

## **Technical Guideline: Asphalt reinforcement for Road Construction**

**TG3 3<sup>rd</sup> Edition – January 2022**

# Asphalt Reinforcement for Road Construction

## TECHNICAL GUIDELINE TG 3

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Manual 22	Hot mix paving in adverse weather
Manual 23	Code of practice: Loading bitumen at refineries
Manual 24	User guide for the design of asphalt mixes
Manual 25	Code of practice: Transportation, off-loading and storage of bitumen and bituminous products
Manual 26	Interim guidelines for primes and stone pre-coating fluids
Manual 27	Guidelines for thin hot mix asphalt wearing courses on residential streets
Manual 28	Best practice for the design and construction of slurry seals
Manual 29	Guide to the safe use of solvents in a bituminous products laboratory
Manual 30	A guide to the selection of bituminous binders for road construction
Manual 31	Guidelines for calibrating a binder distributor to ensure satisfactory performance
Manual 32	Best practice guideline and specification for warm mix asphalt
Manual 33	Design procedure for high modulus asphalt (EME)
Manual 34	(A) Guidelines to the transportation of bitumen and (B) Bitumen spill protocol (booklets)
Manual 35 / TRH8	Design and use of Asphalt in Road Pavements
Manual 36 / TRH21	Use of Reclaimed Asphalt in the Production of Asphalt
Manual 37 / TMH5	Sampling Methods for road construction materials
Manual 38	A Health and Safety Guide for material testing laboratories in the road construction industry
Manual 39	Laboratory testing protocols for binders and asphalt
Manual 40 / TRH3	Design and construction of surfacing seals ( <i>Due for completion by year-end</i> )
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DVD 440	Firefighting in the bituminous products industry
DVD 450	Safe loading and off-loading of bitumen
(The following manuals have been withdrawn: 3, 4, 6, 9, 11, 14, 15, 16 and 21)	

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# Glossary of terms

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A review of the literature indicates that the international geosynthetic community has adopted the term “stabilisation” when a geosynthetic is included in a pavement layer to keep the layer as close as possible to its initial state for as long as possible, limited to low strain conditions (Giroud and Han, 2016). Inclusion of a geosynthetic product in bituminous bound materials to enhance structural performance is termed “reinforcement”. These terms have also been embraced by the ISO Technical Committee TC 221 Working Groups on design using geosynthetics and are therefore adopted by the TG3 committee.

In the South African context, however, the term “stabilisation” has largely been reserved for chemical stabilisation of natural gravels with bitumen, cement or lime. Similarly, the term “mechanical stabilisation” is entrenched in the local industry and refers to enhancement of natural material characteristics through blending of two or more natural materials. For these reasons, structural enhancement of pavement layers using geosynthetics is termed “geosynthetic stabilisation” in the TG3 guideline.

Aperture	Opening between adjacent ribs linked at joints or nodes. Aperture size and shape are important properties that dictate the effectiveness of geogrid-aggregate interaction.
Base Course Reduction Ratio (BCR)	The reduction in the base layer thickness of a geosynthetic inclusive pavement such that equivalent performance is obtained between the geosynthetic inclusive design and benchmark design.
Biaxial geogrid	Type – Refers to square pattern formed by geogrid ribs of equal length between junctions (or nodes).
Bonded	Manufacturing – Joining geosynthetic material by thermal, chemical, or mechanical processes. Also see Welded.
Crack propagation law	An equation used for calculating the size of a fatigue crack growing from cyclic loads.
Confinement	The effective height or thickness associated with the confinement mechanism facilitated by a planar or cellular geosynthetic.
Geocomposite	Combines the positive properties of more than one geosynthetic material, such as a geotextile bonded on one or both sides of a geogrid.
Extruded	Manufacturing – punched and stretched from a polymeric sheet oriented in a biaxial or multiple, equilateral direction, to form rectangular or triangular apertures.
Elastic modulus	Also referred to as elastic stiffness. The ratio of applied stress to induced strain – assumes the behaviour of the material is linear.
Paving Fabric	Nonwoven geotextiles having high elongation and low tensile strength and are used for either stress relief, or waterproofing (when impregnated with selected bituminous binders).

Flexible geogrid	Geogrid manufactured by interlacing, knitting or bonding, two sets of yarns, fibres, filament, tapes or other elements – uncoated or coated to improve adhesion.
Fracture mechanics	The field of mechanics concerned with the study of crack propagation in materials containing one or more cracks (or flaws) to predict the conditions where failure occur.
Geotextile	A planar, permeable, synthetic textile material, which may be nonwoven, knitted, or woven, used in contact with natural materials used in civil engineering applications.
Geosynthetic	A synthetic material used in contact with natural building materials (soil/gravel/aggregate/bitumen) in civil engineering applications.
Geogrid	A planar synthetic structure consisting of a regular open network of integrally connected tensile elements (ribs), interlocking with natural materials/aggregates to form a stronger structure.
Knitted	Manufacturing – geogrids or geotextiles manufactured by knitting together yarns or elements, usually at right angles to each other.
Load transfer stiffness	Also known as shear modulus across the crack or joint. The relationship between vertical shear stresses at the crack face and relative vertical movement across the crack.
Layer Coefficient Ratio (LCR)	A ratio of layer coefficient (as defined by AASHTO).
Nonwoven	Geotextile in the form of a sheet, web, or mat of directionally or randomly orientated fibres, filaments or other elements; mechanically and/or thermally and/or chemically bonded.
Output-based improvement factor	Also known as performance improvement factors – ratio of the design output/performance parameters between an otherwise identical geosynthetic inclusive pavement and the conventional or benchmark pavement design; examples are the base course reduction factor (BCR) and the traffic benefit ratio (TBR).
Poisson's ratio	The ratio of horizontal strain to vertical strain – controls the degree to which a material compresses under load.
Reinforcement	The use of high tensile properties of a geosynthetic material to resist stresses in asphalt materials at low strains or contain deformations in geotechnical structures at high strain levels.
Shear modulus	Also termed the modulus of rigidity – defined as the ratio of shear stress to shear strain. A high value indicates a high rigidity.
Specific heat capacity	The amount of heat energy required to raise the temperature of a given mass of material by 1 Kelvin.
Stabilisation	The use of geosynthetic materials to keep the layer as close as possible to its initial state for as long as possible – the mechanism of lateral restraint at low strain conditions applies.

Stiffness	Commonly and loosely used to refer to any ratio of load to deformation, and more generally the resistance of a material to stress – such as bending stiffness, load transfer stiffness etc.
Stiffness modulus	Although a measure of the applied stress divided by induced strain, the term implies the absence of a single linear elastic property. Term generally used for asphalt materials due to its temperature-dependent (viscous) component. At a given temperature and loading rate, the definition of stiffness modulus is the same as that for elastic modulus.
Stress-intensity factor	A non-dimensional scaling factor used to express the stresses around the crack tip – which depends on the geometry, size and location of the crack as well as the magnitude and distribution of the loads in the material.
Thermal conductivity	The efficiency or rate with which a material allows heat energy (watts) to flow through a 1m length of material, 1m <sup>2</sup> cross-section, caused by a 1 Kelvin temperature difference across the length – impacts temperature distribution with depth in a layer.
Thermal expansion coefficient	The propensity of a material to change its volume slightly with temperature; the proportional change in a given linear dimension due to a 1°C rise in temperature.
Traffic Benefit Ratio (TBR)	Indicates the additional amount of traffic loads that can be applied to a pavement when a geosynthetic is added, with all other pavement design aspects being equal.
Unpaved	With gravel surface. Unpaved and unsealed used interchangeably.
Wearing course	Pavement surface layer exposed to traffic, either bituminous or gravel. In the context of gravel roads, internationally, the wearing course is usually of substantial thickness and for structural purposes often referred to as the base course.
Welded	Manufacturing/seaming – Softening the polymer surfaces by heat or solvents before joining.
Woven	Manufacturing by interlacing, usually at right angles, two sets of yarns, fibres, filament, tapes or other elements.

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# 1. INTRODUCTION

## 1.1 Context and scope

TG3 is a best-practice guideline for the use of geosynthetics in load bearing trafficked pavement infrastructure, such as roads, airports and industrial pavements. The guideline is based on national, regional, and international standards, trends, knowledge and experience. A spectrum of geosynthetic types are covered and application to asphalt pavement components, typically in surfacing and base layers.

The goal of this guideline is to equip industry to use geosynthetics with confidence to:

- improve the overall effectiveness and performance of pavements;
- reduce cost of new construction, rehabilitation and maintenance;
- contribute to socio-economic upliftment, and
- to contribute to preserving natural resources.

The guideline is aimed at a wide range of practitioners, including consultants, contractors, material suppliers, road owners and researchers who are involved in different but complementary aspects of provision and maintenance of pavement infrastructure.

## 1.2 Background

In November 2003 the Road Pavement Forum resolved that a technical working group should be formed to investigate the development of a national guideline (or code of practice) on the use of Asphalt Reinforcement. This led to the publication of the first edition of this document in November 2008. A second phase of development, during 2020, incorporated presentation of a comprehensive section on the structural design of bituminous layers reinforced with geosynthetic materials to prolong service life of such composite layers.

For the purposes of this document the main functions of Asphalt Reinforcement Interlayer (ARI) is to:

- prevent or reduce reflective cracking from underlying layers,
- protect asphalt layers against traffic induced cracking,
- avoid or reduce development of rutting in asphalt layers.

## 1.3 Purpose and Scope

The main purpose of the Guideline is to provide a synthesis of practical, state-of-the-art approaches to the use of ARI, based both on international best practice plus regional knowledge and experience. The primary goal therefore is to contribute towards a reduction in the cost of rehabilitating and thereafter maintaining asphalt pavement layers, leading to more sustainable road infrastructure provision in the southern African environment.

This Guideline covers the following materials and types of reinforcement:

- All types of materials for interlayers
- Interlayers placed in or under asphalt layers

The Guideline is aimed at a wide range of practitioners, including consultants, contractors, materials suppliers, road owners and researchers who, in various ways, are all involved in different but complementary aspects of provision and maintenance of asphalt pavement layers.

Because the southern African region is a diverse one, it would be impractical and inappropriate to provide recipe solutions for specific situations. Instead, emphasis has been placed on guiding the practitioner towards evaluating the ARI options and considering their pros and cons as a basis for decision making and application to specific situations. This is achieved by collating together in one document key background knowledge and experience in the application and performance of tried and tested, new and innovative solutions in all aspects of the provision of ARI.

Issues that are covered by the guideline include the following:

- Requirements for good performance (e.g. material composition, geometry, constructability, boundary operating conditions)
- Design guidelines
- Specification guidelines
- Product performance guarantee
- Standard conformance testing

The Guideline does not deal with:

- Loose fibres added into the asphalt mixes, or
- Interlayers under surfacing seals (covered in the Sabita Manual 40/TRH3: *Design and Construction of Surface Treatments*)
- Geosynthetics in layers other than bituminous ones

## **1.4 Focus**

The focus of the Guideline is on the construction and rehabilitation of roads with asphalt pavement layers. These pavement layers are generally used in higher category and higher volume roads as the initial construction costs of asphalt layers are higher than for granular layers.

## **1.5 Structure and content**

The Guideline is divided into eight chapters as below:

1. Introduction
2. Functions and benefits of asphalt reinforcement
3. Types and selection of reinforcement product
4. Evaluation of existing pavement condition
5. Design guidelines
6. Specifications of materials
7. Practical construction issues

8. Quality control and material testing

## **1.6 References**

SATCC *SADC Guideline on Low Volume Sealed Roads*. SADC, Botswana, July 2003.

Sabita, Manual 40/TRH3 - *Design and Construction of Surfacing Seals*, November 2020

## 2. FUNCTIONS AND BENEFITS OF ASPHALT REINFORCEMENT

### 2.1 Introduction

The use of reinforcement for the maintenance and rehabilitation of flexible pavements in South Africa is gradually gaining acceptance. In recent years reinforcement of road-pavements with grids and other non-traditional materials has increased rapidly. However the market has since been flooded with a number of 'reinforcement' products, which have been applied with varying degrees of success. The products have generally been polymer type grids and fabrics, but now include glass-fibre and steel mesh products.

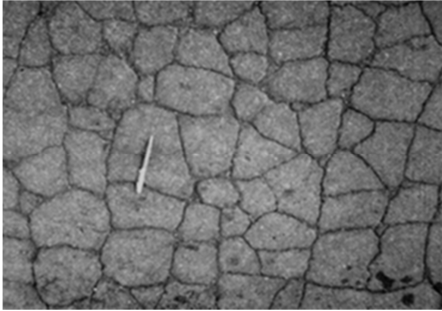


Figure 2-1: Example of asphalt pavement where reinforcement could provide a benefit

While the term “reinforcement” generally implies an improvement in bearing capacity, many so-called “reinforcement products”, do not achieve any structural improvement at all, but merely delay pavement distress processes such as crack propagation and water ingress. Many products have been touted as a reinforcing when in fact these products serve only a separation-barrier function, either between poor quality and good quality materials or a barrier against crack propagation. Designers should have a clear understanding of the limitations all these different reinforcement products offer in terms of position and stress-strain characteristics within the pavement and layer structure. In most cases, the

expectation of strength or bearing-capacity improvements from the use of these materials is unrealistic.

Although reinforcement can be used anywhere in the pavement structure where bearing capacity improvement is required for example over a poor quality subgrade, the scope of this guideline deals only with reinforcement in asphalt overlays. In South Africa it is foreseen that reinforcement can be used in the following applications:

- Asphalt overlays over cracked pavements or as interface between cement treated layers and surfacing to prevent crack reflection (see Figure 2-1)
- Asphalt surfacing at high stress regions, such as climbing lanes, intersections, freight terminals
- Airfield runways and taxiways
- Strengthening of gravel layers as an alternative to cement or bitumen stabilisation (Not covered in this document)

A review of existing literature on mesh reinforcing of flexible pavements, show that the main focus of the reinforcing is to prevent reflective cracking in asphalt overlays although some products may achieve one or more of the following objectives within the pavement:

- Prevents reflective cracking, by acting as a barrier against crack propagation
- Maintains uniform load distribution over a cracked layer
- Provides shear resistance against rutting especially in high stress locations
- Improves the fatigue resistance of the asphalt layer

- Additional bearing capacity

Research of reinforcement in pavement structures has mainly been carried out overseas (Europe and USA), where design methodologies, pavements structures and climatic conditions are not necessary the same as those in South Africa. However, the benefits shown, by including reinforcement in pavement structures would similarly apply to our roads in South Africa albeit to a greater or lesser degree.

Finally, it is important to understand that reinforcement in pavements is intended to prevent or impede the development of those strains which are likely to lead to failure. The inclusion of reinforcement will not necessarily result in lower transitory strains or deflections.

## 2.2 Reflective cracking

### 2.2.1 Mechanisms of reflective cracking

One of the more serious problems associated with the use of thin overlays is reflective cracking. This phenomenon is commonly defined as the propagation of cracks from the movement of the underlying pavement or base course into and through the new overlay as a result of load-induced and/or temperature-induced stresses. Increasing traffic loads, inclement weather, and insufficient maintenance funding compound this problem and inhibit the serviceable life of these pavements.

The above factors decrease the useful life of HMA overlays and/or increase the need or cost-effective preventive maintenance techniques. Some of the latest techniques include incorporating geosynthetic products, defined herein as grids, fabrics, or composites, into the pavement structure. This procedure is typically accomplished by attaching the geosynthetic product to the existing pavement (flexible or rigid) with an asphalt tack coat and then overlaying with a specified thickness of HMA pavement. These materials have exhibited varying degrees of success, and their use within a particular agency has been based primarily on local experience or a willingness to try a product that appears to have merit.

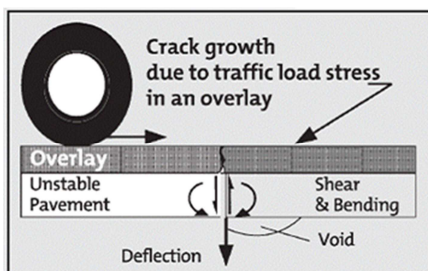


Figure 2-2: Mechanism of crack reflection

In order to quantify the effect of reinforcement, it is first of all necessary to understand the way in which the reflective cracks in asphalt overlays initiate and propagate.

It should be kept in mind that these types of cracks do not necessarily grow with a constant rate throughout the entire cross-section of an overlay (the variation of this rate

is mainly due to the types of loading of these layers).

Overlays are the most commonly used method for pavement rehabilitation. However, they often do not perform as desired due to existing cracks, which can quickly propagate through the new overlay. This cracking is a result of the differential vertical and horizontal movements above the old crack tip. Such movements, also called crack activity, are caused by thermal stresses, traffic loads or by a combination of these two mechanisms. Stress concentrations are induced in the new overlay by virtue of crack activity. Thus the existing crack pattern observed in the original pavement more than often propagates quickly through the new overlay.

Pavement cracks that existed before overlay exhibit varying degrees of crack activity as a function of pavement properties, mainly pavement layer thickness and stiffness as well as applied load. After overlay, the existing cracks exhibit crack activity as a function of the crack activity before overlay and of the overlay properties (thickness and stiffness).

The crack activity before overlay plays an important role in the mechanistic characterisation of existing pavements, but when conducting an overlay design the crack activity after overlay is required to evaluate the pavement's resistance to reflective cracking in bituminous (asphalt) overlays.

### 2.2.2 Thermal Induced Cracking

Quite a lot of debate has taken place over the issue whether cracks caused by temperature variations in time initiate at the surface of a pavement overlay and grow downwards or propagate from the old crack, or joint in the existing pavement structure, upwards.

Depending on the level from which the temperature drops, tension is introduced in the overlay. This can occur in two different ways, which need to be distinguished. Firstly, restrained shrinkage of the overlay itself causes transverse and longitudinal tensile stresses. It is obvious that these stresses are at their maximum at the pavement surface due mainly to the larger temperature drops experienced at this position. Given the fact that bitumen degradation takes place at the surface, it is obvious that cracks initiate at and propagate from the surface downwards in this case.

