to eliminate or limit the occurrence of reflection cracking than fine cracks or 'fractures' of the pavement surface.

10.3.2 Crack Activity

Cracks that move in one or more directions, and the degree to which they move when under load, either seasonal or diurnal environmentally induced, or traffic induced loads, have a direct effect upon the ability of most treatments to eliminate or limit crack reflection.

10.3.3 Crack Type

Crack type influences the above two factors. Cracking due to fatigue tends to be finer than that caused by material shrinkage. Thus fatigue cracked pavements would typically have greater load transfer ability resulting in lower crack activity, than for pavements exhibiting block or transverse type cracking due to material shrinkage.

10.4 Key Non-Surfacing Factors Affecting Reflection Crack Control Treatment Performance

The following parameters are briefly outlined as they will all have a direct influence on the performance of any reflection crack control treatment and must be measured, assessed and taken into account prior to the selection of trial sites.

10.4.1 Drainage

As mentioned earlier in this report, effective drainage of surface and subsurface moisture is a key issue for the continued performance of flexible pavements. Moisture in the base, subbase and in the cracked zone has the effect of weakening and eroding materials such that severe loss of traffic load carrying capacity is realised.

10.4.2 Traffic Loading

Cracking of pavements would be not present a problem if no loading via traffic were to occur. Erosion of crack faces and at horizontal layer interfaces due to the presence of moisture with repeated loading would not occur. Hence nil loss of load transfer would occur at the crack locations and primarily environmental loads would affect crack widths.

Sustained loading by heavy vehicles will, depending upon on the degree of support offered by the underlying pavement system, have a direct bearing upon the performance of any applied crack treatment. Austroads (1998) suggests load levels for treatment types. Laurent *et al.* (1996) suggests a limit of 300 HCV/day for the effectiveness of a surface dressing to limit reflection cracking in CTBs.

10.4.3 Environmental Loading

Moisture fluctuations cause seasonal movements of longitudinal cracking, whereas temperature changes have a more pronounced effect on transverse crack activity; this latter phenomenon being dependent upon the thermal characteristics of the aggregates used and thickness of the overlying treatments in insulating the temperature sensitive materials.

10.4.4 Base Strength

Most guides to treating and rehabilitating cracked pavements emphasise the importance of treatments being placed upon a sound pavement structure. This refers to the ability of the base to transfer load across the joint or crack. Typically pavements having very little absolute vertical movement in response to traffic loading achieve this, i.e. pavements have sufficient strength so that the relative vertical movement of one pavement one side of the crack is very small (Laurent *et al.* suggested a maximum of 0.3 mm).

10.5 Why Shrinkage Cracking is the Critical Crack Type

Cracking of a cemented base layer induced by trafficking may develop either as block cracking, as in the fracture of a large cemented block of base material into two smaller blocks, or by the ultimate progression of division of these successively smaller blocks into fine crocodile or fatigue cracking.

Where the cracking is fatigue-like, i.e. very closely spaced platelets of base material, the cracks that form these plates tends to be very fine so that the pavement surface is fractured at very close intervals. Where cracking originates from a fatigue failure mechanism such as this fine, closely spaced cracking, the SAM and SAMI treatments tend to be more effective than where environmental crack activity is present (Austroads 1998).

Conversely, where cracks are active, such activity being due to either wide cracks with lower interlock across the crack - thus allowing greater differential movement as the wheel load passes from one side of the crack to the other - or to where base materials are thermally sensitive - thus causing cyclic longitudinal movement across the crack - treatments to suppress reflection cracking will be less effective. It is the shrinkage cracking, due to the cementing action of the binding agent, which produces cracking having these characteristics.

Trials of reflection crack treatments are generally associated with stabilised or bound substrates (CTB, lean-mix and Portland cement concrete) because these crack types are the most aggressive for overlaying surfacings. Therefore, when assessing treatments suitable for the control of reflective cracking, those which control cracking due to bound or cemented base courses, such as those reported herein, is appropriate.

10.6 Industry and Client Accommodation of Specialist Treatments

In New Zealand, tenders can not specifically name a product, rather a generic process or specify an outcome of the application called for by the tender. Processes or techniques that are new to a market face the challenge of acceptance by clients and contractors alike to penetrate the existing marketplace.

Australian road authorities have provided leadership in the dissemination of objective technical information for existing and emerging techniques via the publication of guides and technical notes (VicRoads 2000, RTA 1994 and 1995, QDoT 1994 etc.). This information is often vital for clients to have the confidence to either specify or accept a new process or technique.

Some cost-effective techniques or processes, by virtue of their higher set-up costs in a relatively small market as New Zealand, will require greater marketing and information dissemination to allow their acceptance and establishment.

Information from industry regarding the likely order of establishment costs in New Zealand is included in Table 6.

Table 6: Crack Reflection Reduction Surfacing Techniques and Processes Magnitude of Establishment Costs

Treatment / Process	Current status of use in New Zealand	Likely establishment cost given current usage
Scrap rubber SAMs and SAMIs	Little	Moderate
PMB SAMs and SAMIs	In use	Low
Geotextile seals	In use	Moderate
Insitu (fibre-reinforced) geotextile seals	Nil	Moderate
Scrap rubber asphalts	Little	Moderate
PMB asphalts	In use	Low
Ultra-thin asphalt	In use	Low
Bandage type treatments	In use	Very low
Stone-mastic asphalt	In use	Low
Slurry seals	NA	NA
Other(s)		
1. Other(s)		

NA. Not appropriate treatment

11 Performance Trends for Treatments

As part of this investigation, consideration has been given to producing a tabulation of treatments taking into account the key factors which influence the performance of thin bituminous surfacings in resisting the transmission of cracking from the cemented substrate through the applied surfacing. One way of presenting such data may be to place, in a matrix, the expected upper traffic design loading (in ESAs) for the various treatments versus the major factors affecting the performance of these treatments. However, the nature of the trials undertaken to date, and the complexity of the interaction of the various factors affecting the crack-suppressing performance, do not readily allow such a neat solution.

It is considered, on the basis of the data to hand, that it is more appropriate to present those surfacing treatment characteristics which have indicated good performance in trials, and to also present those pavement and loading factors which contra-indicate good performance. Table 7 (*next page*) provides these data.

Table 7: Performance Trends for Factors Influencing Reflective Crack Treatments

Treatment Characteristics	Trend	Comments
Bitumen content	The greater, the better performing the treatment.	
Binder modification	By use of polymers and additives, such as scrap rubber, improve the efficacy of these treatments.	
Geofabric	Inclusion provides greater reservoir for bitumen and ability to alleviate strain within surfacing.	
Mastic type asphalts	Higher mastic content (than conventional DGA) assists in proving additional elasticity to the mat.	
Pavement Characteristics	**Trend**	**Related to**
Sound; structurally adequate	Very difficult to mask reflection cracking if pavement is structurally inadequate.	Drainage, traffic loading and inadequate thickness
Active cracks	The greater the movement, the more aggressive the wear on the treatment.	Loading and soundness of pavement
Crack widths	Wider cracking is more difficult to effectively treat.	Base material characteristics
Drainage	Good drainage is generally essential to providing the best performance for any treatment.	
Loading	**Trend**	**Related to**
Environmental; thermal & moisture	The lower the loading, the lower the crack activity.	Drainage and base material characteristics
Traffic; heavy vehicle axle masses and number	The lower the loading (in axle mass and numbers), the lower the activity.	

12 Proposal for Treatment Evaluation

12.1 Objective of Further Work

This research has provided surfacing techniques and processes which can be applied to existing pavement surfaces and potentially to newly constructed pavements where the base material has a likelihood of having a cementing action, hence the ability to crack due to environmental and continued traffic loading.

The environmental cracking as discussed earlier in this report initially manifests itself as transverse shrinkage cracking. Continued exposure to the environment (moisture and temperature changes) then will primarily lead to additional transverse oriented cracking, with some joining meandering cracking. Traffic loading will tend to produce more longitudinally oriented cracks to form the block-cracking pattern, refer to Figure 11. Both these crack mechanisms require to be treated to prevent or substantially delay reflection cracking.

Further very closely spaced cracking of the surface due to excessive flexure/strain of the surfacing or of both the base and surfacing layers to cause crocodile or fatigue cracking may also be inhibited by the application of the specialist surfacings.

However, some structural inadequacies will not be able to be masked or 'held together' by a thinly applied bituminous surfacing, with consequent distress appearing in the pavement base and surfacing.

It is therefore considered that the reflective crack suppressing techniques should apply to cracks caused by the initial environmental and to subsequent traffic loadings where the distress mode is cemented-material related.

12.2 Trial Parameters

12.2.1 Nomenclature

In the following Section the terms Site and Section are used. They are defined as follows and represented in the graphic:

Site: A length of selected pavement upon which a number of treatments Sections are placed.

Section: A length of pavement containing a single crack suppression treatment.

Section; SRS treatment	**Section**; SMA treatment	**Section**; Bandage treatment	**Section**; Nil treatment

◄——— **Site A** ———►

12.2.2 Pavement Type

As foreshadowed by Transfund, any field trials would necessarily be undertaken on existing and new pavements where the presence of cemented material has caused (or would be likely to cause, for new pavements) classical transverse and block cracking given normal surfacing application. Such a trial would not be designed to assess suppression of cracking, not related to the base material properties, ie. thin pavements, excessive flexure of base and material degradation, but these other crack may by default be included and form part of the project.

Trials with published outputs in Australia and other countries have typically comprised those on existing cracked pavements where the crack severity (width and activity) and extent is likely to be greater than that due to a well designed and constructed materials' modification or light stabilisation. These pavement types comprise cement-treated base (CTB) and jointed rigid (Portland cement concrete) pavements that produce very regularly spaced and relatively severe (wide and active) cracks that can be readily monitored for crack reappearance over the monitoring period. These pavements owe their cracking substantially to the base material's physical properties with less influence due to the effects of drainage, subgrade support and traffic loading.

Where the base material is less rigid or modified such that light or partial cementing occurs, the influence of these other factors becomes more dominant on the occurrence and severity of the cracks and reflection cracking, as compared to the influence of the material itself. Thus trials in such pavement types typically require longer lengths of discrete treatments and control Sections for comparison, and may require additional testing or monitoring to track changes in the other external influences on the pavement performance.

Establishment of a successful trial on a 'yet-to-be-built' pavement to assess crack reflection suppression treatments may be difficult to achieve with only a modified pavement base material. The difficulty lies in having the pavement crack in a uniform and desired manner. It is likely that unless the technique of construction such pavements which will provide the requisite crack pattern is well known, the pavement will either produce insufficient or non-uniform cracking to permit a faithful assessment of crack suppression treatments to be made.

It is recommended therefore that existing flexible pavement Sites showing ideally classical shrinkage or block cracking be selected for comparison of crack reflection suppression techniques. Where the ideal crack types can not be located in sufficient extent within a reasonable length Site, consideration can be given to the inclusion of other crack types such as crocodile and general cracking for inclusion into the trial Sites.

12.2.3 Distress Type and Severity

Transverse or block cracking is the dominant distress type requiring to be suppressed from reappearing through new surfacing, as shown in Figures 10 and 11. Transverse cracking would ideally occur across the whole pavement width at regular intervals of less than 15 m.

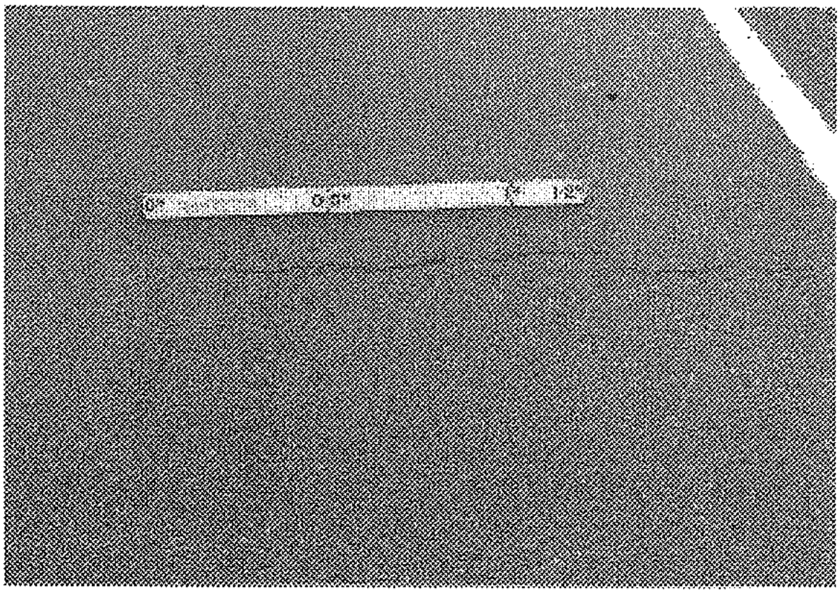

Figure 10: Transverse Cracking (Austroads 1987)

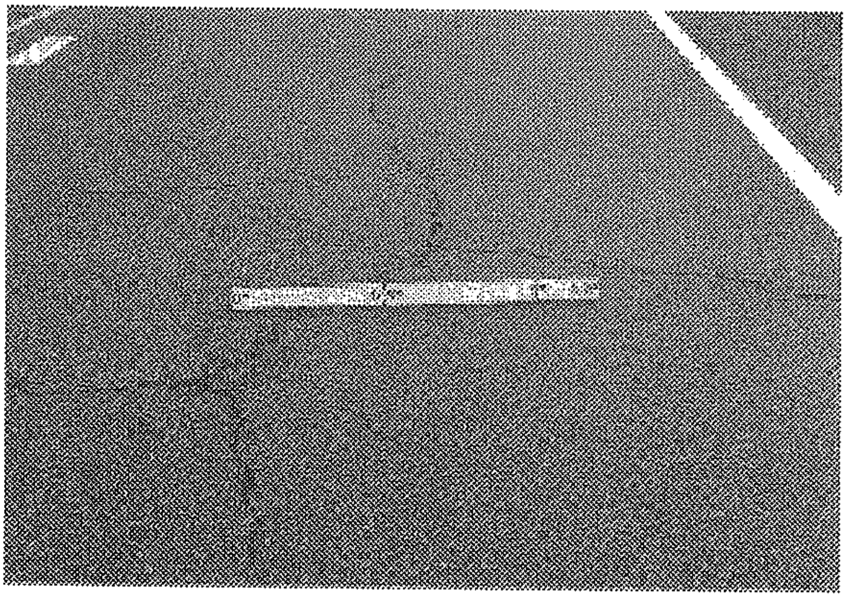

Figure 11: Block Cracking (Austroads 1987)

Crack width and activity determine crack severity. Crack width can be adequately estimated using a calibrated card as shown on page 29.4 of ARRB (1995). Crack activity due to trafficking (movement) can usually be estimated by careful observation under heavy commercial vehicle loading.

It is recommended that Sites be selected having cracks, reasonably uniform in severity and activity within the one Site (so that individual treatment Sections have an equal chance of performance), but differing between the Sites to provide for the potential to discriminate between treatments if one Site does not provide such indication. One of these Sites may thus qualify for a 'recently constructed' pavement as foreshadowed by Transfund in the project brief.

It is recommended that an estimate be made of crack severity at least for the initial survey, for possible use in discriminating between surface treatment performance.

12.2.4 Treatment Details

Record binder application rates where applicable. If the performance indicator is the same for different Sites it may be concluded that if the mode of failure is the same for both Sites, the real difference between Sites may be the binder application rate of the treatment and not say traffic level.

12.2.5 Seasonal Effects

Timing for the collection of this data should correspond with the period of maximum crack width. Since any data collected in say August is likely to show greater crack width and general levels of cracking, care must be exercised if further performance indicators are developed based on data sets collected at other times.

Cognisance should be made for any dynamic seasonal behaviour of the cracks. As a result of relevant observations, the timing of further assessments may need to be scheduled for the coolest/warmest period of the year.

A further observation relating to any seasonal effect concerns the increasing roading authority interest in pavement assessment tools that can recognise cracking at highway speeds. Recent industry comments suggest that the threshold for the CSIRO[9] video based crack assessment device is approximately 0.8 mm. Clearly, if an assessment of a treatment trial was performed in August, and again say in January, the measured cracking may differ significantly ie. extensive cracking would be reported in August (if the crack width were above the detection threshold of the survey instrument) and virtually no cracks may be reported in January. The consequence of seasonal variation in crack width on network assessment tools should be identified if these tools are to be of practical value.

12.2.6 Moisture Effects

Cognisance needs to be made of the contribution of pavement moisture to longitudinal crack dynamics. If the maximum rainfall occurs at about the same time as maximum air temperatures, refer to Figure 12, this will add to the magnitude of the seasonal crack activity, ie. the cracks will be at their minimum during the wet season and consequently be less affected by water damage than by say more temperate zones in southern New Zealand where the cracks will be at their maximum width during the wet season. This moisture differential due to seasonal differences may not be of a major consequence in New Zealand where the north to south spread of major roads is 12^0 of latitude.

Since rainfall may cause the edges of the pavement shoulder to swell, the sealed pavement is likely to experience compression from expansive soil forces. This may contribute to the closing of any longitudinal and centre-line cracks. Thus cracks may be effectively sealed against water entry, not by a treatment but by the compressive action of the volume increase acting on the pavement base to close the cracks.

Thus the climatic data for each candidate Site should be considered as part of the selection process.

12.2.7 Pre-treated Cracks

Some cracking on existing pavements may be treated by crack sealing or by another localised treatment. This must be noted as the presence of additional bituminous binder in the crack vicinity (to that of the applied treatment) will assist in prevention of the reflection cracking re-appearing. It is recommended that where possible such pre-treated cracks not be included in the sample. If these cracks are included, they may only be recorded as a crack if a fissure is discernible.

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[9] Commonwealth Scientific Industrial Research Organisation

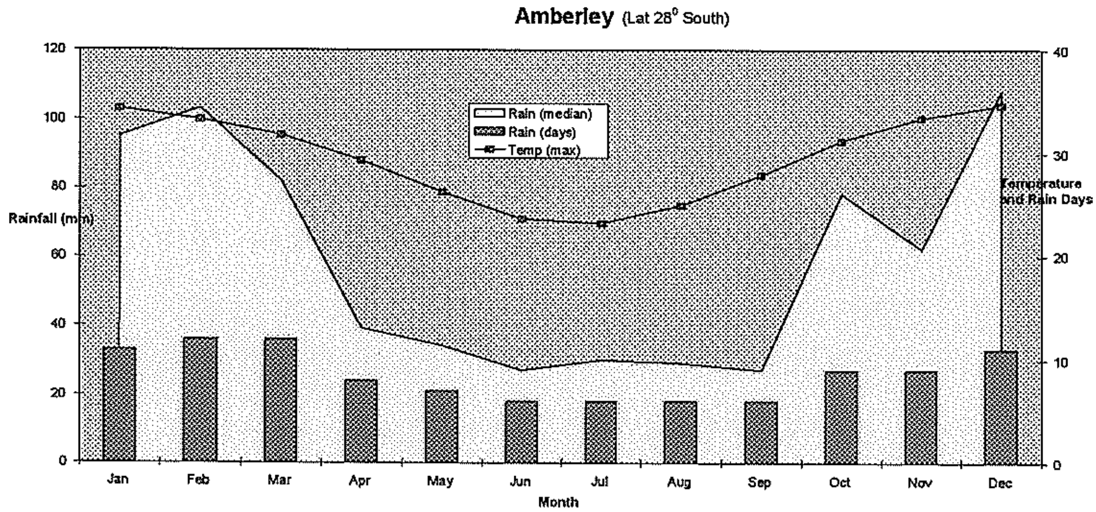

Figure 12: Maximum and Minimum Daily Air Temperatures and Rainfall

Note that for this location selected from southern Queensland, the correspondence between maximum temperature (maximum pavement volume closing the cracks) and maximum rainfall in the period December through February.