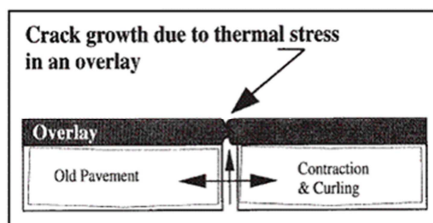


Figure 2-3: Mechanism of thermal induced cracking

Secondly, when an existing crack, directly below an uncracked asphalt overlay is exposed to temperature variations, tensile strains are induced in the overlay with the result that the crack propagates from the bottom upwards. These temperature variations continue to play a role in the propagation of the crack as the tensile strains continue to exist at the tip of the crack as it propagates upwards. Thermal expansion and contraction of an underlying cement-treated layer can cause large strains in the overlay above the cracks. Warping of the underlying layer may also contribute to reflective cracking. (Figure 2-3).

Traffic-induced reflection cracking is caused by transient strains in an asphalt overlay resulting from the relative movement of the underlying material either side of the crack. These movements may either result in mode I or mode II cracking, representing the horizontal and vertical movements between the two edges of a crack. The respective modes of cracking are shown in the adjacent

### 2.2.3 Traffic induced cracking

Traffic-induced reflection cracking is caused by transient strains in an asphalt overlay resulting from the relative movement of the underlying material either side of the crack. These movements may either result in mode I or mode II cracking, representing the horizontal and vertical movements between the two edges of a crack. The respective modes of cracking are shown in Figure 2-4.

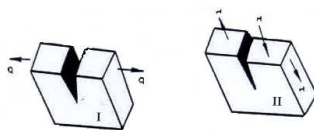
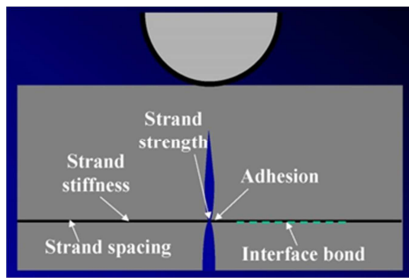


Figure 2-4: Traffic induced loading

The primary effect of grid reinforcement is to hold the two sides of a developing crack together. If the two ends are held together it will result in a reduction of the stresses and strains at the tip of the crack region. This reduction in stress and strain decreases the propagation rate of the crack and thus increases the time until a reflected crack reaches the surface.

### 2.2.4 Benefits of Reinforcement



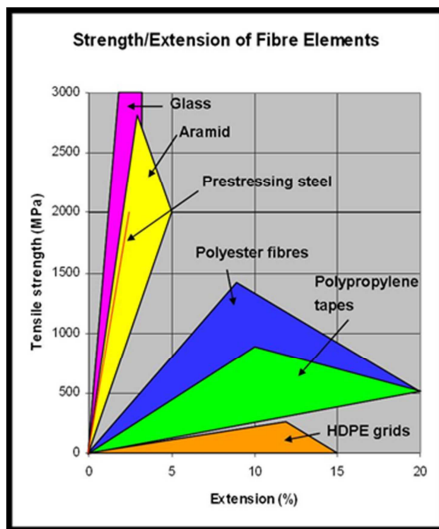
**Figure 2-5: Factors affecting effectiveness of ARI**

The primary effect of grid reinforcement is to hold the two sides of a developing crack together. If the two ends are held together it will result in a reduction of the stresses and strains at the tip of the crack region. This reduction in stress and strain decreases the propagation rate of the crack and thus increases the time until a reflected crack reaches the surface.

A number of other factors play an important role in the effectiveness of grid reinforcement to combat reflective cracking. The underlying are critical factors that enhance the effectiveness of grids in reducing the rate of propagation of reflective cracking (see Figure 2-5):

- The stiffness of the grid
- The geometry of the grid.
- Interface bond strength between the grid and the asphalt (discussed later in the section)

## 2.3 Asphalt Fatigue and Rut Resistance



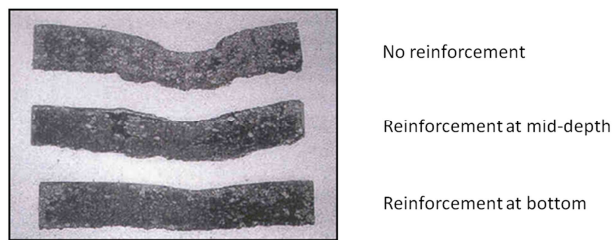
**Figure 2-6: Strength extension properties for various reinforcing materials**

Asphalt Reinforcement Interlayers can dampen stress, relieve strain, and provide tensile reinforcement to the asphalt. Asphalt Reinforcement must provide increased tensile strength at a very low deformation. It must be stiffer than the material to be reinforced. The geometric configuration of an interlayer will greatly affect its reinforcement capability. The cross-sectional area must be sufficient so that it will redirect tensile stresses. The width of the product must exceed the limits of the redirected stress energy. The steeper the stress-strain curve for Asphalt Reinforcement the better (see Figure 2-6).

Research has shown that the use of reinforcement for asphalt could be effective, provided that appropriate installation techniques are used on site. Steel grids and high strength polymer grids were seen to significantly improve the fatigue life of an asphalt mixture and the life to critical rut depth. The effect of grids in pavement structures is not a simple procedure. It requires a good

insight of the characteristics of the grid in use, as well as the properties of the material it is being applied to.

In all cases, it has been found to be essential to locate the grid at the correct level within the asphalt layer. If the grid is not located at the correct level it will not be as effective, and its use will be of little significance in protecting the pavement against cracking, rutting etc. Figure 2-7 shows three asphalt layers with or without reinforcement at different depths in their respective layers. The tests were carried out by the Nottingham Pavement Test Facility to investigate the influence of grid placement within an asphalt layer.



**Figure 2-7: Pavement cross section after trafficking**

All tests were carried out at the same temperatures and load conditions. It was very evident that the unreinforced section had failed comprehensively by cracking and the significant rut depth included a large contribution from the supporting layers. With the grid in the centre of the layer, there was evidence of cracking but the rutting was contributed only from the supporting layers. It can thus be said that by placing the grid at mid-depth, it was positioned in the zone of maximum permanent shear strains, which is the main cause of rutting.

In the case of the asphalt layer with reinforcement situated at the bottom, there is very little evidence that fatigue had taken place. This confirms that placing the grid at the bottom of the layer is the correct location to counteract the tensile strains that cause cracking, which have a maximum value in this zone.

## 2.4 Bearing Capacity

Not much literature is available in terms of the benefits that asphalt reinforcing provides in bearing capacity, particularly in lieu of the fact that in South Africa, asphalt overlays are thin when compared to countries such as the USA and Europe.

Research available from Giroud et al, on the effects of incorporating geotextile in unpaved roads, suggest that a geotextile incorporated as separation, between unbound coarse aggregate and poor underlying soil, has the effect of confining the sub-grade and improving the spread of loading, all which help with the control of local shear and improve the bearing capacity. In paved roads, the situation is different since tolerable deformations are considerably less than in unpaved roads. The maximum horizontal strains induced in geotextiles at the base of the unpaved road can be anywhere from 5 to 15%, whereas in the asphalt pavement, the likely region is 0,04 to 0,08%.

In general, when an asphaltic wearing course fails due to poor bearing capacity from the underlying base layer, incorporating reinforcement within the asphalt is not the solution since the problem is the base layer and not the asphalt.

The use of asphalt reinforcement for the improvement of bearing capacity is not covered in this guideline document.

## 2.5 Interface Bond

In terms of the geometry, the compatibility between the grid, particularly the aperture (opening) size, and the aggregate size used in the asphalt is an important factor. If the aggregate size is too large, then the interlock between the grid and the surrounding asphalt may be compromised decreasing the interface bond strength and increasing the crack propagation rate. The aperture of the mesh or grid structure must be such that optimum shear adhesion is achieved while promoting aggregate interlock and confinement. The polymer coating of paving fabrics and grids (such as the woven and warp knit grids) must have high asphalt compatibility and provide protection against a wide range of chemical attack. Each fibre must be completely coated to ensure no slippage within the composite asphalt.

Also when the strands of the reinforcement are at angles or are of varying cross-sections, the interface bond strength is improved. In this way the asphalt is able to penetrate through angles that it was not able to beforehand when the reinforcement was uniform and at right angles to the plane of the crack. The asphalt is able to form a stronger bond with these geometrically varying strands thus improving the interlock.

Asphalt gains its compressive strength through compaction. The mix aggregate is specifically selected to provide interlock and confinement within the load bearing stone structure, and bitumen is the glue that holds the particles together. The particles strike through or become embedded within the grid structure, thus becoming mechanically interlocked within the composite system. This confinement zone impedes particle movement which may result in better asphalt compaction. If this is achieved it could lead to greater bearing capacity, and increased load transfer with less deformation. This would reduce shoving as it keeps the asphalt particles confined.

The ARI must be compatible with the asphalt to provide a strong internal bond within the composite. It must be thermally stable and physically durable to withstand the rigors of the paving operation. Best performance and adhesion is achieved on a smooth, asphaltic levelling course surface.

Interface bond tests, carried out by the Nottingham Pavement Test facility on various grids, considered the strength and stiffness interface parameters as the two most important parameters in determining the effectiveness of the bond strength. If these two parameters are low, the effect of reinforcement could be ignored as slippage failure would take place and little bond strength would be present. The tests illustrated a reduction in shear stiffness and strength when reinforcement is present. Only in the case of steel reinforcement was the strength/ stiffness reduction negligible, implying a strong interface bond.

## 2.6 References

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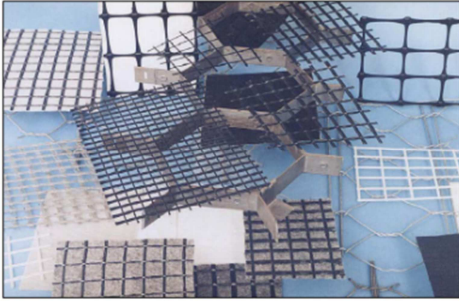
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## 3. TYPES AND SELECTION OF REINFORCEMENT PRODUCT

### 3.1 Introduction



Three main types of ARI with variations thereof are covered in this section, namely, paving fabrics, paving grids (steel, glass fibre and polymeric) and composites thereof. Their construction, function and application are discussed. Their benefit in the use of joint and localised (spot) pavement repairs; full width (curb-to-curb) coverage to provide a moisture barrier for the pavement structure and retard reflective cracking and rutting in asphalt overlays is described according to the general considerations highlighted below.

### 3.2 General Considerations

Experience has shown that the existing pavement section must show no signs of pumping, excessive movement, or structural instability. To maximise the benefits of specialist, high strength ARI's, pavements must be structurally sound. If a pavement is structurally unstable, the Engineer should design to first address the structural problem and then focus on addressing secondary problems of reflective cracking, asphalt fatigue, etc. When selecting an ARI product, the designer's ultimate choice would depend on (but not limited to) the following factors and considerations:

- Overlay Stress Absorption – Ability of the ARI to absorb stress, relieve strain and provide tensile strength
- Overlay Thickness - The minimum recommended thickness of asphalt overlay for each type of ARI must be complied with to optimise performance.
- Compatibility / Bond with Asphalt – The application of any ARI requires the ability to adapt to any paving operation. Placement must be quick and easy, and the product must remain secure during the paving operation.
- Durability and / or Corrosion – If using polymer ARI, the fibres or threads used in the manufacturing or for the joining of ARIs shall be heat stable to temperatures of 205°C. Polymer ARI and coatings shall be treated to resist biological attack, UV light, weather and creep deformation or chemical breakdown over time and for protection from physical abrasion. If using steel reinforcement the steel shall be suitably protected against corrosion by the adhesion of heavily galvanised or Galfan coatings.
- Milling and Recycling – Where recycling will be an option in the future life of the pavement, careful consideration should be given to the implication and ease of recycling ARI products. The ARI with the best recycling ability should be selected otherwise for straight milling the best fit-for-purpose ARI should be selected.
- Boundary Operating Conditions / Limitations / Constraints – Most ARIs will have certain boundary operating conditions and limitations peculiar to their structure and make-up. Careful consideration should be given to the manufacturer's recommendations.

Table 3.1 provides a summary of the above factors to consider when selecting Reinforcement Products, mentioned above. The information is also provided in more detail in **Error! Reference source not found..**

### 3.3 References

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- S F Brown and N H Thom, **A Study Of Grid Reinforced Asphalt To Combat Reflection Cracking**, University of Nottingham and P J Sanders, Transport Research Laboratory, Association of Asphalt Paving Technologists 2001 Annual meeting
- FP Jaecklin and J Scherer, **Asphalt Reinforcing using Glass Fibre Grid "Glasphalt"**, Reflective Cracking in Pavements, RILEM 1996.
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- Gregory S. Cleveland, Joe W. Button, And Robert L. Lytton, **Geosynthetics In Flexible And Rigid Pavement Overlay Systems To Reduce Reflection Cracking**, Report No. FHWA/TX-02/1777-1, October 2002
- Gregory S. Cleveland, Robert L. Lytton and Joe W. Button, **Reinforcing Benefits of Geosynthetic Materials in Asphalt Concrete Overlays using Pseudo Damage Theory**, Paper (03-2198), Transportation Research Board Record, November, 2002.

Table 3-1: Summary of issues to consider when selecting reinforcement products

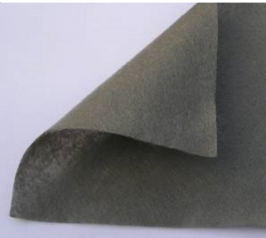
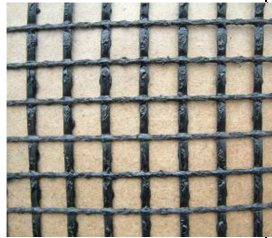
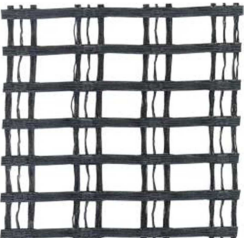

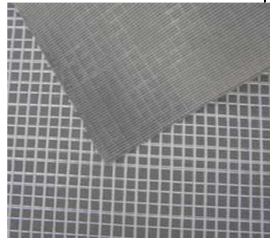
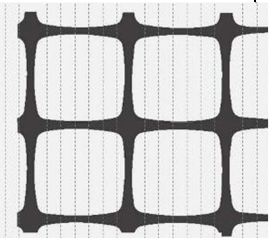
Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene <sup>1)</sup>	a) Glass fibre grids <sup>2)</sup>	b) Polyester grids <sup>3)</sup>	c) Steel mesh <sup>4)</sup>	a) Stitched or Warp knitted <sup>5)</sup>	b) Bonded <sup>6)</sup>
Photos of Typical Products						
Overlay Stress Absorption	<ul style="list-style-type: none"> <li>i. Act as stress absorbing interlays</li> <li>ii. Prevent ingress of water into pavement layers</li> <li>iii. Bridge shrinkage cracks</li> <li>iv. Provides increased overlay performance by 20 to 40%</li> </ul>	<ul style="list-style-type: none"> <li>i. Modulus ratio of up to 20:1 over asphalt</li> <li>ii. High stiffness redirects crack energy</li> <li>iii. High stiffness resists deformation</li> </ul>	<ul style="list-style-type: none"> <li>i. Increases tensile strength of asphalt layer</li> <li>ii. Reduces tensile peak stress</li> <li>iii. Assists with asphalt fatigue</li> <li>iv. Reduces formation of ruts</li> </ul>	<ul style="list-style-type: none"> <li>i. Reduces peak tensile stress</li> <li>ii. Improves asphalt fatigue</li> <li>iii. Absorbs crack discontinuities</li> <li>iv. Good rut resistance</li> </ul>	<ul style="list-style-type: none"> <li>i. High stiffness redirects crack energy</li> <li>ii. Reduces peak tensile stress</li> <li>iii. Improves asphalt fatigue</li> </ul>	<ul style="list-style-type: none"> <li>i. Increase fatigue life of pavement with weak foundations</li> <li>ii. Used in above application, reduces rutting and controls reflective cracking</li> <li>iii. Susceptible to creep</li> </ul>
Overlay Thickness	<ul style="list-style-type: none"> <li>i. Generally 35mm but can be as little as 25mm</li> </ul>	<ul style="list-style-type: none"> <li>i. Minimum overlay thickness of 40mm</li> <li>ii. 25mm overlay thickness achieved under controlled conditions</li> </ul>	<ul style="list-style-type: none"> <li>i. 50mm with paver</li> <li>ii. 40mm manual installation</li> </ul>	<ul style="list-style-type: none"> <li>i. 50mm minimum</li> <li>ii. 60mm unsupervised</li> </ul>	<ul style="list-style-type: none"> <li>i. 40mm Minimum</li> <li>ii. 25mm used successfully in light trafficked areas with low loadings</li> </ul>	<ul style="list-style-type: none"> <li>i. Stiff bi-axial grids used in 70mm overlays</li> <li>ii. Thinner composite polyester grids used in 50mm overlays</li> </ul>

Table 3-2: Summary of issues to consider when selecting reinforcement products

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene <sup>1)</sup>	a) Glass fibre grids <sup>2)</sup>	b) Polyester grids <sup>3)</sup>	c) Steel mesh <sup>4)</sup>	a) Stitched or Warp knitted <sup>5)</sup>	b) Bonded <sup>6)</sup>
<b>Compatibility / Bond with Asphalt</b>	<ul style="list-style-type: none"> <li>i. Paving fabrics resistant to shrinkage</li> <li>ii. Polyesters heat resistance at 210° C and perform better than polypropylenes which are sensitive at temperatures &gt; 145° C</li> <li>iii. Rough texture provides interlock adhesion</li> <li>iv. Robustness which withstands high installation damage</li> </ul>	<ul style="list-style-type: none"> <li>i. Melting point 1000° C</li> <li>ii. Polymer modified bitumen coat of grid has good compatibility with tack coat and asphalt</li> </ul>	<ul style="list-style-type: none"> <li>i. Polyester heat resistance up to 210° C</li> <li>ii. Good compatibility with tack coat and asphalt</li> </ul>	<ul style="list-style-type: none"> <li>i. High interlock with asphalt matrix</li> <li>ii. Tensioned and nailed at regular intervals to sub-structure</li> </ul>	<ul style="list-style-type: none"> <li>i. No pre-dressing or tensioning required</li> <li>ii. Fabric impregnated with bitumen</li> <li>iii. Impregnated layer provides moisture proofing</li> <li>iv. Non-woven fleece good compatibility with tack coat and asphalt</li> <li>v. Check stability of reinforcement when subjected to operation heat. Glass 1000° C. Polyester 260° C, polypropylenes. 165° C</li> </ul>	<ul style="list-style-type: none"> <li>i. No pre-dressing or tensioning required</li> <li>ii. Fabric impregnated with bitumen</li> <li>iii. Impregnated layer provides moisture proofing</li> <li>iv. May increase pavement life by a factor of 3</li> </ul>
<b>Durability and Corrosion</b>	<ul style="list-style-type: none"> <li>i. Polyesters or polypropylenes are non-corrodible and resistant to most chemicals</li> </ul>	<ul style="list-style-type: none"> <li>i. Non corrodible</li> <li>ii. Resistant to oil and fuel spillage, biological attack, UV light, weather</li> </ul>	<ul style="list-style-type: none"> <li>i. Non corrodible</li> <li>ii. Resistant to oil and fuel spillage</li> </ul>	<ul style="list-style-type: none"> <li>i. Steel mesh coated by bitumen when installed</li> <li>ii. Heavily zinc coated (durability)</li> </ul>	<ul style="list-style-type: none"> <li>i. Non corrodible</li> <li>ii. Resistant to oil and fuel spillage</li> <li>iii. Thermally stable up to 165° C</li> </ul>	<ul style="list-style-type: none"> <li>i. Non corrodible</li> <li>ii. Resistant to oil and fuel spillage</li> <li>iii. Thermally stable up to 165° C</li> </ul>