12.3 Crack Assessment Method

12.3.1 General

Assessment of the retarding ability of a thin surfacing treatments may comprise methods of varying levels of rigour form a relatively simple monitoring inspection of say a reseal patch with an estimate of the length or some other measure of cracking that has reflected through, so a system as shown below and used in contemporary Austroads seal trials. [adapted from Tredrea (1999)]

12.3.2 Site Inspection

The method used to obtain a measure of relative treatment performance will be dependent on the precision of each assessment, especially if teams comprising different personnel are to be used.

As it is difficult to quantify the consequence of using two independent teams for assessments, the best test scheme would use the same staff for each of the assessments since the differences are considered most important for the performance indicator, rather than the absolute levels of crack length.

Determine if cracking appears to be uniform across the whole lane width, the likely conclusion of this would be the confirmation of a longer-term environmental movement being the main cause of distress and continued crack reflection (the object crack type of this study). An additional cold/warm season survey may clarify this observation.

12.3.3 Crack Measurement

Various methods of before and after crack measurements have been tried in Australia. Where cracking is closely spaced and Sections are of reasonable length plastic sheeting has been used, upon which tape is placed to mark the crack location and extent (length). The sheets are either weighed or measured to determine the quantum of crack.

A better method for this study, and typically used in other similar studies is that of physically mapping the Sections based on discrete chainages, annotated with a general indication of crack severity (width and activity).

12.3.4 Grouping and presentation of results

12.3.4.1 Transverse Cracking

In order that the influence of the trial treatments on transverse cracks can be examined, the data summary needs to be developed separately for transverse and longitudinal cracks. Table 8 summarises example data for a Site 'A'. Transverse crack length is reported for each treatment Section and for each of the survey years designated as say 2001 and 2004. Note that the treatments shown in the example are not necessarily those that must be used.

12.3.4.2 Longitudinal Cracking

Table 8 (*next page*) summarises the data for a Site A.

Note that the comparison of the before and after monitoring (ie. year 2001 and year 2004) a normalisation procedure is used (refer to Section 12.4) to produce the "Delta (Δ) Original" value shown in Table 8.

Figures (13 and 14) present example crack length data for each Site, Section (treatment) and crack category.

12.4 Crack Length Normalisation

For each of the crack types, to minimise the consequence of different crack levels between treatment types the data can be presented as a percentage change from original crack length related to the 2001 reference year. In its simplest form, this approach will result in (-)100 percent for a location with no recorded cracking in say the 2004 survey, 0 percent where the crack length is the same in 2004 (compared with the 2001 data), and (+) 100 percent where the crack length is double the original value.

To improve the data presentation the following equation can be adopted:

$$\boldsymbol{\Delta\ Original}\ (\%) = \left[\frac{2004-2001}{2001}\right]*100+100$$

where 2001 is the crack length in metre for a 2001 survey, and
2004 is the crack length in metre for a 2004 survey.

Table 8: Example Crack length Summary

	SITE A								
	Longitudinal			Transverse			Total		
	2001 metre	2004 metre	Δ Original (percent)	2001 metre	2004 metre	Δ Original (percent)	2001 metre	2004 metre	Δ Original (percent)
GTS[1]	19.4	0.0	**0.0**	64.3	70.0	**108.9**	83.7	70.0	**83.7**
FRS	54.6	0.0	**0.0**	40.9	47.3	**115.7**	95.4	47.3	**49.5**
SRS	28.8	24.8	**86.2**	30.5	18.7	**61.3**	59.3	43.5	**73.4**
PMB	35.1	24.5	**69.8**	69.2	48.3	**69.8**	104.3	72.8	**69.8**
SMA	4.4	2.1	**47.3**	35.2	28.9	**82.0**	39.7	31.0	**78.1**
CON	17.8	0.0	**0.0**	25.6	27.8	**108.5**	43.4	27.8	**64.1**
NIL	1.1	0.0	**0.0**	14.3	14.6	**102.2**	15.4	14.6	**94.8**

1. Geo Textile Seal; Fibre Reinforced Seal; Scrap Rubber Seal; Poly Mod Binder seal; Stone Mastic Asphalt; CONventional reseal; NIL treatment.

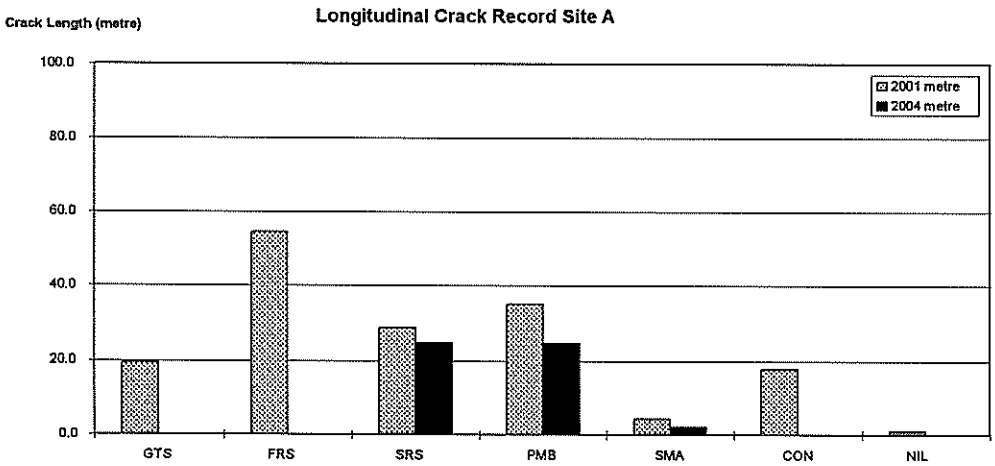

Figure 13: Example Longitudinal Crack Record

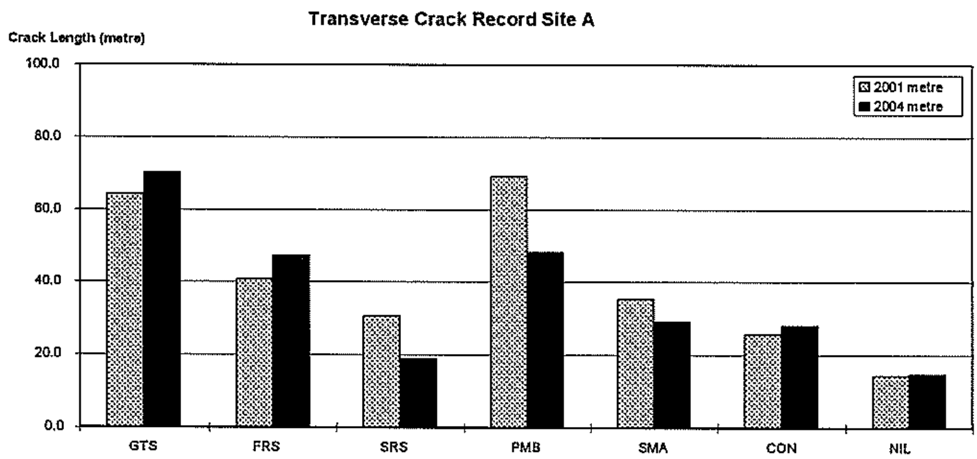

Figure 14: Example Transverse Crack Record

This equation results in the following levels:

1. Zero percent represents no measured cracking in 2004 ie. complete suppression of the cracks measured in 2001 (the objective of the treatment).
2. 100 percent represents the same measured crack length in 2004 compared with the 2001 data. This can be a combination of new cracks and some old cracks not reflecting through.
3. 200 percent represents a doubling of the measured crack length in 2004 compared with the 2001 data.
4. Where no cracking was recorded in 2001 and 2004 (-) should be reported to avoid confusion.

The crack length treatment performance indicator ***Original*** (%) can be reported as a percentage for both transverse and longitudinal cracks for each Section (treatment) at each of the trial sites. A total crack length (sum of transverse and longitudinal) can also be reported along with the total ***Original*** (%). This is to provide a measure of consistency between sites.

Figure 15 shows an example comparison between Sites for the same treatments; Site B data is not tabulated in this report.

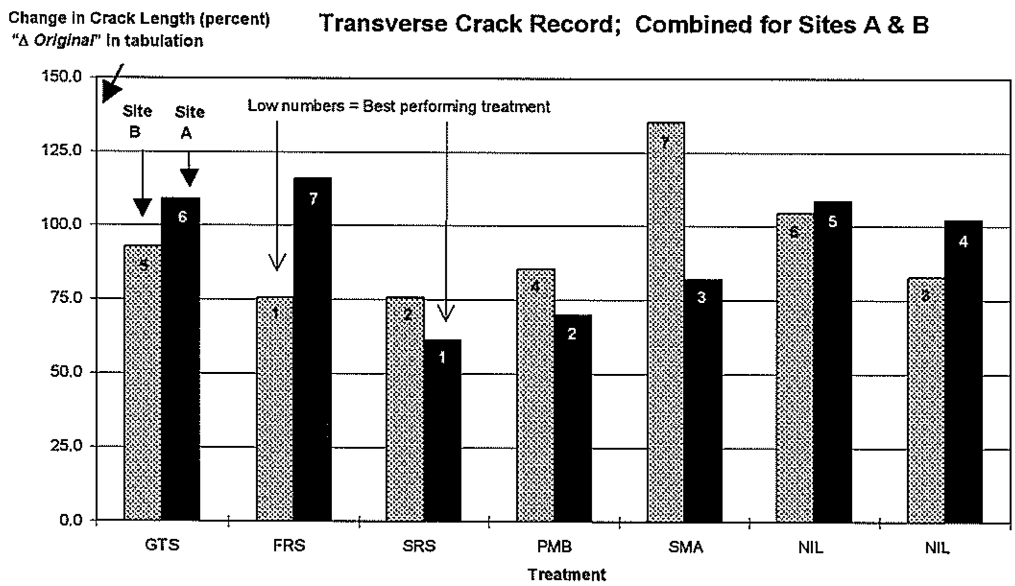

Figure 15: Example Presentation Graphic; Comparison of Sites

12.5 Final Comparison of Treatments

Given the level of uncertainty associated with this crack assessment approach, implying too much precision into the treatment ranking based on absolute length of cracks re-appearing may be unproductive. Grouping the treatment performance together as shown in Table 9 may help identify a broad property/performance relationship:

Table 9: Suggested Groupings for Treatment Ranking

Group	Range of Crack Suppression
1	0 to 25 percent
2	25 to 50 percent
3	50 to 75 percent
4	75 to 100 percent

where Group 1 contains a treatment with a high performance and Group 4 a least performing treatment.