Table 3-3: Summary of issues to consider when selecting reinforcement products

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene <sup>1)</sup>	a) Glass fibre grids <sup>2)</sup>	b) Polyester grids <sup>3)</sup>	c) Steel mesh <sup>4)</sup>	a) Stitched or Warp knitted <sup>5)</sup>	b) Bonded <sup>6)</sup>
<b>Milling and Recycling</b>	<ul style="list-style-type: none"> <li>i. Hot milling and heat scarification can cause problems</li> <li>ii. Cold milling does not usually present problems</li> <li>iii. Fabrics in excess of 150g/m<sup>2</sup> may interfere with milling process</li> <li>iv. Polyester fabrics less susceptible to hot milling</li> <li>v. Chisel teeth preferred over conical teeth</li> <li>vi. Milling speed range: 3 - 6m/min</li> </ul>	<ul style="list-style-type: none"> <li>i. Fibre broken down during milling process and easily recycled</li> </ul>	<ul style="list-style-type: none"> <li>i. Easily milled (including hot milling) by chisel teeth and recycled.</li> </ul>	<ul style="list-style-type: none"> <li>i. Increase overlay thickness to allow cover during milling operation</li> <li>ii. Asphalt milled off just above mesh prior to pulling out</li> <li>iii. No recycling capabilities</li> </ul>	<ul style="list-style-type: none"> <li>i. Cold milling does not present problems</li> <li>ii. Hot milling and heat scarification may cause problem where geosynthetic is present</li> <li>iii. Cognisance should be taken of the different behaviour of the paving fabric as opposed to the grid or mesh component</li> <li>iv. Chisel teeth preferred</li> <li>v. Milling speeds of 3 - 6m/min</li> <li>vi. Glass fibre strands easily mixed into new asphalt design. Paving fabric will determine mixed design which may contain up to 0,5% paving fabric pieces by weight.</li> </ul>	<ul style="list-style-type: none"> <li>i. Strong plastic grids may interfere with milling operations</li> <li>ii. Aggressive milling required due to thick and hard extruded polymer strands.</li> <li>iii. Nonwovens milled as mentioned in Woven Paving Fabrics</li> <li>iv. Recycling unlikely as contamination of mix is high</li> </ul>

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene <sup>1)</sup>	a) Glass fibre grids <sup>2)</sup>	b) Polyester grids <sup>3)</sup>	c) Steel mesh <sup>4)</sup>	a) Stitched or Warp knitted <sup>5)</sup>	b) Bonded <sup>6)</sup>
<b>Boundary Operating Conditions / Limitations and Constraints</b>	De-lamination of the fabric could occur if: i. Presence of water in base ii. Insufficient tack coat or saturation of the fabric iii. Fabric laid in rain or wet conditions iv. Fuel leakage or contamination between fabric and overlay  Shoving or heaving could occur: due slippage on an old, rich surface  Bleeding could occur if: i. Too much binder applied as a tack or saturation coat ii. Volatiles from cutback or winter grade bitumens cannot escape before applying overlay. iii. If cut or winter grades have to be used, avoid using them in the tack coat.	i. Glass grids with adhesive surface cannot be applied in wet conditions ii. Tack coat must be cured iii. Glass fibre is skin irritant, workers must wear PPE iv. Laid glass fibre paved same day v. Sensitive to mechanical abrasion when exposed	i. Tack coat applied to clean dry sub-structure ii. Poor resistance to creep	i. Inherent curvature during unrolling removed with rubber tyred roller ii. 1 <sup>st</sup> 4m securely fastened with nails or screws (1/m <sup>2</sup> ) iii. Remainder to be tensioned and fixed by nailing / screws iv. Fixing in direction of paver v. Overlap by 150mm	De-lamination of the grid could occur due to: i. Presence of water in base ii. Insufficient tack coat or saturation of the fabric iii. Fabric laid in rain or wet condition iv. Fuel leakage or contamination between fabric and overlay  Shoving or heaving could occur: due slippage on an old, rich surface  Bleeding could occur if: i. Too much binder applied as a tack or saturation coat ii. Volatiles from cutback or winter grade bitumen cannot escape before applying overlay.  If cut or winter grades have to be used, avoid using them in the tack coat.	De-lamination of the fabric could occur if: i. Presence of water in base ii. Insufficient tack coat or saturation of the fabric iii. Fabric laid in rain or wet conditions iv. Fuel leakage or contamination between fabric and overlay  Shoving or heaving could occur: due slippage on an old, rich surface  Bleeding could occur if: i. Too much binder applied as a tack or saturation coat ii. Volatiles from cutback or winter grade bitumen cannot escape before applying overlay.  If cut or winter grades have to be used, avoid using them in the tack coat.

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene <sup>1)</sup>	a) Glass fibre grids <sup>2)</sup>	b) Polyester grids <sup>3)</sup>	c) Steel mesh <sup>4)</sup>	a) Stitched or Warp knitted <sup>5)</sup>	b) Bonded <sup>6)</sup>
	Mechanical failure if:  i. Crack movement is excessive and tears fabric  ii. Insufficient or no overlap of fabric  iii. Laid in areas of extreme shear stress conditions  iv. Potholes not repaired  v. Cracks > 7mm not pre-filled					

Notes:

- 1) *Nonwoven continuous polyester or polypropylene filaments either needle-punched or thermally bonded*
- 2) *Coated multi filament woven or warp knit glass fibre grids*
- 3) *Coated multi filament woven or warp knit polyester grids*
- 4) *Double twist hexagonal woven steel mesh galvanized (Class A), reinforced transversally with steel rods*
- 5) *A glass fibre or polymeric grid structure stitched or knitted to a nonwoven paving fabric*
- 6) *An extruded or woven polymer grid bonded to a light nonwoven fabric*

## 4. EVALUATION OF EXISTING PAVEMENT CONDITION

### 4.1 Introduction

Before embarking on a rehabilitation or maintenance project, it is important to understand the current condition of the road pavement. Maintenance or rehabilitation should only be instituted once the correct mechanisms that lead to failure / distress mechanisms have been pin pointed. The condition of the pavement is considered from two points of view, namely that of an engineer (surfacing and structural) and that of a road user (functional).

To determine if the pavement is suitable for the use of ARI products it is important to know that:

- The integrity of the surfacing is adequate to support the ARI without disintegrating (alternatively replace it);
- The pavement structure has sufficient bearing capacity to carry future traffic loading (alternatively it has to be replaced or strengthened;
- The functional road condition is acceptable to the road user (alternatively major improvements to the riding quality may be required.



These parameters can be observed and evaluated using both simple and complicated techniques. This section is an overview of the existing methodologies available to determine the condition of the pavement. The objective is not to provide an overall in-depth procedure for such an evaluation exercise, but rather for a brief summary to guide the practitioner towards planning for collection of the relevant information.

### 4.2 Evaluation Techniques

In pavement condition evaluation there are both surfacing, structural and functional aspects to consider. Broadly speaking, surfacing aspects refer to the integrity of the wearing course, structural aspects cover those parameters that describe the ability of the pavement structure to carry loads, while functional parameters cover those aspects that allow traffic to use the facility safely and economically.

Evaluation of the pavement condition can be undertaken by:

- Visual assessment
- Using sophisticated equipment, such as Falling Weight Deflectometer (FWD) and Crack activity meters (CAM)
- Intrusively by Penetrometer tests or by removing samples for laboratory testing.
- Accelerated pavement testing using such equipment as the MMLS or HVS

## 4.2.1 Visual Assessment

A visual assessment is a quick way to highlight and identify which sections of road should be prioritised. The assessments carried out during visual inspections can be categorised into:

- Surfacing assessments
- Structural assessments
- Functional assessments

The visual assessment provides a very cost effective technique of determining the current status of the road with regard to suitability for the use of reinforcement products. It should however be used in conjunction with other methods in a multi criteria approach.

### 4.2.1.1 Surfacing Assessments



Surface assessment relates to the wearing course, namely the asphalt layer. The decision to use ARI will depend on the integrity of the surface and the severity of cracks in the surface. During a visual inspection, the following should therefore be assessed:

- Texture (Is a texture treatment required?)
  - Surfacing Failure (Must the surface be replaced or repaired due to potential delamination?)
- Surfacing cracks (Are the cracks too wide, too active making an ARI unsuitable?)
  - Aggregate loss (Is pre-treatment of aggregate loss required?)
  - Binder condition (Is binder too soft or too hard and brittle?)
  - Bleeding / Flushing (Will bleeding affect the effectiveness of the ARI?)

### 4.2.1.2 Structural Assessment



Problems related to structural assessment have to do with the pavement layers underlying the wearing course. The decision to use ARI will depend on the type and severity of the structural distress types.

- Block / stabilization cracks (ARI may not be in containing very wide, spalled and active cracks)
  - Longitudinal / slip cracks (As above)
- Transverse cracks (As above)
  - Crocodile cracks (As above)
  - Pumping (Pumping provides an indication of moisture in the layer works and crack activity)
  - Rutting (Rutting needs to be milled off before any further work is considered)
  - Undulating / settlement (Could be an indication of settlement or active clay sub-grades)

- Patching (The integrity of the surface needs to be reinstated before any ARI work is undertaken)
- Potholes (As above)

#### 4.2.1.3 Functional Assessment

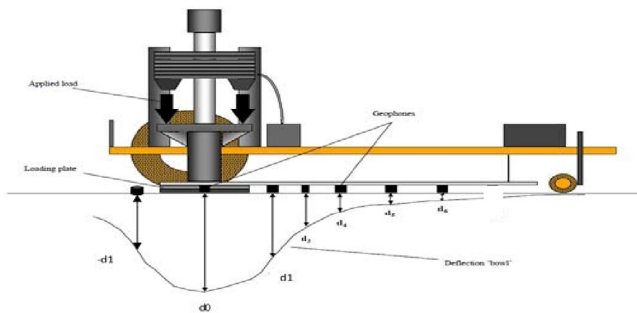
Functional aspects have to do with comfort and safety of the road user. These aspects do not contribute directly to the decisions on the use of ARI but provide information on the overall condition of the road.

The following aspects are related to the functional condition of the pavement:

- Riding Quality (Poor RQ needs to be addressed before ARI can be considered)
- Skid resistance (Not relevant to ARI)
- Drainage (This must be addressed for road user safety and to keep moisture away from the pavement layers)
- Edge breaking (Repair edge breaks before application of ARI)

For further reading on how to classify the distress according to the above, the reader should refer to TMH9:1992.

#### 4.2.2 Deflection Measurements



Some structural pavement evaluation procedures rely on the measurement of surface deflections, to back-calculate the elastic moduli of the layers and subsequently the stresses and strains in the pavement. Most of these procedures are based on linear elastic theory and so the deflection bowls that are used for the input of the analysis should reflect the linear elastic

behaviour of the pavement.

A Falling Weight Deflectometer (FWD) is a testing device used to evaluate these physical properties of a pavement by measuring the surface deflections. It can also be used to measure the load transfer across cracks in the pavement and thereby provide an indication of the activity of the crack. Sensors are placed both sides of the crack at equal distance from the level plate.



A Benkelman Beam measures the deflection at a point on a pavement due to the passage of a wheel load. The loading consists of a rear axle of two axle truck with two twin wheel arrangements at the rear loaded symmetrically. This deflection measurement can also be used for determining the pavement stiffness and crack activity. This procedure is slow and therefore only suitable for short lengths of pavement, taking as much as a day to monitor a kilometre of road with an experienced team.

The Road Surface Deflectometer (RSD) is essentially an electronic version of the Benkelman Beam. It is used to measure the surface deflection bowl under or separate to the heavy vehicle simulator (HVS) loading. Data collection is automated and thus the RSD can be utilised to capture the entire deflection basin, consisting of 256 data points, as the dual wheel traverses the RSD at creep speed.

#### 4.2.3 Crack Activity Measurements

The Crack Activity Meter (CAM) was designed to measure relative crack movements directly with reasonable accuracy. The CAM can measure both relative vertical and horizontal crack movements simultaneously. Data are recorded continuously as the wheel approaches the point of measurement and passes over it.

Below is an extract from Rust et al, highlighting the degree of crack activity versus suggested remediation.

Crack Movement	Classification	Suggested Remediation
< 0,1mm	Low	Conventional Surface Treatment
0,1mm – 0,2mm	Medium	Surface treatment with homogeneous modified binder
0,2mm – 0,3mm	High	Surface treatment with bitumen rubber binder
> 0,3mm	Very High	Thick overlay (e.g. SAMI) *

\* The use of ARIs could be considered as an alternative to the use of thick overlays with SAMI

### 4.3 Logistics

The logistics of pavement evaluation describes the procedure of selecting an appropriate time and location for the measurements / evaluation to be performed. For the purpose of this document, it is important to select at least two opportunities for these evaluations. The first would be before anything is done to the pavement in terms of the preparations and installation of the asphalt reinforcement, and the next being after completion of the installation. Further, regular opportunities should be planned after installation to determine the changes (if any) in the parameters with time and traffic. Keep in mind that parameters change with changes in seasons and traffic and therefore an old set of parameters cannot be used as a typical condition for the specific pavement. Further, any pavement experiences its own changes due to the local environment and traffic and therefore a generic set of pavement conditions can also not be used to base any decisions regarding a specific pavement on.

The density of the various measurements should be adequate to ensure that any specific features on the pavement are observed and documented. The size of the area to be treated using the asphalt reinforcement would typically influence the density of the observations. The principle to be followed is to ensure that the overall condition of the pavement can be obtained from the set of observations.

### 4.4 Data Collection and Analysis

Data is collected for two purposes. One is to evaluate the data and determine if the ARI is the most appropriate treatment measure. Data can also be collected to monitor the future long-term effectiveness of the selected measures.

Specific methods for pavement condition evaluation are not covered in this document. Good standard documents are available on the topic, and it is recommended that the standard methods used by the specific roads authority (municipal, provincial or national) to which the road belongs will be used.

Several methods are available for data collection (structural and functional). It is important to ensure that the method selected is a standard and recognised method, and that the data will thus be comparable to similar performance data from other sections and sites. It is important to ensure that all the relevant preparation and calibration procedures have been adhered to when using instruments.

Control sections are needed for any project to ensure that the data from the treated section can be compared to data from a similar section where the only difference is that it did not receive the same treatment in terms of the asphalt reinforcement (i.e. similar environment and traffic).

Data collection and management refers to the methods used to ensure that the collected data are correctly named, stored and managed. This is required to ensure that follow-up investigations can be made at the same locations and that it is always clear where the specific data originate from and what the specific circumstances around its collection are. If any anomalies are experienced during data collection these need to be logged.

The data management process is required to ensure that data can be retrieved with relative ease and that it can also be shared with relevant parties where required.

## **4.5 References**

***Flexible Pavement Evaluation and Rehabilitation Course Notes***, 11 – 15 November 2002, University of Stellenbosch

TMH9 – ***Pavement Management Systems: Standard Visual Assessment Manual for Flexible Pavements***, South African Department of Transport, 1992

Internet related articles in particular <http://www.gautrans-hvs.co.za>

***Recommendations on the use of modified binders to retard reflective cracking***, Coetser K, Strauss P, Rust FC, Vos RM, 6<sup>th</sup> Annual Conference on Asphalt Pavements for Southern Africa, 1994

## 5. DESIGN GUIDELINES

Although numerous field, laboratory and numerical studies have demonstrated the benefits of using geosynthetics to improve pavement performance, official design guidelines have largely been unavailable or vague. In recent years, the International Standards Organization committee on geosynthetics (ISO/TC221) Working Group 6 developed a suite of Technical Reports that provide high level guidance to designers using geosynthetics, together with other regional guidelines such as the Dutch Design Guidelines (Vega et al, 2018). In this section methods are recommended for use in southern Africa and detailed guidance offered for implementation. The design philosophy, mechanisms responsible for improved performance with geosynthetic inclusion, and design concepts and principles are also introduced.

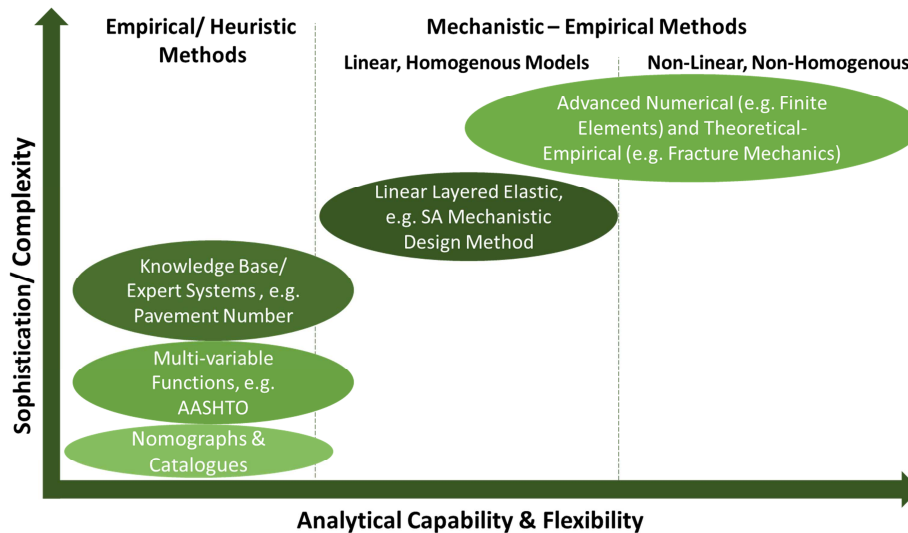


Figure 5-1: Analytical capability and flexibility

Various methods of sophistication are available for design as depicted in **Error! Reference source not found.** Purely empirical and nomograph type implementations are normally limited to specific products, materials, and environmental conditions. The AASHTO Method (AASHTO, 1993) is well-established and widely used to design pavements including geosynthetic enhancement. Mechanistic-empirical (M-E) methods using layered elastic models are considered more generic and therefore more promising as a framework to incorporate the use of geosynthetics in pavement design. While computers can nowadays accommodate sophisticated numerical analysis, such as finite element analysis, these techniques are still considered to be research tools given their complexity and user skill requirements. Commonly used empirical as well as simplified, practical, yet fundamentally based approaches are offered in the guidelines to follow. A broad overview of the design philosophy and process is introduced since details are covered in other guidelines. Aspects of terminology adopted are briefly clarified. This section is mainly divided into design methods for paved roads and unpaved roads. Under paved roads, design methods for asphalt reinforcement and geosynthetic stabilised layers are included. Each of these subsections addresses mechanisms involved, concepts and principles, followed by design methods. Each method is accompanied by an example that illustrates implementation of the method.

### 5.1 Design philosophy and process

Pavement design philosophy evolved from Roman times to an approach today that utilises natural and manufactured materials to provide an optimised, cost-effective layered system to:

- Protect the subgrade from expected traffic loads, and
- Maintain the required level of service throughout the selected structural design period under prevailing environmental conditions.

The design philosophy encompasses policy driven or management directives that dictate basic inputs to the project level design process, i.e. service objectives, functional service level, analysis period, structural design period, and life cycle strategy. Figure 5-2 demonstrates the generic design process.

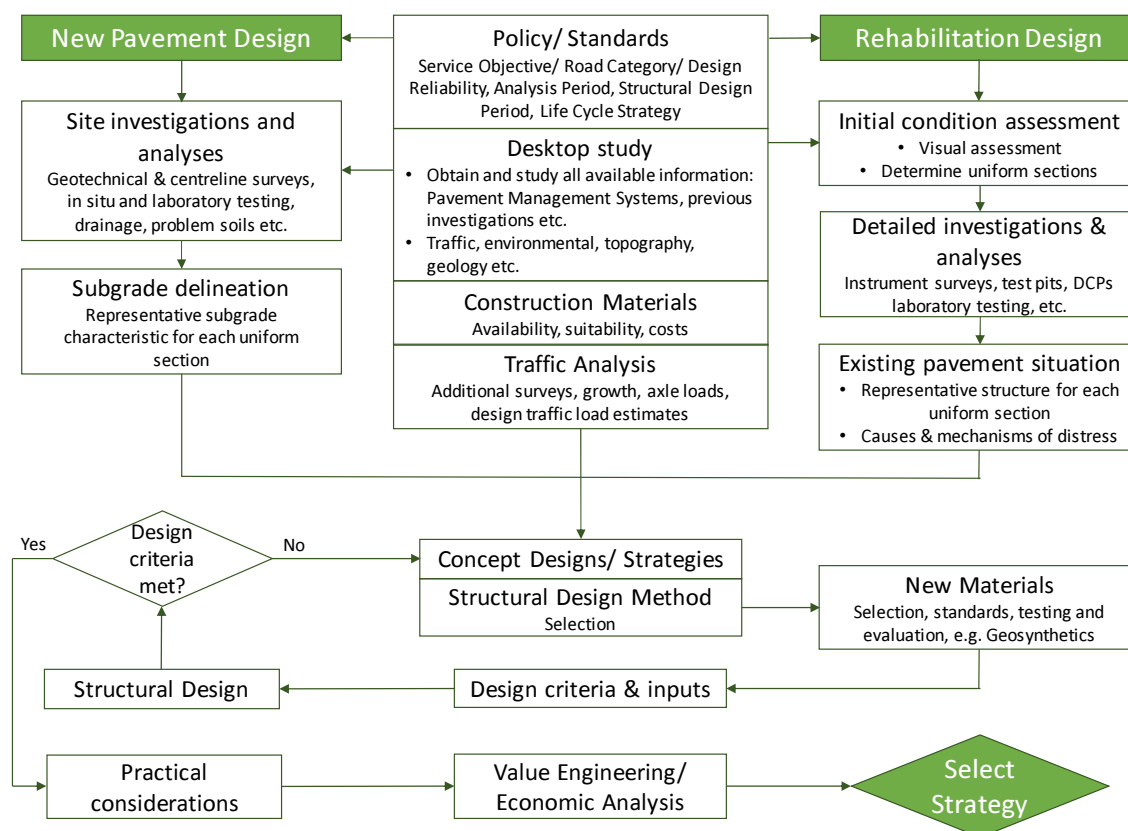


Figure 5-2: Pavement design philosophy and process

Pavement design and rehabilitation processes are described in more detail in relevant industry guidelines including Technical Recommendations for Highways (i.e. TRH4, TRH12) and the South African Pavement Engineering Manual (SAPEM, 2014). Subsequent discussions on design methods will show that selection of the appropriate method is influenced by the geosynthetic application, which may simply be considered as an alternative design or effective solution to address the causes and mechanisms of distress as part of rehabilitation designs. In addition, the importance and function of the road also play a role in the selection of a design method.

## 5.2 Asphalt reinforcement

Apart from traditional load and age-related cracking, premature cracking in asphalt surfacing layers and overlays may develop due to the inability of the layer to withstand yielding and movement of the underlying layers – associated with differential deflections, thermal movement, and/or moisture sensitive subgrades. Within the context of this section, the functions of geosynthetic interlayers are generally to enhance asphalt performance, to mitigate reflective cracking from existing substrates, or a combination thereof.

### 5.2.1 Mechanisms

The pavement system is subjected to external elements such as dynamic traffic loads, temperature variations, humidity and oxygen. Direct exposure of the asphalt surface to the atmosphere facilitates ageing of the binder at the top of the layer, and therefore brittleness. Combined with heavy traffic loading cracking is initiated at the surface that propagates downwards, known as *top-down cracking*. In addition, pavements that exhibit high deflections experience high traffic induced stresses at the bottom of the asphalt layer that initiate a zone of cracking or disintegration that propagates upwards, known as *bottom-up or classic fatigue cracking*. This fatigue mechanism is also triggered in older asphalt surfacing layers that have reached an advanced stage, or threshold level of ageing.

Thermal cracking includes both low-temperature cracking and thermal fatigue cracking. Although low-temperature cracking is not common in southern Africa, *thermal fatigue cracking* can occur where harder binders are used or where binders have aged. Thermal fatigue cracking is similar to classic fatigue but is caused by tensile strains induced by daily temperature cycles (Huang, 2004).

Rehabilitation often includes construction of asphalt overlays on existing pavements. Even after preparation of the substrate by milling the old asphalt, cracks may still be present. In some cases, the existing pavement may be jointed or cracked concrete, or comprise a cracked cemented layer. These cracks or discontinuities can propagate rapidly to the top of the new overlay, known as *reflective cracking*. This is due to stress concentrations at the tips of these cracks/discontinuities, caused by traffic loads and temperature variations. Pavement geometry, composition and age also impact differential vertical and horizontal movements, also called crack activity or load transfer in concrete pavements. These aspects determine the mode of cracking, magnitude of stress concentrations, time/load cycles to crack initiation, and speed of crack propagation in overlays. For traffic loads, both crack initiation and crack propagation phases determine overall layer life, whilst for thermal cycles the crack initiation phase dictates layer life (de Bondt, 2009). Figure 5-3 depicts the mechanisms of reflective cracking.

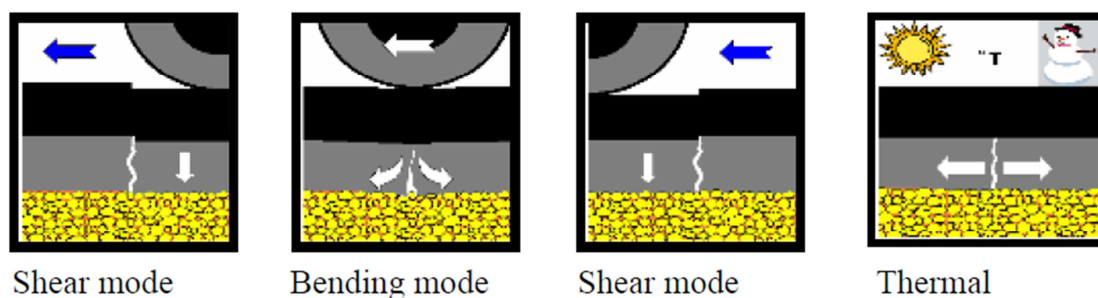


Figure 5-3: Reflective cracking failure modes (Elsing and Schröer, 2005)

New asphalt layers and overlays in rehabilitation applications can be reinforced to enhance asphalt performance in terms of cracking and rutting compared to unreinforced asphalt performance. In providing reinforcement, paving geogrids structurally strengthen the layer by enhancing its response to load; effectively absorbing and distributing tensile stresses over a larger area thereby increasing its resistance to cracking. Although rutting is traditionally addressed through asphalt mix design considerations and not explicitly addressed in this section, the mechanisms introduced subsequently also enhance the shear properties of the mix and therefore its resistance to permanent deformation. A number of factors contribute to the effectiveness of asphalt reinforcement:

- Effective load transfer between the asphalt components and the paving geogrid through establishment of a good bond between the asphalt and the geogrid facilitated by the type of

strand and coatings, geogrid geometry (notably aperture size) and sufficient anchorage length.

- Adequate tensile strength and elastic stiffness of the geosynthetic that is larger than the surrounding asphalt.

Fundamentally the bond is achieved through:

- Adhesion: Dictated by physical characteristics of the strands and use of strand coatings to enhance physio-chemical characteristics between the binder and the geogrid;
- Interlock: Through appropriate selection of aperture size with consideration of the asphalt mix type, aggregate in the mix mechanically interlocks with the geogrid; essentially facilitating mechanical adhesion on a macro scale;
- Friction: Both aperture size and characteristics of the strands appropriately selected for optimum compatibility with the mix, produce friction that enhances the bond.

The contribution of the reinforcement mechanisms introduced above varies depending on the properties of the geosynthetic, including stiffness. More flexible systems tend to rely on physio-chemical bonding while more rigid systems tend to rely on mechanical bonding. It should be noted that systems such as geotextiles or fabrics focus on strain-relief, with elastic moduli less than the surrounding asphalt, and do not function as reinforcement; these systems only retard reflective cracking.

Since adequately designed overlays against fatigue and rutting may still be subjected to propagation of existing cracks from the substrate, the use of geosynthetic interlayer systems has almost become synonymous with applications where risks of reflective cracking exist. The mechanisms of asphalt reinforcement resisting reflective cracking of different modes are illustrated in Figure 5-4. Following on from the general mechanisms described above, the introduction of the geosynthetic in a situation where an existing crack or discontinuity exists will reduce the stress concentration at the crack tip. In addition, under shearing action, the normal force produced by adequately anchored reinforcement indirectly generates friction along the teeth of the crack that increases aggregate interlock between the two crack faces (de Bondt, 2009).

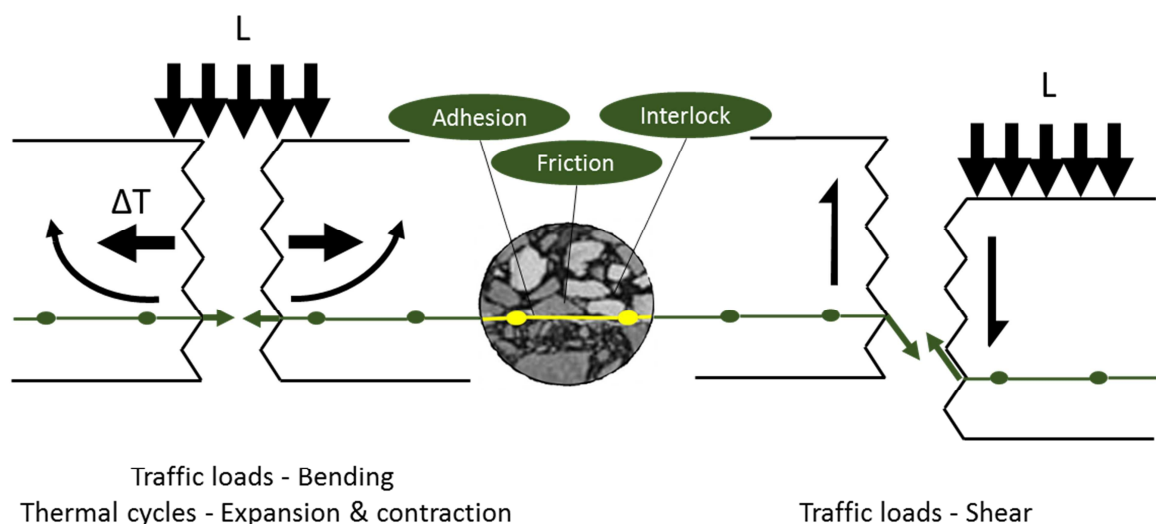


Figure 5-4: Mechanisms of asphalt reinforcement for different modes of reflective cracking

### 5.2.2 Concepts and principles

The design methods presented below were selected due to the more fundamental approaches adopted, with consideration of simplicity and ease of application. The concepts and principles are introduced below as background to the methods. Inclusion of the details to follow is warranted since such an approach has not been used widely by the industry in routine analyses and design.

#### **Fracture Analysis of Asphalt**

Fracture mechanics have been applied to predict life of asphalt mixes under cyclic loading. The rate of crack growth can be described using the power law developed by Paris and Erdogan (Lytton, 1989); Paris' Law:

$$\frac{dc}{dN} = A \cdot K^n \quad \text{Equation 5-1}$$

where,

$dc/dN$ : differential coefficient of  $c$  with respect to  $N$ , i.e. crack growth rate

$c$  : crack length

$N$  : number of load cycles

$K$  : stress intensity factor

$A, n$  : fracture properties of the material

$A$  and  $n$  can be determined from crack growth analyses based on beam fatigue and thermal fatigue test results. Theoretical expressions for  $A$  and  $n$  have also been developed in terms of creep, tensile strength, and fracture energy properties of the material – these constants are therefore true material properties representing the crack propagation resistance. For both traffic fatigue and thermal fatigue (Lytton, 1989),

$$n = \frac{2}{m} \quad \text{Equation 5-2}$$

Where

$m$  is the slope of the creep compliance curve, i.e. the simple general relationship between the logarithm of the mix stiffness modulus versus logarithm of loading time.

For traffic-associated cracking and typical asphalt mixes, the slope of the crack growth relation is given as a function of the fracture constant ( $A_F$ ) (Lytton, 1989),

$$n = -2.2 - 0.5(\log A_F), \text{ and} \quad \text{Equation 5-3}$$

for thermal fatigue cracking and typical asphalt mixes as a function of the fracture constant ( $A_T$ ),

$$n = -0.72 - 0.42(\log A_T) \quad \text{Equation 5-4}$$

Since  $n$  can be determined from the slope of the creep compliance curve,  $A_F$  and  $A_T$  can be calculated using the form of equations shown above. In principle the life of an asphalt layer with thickness  $D$  can be calculated using (Molenaar, 1996):

$$N = D / \frac{dc}{dN} \quad \text{Equation 5-5}$$

Peak stresses that develop at the crack tip are described using the stress intensity factor ( $K$ ). Intuitively,  $K$  depends on the overall stress applied and the crack length. Figure 5-5 shows the non-dimensionalised stress-intensity factors for bending and shear –  $\hat{K}_B$ ,  $\hat{K}_S$  respectively – as a function of the non-dimensionalised crack length  $c/d$ ; where  $c$  and  $d$  represent the crack length and the combined thickness of the existing bound layer with the overlay, respectively.

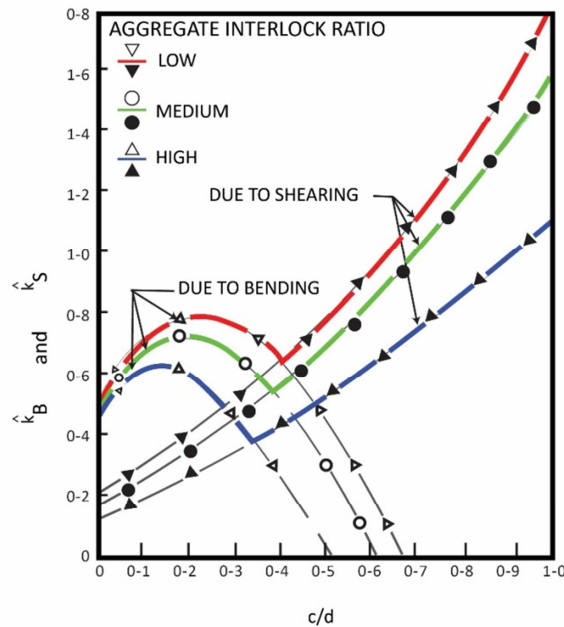


Figure 5-5: Non-dimensional stress intensity factors for bending and shear as a function of crack length

Figure 5-5 indicates that for traffic/load associated stresses, two stages of crack growth development exist. Crack growth induced by bending dominates up to a crack length 0.5 to 0.65 the combined depth of the bound layers, depending on the degree of interlock. At this point, the crack hits the compressive zone at the top of the layer and crack growth continues due to increased shear stresses. Table 5-1 provides guidelines for the selection of aggregate interlock. For thermal cycles, the crack grows upwards through the entire layer proportional to the non-dimensional thermal stress intensity factor shown in Figure 5-6. (Lytton, 1989).