Recognition of a range of other factors would be given in addition to the absolute 'crack length suppression' values, eg. changed conditions during the trial such as shoulders, drainage, traffic or differing levels of traffic or binder application rate (for a specific treatment) for the whole monitoring period.

12.6 Recommended Treatments

Treatments for reflection crack control include:

- Geosynthetic reinforced seals,
- Glass fibre (insitu) reinforced bituminous treatment,
- High mastic type asphalt, and
- Strain Alleviating Membrane Interlayer (SAMI) and Strain Alleviating Membrane (SAM) treatments.
-

The above treatments include:

- conventional unmodified binders.
- Polymer Modified Binders (PMBs), and
- scrap rubber additive to the binder.

Based on the evidence gathered for this report strong consideration should be given to the following treatments:

- Scrap rubber SAM,
- PMB SAM,
- Geosynthetic reinforced seal, and
- Glass fibre reinforced bituminous treatment
-

These would be in addition to a conventional reseal using a non-modified binder, and if possible, a section where no treatment is applied. The latter section would serve as an absolute reference to determine any extent of crack healing or other environmental occurrences during the monitoring period.

Suppliers of the geosynthetic (*in situ* chopped strand and in roll form) reinforcement can advise the appropriate binders and application for use based upon the actual surface conditions at the individual Sites. Information from the Austroads specification framework for PMBs (1997) in Appendix A would also be applicable to assist in determining the correct grade binder given traffic loadings, crack widths and geotextile type to be used.

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APPENDIX A
AUSTROADS SPECIFICATION FRAMEWORK FOR POLYMER MODIFIED BINDERS (PMB) (AUSTROADS 1997)

PMB Selection Criteria For Sprayed Sealing Applications

A. —Strain Alleviating Membrane Interlayer (SAMI)

SAMIs are used to absorb strains that can cause reflection cracking in applied asphalt overlays (Note 1).

Type of Cracking	Slow Movement (Environmental) (Notes 2 and 3)	Rapid Movement (Traffic induced)	
Cracking Severity	All crack widths	All crack widths	
Traffic Loading	All loadings	High (Note 6)	Low (Note 4)
Consistency at 60°C or 45°C	✓	✓	✓
Stiffness at 15°C	✓	✓	✓
Elastic Recovery at 15°C (Note 5)	✓	✓	✓
Toughness at 4°C	✓	✓	✓
Compression Limit at 70°C	-	✓	✓
Suggested PMB Materials (Note 6)	S20E S50R S55R	S25E S30E S55R S60R	S20E S25E S50R S55R

Support notes to selection criteria

1. Prior to using SAMIs and SAMs, a program of crack sealing treatment must be performed on existing cracks.
2. Slow movement or environmental cracks are induced by diurnal or seasonal changes. Where large environmental cracks are present and where crack movement is > 0.5 mm, a PMB alone is unlikely to provide a long-term solution, and should be used in association with a geotextile. If fatigue (traffic induced) cracking is not evident is such circumstances, a lightly modified or unmodified binder may be used with the geotextile.
3. Where geotextiles are used, care should be exercised in ensuring that the application temperature for the PMB does not exceed the melting point of the geotextile material type. For this reason, crumb rubber binders are inappropriate for use with polypropylene geotextiles.
4. For SAMI purposes, high traffic loading is defined as $> 5 \times 10^6$ ESA whereas other loadings are $\leq 5 \times 10^6$ESA [ESA – equivalent standard axle].

5. For SAMI or SAM applications expected to accommodate slow crack movements, it is perceived that a maximum limit on elastic recovery may be required to provide suitable materials.
6. Different products even within the same polymer group are suggested due to the diversity across Australia in environmental and service conditions and in local design and construction practices.

Where more than one set of conditions prevail such that none of the selection criteria described cover the circumstances, a judgement will be required as to which PMB class is most suitable. If uncertain, the practitioner should seek specialist advice..

B. — Strain Alleviating Membrane (SAM)

SAMs are used to absorb strains that can cause reflection cracking in the applied sprayed seal (Note 1).

Types of Cracking	Slow Movement (Environmental) (Notes 2 and 3)	Rapid Movement (Traffic induced)	
Cracking Severity	All crack widths	High (Note 6)	Low (Note 6)
Traffic Loading	All loadings	All Loadings	All Loadings
Consistency at 60°C or 45°C	✓	✓	✓
Stiffness at 15°C	✓	✓	✓
Elastic Recovery at 15°C (Note 4)	✓	✓	✓
Toughness at 4°C	✓	✓	✓
Aggregate Retention	✓	✓	✓
Compression Limit at 70°C	✓	✓	✓
Suggested PMB Materials (Note 5)	S10E S35E S40R S45R	S20E S25E S50R S55R	S15E S20E S35E S45R

Support notes to selection criteria

1. Prior to using SAMIs and SAMs, a program of crack sealing treatment must be performed on existing cracks.
2. Slow movement or environmental cracks are induced by diurnal or seasonal changes. Where large environmental cracks are present and where crack movement is >0.5 mm, a PMB alone is unlikely to provide a long term solution, and should be used in association with a geotextile. If fatigue (traffic induced) cracking is not evident in such circumstances, a lightly modified or unmodified binder may be used with the geotextile.
3. Where geotextiles are used, care should be exercised in ensuring that the application temperature for the PMB does not exceed the melting point of the geotextile material type. For this reason, crumb rubber binders are inappropriate for use with polypropylene geotextiles.

4. For SAMI and SAM applications expected to accommodate slow crack movements, it is perceived that a maximum limit on elastic recovery may be required to provide suitable materials.
5. Different products even within the same polymer group are suggested due to the diversity across Australia in environmental and service conditions and in local design and construction practices.
6. High cracking severity is defined by conditions where some crack widths are > 2 mm and/or the incidence of surfacing defects (patches etc) is frequent whereas low cracking severity is applicable where almost all crack widths are ≤ 2 mm and the incidence of surface defects is isolated.

Where more than one set of conditions prevail such that none of the selection criteria described cover the circumstances, a judgement will be required as to which PMB class is most suitable. If uncertain, the practitioner should seek specialist advice.

PMB SELECTION CRITERIA FOR ASPHALT APPLICATIONS

B. — Fatigue Resistance

PMBs with enhanced fatigue resistance are used to minimise asphalt cracking under severe service conditions where unmodified binders are likely to ensure adequate performance.

Traffic Loading	Very high/Very heavy (Note 2)		High/Heavy (Note 2)	
Pavement Temperature	High or Medium (Note 3)	Low (Note 3)	High or Medium (Note 3)	Low (Note 3)
Stiffness at 25°C	✓	✓	✓	✓
Elastic Recovery at 25°C	✓	✓	✓	✓
Retained Strength	✓	✓	✓	✓
Compression Limit at 70°C	✓	✓	✓	✓
Suggested PMB Materials (Note 1)	A10E A40R (Note 4)	A10E A15E A40R (Note 4)	A10E A15E A30P A40R (Note 4)	A10E A15E A40R (Note 4)

Support notes to selection criteria

1. Different products even within the same polymer group are suggested due to the diversity across Australia in environmental and service conditions and in local design and construction practices.
2. For asphalt purposes, the following definitions [ESA – equivalent standard axle, CA – commercial vehicle].for traffic loading apply:

Very high/very heavy traffic is here defined as:

(i) > 2×10^7 ESA **or** > 1000 CV/lane/day which is generally moving at a speed > 25 km/h, or

(ii) > 5×10^6 ESA **or** > 500 CV/lane/day which involves stop/start, in climbing lanes or generally moving at a speed $\leq$ 25 km/h.

High/heavy traffic is here defined as:

(i) 5×10^6 to 2×10^7 ESA **or** 500 to 1000 CV/lane/day which is generally moving at a speed > 25 km/h, or

(ii) 5×10^5 to 5×10^6 ESA **or** 100 to 500 CV/lane/day which involves stop/start, in climbing lanes or generally moving at a speed < 25 km/h.

APPENDIX B

Queensland Department of Transport (DoT)
Technical Note 8, issued November. 1994.
Paving Fabrics in Asphalt and Sprayed Seal Surfacings

1. Description of Treatment

The paving fabric is used in conjunction with a sprayed bituminous film to create a bitumen impregnated interlayer between the existing pavement and the new surfacing treatment. The use of paving fabrics in surfacings is now widespread throughout Queensland and the materials are being used in a wide range of applications including:

- Sprayed bitumen reseals
- New sprayed seals on pavements with cement treated bases (CTB)
- Asphalt overlays
- Fabric reinforced seals on clay pavements (not covered here)

2. Functions

2.1 Sprayed Seal or Reseal

In the case of a new sprayed seal or reseal on fabric, the aim of the treatment is to provide a membrane under the bituminous surfacing that will delay the occurrence of cracking (new work) and delay and/or inhibit crack propagation (rehabilitation work). This is achieved by mobilising the tensile strength of the fabric and/or by allowing a limited amount of slippage across a pre-existing crack. In addition to these crack relieving benefits, the bitumen impregnated fabric interlayer aims to provide a waterproof membrane to the pavement.