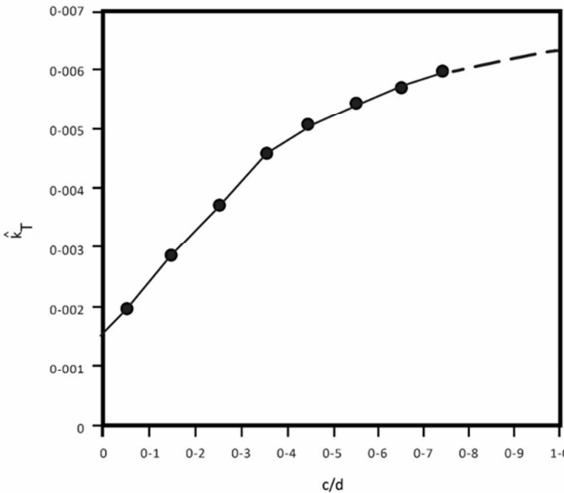


Figure 5-6: Non-dimensional thermal stress intensity as a function of crack length

Table 5-1: Selection of aggregate interlock based on crack width (Molenaar, 1995)

Crack Classification	Width	Interlocking (Input to Figure C.5)
Narrow	< 3 mm	High
Medium	3 mm to 6 mm	Medium
Wide	> 6 mm	Low

The dimensionless stress-intensity factors provided graphically in Figure 5-5 and Figure 5-6 are used with the following equations to calculate the actual  $K$  values (Lytton, 1989).

$$K_B = \hat{K}_B \left( \frac{q \cdot e^{-\beta/2}}{\beta^2 \cdot d^{3/2}} \cdot \sin \left( \frac{\beta l}{2} \right) \right) \quad \text{Equation 5-6}$$

$$K_S = \hat{K}_S \left( \frac{q}{4\beta \cdot d^{1/2}} \cdot [1 + e^{-\beta l} (\sin \beta l - \cos \beta l)] \right) \quad \text{Equation 5-7}$$

$$K_T = \hat{K}_T \left( \frac{E}{(1-\nu^2)d^{1/2}} \cdot s \cdot \alpha \cdot \Delta T \right) \quad \text{Equation 5-8}$$

Where,

$q$ : : tyre inflation pressure (MPa)

$l$  : : length of tyre footprint (mm)

$d$  : : combined thickness of old bound layers (substrate) and asphalt overlay (mm)

$E, \nu$  : : stiffness (MPa) and Poisson's ratio of asphalt overlay material

$\alpha$  : : thermal coefficient of expansion of old substrate material

$s$  : : crack spacing of old substrate material (mm)

$\Delta T$  : : maximum change of temperature in old substrate layer (°C)

with (Molenaar, 1995),

$$\beta = \frac{1}{0.55 d} \sqrt[3]{\frac{E_{sup}}{E}} \quad \text{Equation 5-9}$$

Where  $E_{sup}$  is the elastic modulus of the subgrade/support and  $E$  the modulus of the bound layer(s).

From the equation for  $\beta$  it is evident that the formulation is based on a two-layer system. The pavement structure therefore needs to be converted to a two-layer system first, and approaches introduced subsequently under Equivalent Modulus Estimates for granular layers can be used. Each of the fracture mechanisms is related to the number of cycles to failure and the fracture properties as follows:

$$\log N = -n \log K - \log A \quad \text{Equation 5-10}$$

Lytton (1989) states that with calibration of these relationships to field data the observed cycles to failure were predicted reliably with a linear combination of the outcomes for the three mechanisms.

The general relationship implies that smaller values of  $A_r$ ,  $A_T$  and  $n$ , correspond to longer asphalt layer lives.

### Asphalt Reinforcement Improvement Factors

The effect of asphalt reinforcement in design is generally accounted for by the application of improvement or benefit factors – the reinforced case compared to the unreinforced case. This can be expressed simply in terms increased life ( $N_r/N_u$ ) which is essentially a traffic benefit ratio (TBR), or the benefit of reduction in layer thickness. These concepts are introduced in more detail under Performance or Output-based Improvement Factors for granular layers.

Factors that capture the influence of geosynthetics on material properties provide an approach that could be included directly into the design method. For an approach based on fracture mechanics, the influence of reinforcement on the fracture properties could be considered. However, determination of the fracture parameters  $A$  and  $n$  for a material entails monitoring and recording the stable crack growth of asphalt beam samples under cyclic loading conditions, which is a tedious and expensive process.

Kunst and Kirschner (1993) performed semi-static bending beam tests to evaluate the performance of various geosynthetics imbedded in asphalt beams. They showed that the overall effect of the reinforcement can be reflected by a reduction in the value of  $A$ ; the value of  $n$  remains unaffected (Molenaar, 1996). The property  $A$  is a function of the calculated stress at failure and energy required for propagation of the crack – the area under the load-deformation curve. The two values derived from the bending beam test are used to determine the ratio of  $A$  for the reinforced and unreinforced case ( $A_r/A_u$ ). The results of this study are included in Table 5-2. A smaller fracture ratio ( $FR$ ) suggests a more effective reinforcement effect and based on this study values typically ranged between 0.2 for polyester geogrids to 0.6 for nonwoven polypropylene geotextiles.

$$A_r = FR \cdot A_u$$

Equation 5-11

Table 5-25: Fracture Ratios for various Geosynthetics (Kunst & Kirschner, 1993)

Geosynthetic	Strength Longitudinal/ Transverse (kN/m)	Bitumen Emulsion Bond Coat (ℓ/m <sup>2</sup> )	$FR = \frac{A_r}{A_u}$
Woven polyester (PET) grid	50/50	0.4	0.25
Woven PET grid	50/50	0.4	0.27
Woven PET grid	40/40	0.4	0.22
Woven glass grid	35/56	0.4	1.12 <sup>a</sup>
Extruded polypropylene (PP) grid	14/18	1.3	2.15 <sup>b</sup>
Non-woven PP geotextile – filament	8.5	1.6	0.45
Non-woven PP geotextile – staple mesh	8.5	1.6	0.60

*Notes: <sup>a</sup>Poor performance; considered unrealistic - No details of glass geogrid or discussion provided in reference. Beam length of 600mm used compared to 400mm used in Nottingham study (see Table C.5 and related discussion);*

*<sup>b</sup>Only sample not failing in bending, but in shear at interface due to 10kg/m<sup>2</sup> chippings used on interface*

### 5.2.3 Design Methods

The methods proposed for design of geosynthetic reinforced asphalt in this guideline were developed at Delft University and Nottingham University. Since little experience exists with the application of these methods in southern Africa, they are introduced in this edition and recommended for use in an analytical or comparative way. It is believed that these methods provide a good platform for design and future refinement as experience is gained through implementation and monitoring.

#### **Delft University – Molenaar (1995, 1996)**

This method uses fracture mechanics principles and models the effect of plain and reinforced overlays. The method is attractive due to its simplified, practical approach while using sound engineering principles. The effect of reinforcement is modelled as an increased resistance to cracking of the asphalt through enhanced fracture properties. Both a benchmarking approach (for preliminary design) and a more detailed approach are presented below.

#### **Reinforced Asphalt Overlay Thickness Benchmarking**

The recommended application of this method is to perform a quick reinforced asphalt alternative design compared to an existing overlay design. In such an analysis, approximations of the relevant properties are used. The steps to be followed are outlined below:

- Obtain basic details of the existing pavement, its condition, and proposed conventional overlay design. It is important to define the thicknesses of the existing bound layers and the proposed thickness of the new, unreinforced, asphalt overlay,  $D_u$ .
- Since reflective cracking originates from the existing cracked bound layer(s), the total thickness of the existing bound layer(s) = existing crack length,  $c$ , of the substrate.
- The thickness of the existing bound layer(s) + new overlay thickness =  $d$ . Calculate the ratio  $c/d$
- From Figure 5-5 and using the  $c/d$  ratio, obtain the dimensionless stress intensity factor that represents the dominating mode of cracking for the unreinforced case, defined as  $\hat{K}_u$
- Obtain an appropriate Fracture Ratio ( $FR$ ) for the geosynthetic under consideration. This should be available from the supplier or can be estimated from published data, such as Table 5-2. From Equation 5-11,

$$A_r = FR \cdot A_u$$

- Determine the fracture property  $n$  based on climate using the following guidelines.

Table 5-3: Approximate values for fracture property  $n$  based on climatic conditions

Climatic Condition*	Approximate value for fracture property $n$
Hot, tropical regions	3.5
Moderate coastal regions	4.5
Cold regions	7.0

*Note: \*Caution – Categories based on European climatic conditions*

- A formulation for the reinforced overlay thickness can be obtained by keeping the design traffic constant,  $N_r = N_u$ ; the number of load repetitions  $N$  expected to drive the crack through the new overlay can be replaced with the parameters in Equation 5-5 and Equation 5-1, respectively:

$$N = D / \frac{dc}{dN} \quad \text{with} \quad \frac{dc}{dN} = A \cdot K^n$$

therefore, the estimated reinforced asphalt thickness is:

$$D_r = FR \left( \frac{D_u}{K_u^n} \right) \hat{K}_r^n \quad \text{Equation 5-12}$$

with  $D_u$ ,  $FR$ , and  $\hat{K}_u^n$  known, and the dimensionless stress intensity factor for the reinforced case defined as  $\hat{K}_r^n$ , estimated from Figure 5-5.

Since  $\hat{K}_r^n$  depends on the ratio  $c/d$ , reinforced asphalt thickness  $D_r$  is solved by iteration.

**Example: Delft Method – Reinforced Asphalt Overlay Benchmarking**

1) Existing pavement and proposed rehabilitation

- A rehabilitation design makes provision for an asphalt overlay with thickness of 100 mm. The main objective is to sustain at least 1 million E80s without any reflective cracking during the design period.
- Visual: Degree 3 block cracking, crack width  $\approx 3$  mm and block dimension approximately 2 m x 2 m.
- Following a detailed rehabilitation investigation, the following model pavement structure was compiled:

Existing Pavement Description	Thickness (mm)	Modulus (MPa)
Multiple bituminous seals	20	1000
Cemented base exhibiting cracks (C3/4)	150	1000
Cemented subbase with equivalent granular stiffness (EG4)	150	300
Natural gravel selected (G6)	150	150
Gravel-soil subgrade (G8)	-	100

*Note: Refer to SAPEM (2014) for definitions of South African material codes*

2) Unreinforced asphalt overlay fracture properties

- Two existing cemented layers and old bituminous seals exhibit cracking. The sum of these layers, 320 mm, can therefore be assumed as the existing crack length,  $c$ . Note that “equivalent granular” in the South African Mechanistic Design context refers to a layer exhibiting high-degree block cracking with stiffness equivalent to a good quality granular layer.
- The total thickness of bound layers,  $d$ , including the planned 100 mm overlay, is therefore 420 mm.
- The ratio  $c/d$  is 0.76. The existing pavement condition suggests “medium interlock” based on the definitions presented in Table C.1. Entering Figure C.5 using this information indicates that crack

<p>progression will be dictated by shear action, with a dimensionless stress intensity factor, <math>\widehat{K}_u = 1.1</math>.</p> <ul style="list-style-type: none"> <li>The project is located in a moderate climatic region, dry sub-humid conditions. Considering Table 5-3, a crack growth exponent <math>n = 4</math>, is selected.</li> <li>With reference to Eq.C12, <math>D_u/\widehat{K}_u^n = 68.3</math></li> </ul> <p>3) Reinforced asphalt overlay benchmarking</p> <ul style="list-style-type: none"> <li>A polyester paving geogrid with Fracture Ratio (FR) of 0.3 is selected (see Section C.2.2.2) based on valid data made available by the supplier.</li> <li>The following table shows the iterative process to establish the reinforced asphalt thickness, <math>D_r</math>.</li> </ul>			
Selected $D_r$	c/d	$K_r$ (Fig. C.5)	$D_r$ (Eq.C12)
60	0.84	1.25	50
50	0.86	1.30	57
55	0.85	1.28	55
<ul style="list-style-type: none"> <li>This initial analysis shows that the asphalt thickness can be reduced to 55 mm by introducing a paving grid.</li> </ul>			

### Reinforced Asphalt Overlay Design – Detailed Approach

The simplified method introduced above excludes the conversion of dimensionless stress intensity factors (Figure 5-6) to actual K-values and uses rough estimates of the fracture parameters of the unreinforced asphalt. The same basic process introduced above holds, with the following more detailed approach to determine the stress intensity factors and fracture parameters.

- Convert the pavement to a two-layer system, combining bound layers and unbound layers. For the bound layers (asphalt and cemented) an equivalent modulus ( $E$ ) can be calculated using the Nijboer equation:

$$E = E_a \left[ \frac{a^4 + 4a^3b + 6a^2b^2 + 4ab^3 + b^4}{b(a+b)(a+1)^3} \right] \quad \text{Equation 5-13}$$

where,

$E_a$  : stiffness modulus of asphalt top layer

$a$  :  $D_b/D_a$

$D_a$  : thickness of asphalt layer

$D_b$  : thickness of cemented base layer

$b$  :  $E_a/E_{base}$

- The unbound layers are combined by calculating an equivalent subgrade modulus ( $E_{sup}$ ) using the method proposed subsequently for granular layers under Equivalent Modulus Estimates.
- Convert the dimensionless stress intensity factors to actual K-values using Equation 5-6 and/or Equation 5-7. The contact pressure ( $q$ ), contact length ( $l$ ) and  $\beta$  factor (function of  $E$  and  $E_{sup}$ ) are inputs.
- The fracture parameters  $A$  and  $n$  for the asphalt mix are determined in more detail based on the relation between the logarithm of loading time vs the stiffness modulus of the mix – the slope ( $m$ ) at the design loading time ( $t$ ) and reference temperature of 20°C is required. A loading time of 0.02 seconds for road vehicles and 0.1 seconds for slow moving aircraft (taxiways) are reasonable. The slope parameter can be established in the following ways:

- Nomographs: The nomographs published by Shell (1990) allow the stiffness modulus of a mix to be determined from simple test inputs, including bitumen penetration, Ring & Ball Temperature, and mix volumetric properties. This data is used to construct a graph showing the dependency of mix modulus on loading time at the reference temperature. However, these properties are being phased out with the implementation of the modern performance grade (PG) approach to binder classification.
- Laboratory testing: Test method AASHTO TP 79 for determining the dynamic modulus for a range of loading frequencies and temperatures forms part of Level I and II asphalt mix designs as required by SABITA Manual 35.

- In this method, the fracture parameter  $n$  is calculated from:

$$n = \frac{2}{m \cdot k} \quad \text{Equation 5-14}$$

where  $k$  is a correction factor calculated from:

$$\ln k = 0.34 - 3.58 \times 10^{-4} E_{mix} - 6.67 \times 10^{-3} E_{bit} + 1.01 \times 10^{-4} E_{mix} \ln E_{bit} \quad \text{Equation 5-15}$$

where the stiffness modulus of the bitumen  $E_{bit}$  and stiffness modulus of the mix  $E_{mix}$  are in MPa and can be determined from either nomographs or laboratory testing.

- For design purposes a sufficiently accurate estimation of the fracture parameter  $A$  can be determined using the following relationship:

$$\log A = -2.36 - 1.14 \cdot n \quad \text{Equation 5-16}$$

#### **Example: Delft Method - Reinforced Asphalt Overlay: Detailed Approach**

##### 1) Existing pavement condition and proposed rehabilitation

- Visual: Degree 3 block cracking, crack width  $\approx 3$  mm and block dimension approximately 2 m x 2 m.
- The same pavement structure used for the Reinforced Asphalt Overlay Benchmarking analysis is applicable. Having shown the potential effectiveness of the paving grid in the previous analysis, the road authority wishes to investigate an extended service life incorporating a woven polyester paving geogrid.
- Rehabilitation in the form of an asphalt overlay is still preferred to reduce disruption of traffic. Conventional analysis shows that a 100 mm unreinforced asphalt overlay should be able to accommodate 3 million E80s based on classic fatigue and deformation criteria.
- 2) Conversion to two-layer system

Two-layer Pavement Description		Thickness (mm)	Modulus (MPa)	Equivalent Modulus (MPa)	Comment/Reference
Bound	Asphalt overlay	100	6000	1385	Eq.C13
	Cemented base (C3/4)	320	600		Eq.C30
	Cemented subbase (EG4)				
Unbound	Natural gravel selected (G6)	-	110	110	Eqs.C28 & C29
	Gravel-soil subgrade (G8)				

##### 3) Stress intensity factors

- Since the stress intensity factor varies with thickness, the overlay is divided into a bottom and top part.

Parameter	Value		Comment/ Ref.
Assumed existing crack length, c (mm)	320		Cemented layers Including overlay
Total bound layer thickness, d (mm)	420		
Stress Intensity Factor zone	Bottom 50 mm	Top 50 mm	100 mm overlay

Crack length range, c (mm)	320 to 370	370 to 420	
Ratio c/d variation	0.76 to 0.88	0.88 to 1.00	Consider c/d, Fig. C5
Average c/d ratio	0.82	0.94	Only shear action
Non-dimensional stress intensity factor, $\widehat{K}_S$	1.20	1.41	Fig. C.5, only shear
$\beta$ parameter	$1.86 \times 10^{-3}$	$1.86 \times 10^{-3}$	Eq. C9
Stress intensity factor for shear, $K_S$	4.82	5.67	Eq. C7

4) Asphalt overlay life

Fracture parameter calculation	Value	Reference	
Binder stiffness modulus, $E_{bit}$ (MPa)	20	Binder test data	
Mix stiffness modulus, $E_{mix}$ (MPa)	6000	Mix test data	
Mix stiffness - log time slope, m	0.39	Mix test data	
Correction factor for fracture par. n, k	1.369	Eq.C15	
Fracture parameter, n	3.75	Eq.C14	
Unreinforced asphalt fracture par., $A_u$	$2.32 \times 10^{-7}$	Eq.C16	
Fracture Ratio (FR) for paving geogrid	0.3	Sect.C.2.2.2/ Bending beam data	
Reinforced asphalt fracture par., $A_r$	$6.95 \times 10^{-8}$	Eq.C11	
Life calculation	Unreinforced	Reinforced	Reference
Crack speed (Bottom/Top) dN/dc	$8.44 \times 10^{-5}/1.55 \times 10^{-5}$	$2.35 \times 10^{-5}/4.66 \times 10^{-5}$	Eq. C1
Repetitions to progress (Bottom/Top)	$5.92 \times 10^6/3.22 \times 10^5$	$1.97 \times 10^6/1.07 \times 10^6$	Eq. C5
Total repetitions/life, N	$9.14 \times 10^5$	$3.05 \times 10^6$	$N_{(Bottom + Top)}$

- The analysis shows that a 100 mm unreinforced asphalt overlay will not be able to sustain reflective cracking and effectively extend the service life.
- Inclusion of the polyester paving geogrid will mitigate the risk of reflective cracking and extend the service life to accommodate 3 million E80s.

### Nottingham University – Brown et al (1999)

Models for the design of reinforced asphalt pavements developed at Nottingham University aimed at advancing purely empirically based procedures to a more fundamental, yet relatively simple approach. The development was funded in part by the geosynthetics industry and the programs OLCRACK and THERMCRC were made available in spreadsheet applications.

Geosynthetics included in this study represented the available spectrum of products at the time and covered a range of aperture sizes (25 to 85 mm), material types (polymer, glass, and steel), and node detail (fully integrated, bonded, and woven) while a geotextile was included for comparison. The methods facilitate direct inclusion of relevant geosynthetic characteristics as part of the design process. The two methods address the following design situations:

- OLCRACK Model: Design against traffic induced cracking in asphalt layers on old-cracked substrates and in new pavements.
- THERMCR Model: Design against reflective cracking in overlays resulting from thermal movements at low temperature; typically relevant for overlays on cemented base and jointed concrete pavements, and situations where environmental conditions combined with low traffic volumes dictate performance.

### OLCRACK Model: Design for Traffic Loading

Figure 5-7 shows that the model requires a number of variables. Loading, asphalt surfacing and geosynthetic properties, interface condition, crack spacing and interlock, as well as the basic supporting

OLCRACK is based on extensive laboratory semi-continuous beam fatigue and shear box testing as well as finite element modelling. Pilot-scale pavement tests were conducted as a calibration exercise. Subsequently, many case studies demonstrated the validity of the model.

structure inputs are required. The asphalt surfacing is modelled as a single linear elastic material on a semi-continuous support. Crack growth in the asphalt is predicted using fracture parameter inputs derived from fatigue test results and mechanistic calculation of an approximate strain at the crack tip. The method models both top-down and bottom-up crack progression in an incremental approach.

Supporting structure: Similar to the Delft method, conversion of the supporting structure to a three-layer system is required. This can be achieved following “Concepts and Principles” in the next section, using guidelines for equivalent modulus estimates. Bound layers, such as an old asphalt and cemented base may be combined.

Existing pavement condition: Traffic can cause reflective cracking through an overlay in a relatively short time, depending on the extent and severity of cracking (or crack activity) in the existing pavement. These conditions are provided for as a typical crack spacing input and crack/joint load transfer parameter inputs, namely shear modulus across the crack and a crack width coefficient. Descriptions of these parameters and typical input values are provided below.

- Crack spacing: Typical crack or joint spacing observed through visual assessment. In new pavements or a continuum layer such as a granular base, the crack spacing should be set to zero.
- Crack shear modulus: Load transfer stiffness across the crack; defined as the relationship between vertical shear stresses at the crack face and relative vertical movement across the crack. This input can be quantified through a Crack Activity Meter or Falling Weight Deflectometer (FWD) crack or joint load transfer measurements. These values are normally tied to crack width, dictating the degree of aggregate interlock and typical values are provided in Table 5-4.
- Crack width coefficient: Also known as load transfer coefficient. This input is normally linked to the crack shear modulus as suggested above. A value of 1 represents tight or closed cracks (full load transfer), and 0 represents wide cracks (no load transfer). In doweled jointed concrete pavements, however, the relationship between joint width and load transfer may not be relevant.

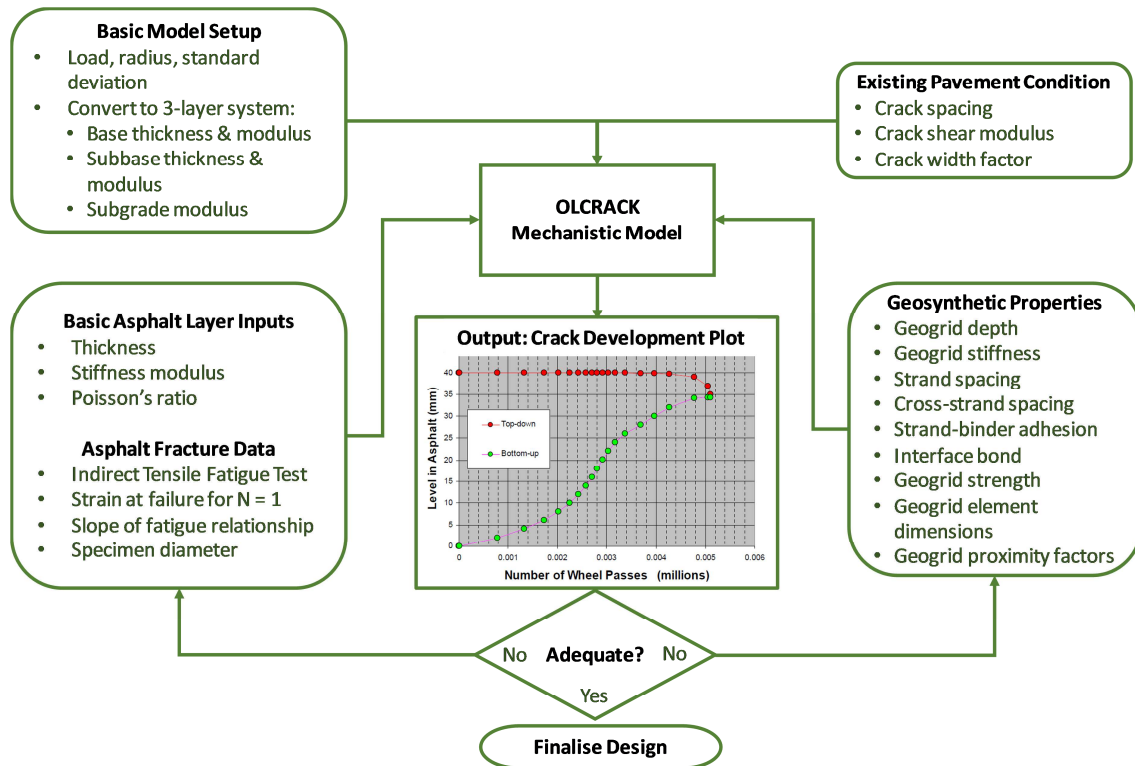


Figure 5-7: OLCRACK Design process

Table 5-4: Typical crack/joint condition classification and inputs

Condition	Crack/Joint Load transfer stiffness (MN/m <sup>3</sup> or kPa/mm)	Crack/Joint Width Coefficient
Poor	100	0.0 (wide, negligible interlock)
Medium	1000	0.5
Good	5000	1.0 (tightly closed)

Asphalt surfacing: While traditional mechanistic functions relate tensile strain to load repetitions, the simplified approach adopted here reinterprets fatigue test data to provide a strain-based law analogous to the stress-based Paris Law used in fracture mechanics.

Thus, the following differential equation describes the crack growth rate with number of traffic cycles.

$$\frac{dc}{dN} = A \cdot \varepsilon^n$$

Equation 5-17

Where  $c$  is the crack length,  $N$  is the number of load cycles, and  $\varepsilon$  the tensile strain at the crack tip. The asphalt material fracture parameters  $A$  and  $n$  are derived from constant load indirect tensile fatigue test (ITFT) data.

Typical ITFT laboratory test results with interpretation of the data are illustrated in Figure 5-8. The conversion of the characteristic function to a strain-based crack propagation law inherently assumes an ITFT load-controlled laboratory test configuration and data where:

The Indirect tensile fatigue test (ITFT) forms part of the Nottingham Asphalt Test (NAT) suite of tests (Cooper and Brown, 1989). This is a simple, inexpensive test with the advantage of using cylindrical specimens manufactured in the laboratory or cored from a pavement.

- $\varepsilon_1$ , the failure strain for a single load cycle ( $N=1$ ) is related to the fracture parameter  $A$ , and  $n$ , the slope of the characteristic fatigue relationship

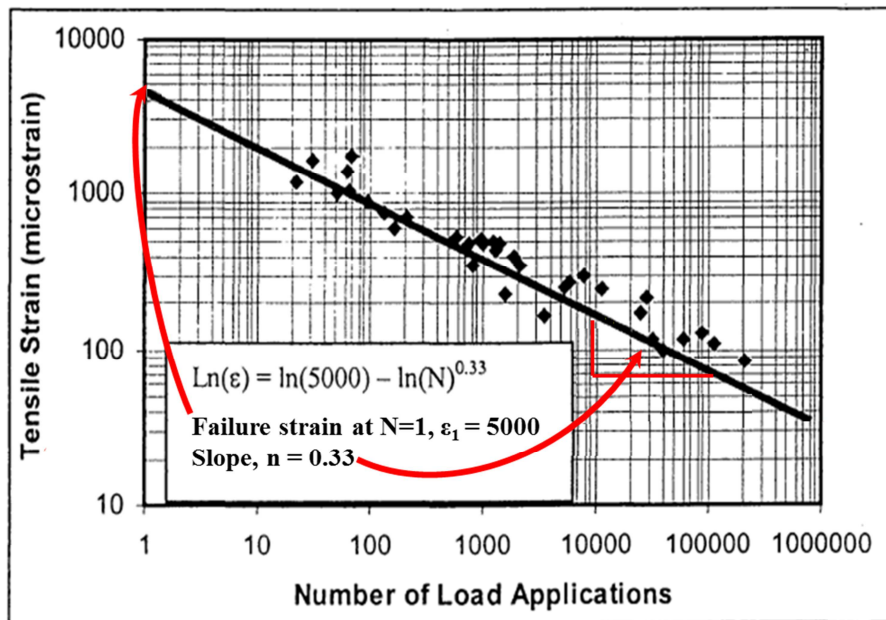


Figure 5-8: Typical ITFT Load Control Test Data and Interpretation

Geosynthetic: Figure 5-7 lists the variables associated with the geosynthetic physical characteristics, as well as parameters defining interaction with and effect on the surrounding asphalt. The position or depth of a geosynthetic within the layer is specified. Table 5-5 provides typical characteristics for geosynthetic types included in the original research.

- Stiffness and strength values are readily available from suppliers. It should be noted that bending and shear effects during loading (construction and post construction) could result in damage and therefore reduced strength of some products, particularly glass fibres.
- Strand spacing is highly significant – closer strand spacing increase the reinforcing benefit. It should be noted that inherent model assumptions will cause the model to exaggerate the benefit for strand spacing inputs well below ten times the effective strand diameter.
- Strand diameter and strand-asphalt bond: These parameters are highly significant. A large perimeter increases the effective bond area and at the same time causes more efficient interaction with the surrounding asphalt (generating larger stresses). A bond strength of about 1 MPa is expected when good interfacial interaction exists.

Table 5-5 shows that values up to 10 MPa were achieved in some cases based on repeated load shear box test results – presumably influenced by product geometry, i.e. strand section variation and inclination. As noted above, although rational trends were observed during the study, practicality and limitations of solutions should always be scrutinized – thicker strands and smaller aperture sizes can undermine compatibility of the paving geogrid with the asphalt which may cause debonding.

- Interface shear stiffness: Loss of shear stiffness may be expected when a geosynthetic is introduced. This effect may be marginal if optimum compatibility between the geogrid and asphalt is achieved; i.e. maximum interlock. A distinction should be made between bond

strength and interface stiffness – some products may have an excellent strand to asphalt bond but other factors such as inclusion of a geotextile or fabric backing may result in low interface stiffness.

- A geogrid proximity factor (GPF) was introduced based on theoretical analyses and pilot scale performance to account for a reduction in the crack propagation rate when the crack tip is in the region of the reinforcement; i.e. damage occurs before any apparent visible signs of cracking. A reduction factor is therefore applied peaking at the geosynthetic position and dissipating to unity typically 20 mm above and below this level. For the unreinforced case, this *factor* is set to 1. For a geogrid with geotextile or fabric backing, the *distance* below the geogrid is set to 0.

**Table 5-5 : Input parameters and typical values for various geosynthetics used in study**

Geosynthetic Type	Stiffness (MN/m)	Strength (kN/m)	Interface Stiffness (MPa/m m)	Aperture size (mm)	Strand diameter (mm)	Bond Strength (MPa)	GPF
Grid – PP	0.33	21	25	64 x 64	3.8	10	4/4
Grid + fabric – PP	0.34	24	8	64 x 64	3.8	10 <sup>d</sup>	4/1
Grid – GF	0.35 (1.1) <sup>a</sup>	34 (70) <sup>a</sup>	36	26 x 40	3.5	0.1 <sup>e</sup>	4/4
Grid + fabric – GF	0.60 (1.1) <sup>a</sup>	32 (70) <sup>a</sup>	14	26 x 40	3.5	0.1 <sup>e</sup>	4/1
Grid – GF	0.33	34	36	25 x 25	2.5	0.1 <sup>e</sup>	2/2
Grid + fabric – GF	0.33	34	14	25 x 25	2.5	0.1 <sup>e</sup>	2/1
Fabric – PP	0.02	40	14	0.1 x 10	0.1	0.1	1/1
Woven Grid - S	22.7 <sup>b</sup>	49 <sup>b</sup>	100	85 x 170 <sup>c</sup>	3.4	10	4/4
Legend: GPF = Grid Proximity Factor (above and below geosynthetic); PP = Polypropylene; GF = Glass fibre; S = Steel							

**Notes:**

<sup>a</sup>Strength and stiffness much less than expected; manufacturer's data in brackets;

<sup>b</sup>Theoretical values;

<sup>c</sup>Hexagonal aperture parallel to crack;

<sup>d</sup>Bond strength optimistic and lower value expected compared to geogrid without fabric;

<sup>e</sup>Probably unrealistically low due to short beam length.

**Example: Nottingham Method – OLCRACK Reinforced Asphalt Overlay Design**

1) Background information

- The cemented base pavement with condition and structure introduced in previous asphalt reinforced examples is analysed using OLCRACK. Unreinforced and reinforced asphalt overlay

options are investigated.

- An asphalt overlay thickness of 100 mm is proposed, reinforced with a paving geogrid. Validated properties of the candidate geogrid are made available by the manufacturer. The designer selects a glass fibre geogrid stitched to a nonwoven geotextile/fabric backing (also see Table C.5).

## 2) Model Input

- The following table shows the model setup for the reinforced case.
- Due to the relatively thin overlay ( $\leq 100$  mm), deformation (strain) controlled fatigue test data for a medium continuously graded asphalt mix is used.
- For the unreinforced case, geogrid stiffness is set to zero (0) and the fatigue shift factor is set to one (1).

### Load setup

Equivalent wheel load (kN)	40
Tyre contact pressure (kPa)	566
Load radius (m)	0.15
Wheel track standard deviation (m)	0.20

### Asphalt overlay characteristics

Overlay thickness (mm)	100
Overlay stiffness modulus (MPa)	6000
Strain at $N = 1$ (??)	2870
Slope of N-strain relationship	0.195
Specimen diameter (mm)	100

### Existing pavement condition and structure

Crack spacing (m)	2.0
Crack width factor (Table C.4)	0.5
Crack shear modulus (MN/m <sup>3</sup> ) (Table C.4)	2500
Base layer thickness (mm)	320
Base layer elastic modulus (MPa)	600
Subbase thickness (mm)	150
Subbase elastic modulus (MPa)	150
Subgrade elastic modulus (MPa)	100

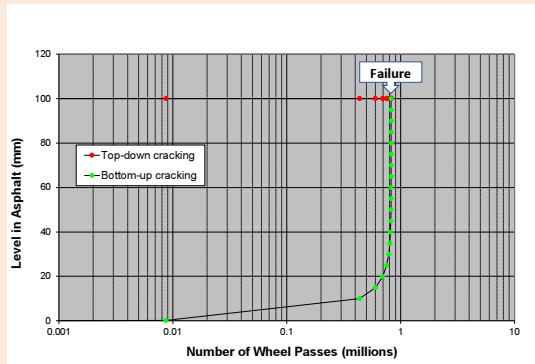
### Paving geogrid properties

Geogrid depth, from top (mm)	99
Geogrid stiffness (MN/m)	0.33
Geogrid strength (kN/m)	34
Strand spacing (mm)	25
Cross-strand spacing (mm)	25
Strand effective diameter (mm)	2.5
Strand-binder adhesion (MPa)	5
Interface stiffness (MPa/mm)	14
Shift factor at geogrid proximity	2
Extent of effect above geogrid (mm)	20
Extent of effect below geogrid (mm)	20

## 3) Model Output

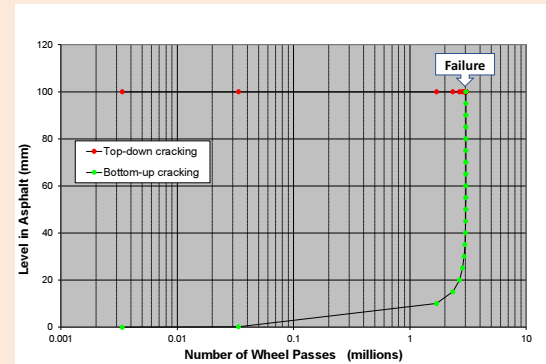
- The output graphs show that bottom-up cracking is dominant.
- The paving geogrid increases pavement life with a factor of approximately 3.

#### Unreinforced Case



Failure: 0.83 million repetitions

#### Reinforced Case



Failure: 3 million repetitions

#### THERMCR Model: Design for Thermal Cycles

This model simulates the stresses and strains caused in an asphalt overlay by thermal opening and closing of a crack/joint in a cemented/concrete base using an incremental damage routine. Figure 5-9 lists the input parameters and illustrates that the process essentially includes a heat flow model and viscosity model that feeds into a mechanistic model.

THERMCR is based on a series of tests that involve ultra-slow extension of a 2 m long asphalt beam over a split concrete base, at a temperature of -5°C. The model was calibrated for the unreinforced case against known

The project minimum and maximum temperature inputs (temperature difference) are used to develop a sinusoidal daily temperature variation at the pavement surface. These inputs dictate the outcome and it is the designer's responsibility to identify temperatures representative of the project area and occurrence in the year.

The heat flow model uses the asphalt thermal properties to relate the daily temperature cycle to temperature distribution in the asphalt layer with depth. Values for asphalt thermal conductivity = 4 W/mK, specific heat capacity = 800 J/kgK, and density = 2400 kg/m<sup>3</sup>, are suggested as reasonable default values. The bitumen penetration input with temperature gradient is used to estimate bitumen and mix viscosities. Since the role of the bond coat (or tack coat) in the model essentially includes an effect of the bitumen in the mix, it is suggested that the same penetration is used for both the bitumen in the bond coat and in the mix. The thickness of the bond coat, however, should be set to 0.3 mm for standard cases as this value resulted from a calibration exercise.