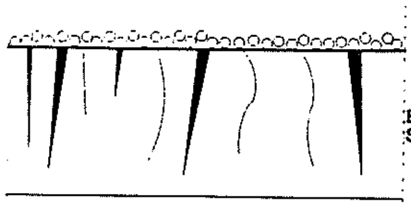

Figure 1 - Paving Fabric in Sprayed Seal

2.2 Asphalt Overlay

In the asphalt overlay case, the aim of the treatment is to provide a membrane under the asphalt that will delay and/or inhibit reflective cracking at the surface of the overlay. This is achieved in a similar manner to above and, more importantly, the bitumen impregnated fabric interlayer also aims to provide a waterproof membrane to the pavement layers below.

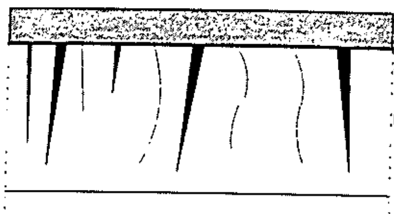

Figure 2 - Paving Fabric in Asphalt Overlay

3. Applications

In the reseal and sprayed seal applications, the bitumen/fabric interlayer treatment can be used on old cracked flexible pavements where the cracking may be due to surfacing age, environmental conditions, pavement design or material quality, and on new or old CTB pavements where the cracking is usually associated with shrinkage, thermal effects, and fatigue of the cemented material. Similarly, for asphalt overlays, the bitumen /fabric interlayer treatment can be used over old asphalt which has cracked due to surfacing age, environmental conditions, pavement design (e.g. asphalt fatigue) or material quality.

In certain applications, where significant shear forces will be applied to the surfacing by traffic (e.g. tight roundabouts), the use of fabrics under sprayed seals and asphalts should be avoided. If the bitumen/fabric interlayer treatment is used on badly cracked and eroded CTB, the success of the operation cannot be guaranteed. Pumping may still occur, however, the likelihood of total success can be dramatically improved through the provision of adequate drainage. Depending on the particular situation, this may be achieved through the use provision of deeper table drains, mitre drains, and/or subsoil pavement drains, as part of the preceding maintenance activities.

4. Materials

4.1 Paving Fabrics

The fabrics recommended for use are non-woven, needle punched polyester or polypropylene fabrics because of their ability to absorb bitumen binder. The grade of the fabric should be 140 g/m^2 (minimum) to 170 g/m^2 (maximum). Some heat bonded or heat calendered fabrics may cause laying difficulties due to their reduced flexibility.
Suitable fabrics currently available include:

Bidim PF1 (polyester)
Polyfelt PGM14 (polypropylene)
ProPex 4599 (polypropylene)
Texcel NW135 (polyester)

Table 1 provides details of these fabrics that are available for paving applications in Queensland. The minimum fabric grade of 140 g/m^2 is consistent with the US Task Force 25 recommendations and it is doubtful that the full benefits of a fabric would be obtained in a paving application if a lighter grade fabric was used. Certain light weight geosynthetics may be recommended by manufacturers as having appropriate other qualities. Pavements Centre staff should be contacted for advice in these instances.

4.2 Bitumen Binder

4.2.1 Hot Bitumen

The bitumen binder used should be such as to allow proper functioning of the strain-relieving interlayer while providing adequate adhesive and shear strength between layers. The binder used shall generally be hot Class 170 or 320 bitumen sprayed at 150 to 170°C (see Section 6.4.5). The use of cutters are not recommended for use in the tack coat since petroleum-based solvents are damaging to most synthetic fabrics. However, cutter may and should be used in the sprayed seal if necessary.

4.2.2 Emulsions

The use of bitumen emulsion is not recommended although it has been used overseas successfully. Emulsions develop bond strength more slowly and, as a result, fabric debonding on windy days has been reported. Emulsions are suitable to secure overlaps at construction joints.

When asphalt emulsions are used with the paving fabric systems, it is important that they be cured prior to the installation of the fabric. Curing time will vary with emulsion type, temperature, humidity and other variables. When cured, not only will the surface be tacky, the characteristic brown hue of uncured material will have turned glossy black when the film is examined in depth.

4.2.3 Polymer Modified Binder

If considered necessary, polymer modifiers may be added to the Class 170 bitumen used with the fabric for either the tack coat (for additional stress relief or to prevent pickup/bleeding problems) or the sprayed seal (for stone retention). EVA polymers are preferred to SBS polymers for the tack coat in sprayed seal applications involving fabrics because of the reported rapid "skinning" of the surface of SBS sprayed membranes and the consequent problem of the fabric adhering to the mat. However, in the asphalt surfacing case, this effect is of little consequence as the placement of hot asphalt on top of the fabric causes softening of the polymer modified binder and impregnation of the fabric. SBS polymers are used extensively in Europe and the United Kingdom for this purpose. If polymer modified bitumens are used, polypropylene fabrics should be avoided because the additional heat used in the spraying operation may cause the fabric to melt.
Recommended guidelines for using polymer modified bitumen in conjunction with fabrics are given in Table 2.

4.3 Asphalt

The asphalt used in overlay works should be a standard mix (14 mm or 20 mm nominal size) conforming to Specification MRS 11.30 (12/93), MRS 11.31 (5/94) or MRS 11.34 (12/93).

5. Design

5.1 General

Table 3 provides a summary of the guidelines for design of bitumen/fabric interlayer treatments.

5.2 Sprayed Seal/Reseal

Dry, precoated cover aggregate should be used, with a nominal size of 7 mm (minimum) to 14 mm (maximum). As previously, the bitumen binder used should be hot Class 170 bitumen with cutter as required.

The design of a paving fabric seal/reseal requires the designer to:

1) Determine the Total Application Rate and,
2) Determine the Tack Coat Application Rate

5.2.1 Total Application Rate

The total application rate of bitumen binder is the addition of the binder required to saturate (fill the voids in the paving fabric) plus the amount of binder required by the seal/reseal as per the AUSTROADS Design of Sprayed Seals, July 1990.

The following steps are recommended to calculate the Total Application Rate:

1) Determine application rate as one would for a normal sprayed seal for the given surface texture (e.g. AUSTROADS).

2) Determine absorption rate of the paving fabric. This should be obtained from the manufacturer of the paving fabric. Table 1 gives a guide to the most commonly used paving fabrics.

3) Add 1) and 2) together to obtain the Total Application Rate.

5.2.2 Tack Coat

The tack coat is primarily laid to ensure an adequate bond of the paving fabric to the existing pavement surface.

Note: The tack coat rate is included in the Total Application Rate.

The tack coat application rate is dependent on:

- the type and grade of paving fabric
- the ambient and pavement temperatures
- the amount of rolling effort applied.

The tack coat rate should typically be between 0.6 l/m^2 as pavement temperatures approach 50°C and up to 0.8 l/m^2 for pavement temperatures between 15°C to 50°C.

Within street intersections, steep grades or in other areas where vehicle speed changes are common, the normal rate should be reduced by 10-20% to prevent shoving of the asphalt overlay or bleeding of the sprayed seal.

5.3 Asphalt Overlay

The minimum thickness of asphalt overlay to be applied over a bitumen/fabric interlayer treatment is 50 mm.
Fabrics are not effective substitutes for AC thickness i.e. they act only as limited reinforcement when the pavement is subjected to traffic loads. The AC overlay thickness should be designed for future traffic considerations and this thickness should not be reduced when a fabric is used.

Open graded friction courses have been trialled in conjunction with paving fabrics to a limited extent. If open graded asphalt is used, there is a risk that if the integrity of the bitumen/fabric interlayer is not maintained, rapid failure of the base may occur following subsequent moisture ingress. The advice of Manager (Pavements) should be sought if the use of open graded friction course directly on a bitumen/ fabric interlayer is intended.

5.3.1 Tack Coat

The tack coat is primarily laid to ensure adequate bond of the paving fabric to the existing pavement surface and to saturate the paving fabric to ensure the formation of a waterproof membrane.

The tack coat application rate is dependent on:

- the type and grade of paving fabric
- the ambient and pavement temperatures.

The maximum tack coat rate should be equal to the absorption rate of the paving fabric as specified by the manufacturer. However, because of high pavement temperatures this tack rate may not be appropriate because of pick up problems during the paving operation. The tack coat rate may be reduced by up to 20% once the pavement temperatures exceed 50°C.

6. Construction Procedure

6.1 Ambient Conditions

Fine weather is necessary for this work. Air and pavement temperatures shall be sufficient to allow fabrics to absorb the bitumen. The air temperature should be a minimum of 18°C (and rising). However, it is also recommended that this type of surfacing treatment be carried out when pavement temperatures are less than 50°C to avoid the likely construction difficulties due to pick-up and bleeding problems (see Section 6.4.5).

6.2 Storage of Paving Fabrics

The rolls of fabric should be stored in a dry place, preferably out of sunlight. Even if the product is marked as "UV Stabilised", protection from direct sunlight is recommended.

The pick-up (or bleeding) potential of fabrics seems to be related, at least in part, to the uniformity or consistency of the fabric. If the fabric supplied appears non-uniform in appearance, the supplier should be notified and the matter rectified.

6.3 Surface Preparation & Preliminary Repairs

Isolated failed areas of pavement should be repaired. However, fabrics should not generally be used in locations where the pavement is badly failed and a significant proportion of the road is affected. If bitumen/fabric interlayer treatments are used in situations where they are seen as little more than "holding" treatments, reoccurrence of the pre-existing failures is likely. If subsoil and/or pavement drains are to be installed as part of the remedial works, it is strongly recommended that they are installed and shown to be effective in "drying out" the pavement structure prior to application of the surfacing treatment.
Existing cracks (>5mm) should be filled and sealed e.g. bitumen emulsion + sand, proprietary crack fillers or overseal banding systems, etc. Filling is necessary to support the fabric (which is yet to be placed and to prevent the fabric from being starved of bitumen). Finer cracks can be sealed as far as practicable using proprietary crack fillers. If necessary, the surface of the pavement should be cleaned and swept.

Surface depressions should be corrected and filled by hand or by applying an asphalt corrector course. If the existing pavement surface is badly deformed due to patching and existing failures, the application of a fine asphalt or slurry seal corrector course will greatly improve the performance of the rehabilitation treatment.