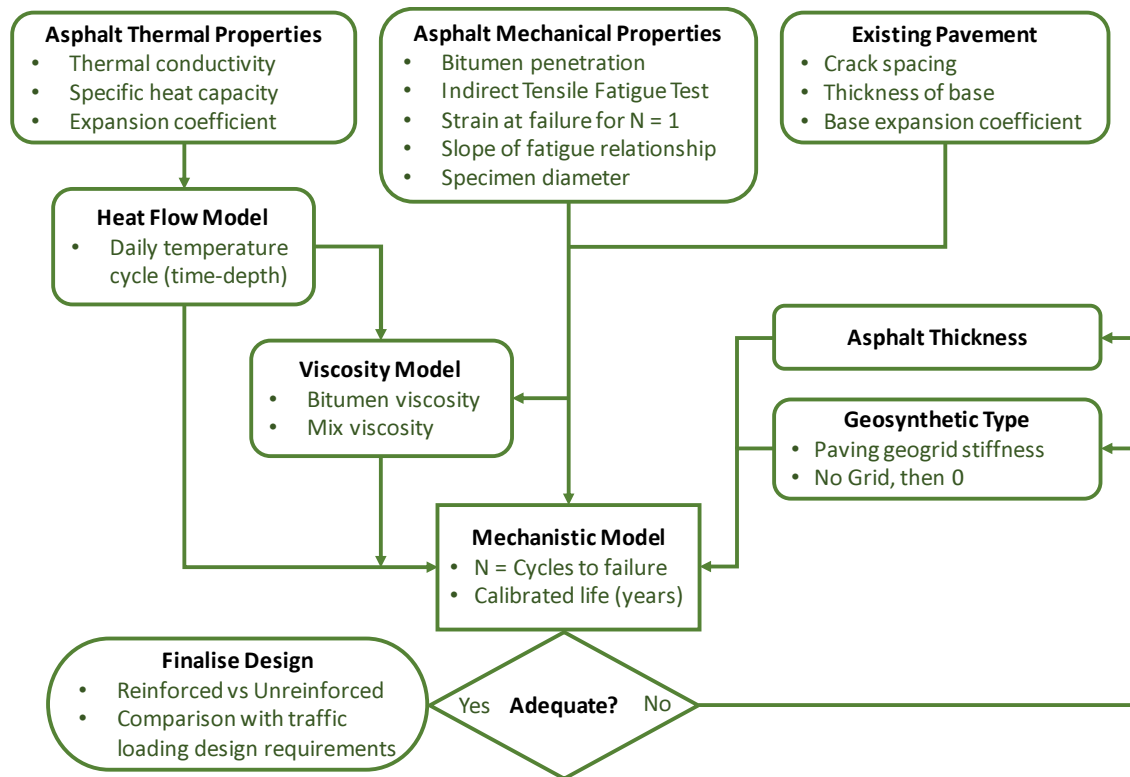


Figure 5-9: THERMCR Design Process

The strain-based crack propagation law introduced above for traffic induced cracking also applies here; it assumes that temperature does not affect the crack propagation rate. The fracture related parameters derived from indirect tensile fatigue testing (ITFT) as defined above, are used as inputs to the model. The routine calculates the number of thermal cycles to cause full crack development through the asphalt layer for the selected thickness under consideration.

The condition of the existing pavement or substrate in terms of crack/joint spacing is significant in calculating the expected crack/joint opening. The base material thermal expansion coefficient depends mainly on the aggregate type and is typically  $10^{-5}$ , ranging from  $1.4 \times 10^{-5}$  for gravel aggregate to  $0.7 \times 10^{-5}$  for limestone aggregate. The model also makes provision for a debonded length across the crack; the asphalt effectively detaches across the crack and extends freely in this zone without resistance.

The model calculates strains due to shearing action in the bond coat, stress compatibility of the mix, mix extension and thermal shrinkage of the asphalt. It then tracks asphalt through a 24 hour cycle and identifies the maximum tensile strain during the night relative to the highest compression daytime state.

In this model, only the geosynthetic stiffness is considered to account for the reinforcing element that absorbs some of the stress as it extends with the surrounding asphalt. Establishing and maintaining a good bond between the reinforcement and asphalt is therefore imperative.

The output in cycles to failure ( $N$ ) is also provided as life in years. However, the original calibration resulted in 520 cycles over 20 years, i.e. 26 cycles per year. Application in southern Africa will require project specific data in terms of daily minimum and maximum surface

THERMCR was originally calibrated for European conditions. Application in southern Africa will require project specific calibration using basic information such as daily minimum and maximum characteristic temperatures, and number of days that represent this design cycle.

temperatures that defines a design cycle (characteristic day), as well as the number of days per year that represent the design cycle.

#### **Example: Nottingham Method – THERMCR Reinforced Asphalt Overlay Design**

##### 1) Background information

- A cemented base pavement exhibiting cracks is to be overlaid near Bethlehem in South Africa; a location where thermal cracking is expected. The THERMCR model will be used in this analysis.
- Analysis of local temperature data reveals that a minimum daily surface temperature of  $-3.5^{\circ}\text{C}$  and maximum daily surface temperature of  $30^{\circ}\text{C}$  represent a winter critical daily cycle. Damage analysis using THERMCR suggests that 36 (equivalent) critical cycles per year can be expected.
- An asphalt overlay thickness of 100 mm is proposed, and reinforcement introducing a paving geogrid will be considered.
- An asphalt overlay life expectancy of 12 to 15 years is specified.

##### 2) Model Input

- The following table shows the model setup for the reinforced case.
- For the unreinforced case, geogrid stiffness is set to zero (0).

Existing Pavement Information		Asphalt Overlay: Basic properties	
Minimum surface temperature ( $^{\circ}\text{C}$ )	-3.5	Overlay thickness (mm)	100
Maximum surface temperature ( $^{\circ}\text{C}$ )	30.0	Bitumen penetration (Pen)	60
Crack/joint spacing (m)	5.5	Bond coat thickness (mm)	0.3
Base thickness (mm)	300	Bond coat bitumen penetration (Pen)	60
Base coefficient of expansion ( $^{\circ}\text{C}^{-1}$ )	$1 \times 10^{-5}$	Mix coefficient of expansion ( $^{\circ}\text{C}^{-1}$ )	$1.8 \times 10^{-5}$
		Mix thermal conductivity (W/mK)	4
		Mix specific heat capacity (J/kgK)	800
		Mix Density ( $\text{kg/m}^3$ )	2400
Paving geogrid and model properties		Asphalt Overlay: Fatigue properties	
Paving geogrid stiffness (MN/m)	0.3	Strain at $N = 1$ (%)	1500
Debonding length, either side of crack (m)	0	Slope of N-strain relationship	0.250
		Specimen diameter (mm)	100

##### 3) Model Output

- Without reinforcement, the model suggests failure in less than 5 years.

- An asphalt overlay thickness of 100 mm including a paving geogrid results in 262 cycles to failure; approximately 7 years.
- Increasing the reinforced overlay thickness to 125 mm results in 539 cycles to failure which equates to approximately 15 years.

### 5.3 References

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## 6. SPECIFICATIONS OF MATERIALS

### 6.1 Introduction

Most standard specifications for road construction do not specify the use of the newer asphalt reinforcing materials. Therefore, the material specifications for the asphalt reinforcement should be sought from the suppliers of the specific material. As a general guide to typical specifications, generic material specifications for both polymeric and steel reinforcement products used in asphalt reinforcement applications are detailed hereunder.

The specifier should be aware of aspects that may affect the process of ARI installation and paving of the asphalt overlay as these could have time, cost and quality implications. These aspects must be covered in the scope of works and specifications to make the contractor aware of constraints that will affect his installation process so that he can include it in his planning and tendered rates. Some of these aspects include:

- Preparation of the surface prior to installation of the ARI must be well specified, measured and billed. This is to ensure that the tenderer can submit a realistic price for the ARI installation, including the preparation works. It is preferable not to include these items in the square meter rate for ARI installation but to provide separate rates for surface preparations items.
- Certain constraints may be applicable to some installation situations that will present challenges to the ARI installation and can affect the efficiency of the installation operation as well as the asphalt paving operation. These constraints must be highlighted in the scope of works and specifications. Examples of some of these constraints include:
  - Installation of small areas of ARI can affect the speed of the asphalt paving operation as the ARI may have to be covered the same day to prevent trafficking of the exposed ARI.
  - Installation of ARI in milled areas at night where the breaking of the emulsion tack coat may present a problem.

### 6.2 Paving Fabrics

#### 6.2.1 Scope

Work shall consist of supplying and placing a paving geotextile as a waterproofing and stress relieving membrane for the purpose of crack-sealing the existing surface or incorporating it into an initially surfaced road.

#### 6.2.2 Materials

##### ***Paving geotextile:***

The paving geotextile used with this specification shall be manufactured from nonwoven polyester synthetic fibres; resistant to chemical attack (from flux oils, paraffin's or any other solvents used in bituminous binders), mildew and rot, and shall meet the physical requirements listed in Table 6-1.



**Table 6-1: Typical specifications for paving fabric**

Table 6.1: Typical Specification for Paving Fabric

Property	Units	Requirements	Test Method
Tensile Strength (min)	kN/m	8	SANS 10221-07
Elongation at break	%	40-60	SANS 10221-07
Penetration Load (CBR)	kN	1.5	SANS 10221-07
Puncture Resistance (DART)	mm	28	EN 13433
Melting Point	°C	260	ASTM D276

***Bitumen:***

As per specifications for conventional surfacings.

***Asphalt:***

As per specifications for conventional surfacings.

### 6.2.3 Plant and Equipment

***Geotextile lay-down apparatus:***

For large areas of patching a specialist lay-down machine as supplied by the geotextile manufacturer shall be used to lay the paving geotextile down smoothly.

### 6.2.4 Construction Methods / Requirements

The manufacturer or their representative supplier's recommended installation procedures for crack sealing and full width sealing shall be strictly adhered to.

### 6.2.5 Measurement and Payment

***Computation of Quantities:***

The paving geotextile shall be measured in square metres. Narrow strip paving geotextile shall be measured in linear metres.

***Schedule items:***

Paving geotextile      Unit:    Square metre (m<sup>2</sup>)

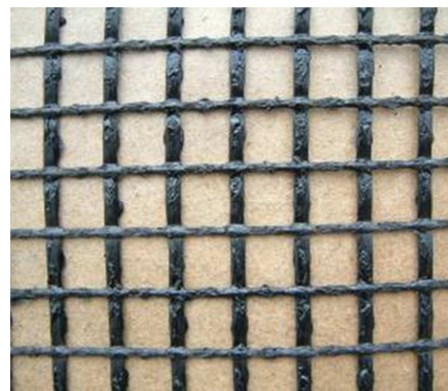
Narrow paving geotextile strips Unit:    Linear metre (m)

## 6.3 Paving Grids

### 6.3.1 Scope

Work shall consist of supplying and placing a paving grid as a stress relieving interlayer for the purpose of reinforcing an asphalt overlay.

### 6.3.2 Materials



**Paving grid:**

The paving grid used with this specification shall be manufactured from a glass fibre woven roving or polymeric grid pattern; resistant to chemical attack (from flux oils, paraffin's or any other solvents used in bituminous binders), mildew and rot, and shall meet the physical requirements listed in Table 6-2.

Table 6-2: Typical specifications for paving grids

Property		Units	Type 1	Type 2	Type 3	Test Method
Mass	Nominal	g/m <sup>2</sup>	185	370	560	ASTM D5261
Tensile Strength	Length	kN/m	50	100	100	Based on component strand strength test method G.R.I.GG 1-87
	Elongation at Break (max.)	%	<5	<5	<5	
	Width	kN/m	50	100	200	
	Elongation at Break (max.)	%	<5	<5	<5	
Melting Point	Min.	°C	>218	>218	>218	ASTM D276
Grab Strength	Warp	N	700	1300	1425	ASTM D4632
	Weft	N	425	750	1250	
Adhesive Backing			Pressure sensitive			
Dimensions	Grid Size	mm	25x25	12.5x12.5	12.5x12.5	
	Roll Length	m	150	100	60	
	Roll Width	m	1.5	1.5	1.5	

**Bitumen:**

As per specifications for conventional surfacings.

**Asphalt:**

As per specifications for conventional surfacings.

**6.3.3 Plant and Equipment****Paving grid lay-down apparatus:**

For large areas a specialist lay-down machine as supplied by the manufacturer shall be used to lay the paving grid down evenly. For smaller areas or for when a lay-down machine is unavailable the paving grid maybe laid by hand.

**6.3.4 Construction Methods / Requirements**

A representative of the manufacturer must be present during installation of this material and all work must be carried out in accordance with the manufacturer's specification and installation guidelines.

**6.3.5 Measurement and Payment****Computation of Quantities:**

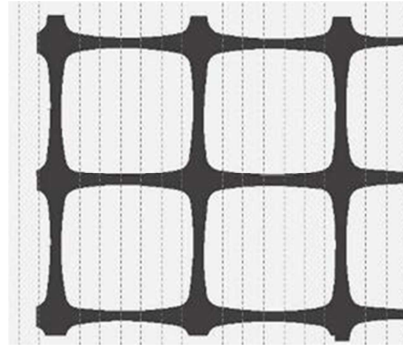
The paving grid shall be measured in square metres.

**Schedule items:**

Paving grid      Unit:    Square metre (m<sup>2</sup>)

**6.4 Composite Paving Grids****6.4.1 Scope**

Work shall consist of supplying and placing a composite paving grid as a waterproofing (the nonwoven component) and stress relieving (the grid component) membrane for the purpose of crack-sealing to existing surface/incorporating into an initially surfaced road and reinforcing the asphalt overlay.

**6.4.2 Materials**

The composite paving grid used with this specification shall be manufactured from a glass fibre woven roving or polymeric grid pattern stitched or attached to a nonwoven continuous synthetic fibres; resistant to chemical attack (from flux oils, paraffin's or any other solvents used in bituminous binders), mildew and rot, and shall meet the physical requirements listed in Table 6-3.

**Bitumen:**

As per specifications for conventional surfacings.

**Asphalt:**

As per specifications for conventional surfacings.

**6.4.3 Plant and Equipment****Geotextile lay-down apparatus:**

For large areas of patching a specialist lay-down machine as supplied by the manufacturer shall be used to lay the composite paving grid down evenly. For smaller areas or for when a lay-down machine is unavailable the composite paving grid maybe laid by hand.

**6.4.4 Construction Methods / Requirements**

The manufacturer or their representative supplier's recommended installation procedures for crack sealing and full width sealing using a composite paving grid beneath an asphalt overlay should be strictly adhered to.

Table 6-3: Typical specifications for composite paving fabrics

Property		Unit	Requirement	Test Method
<b>Grid</b>		Fibre glass reinforced or polymeric grid pattern Grid dimensions: 15mm x 15mm		
<b>Tensile Strength</b>	Tensile Strength	kN/m	50 x 50	
	Elongation at Break	%	3	
	Strength at 2% Strain	kN/m	35 x 35	
		Non-woven Continuous Filament Paving Fabric		
<b>Melting Point</b>		°C	>265	ASTM D276
<b>Penetration Load</b>		kN	2	

	Elongation	%	32	SANS 10221-07
<b>Trapezoidal Tear Strength</b>	Machine	N	215	ASTM D 4533
	Across	N	188	
<b>Grab Strength</b>	Machine	N	390	ASTM D 4632
	Across	N	420	
<b>Puncture Resistance</b>	Diameter of Hole	mm	28	EN 13433
<b>Bitumen Retention</b> ** See Explanation Below	Bitumen Retention	l/m <sup>2</sup>	≥1.2	ASTM D 6140
U.V. Light Stability (150 hours), in excess of 85 % of strength retained. ** Bitumen Retention. The values indicated were established using a Penetration Grade 80/100 Bitumen.				

## 6.4.5 Measurement and Payment

### **Computation of Quantities:**

The composite paving grid shall be measured in square metres.

### **Schedule Items:**

Composite paving grid Unit: Square metre (m<sup>2</sup>)

## 6.5 Steel mesh

### 6.5.1 Scope

Work shall consist of supplying and placing a transversally reinforced woven steel mesh as a stress relieving membrane for the purpose of reinforcing the asphalt overlay, for rut resistance and for crack resistance to the existing/prepared surface.

### 6.5.2 Materials

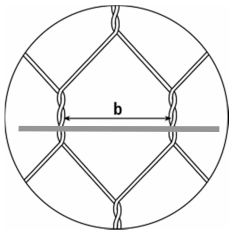
The transversally reinforced hexagonal woven double twist heavily galvanized mild steel mesh should conform to the specifications tabulated in Table 6-4. Type 1 is for asphalt reinforcement applications.



All tests on wire are performed prior to manufacturing the mesh.

- **Tensile strength:** The wire used for the manufacture of the steel mesh shall have a tensile strength between 350-575 N/mm<sup>2</sup> according to SANS 675:1997.
- **Elongation:** Elongation is not less than 10% in accordance with EN 10223-3. Tests are carried out on a sample at least 30 cm long.

Table 6-4: Typical specification for steel mesh

A – Standard Mesh Wire					
Mesh Type	b	Tolerance (mm)		OD Wire O (mm)	
Type 80	80	-4 to +10		2.5	
<p>MESH TOLERANCE</p> <p>The tolerance on the opening of mesh “b” being the distance between the axis of two consecutive twists according to SANS 1580:2005</p>					
B – Properties of Wire and Transverse Steel Rods					
Designation	Wire Type	Wire Diameter	Tolerance (mm)	Qty of Zinc (g/m2)	Tensile Strength (N/mm2)
Type 1	Mesh	2.2	± 0.08	245	350 to 575
	Steel Rod	3.9	± 0.1	290	
C - Standard Road Mesh Sizes					
Designation		Roll Length (m)		Roll Width (mm)	
Type L1		25 to 50		3.0 / 3.5 / 4.0	
Tolerance: Length ± 3%; Width ± b. (All dimensions are nominal)					
D - Strength Characteristics of Steel Mesh					
Designation	Bitumen Adhesion Strength (kN/m)	Transversal Resistance (kN/m)		Longitudinal Resistance (kN/m)	
Type L1	10	35		32	

**Bitumen:**

As per specifications for conventional surfacings.

Asphalt:

As per specifications for conventional surfacings.

**6.5.3 Plant and Equipment****Steel Mesh lay-down apparatus:**

For large areas a specialist lay-down machine in the form of a roller attached to a vehicle shall be used to lay the steel mesh down evenly. For smaller areas or for when a lay-down machine is unavailable the steel mesh maybe laid by hand.

**6.5.4 Construction Methods / Requirements**

The manufacturer or their representative supplier's recommended installation procedures for using a steel mesh beneath an asphalt overlay should be strictly adhered to.