6.4 Placement of Paving Fabrics

6.4.1 General

Fabrics can be installed manually or by machine (mechanical applicators are usually available through suppliers). It is important to stretch the fabric so that it is taut and wrinkle-free and maintain it in this condition while the surfacing is applied. The tack coat should be sprayed approximately 100 mm wider than fabric. The fabric should then immediately be applied by rolling out onto the bitumen tack coat. Wrinkles should be removed by brooming and/or cutting. Folds must be avoided. Where they occur, folds large enough to cause laps or folds greater than 25 mm should be slit and laid flat. Sufficient binder needs to be sprayed over slits to ensure good through bond.

6.4.2 Horizontal Alignment

Curves in the road alignment or around traffic islands are a particular problem as the placement of fabric causes folds. These folds can be cut and the excess fabric removed and the cut faces treated as a join in accordance with the previous paragraphs. Due to the problems at curves serious consideration should be given to using alternatives to fabrics such as polymer modified bitumen SAMs and SAMIs or thicker AC overlays.

6.4.3 Joins

Fabric widths should be selected such that joins of parallel rolls occur only at the centreline or shoulder. Joins should not be placed along anticipated main wheel path locations.

Joins can either be "butt" or "cut and lap". Cut and lap joins are preferred, however, care is required during construction. Cut and lap joins can cause surface failures in an AC overlay if the lap is insufficiently bonded to the layer of fabric below. Alternatively, if too much bitumen is applied, a slippage plane can result in early fatigue cracking or shoving of the AC overlay. Where cut and lap joins are used they should have an overlapped area of 100-150 mm and must have a bitumen coat on the lower layer over this width applied at approximately 0.5 l/m^2. This will normally be applied manually, using a hand held sprayer. A further application of bitumen may be required on the lap to ensure proper bonding of the double layer of fabric. Transverse joins shall be lapped in the direction of paving to prevent edge pickup by the traffic and/or paver. Note that too little bitumen at a join will mean lack of bond whereas too much can cause bleeding, shoving or early fatigue cracking of the mix under braking.

6.4.4 Rolling

Rolling of the fabric into the tack coat should be carried out with a light-weight multi-tyred roller. The mat should be rolled from the middle towards the edges and not from one side to the other. Excessive rolling should be avoided and minimal excess binder should be apparent on the mat i.e. no pick-up on rubber tyred plant.

6.4.5 Pick-up/Bleeding Problems

In general, pick-up and bleeding problems are closely related to:

- Ambient and pavement temperatures
- Grade and uniformity of the fabric
- Film thickness and viscosity of the bitumen binder

Ambient and pavement temperatures are the major cause of the problem and, in very hot weather, the tack coat application rate may need to be dropped and/or the works rescheduled for cooler periods to prevent pick-up of the fabric when trafficked by construction plant. As a guide, pavement temperatures in excess of 50°C have the potential to lead to bleeding/pick-up problems with fabric placement operations. Class 320 bitumen has been used with limited success to overcome major bleeding/pick-up problems (e.g. asphalt overlay on a very hot day using rubber tyred plant). However, relatively little benefit is gained by changing binder class as the Class 170 and 320 bitumens behave similarly at operating pavement temperatures of about 50°C. It is likely that more success will be achieved if a polymer modified binder is used, although no field trials to prove this have been undertaken to date.

6.4.6 Tack Coat Application Rate

The tack coat application rate is more critical in the asphalt surfacing application than the sprayed seal application. This is because if the tack coat is over-applied, flushing or bleeding of the asphalt may result. The tack coat application rate may be reduced to solve this problem however this reduction should not exceed 20% of the absorption of the paving fabric. The following corrective measures may be considered with or without the above reduction in tack coat:

- Hand spread a small amount of asphalt on top of the fabric in the wheelpaths of the paver and trucks.
- Change to Class 320 bitumen or use a polymer modified bitumen for the tack coat.
- Minimise the number of vehicles trafficking the fabric.
- Shorten the distance between fabric placement and the paving machine.
- Application of coarse sand in the wheel paths. This is the least desirable choice since the sand will absorb some of the bitumen which defeats its purpose. Excess sand should be swept off.

In the sprayed seal application, under or over application of the tack coat can be compensated for by similar adjustment to the sprayed seal application rate. As a guide, the application rate is correct if after placing the fabric, the surface of the fabric has a mottled appearance.

6.4.7 Wet Weather

If the fabric gets wet, it will retain the moisture and the immediate application of a sprayed seal will result in blistering of the bitumen. Rain can also cause blistering and subsequent detachment of the fabric. If this occurs the adhesion between the fabric and the tack coat must be restored or enhanced using a pneumatic tyred roller before overlaying with AC or applying a sprayed seal. Drying out of the fabric will be required before applying either a sprayed seal or an asphalt overlay.

6.4.8 Trafficking

Following completion of the bitumen/ fabric interlayer, trafficking should be restricted to essential construction traffic, if at all possible.

6.5 Laying of Sprayed Seals on Paving Fabrics

The hot bitumen binder is sprayed onto the completed bitumen/fabric interlayer. Cover aggregate is applied in the normal manner with the aim of achieving shoulder to shoulder aggregate contact after rolling. The cover aggregate should be "rolled in" using a heavy multi-tyred roller. Additional rolling may be required to adequately embed the aggregate, especially for low traffic situations and in areas outside of traffic lanes. Speed restrictions should be posted on the completed works for several days, if possible. Following initial trafficking, the sprayed seal should be monitored. The surface texture should be checked to ensure that the binder height is at least 50% of ALD, preferably in the range 60 to 70% of ALD. A fog coat of CMS or CRS bitumen emulsion enrichment (or similar) should be considered if the binder is deficient.

6.6 Laying of Asphalt on Paving Fabrics

Thin AC overlays should be placed and rolled soon after the application of the fabric to maximise the bond between the various elements involved. This is not so critical with thicker AC overlays where the heat and weight of the overlay promotes bonding. No tack coat is required to be applied to the top of the completed bitumen/fabric interlayer. The placement of the asphalt is to be carried out in the normal manner as per Specification MRS 11.30 (12/93), MRS 11.31 (5/94) or MRS 11.34 (12/93). To avoid movement or damage to the fabric while turning the pavers and/or trucks, such turning should be gradual and kept to a minimum. The parking of rubber tyred plant on the completed bitumen/fabric interlayer, even for reasonably short periods, should also be avoided.

7. Design Considerations

7.1 Floodways

In floodway situations, considerable hydraulic forces can be imposed of the surface of the pavement during major flood events.

Surfacing treatments which incorporate a bitumen/fabric interlayer may be susceptible to damage (i.e. separation of the interlayer treatment from the pavement surface) during major floods. If bitumen/fabric interlayer treatments are likely to be exposed to such forces, a number of precautionary measures may be taken to reduce the risk of surfacing failure:

- The type cross section should ensure that the free edge of the fabric on the upstream side of the road is securely fixed (e.g. by carrying the fabric down the batter and covering with fill material or concrete, or by securing the fabric into a longitudinal groove cut in the pavement).
- The upstream batter in one way crossfall situations should be sealed to prevent moisture entry.
- Longitudinal joins in the fabric should be lapped in the direction of water flow.
- Particular care is warranted to ensure that the underlying seal is clean and that adhesion agent is incorporated in the tack coat.

7.2 Future Pavement Rehabilitation

The future rehabilitation of the pavement should be considered before applying a bitumen/fabric interlayer treatment. Removing the interlayer treatment and surfacing at a later date is likely to be a problem, particularly in sprayed seal applications (e.g. future widening and overlay scheme).

7.2.1 Hot In-place Recycling

Some problems associated with hot in-place recycling have been the tangling of the fabric interlayer in the milling head because of the hot milling process.

7.2.2 Reclaimed Asphalt Pavement (RAP)

The recycling of asphalt contaminated with bits of fabric may not be possible, depending on the nature of the synthetic fibres and the degree of pulverisation of the fabric.

7.2.3 Cold Insitu Recycling

Cold insitu-recycling of pavements incorporating bitumen/fabric interlayer treatment have not caused any problems to date. The cold insitu-recycling process is capable of breaking the interlayer treatment down without causing the machine to clog or producing large clumps of bitumen/fabric. It should be noted however that this experience has only related to a fabric of only $140 g/m^2$■

TABLE 1: PAVING FABRIC DETAILS

Trade Name	Grade	Supplier	Material Types	Woven/ non-woven	Filament bonding	Unit Mass	Roll Width	Roll Length
BIDIM	PF1 PF2	Geofabrics Australasia	polyester	non-woven	needle punched	140 g/m^2 180 g/m^2	4.0 m	150/300 m 150/300 m
POLYFELT	PGM 14	Geolab Group	polypropylene	non-woven	needle punched	140 g/m^2	1.9 m 3.8 m	150 m 150 m
ProPex	4599	CSR Humes	polypropylene	non-woven	needle punched/heat bonded on one side	155 g/m^2	3.81 m	137 m
Texcel	NW135	Rheem Australia	polyester	non-woven	needle punched	160 g/m^2	4.0 m	100 m

TABLE 2: GUIDELINES FOR USING POLYMER MODIFIED BITUMEN

Treatment Application	Tack coat/ sprayed seal	Polymer type preferred	Additive content Minimum	Maximum
Sprayed seal or reseal	tack coat	EVA	3.0%	5.0%
Asphalt overlay	tack coat	SBS or EVA	5.0%	7.5%

TABLE 3: GUIDELINES FOR DESIGN OF BITUMEN FABRIC INTERLAYER TREATMENTS

Treatment Application	Component	Bitumen Binder	Application Rate (l/m²)	
Sprayed seal or reseal	tack coat	C170, C320 or PMB† (no cutter)	0.6§ (as pavement temperatures approach 50°C) 0.8§ (pavement temperatures between 15°C and 50°C)	Total Application Rate‡
	seal coat	C170, C320 or PMB†	Total Application Rate‡ minus Tack Coat	
Asphalt overlay	tack coat	C170, C320 or PMB† (no cutter)	Maximum tack coat = absorption rate as specified by manufacturer for specific fabric (approx. 0.8 to 1.1). If pavement temperatures in excess of 50°C reduce rate by up to 20%.	

† See Table 2 for guidelines for using polymer modified bitumen (PMB)

§ Normal rate should be decreased by 10-20% for steep grades or other areas where vehicle changes are common.

‡ Refer to Section 5.2.1. of this Technical Note

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APPENDIX B

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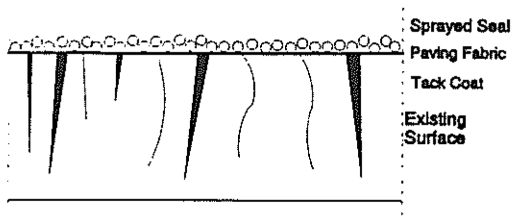

Figure 1 - Paving Fabric in Sprayed Seal

2.2 Asphalt Overlay

In the asphalt overlay case, the aim of the treatment is to provide a membrane under the asphalt that will delay and/or inhibit reflective cracking at the surface of the overlay. This is achieved in a similar manner to above and, more importantly, the bitumen impregnated fabric interlayer also aims to provide a waterproof membrane to the pavement layers below.

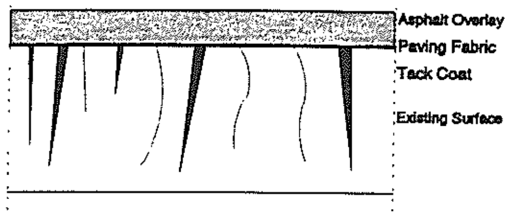

Figure 2 - Paving Fabric in Asphalt Overlay

3. Applications

In the reseal and sprayed seal applications, the bitumen/fabric interlayer treatment can be used on old cracked flexible pavements where the cracking may be due to surfacing age, environmental conditions, pavement design or material quality, and on new or old CTB pavements where the cracking is usually associated with shrinkage, thermal effects, and fatigue of the cemented material. Similarly, for asphalt overlays, the bitumen /fabric interlayer treatment can be used over old asphalt which has cracked due to surfacing age, environmental conditions, pavement design (e.g. asphalt fatigue) or material quality.

In certain applications, where significant shear forces will be applied to the surfacing by traffic (e.g. tight roundabouts), the use of fabrics under sprayed seals and asphalts should be avoided. If the bitumen/fabric interlayer treatment is used on badly cracked and eroded CTB, the success of the operation cannot be guaranteed. Pumping may still occur, however, the likelihood of total success can be dramatically improved through the provision of adequate drainage. Depending on the particular situation, this may be achieved through the use provision of deeper table drains, mitre drains, and/or subsoil pavement drains, as part of the preceding maintenance activities.

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4.2 Bitumen Binder

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4.2.2 Emulsions

The use of bitumen emulsion is not recommended although it has been used overseas successfully. Emulsions develop bond strength more slowly and, as a result, fabric debonding on windy days has been reported. Emulsions are suitable to secure overlaps at construction joints.

When asphalt emulsions are used with the paving fabric systems, it is important that they be cured prior to the installation of the fabric. Curing time will vary with emulsion type, temperature, humidity and other variables. When cured, not only will the surface be tacky, the characteristic brown hue of uncured material will have turned glossy black when the film is examined in depth.

4.2.3 Polymer Modified Binder

If considered necessary, polymer modifiers may be added to the Class 170 bitumen used with the fabric for either the tack coat (for additional stress relief or to prevent pickup/bleeding problems) or the sprayed seal (for stone retention). EVA polymers are preferred to SBS polymers for the tack coat in sprayed seal applications involving fabrics because of the reported rapid "skinning" of the surface of SBS sprayed membranes and the consequent problem of the fabric adhering to the mat. However, in the asphalt surfacing case, this effect is of little consequence as the placement of hot asphalt on top of the fabric causes softening of the polymer modified binder and impregnation of the fabric. SBS polymers are used extensively in Europe and the United Kingdom for this purpose. If polymer modified bitumens are used, polypropylene fabrics should be avoided because the additional heat used in the spraying operation may cause the fabric to melt.
Recommended guidelines for using polymer modified bitumen in conjunction with fabrics are given in Table 2.

4.3 Asphalt

The asphalt used in overlay works should be a standard mix (14 mm or 20 mm nominal size) conforming to Specification MRS 11.30 (12/93), MRS 11.31 (5/94) or MRS 11.34 (12/93).

5. Design

5.1 General

Table 3 provides a summary of the guidelines for design of bitumen/fabric interlayer treatments.

5.2 Sprayed Seal/Reseal

Dry, precoated cover aggregate should be used, with a nominal size of 7 mm (minimum) to 14 mm (maximum). As previously, the bitumen binder used should be hot Class 170 bitumen with cutter as required.

The design of a paving fabric seal/reseal requires the designer to:

1) Determine the Total Application Rate and,
2) Determine the Tack Coat Application Rate

5.2.1 Total Application Rate

The total application rate of bitumen binder is the addition of the binder required to saturate (fill the voids in the paving fabric) plus the amount of binder required by the seal/reseal as per the AUSTROADS Design of Sprayed Seals, July 1990.

The following steps are recommended to calculate the Total Application Rate:

1) Determine application rate as one would for a normal sprayed seal for the given surface texture (e.g. AUSTROADS).

2) Determine absorption rate of the paving fabric. This should be obtained from the manufacturer of the paving fabric. Table 1 gives a guide to the most commonly used paving fabrics.

3) Add 1) and 2) together to obtain the Total Application Rate.

5.2.2 Tack Coat

The tack coat is primarily laid to ensure an adequate bond of the paving fabric to the existing pavement surface.

Note: The tack coat rate is included in the Total Application Rate.

The tack coat application rate is dependent on:

- the type and grade of paving fabric
- the ambient and pavement temperatures
- the amount of rolling effort applied.

The tack coat rate should typically be between 0.6 l/m^2 as pavement temperatures approach 50°C and up to 0.8 l/m^2 for pavement temperatures between 15°C to 50°C.

Within street intersections, steep grades or in other areas where vehicle speed changes are common, the normal rate should be reduced by 10-20% to prevent shoving of the asphalt overlay or bleeding of the sprayed seal.

5.3 Asphalt Overlay

The minimum thickness of asphalt overlay to be applied over a bitumen/fabric interlayer treatment is 50 mm.
Fabrics are not effective substitutes for AC thickness i.e. they act only as limited reinforcement when the pavement is subjected to traffic loads. The AC overlay thickness should be designed for future traffic considerations and this thickness should not be reduced when a fabric is used.

Open graded friction courses have been trialled in conjunction with paving fabrics to a limited extent. If open graded asphalt is used, there is a risk that if the integrity of the bitumen/fabric interlayer is not maintained, rapid failure of the base may occur following subsequent moisture ingress. The advice of Manager (Pavements) should be sought if the use of open graded friction course directly on a bitumen/ fabric interlayer is intended.

5.3.1 Tack Coat

The tack coat is primarily laid to ensure adequate bond of the paving fabric to the existing pavement surface and to saturate the paving fabric to ensure the formation of a waterproof membrane.

The tack coat application rate is dependent on:

- the type and grade of paving fabric
- the ambient and pavement temperatures.

The maximum tack coat rate should be equal to the absorption rate of the paving fabric as specified by the manufacturer. However, because of high pavement temperatures this tack rate may not be appropriate because of pick up problems during the paving operation. The tack coat rate may be reduced by up to 20% once the pavement temperatures exceed 50°C.

6. Construction Procedure

6.1 Ambient Conditions

Fine weather is necessary for this work. Air and pavement temperatures shall be sufficient to allow fabrics to absorb the bitumen. The air temperature should be a minimum of 18°C (and rising). However, it is also recommended that this type of surfacing treatment be carried out when pavement temperatures are less than 50°C to avoid the likely construction difficulties due to pick-up and bleeding problems (see Section 6.4.5).

6.2 Storage of Paving Fabrics

The rolls of fabric should be stored in a dry place, preferably out of sunlight. Even if the product is marked as "UV Stabilised", protection from direct sunlight is recommended.

The pick-up (or bleeding) potential of fabrics seems to be related, at least in part, to the uniformity or consistency of the fabric. If the fabric supplied appears non-uniform in appearance, the supplier should be notified and the matter rectified.

6.3 Surface Preparation & Preliminary Repairs

Isolated failed areas of pavement should be repaired. However, fabrics should not generally be used in locations where the pavement is badly failed and a significant proportion of the road is affected. If bitumen/fabric interlayer treatments are used in situations where they are seen as little more than "holding" treatments, reoccurrence of the pre-existing failures is likely. If subsoil and/or pavement drains are to be installed as part of the remedial works, it is strongly recommended that they are installed and shown to be effective in "drying out" the pavement structure prior to application of the surfacing treatment.
Existing cracks (>5mm) should be filled and sealed e.g. bitumen emulsion + sand, proprietary crack fillers or overseal banding systems, etc. Filling is necessary to support the fabric (which is yet to be placed and to prevent the fabric from being starved of bitumen). Finer cracks can be sealed as far as practicable using proprietary crack fillers. If necessary, the surface of the pavement should be cleaned and swept.

Surface depressions should be corrected and filled by hand or by applying an asphalt corrector course. If the existing pavement surface is badly deformed due to patching and existing failures, the application of a fine asphalt or slurry seal corrector course will greatly improve the performance of the rehabilitation treatment.

6.4 Placement of Paving Fabrics

6.4.1 General

Fabrics can be installed manually or by machine (mechanical applicators are usually available through suppliers). It is important to stretch the fabric so that it is taut and wrinkle-free and maintain it in this condition while the surfacing is applied. The tack coat should be sprayed approximately 100 mm wider than fabric. The fabric should then immediately be applied by rolling out onto the bitumen tack coat. Wrinkles should be removed by brooming and/or cutting. Folds must be avoided. Where they occur, folds large enough to cause laps or folds greater than 25 mm should be slit and laid flat. Sufficient binder needs to be sprayed over slits to ensure good through bond.

6.4.2 Horizontal Alignment

Curves in the road alignment or around traffic islands are a particular problem as the placement of fabric causes folds. These folds can be cut and the excess fabric removed and the cut faces treated as a join in accordance with the previous paragraphs. Due to the problems at curves serious consideration should be given to using alternatives to fabrics such as polymer modified bitumen SAMs and SAMIs or thicker AC overlays.

6.4.3 Joins

Fabric widths should be selected such that joins of parallel rolls occur only at the centreline or shoulder. Joins should not be placed along anticipated main wheel path locations.

Joins can either be "butt" or "cut and lap". Cut and lap joins are preferred, however, care is required during construction. Cut and lap joins can cause surface failures in an AC overlay if the lap is insufficiently bonded to the layer of fabric below. Alternatively, if too much bitumen is applied, a slippage plane can result in early fatigue cracking or shoving of the AC overlay. Where cut and lap joins are used they should have an overlapped area of 100-150 mm and must have a bitumen coat on the lower layer over this width applied at approximately 0.5 l/m^2. This will normally be applied manually, using a hand held sprayer. A further application of bitumen may be required on the lap to ensure proper bonding of the double layer of fabric. Transverse joins shall be lapped in the direction of paving to prevent edge pickup by the traffic and/or paver. Note that too little bitumen at a join will mean lack of bond whereas too much can cause bleeding, shoving or early fatigue cracking of the mix under braking.

6.4.4 Rolling

Rolling of the fabric into the tack coat should be carried out with a light-weight multi-tyred roller. The mat should be rolled from the middle towards the edges and not from one side to the other. Excessive rolling should be avoided and minimal excess binder should be apparent on the mat i.e. no pick-up on rubber tyred plant.

6.4.5 Pick-up/Bleeding Problems

In general, pick-up and bleeding problems are closely related to:

- Ambient and pavement temperatures
- Grade and uniformity of the fabric
- Film thickness and viscosity of the bitumen binder

Ambient and pavement temperatures are the major cause of the problem and, in very hot weather, the tack coat application rate may need to be dropped and/or the works rescheduled for cooler periods to prevent pick-up of the fabric when trafficked by construction plant. As a guide, pavement temperatures in excess of 50°C have the potential to lead to bleeding/pick-up problems with fabric placement operations. Class 320 bitumen has been used with limited success to overcome major bleeding/pick-up problems (e.g. asphalt overlay on a very hot day using rubber tyred plant). However, relatively little benefit is gained by changing binder class as the Class 170 and 320 bitumens behave similarly at operating pavement temperatures of about 50°C. It is likely that more success will be achieved if a polymer modified binder is used, although no field trials to prove this have been undertaken to date.

6.4.6 Tack Coat Application Rate

The tack coat application rate is more critical in the asphalt surfacing application than the sprayed seal application. This is because if the tack coat is over-applied, flushing or bleeding of the asphalt may result. The tack coat application rate may be reduced to solve this problem however this reduction should not exceed 20% of the absorption of the paving fabric. The following corrective measures may be considered with or without the above reduction in tack coat:

- Hand spread a small amount of asphalt on top of the fabric in the wheelpaths of the paver and trucks.
- Change to Class 320 bitumen or use a polymer modified bitumen for the tack coat.
- Minimise the number of vehicles trafficking the fabric.
- Shorten the distance between fabric placement and the paving machine.
- Application of coarse sand in the wheel paths. This is the least desirable choice since the sand will absorb some of the bitumen which defeats its purpose. Excess sand should be swept off.

In the sprayed seal application, under or over application of the tack coat can be compensated for by similar adjustment to the sprayed seal application rate. As a guide, the application rate is correct if after placing the fabric, the surface of the fabric has a mottled appearance.

6.4.7 Wet Weather

If the fabric gets wet, it will retain the moisture and the immediate application of a sprayed seal will result in blistering of the bitumen. Rain can also cause blistering and subsequent detachment of the fabric. If this occurs the adhesion between the fabric and the tack coat must be restored or enhanced using a pneumatic tyred roller before overlaying with AC or applying a sprayed seal. Drying out of the fabric will be required before applying either a sprayed seal or an asphalt overlay.

6.4.8 Trafficking

Following completion of the bitumen/ fabric interlayer, trafficking should be restricted to essential construction traffic, if at all possible.

6.5 Laying of Sprayed Seals on Paving Fabrics

The hot bitumen binder is sprayed onto the completed bitumen/fabric interlayer. Cover aggregate is applied in the normal manner with the aim of achieving shoulder to shoulder aggregate contact after rolling. The cover aggregate should be "rolled in" using a heavy multi-tyred roller. Additional rolling may be required to adequately embed the aggregate, especially for low traffic situations and in areas outside of traffic lanes. Speed restrictions should be posted on the completed works for several days, if possible. Following initial trafficking, the sprayed seal should be monitored. The surface texture should be checked to ensure that the binder height is at least 50% of ALD, preferably in the range 60 to 70% of ALD. A fog coat of CMS or CRS bitumen emulsion enrichment (or similar) should be considered if the binder is deficient.

6.6 Laying of Asphalt on Paving Fabrics

Thin AC overlays should be placed and rolled soon after the application of the fabric to maximise the bond between the various elements involved. This is not so critical with thicker AC overlays where the heat and weight of the overlay promotes bonding. No tack coat is required to be applied to the top of the completed bitumen/fabric interlayer. The placement of the asphalt is to be carried out in the normal manner as per Specification MRS 11.30 (12/93), MRS 11.31 (5/94) or MRS 11.34 (12/93). To avoid movement or damage to the fabric while turning the pavers and/or trucks, such turning should be gradual and kept to a minimum. The parking of rubber tyred plant on the completed bitumen/fabric interlayer, even for reasonably short periods, should also be avoided.

7. Design Considerations

7.1 Floodways

In floodway situations, considerable hydraulic forces can be imposed of the surface of the pavement during major flood events.

Surfacing treatments which incorporate a bitumen/fabric interlayer may be susceptible to damage (i.e. separation of the interlayer treatment from the pavement surface) during major floods. If bitumen/fabric interlayer treatments are likely to be exposed to such forces, a number of precautionary measures may be taken to reduce the risk of surfacing failure:

- The type cross section should ensure that the free edge of the fabric on the upstream side of the road is securely fixed (e.g. by carrying the fabric down the batter and covering with fill material or concrete, or by securing the fabric into a longitudinal groove cut in the pavement).
- The upstream batter in one way crossfall situations should be sealed to prevent moisture entry.
- Longitudinal joins in the fabric should be lapped in the direction of water flow.
- Particular care is warranted to ensure that the underlying seal is clean and that adhesion agent is incorporated in the tack coat.

7.2 Future Pavement Rehabilitation

The future rehabilitation of the pavement should be considered before applying a bitumen/fabric interlayer treatment. Removing the interlayer treatment and surfacing at a later date is likely to be a problem, particularly in sprayed seal applications (e.g. future widening and overlay scheme).

7.2.1 Hot In-place Recycling

Some problems associated with hot in-place recycling have been the tangling of the fabric interlayer in the milling head because of the hot milling process.

7.2.2 Reclaimed Asphalt Pavement (RAP)

The recycling of asphalt contaminated with bits of fabric may not be possible, depending on the nature of the synthetic fibres and the degree of pulverisation of the fabric.

7.2.3 Cold Insitu Recycling

Cold insitu-recycling of pavements incorporating bitumen/fabric interlayer treatment have not caused any problems to date. The cold insitu-recycling process is capable of breaking the interlayer treatment down without causing the machine to clog or producing large clumps of bitumen/fabric. It should be noted however that this experience has only related to a fabric of only 140g/m^2 ■

TABLE 1: PAVING FABRIC DETAILS

Trade Name	Grade	Supplier	Material Types	Woven/ non-woven	Filament bonding	Unit Mass	Roll Width	Roll Length
BIDIM	PF1 PF2	Geofabrics Australasia	polyester	non-woven	needle punched	140 g/m^2 180 g/m^2	4.0 m	150/300 m 150/300 m
POLYFELT	PGM 14	Geolab Group	polypropylene	non-woven	needle punched	140 g/m^2	1.9 m 3.8 m	150 m 150 m
ProPex	4599	CSR Humes	polypropylene	non-woven	needle punched/heat bonded on one side	155 g/m^2	3.81 m	137 m
Texcel	NW135	Rheem Australia	polyester	non-woven	needle punched	160 g/m^2	4.0 m	100 m

TABLE 2: GUIDELINES FOR USING POLYMER MODIFIED BITUMEN

Treatment Application	Tack coat/ sprayed seal	Polymer type preferred	Additive content Minimum	Maximum
Sprayed seal or reseal	tack coat	EVA	3.0%	5.0%
Asphalt overlay	tack coat	SBS or EVA	5.0%	7.5%

TABLE 3: GUIDELINES FOR DESIGN OF BITUMEN FABRIC INTERLAYER TREATMENTS

Treatment Application	Componen t	Bitumen Binder	Application Rate (l/m^2)	
Sprayed seal or reseal	tack coat	C170, C320 or PMB† (no cutter)	0.6§ (as pavement temperatures approach 50°C) 0.8§ (pavement temperatures between 15°C and 50°C)	Total Application Rate‡
	seal coat	C170, C320 or PMB†	Total Application Rate‡ minus Tack Coat	
Asphalt overlay	tack coat	C170, C320 or PMB† (no cutter)	Maximum tack coat = absorption rate as specified by manufacturer for specific fabric (approx. 0.8 to 1.1). If pavement temperatures in excess of 50°C reduce rate by up to 20%.	

† See Table 2 for guidelines for using polymer modified bitumen (PMB)
§ Normal rate should be decreased by 10-20% for steep grades or other areas where vehicle changes are common.
‡ Refer to Section 5.2.1. of this Technical Note

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