**6.5.5 Measurement and Payment**

**Computation of Quantities:**

Woven steel mesh transversally reinforced shall be measured in square metres.

**Schedule items:**

Woven steel mesh (incl. of fixing accessories)    Unit:    Square metre (m<sup>2</sup>)

**6.6 References**

***Geosynthetics In Flexible And Rigid Pavement Overlay Systems To Reduce Reflection Cracking***, Report No. FHWA/TX-02/1777-1, Gregory S. Cleveland, Joe W. Button, and Robert L. Lytton, October 2002

***Draft Standard Specification for Inorganic Paving Mat for Highway Applications***, ASTM Subcommittee D35.03. *This Document is not an ASTM Standard; it is under consideration within an ASTM Technical Committee but has not received all approvals required to become an ASTM Standard. ASTM Copyright. All rights reserved.*

***Typical manufacturers' specifications and guidelines on products for asphalt reinforcement***, Maccaferri SA, Kaytech, Tensar International

## **7. PRACTICAL CONSTRUCTION ISSUES**

### **7.1 General Preparation Work Prior to Paving**

The existing pavement must show no significant signs of pumping, movement or structural instability.

All patches, pothole repairs and crack sealing should be done prior to paving.

Asphalt reinforcing (ARI) adheres best to a smooth, flat asphalt surface. Therefore an asphalt levelling layer may be necessary:

- On a coarsely milled or very rough surface
- On a very uneven (rutted) surface

A levelling layer is not normally necessary:

- For an overlay on an old surface that is smooth and flat
- On a finely milled surface

The surface must be clean and dry before placing the ARI

- Clean for good adhesion
- Dry (of moisture) also for adhesion
- Dry bitumen (tack or fresh asphalt) to avoid pick-up on construction vehicle tyres that may in turn lift the ARI

### **7.2 Repair of Defects Prior to Paving**

The degree and extent of surfacing defects and failures necessitate certain methods of repair to render the road surface serviceable again. Asphalt Reinforcement is an alternative to the reworking of pavement layers and usually applied before a road surface is resealed or overlaid with asphalt. Certain requirements, materials types and references in Sections 3900 and 4800 of the COLTO Standard Specifications for Road and Bridge Works for State Road Authorities: 1998 should be adhered to.

The different types of surfacing defects that may require attention are documented in TMH 9: 1992.

#### **7.2.1 Pothole patching**

All loose materials of the damaged surfacing and base layers must be removed to the full depth and backfilled with approved bituminous mixtures as described in various handbooks or as specified. The shape of the repair area should be square or rectangular and the surfacing cut 75 to 100mm wider than the cleaned - out area.

#### **7.2.2 Seal cracks**

Only 3mm and wider cracks are sealed as specified. Modified binder types to be used are CH-E1, CC-E1 and CH-R1 for cracks up to 15mm wide. Cracks wider than 15 mm are filled with a sand/ lime slurry to a depth 20mm below the surrounding surface and then with a rubber crumb/crusher dust slurry to final level after which a seal bandage is applied.

Certain types of Asphalt Reinforcement do not require cracks to be sealed beforehand.

### **7.2.3 Levelling course**

When required to remove unacceptable irregularities, bumps or slacks, a screed of densely graded asphalt should be placed. It is also possible to remove high spots and ridges by planning, in which case it is recommended that the milled surface be left rough.

### **7.2.4 Rut filling**

Rut depths of up to 15mm, or as specified, can be filled with coarse slurry. It is recommended that rapid setting slurry be used. Rut depths up to 25mm can be filled with hot, densely graded asphalt. Ruts deeper than 25mm should be removed by surface patching methods.

## **7.3 Paving Fabrics, Grids (excluding steel) and Composites**

### **7.3.1 Packaging, Storage and Handling**

1. Each ARI roll must be wrapped with a material that will protect the product, including the ends of the roll, from damage due to shipment, water, and contaminants.
2. The protective wrapping must be maintained during periods of shipment and storage.
3. Product labels must clearly show the manufacturer or supplier name, style name, and roll number.
4. ARI must be stored in a dry covered area, free from dust, dirt and moisture.
5. During storage, ARI rolls must be elevated off the ground and adequately covered to protect them from the following:
  - site construction damage,
  - precipitation,
  - chemicals that are strong acids or strong bases,
  - flames including welding sparks,
  - temperatures in excess of 71oC, and
  - any other environmental condition that may damage the physical property values of the product.
6. Rolls of ARI should be free of cuts or rips in the outer covering that may cause damage to the integrity of the product. Minor scuffing or damage to the roll may be removed by cutting off the damaged section of the product.
7. The ends of the cardboard tubes that serve as the core around which the ARI is wrapped should be free of serious damage that might impede smooth rollout of the product during application.
8. Minor denting or tearing will not impede normal application, but severely damaged rolls shall be returned for credit to the supplier.

### **7.3.2 Placing of Reinforcement**

1. The standard width of the ARI is 1.5m and therefore usually needs to be cut to fit. An angle grinder is one way to cut it.
2. ARI can be laid by hand or by mechanical means. It must be laid with sufficient tension to eliminate ripples. Should ripples appear, these must be removed by pulling the grid tight, or in extreme cases, by cutting and laying flat with overlaps.
3. Transverse joints must overlap by a minimum of 100mm. Longitudinal joints by 25-50mm.

### **7.3.3 Construction Recommendations**

1. If a levelling layer is placed, allow it to cool before placing the ARI. No adhesion or pick-up problems have been experienced when ARI has been placed the day after the levelling layer.
2. Surface temperature before laying the ARI should be between 5°C and 60°C.
3. A vacuum truck plus hand crew is recommended for ensuring the surface is very clean.
4. The ARI should be rolled with two passes of a pneumatic roller to activate the self-adhesive process. Tyres must be clean to avoid pick up of the grid. Keep the tyres dry while rolling.
5. Minimum recommended thickness for an overlay is 40mm.

### **7.3.4 Application of Tack Coat**

Tack can be sprayed before or after the ARI has been placed.

If sprayed BEFORE:

- It must be completely dry before placing the ARI to avoid pick-up
- ARI sticks well to dry tack

If sprayed AFTER:

- Again it must be completely dry before paving
- If not, the tyres of the trucks and paver will pick up bitumen, which in turn will pick up the ARI.

### **7.3.5 Problems and Precautions**

1. The surface has to be smooth enough for the ARI to stick.
2. Make sure the surface is thoroughly cleaned before the ARI is placed. Any dust will prevent the ARI from sticking
3. The surface must be dry (of moisture) before placing the ARI; otherwise it will not stick.
4. Night work can cause adhesion problems because of dew forming on the surface.
5. Make sure the ARI is flat on the surface before the pneumatic rolls it.
6. If it is placed on a hot, tacky levelling layer, the pneumatic roller may pick up bitumen on its tyres, which in turn may pick up the ARI.

7. If tack or levelling layer asphalt is still fresh, the trucks and paver tyres will pick up bitumen and fine aggregate, which in turn will pick up the ARI.
8. Avoid the paver or trucks turning on the ARI as this may pull it loose
9. If there is poor adhesion, the ARI moves in front of the paver and forms ripples. These must be flattened, or cut and lapped, otherwise:
  - The ripples reflect through to the asphalt surface
  - The ARI can project right through the asphalt surface
  - The effectiveness of the ARI is affected
  - Final rideability is affected

## **7.4 Woven Mesh Steel Grids**

### **7.4.1 Delivery, Storage and Handling**

1. Woven mesh steel grids used for ARI are supplied to site in roll lengths or 25m or 50m.
2. The individual steel ARI rolls are tied with lacing wire to prevent their unravelling whilst in transit.
3. Product labels must clearly show the manufacturer or supplier name, product name, style name, and date and time of manufacture.
4. The rolls must be stored in a dry covered area, free from dust, dirt and moisture.
5. During storage, the rolls must be elevated off the ground and adequately covered to protect them from the following:
  - site construction damage,
  - precipitation,
  - chemicals that are strong acids or strong bases,
  - flames including welding sparks, and
  - any other environmental condition that may damage the physical property values of the product.
6. ARI steel rolls should be free of cuts or dents in the outer covering that may suggest damage to the integrity of the product.
7. Minor damage or denting will not impede normal application, but severely damaged rolls shall be returned for credit to the supplier.

### **7.4.2 Placing of Reinforcement**

1. The standard width of the ARI steel rolls is 3,0m, 3,5m and 4,0m, and therefore does not require cutting to fit on site. In exceptional circumstances where cutting is required an angle grinder may be used.

2. Steel ARI rolls can be laid by hand or by mechanical means.
3. The rolls are unwound from the top such that the curvature of the mesh is in contact with the road surface.
4. Following deployment a rubber tyred roller is used to remove any inherent curvature from the mesh. A minimum of 2 passes (4 runs) in straight lines are required by the roller.
5. Overlaps of 300mm longitudinally and 150mm transversally are recommended.

#### **7.4.3 Fixing Recommendations**

1. A minimum of the first 4m of each roll to be securely fixed to the existing surface by anchors.
2. Depending on condition and type of base layer or wearing surface, either Hilti nails or screws are used at a rate of 1/m<sup>2</sup>.
3. Once the beginning of the roll is secured, the opposite end of the mesh to be tensioned and stretched prior to fixing.
4. Power actuated tools are used for the fixing.
5. Fixing to be in the direction n of travelling
6. Length of anchor such that it will not pull out during the asphaltting process.
7. Clips to secure the transverse steel rods are supplied with the anchors.
8. Manufacturers' guideline to be adhered to.
9. A minimum recommended thickness for an overlay is 50mm.

#### **7.4.4 Application of Tack Coat**

1. Tack coat should be applied to improve bonding of the asphalt to the existing surface.
2. Tack should be sprayed after the steel ARI mesh has been placed.
3. The tack coat must be completely dry before paving. If not, the tyres of the trucks and paver will pick up bitumen, which in turn may lift up the steel ARI.

#### **7.4.5 Problems and Precautions**

1. The surface has to be clean and free of dirt for the asphalt to bond.
2. Woven steel ARI rolls have inherent flexibility. If not adequately secured and tensioned prior to fixing, it may lift during placement of the asphalt.
3. The fixing process involves time. Site personnel should plan the delivery of the asphalt accordingly.
4. Night fixing is not recommended.
5. Where used in less than 50mm overlay, the mesh has been known to lift to surface affecting final rideability.
6. Preferable to use with 60mm overlay thickness.

## 7.5 Health, Safety and Environmental Issues (HSE)

### Safety and the environment

There are several hazards attached to the installation of hot mix asphalt. These hazards are not addressed in this guideline document. The reader is referred to Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous products*. In addition there are also some HSE aspects that need to be addressed when installing ARIs.

At the paving site tally-clerks, screed operators, rake men, laboratory staff taking samples and haul truck assistants are all exposed to the hazards of passing traffic and moving plant.

Proper induction of new employees into the company's safety programmes, as well as ongoing training in the safe handling of materials and proper operation of plant and equipment, is therefore essential. Manuals and courses have been developed by Sabita that will assist in minimising exposure to the risks associated with the handling of bituminous products, as well as first level treatment of injuries and the prevention and fighting of fires. In addition to this, the manuals and installation guidelines of the ARI manufacturers with regard to HSE should be adhered to.

The Occupational Health and Safety Act of South Africa (Act No. 85 of 1993) centres on the health and safety aspects of employees in the workplace, and of those likely to be affected by their activities. In terms of this Act the employer and employee have distinct responsibilities and duties to ensure health and safety in the working environment:

- Employers shall provide and maintain, as far as is reasonably practicable, a working environment that is safe and without risk to the health and safety of employees;
- Employers must ensure that employees are fully conversant with hazards in their workplace, and precautionary measures to minimise or eliminate these hazards must be in place;
- The Chief Executive Officer is the official with overall responsibility and accountability for health and safety;
- Employees shall adhere to health and safety regulations and take reasonable care for the health and safety of themselves and of other persons affected by their activities.

It is therefore essential that employers and employees be conversant with the regulations promulgated in terms of the Act and that they are understood and followed by each person involved in the project.

The Sabita Contract Safety File will assist in the compilation of statutory procedures as stipulated in the Act and the South African Construction Regulations promulgated in terms of the Act in 2003. Guidance provided covers the development of an occupational health and safety policy, the principles governing company commitment to the health and safety of its employees, general duties of staff at work and the appointment and functions of those staff members with responsibility for implementing the company's health and safety plan.

Examples of HSE issues in ARI installation include:

- The manufacturers of ARI shall supply the contractor with details on the flammability (if any) of their products in the event of them being milled for use in recycled asphalt pavement construction (RAP). Most generic ARIs contain no volatiles and are thus not susceptible to ignition in the mixing drum.

- Glass fibre grids may cause skin irritation and workers must wear personal protective equipment (PPE) during handling and placement
- The handling and installation of steel mesh ARI requires extra precaution due to the weight of the rolls (>120kg) and harshness of the steel mesh. Also, personnel using power actuated fixing tools should be adequately trained in the use thereof. The use PPE is thus compulsory.
- ARIs contain no harmful chemicals.
- Good housekeeping practices for the storage and handling of ARI rolls is recommended in terms of HSE issues.

## 7.6 References

***COLTO Standard Specifications for Road and Bridge Works for State Road Authorities***, 1998

***TMH9 – Pavement Management Systems: Standard Visual Assessment Manual for Flexible Pavements***, South African Department of Transport, 1992

Refer to Product Manufacturers Specifications and Guidelines

## **8. QUALITY CONTROL and MATERIAL TESTING**

### **8.1 Introduction**

Quality assurance on construction sites is an integral part of ensuring that the design performance goals are achieved in practice. The section provides guidelines on quality assurance and material testing for site supervisory staff which if implemented will contribute towards the good performance of the ARI.

### **8.2 Manufacturing Process**

Paving fabrics, paving grids, composite paving grids or steel mesh (or Asphalt Reinforcement Interlayers), shall be manufactured according to the material specifications as described in Chapter 6. The following actions relate to the manufacturing process:

- The manufacturer of ARI should be subscribed to and be certified to the ISO 9001-2000 quality management process.
- Manufacturer's Quality Assurance certification shall be made available on request from the Engineer.
- The width and length of the rolls shall comply with the manufacturer's specification.
- ARI shall be supplied in securely wrapped or strapped rolls for easier handling and transporting.
- Each roll is to be clearly marked for identification purposes indicating:
  - source,
  - product name,
  - product grade,
  - roll length,
  - roll width,
  - roll number, and
  - manufacturing date.
- The manufacturer is responsible for establishing and maintaining a quality control programme to assure compliance with the requirements of the specification.

### **8.3 Delivery to Site**

It is important that the product delivered to the construction be checked before being accepted. The following items should form part of the check list:

- Ensure that the rolls delivered to site are undamaged, as rolls may incur damage during transportation.
- If rolls have incurred excessive damage, the manufacturer's quality manager must be notified to initiate action.

- The manufacturer's offloading instructions for the rolls shall be strictly adhered to.
- Ensure that rolls are of the correct width and length
- Ensure that the correct amount has been delivered according to the packaging label.
- Product installation guidelines shall be delivered to site and the manufacturer's representative shall be available for installation training and guidance during the installation of at least the first roll.
- To facilitate installation, rolls should be off-loaded at intervals commensurate with the length and width of the ARI rolls.
- Ensure that the correct installation equipment and tools are delivered to site.

## 8.4 Sampling



Figure 8-1: Cored sample showing effectiveness of ARI

It is recommended that if possible, the material delivered to site be sampled and tested to verify conformance with the specification. Sampling should be done in accordance with the most current ASTM Standard D 4354, using the section titled, "Procedure for Sampling for Purchaser's Specification Conformance Testing."

In the absence of purchaser's testing, verification may be based on manufacturer's certifications as a result of testing by the manufacturer of quality assurance samples obtained using the procedure for Sampling for Manufacturer's Quality Assurance (MQA) Testing. A lot

size shall be considered to be the shipment quantity of the given product, or a truckload of the given product, whichever is smaller.

## 8.5 Number of Tests and Retests

Testing shall be performed in accordance with the methods referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method. ARI product acceptance shall be based on ASTM D 4759.

Product acceptance is determined by comparing the average test results of all specimens within a given sample to the specification MARV. Refer to ASTM D 4759 for more details regarding acceptance procedures.

### **ASTM, EN and SANS Standards:**

- ASTM D 123 Standard Terminology Relating to Textiles
- ASTM D 276 Test Methods for Identification of Fibres in Textiles
- ASTM D 4354 Practice for Sampling of Geosynthetics for Testing
- ASTM D 4439 Terminology for Geosynthetics
- ASTM D 4595 Tensile and Elongation
- ASTM D 4751 Test Method for Determining the Specification Conformance of Geosynthetics

- ASTM D 4759 Practice for Determining the Specification Conformance of Geosynthetics
- ASTM D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
- ASTM D 4873, Guide for Identification, Storage, and Handling of Geotextiles
- ASTM D 5035 Test Method for Breaking Force and Elongation of Textile Fabrics
- ASTM D 5261 Test Method for Measuring Mass per Unit Area of Geotextiles
- ASTM D 6140 Test Method for Determining the Asphalt Retention of Paving Fabrics
- EN 1031 Wide Width Tensile Test
- EN 10223-3 Wire Tensile Strength and Elongation
- EN 13433 Puncture Resistance (DART)
- G.R.I.G.G 1-87 Tensile Strength (Strands)
- SANS 675 Table 3, Metallic Wire Coatings
- SANS 1580 Woven Steel Mesh Gabions
- SANS 10221 Code of Practice, Testing of Geotextiles, 2007

## 8.6 Inspection

The contract or purchase order should specify that the supplier shall be responsible for the performance of all inspection requirements.

Except as otherwise specified, the supplier should use their own facilities or any commercial laboratory acceptable to the purchaser for analysis of material. The purchaser should however reserve the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

## 8.7 Rejection and Resubmission

The ARI should be subject to rejection if it fails to conform to any of the requirements of this specification. Rejection should promptly be reported to the producer or supplier quality manager and follow up in writing. In case of dissatisfaction with the results of the test, the producer or supplier may normally make claim for a resubmission.

## 8.8 Certification

The contractor should provide the engineer with a certificate stating:

- the name of the manufacturer,
- product name,
- ARI type,
- composition of the ARI (polymer or steel) and filaments or yarns, and
- other pertinent information to fully describe the ARI.

For paving fabrics or composite paving grids the manufacturer's certificate should state the bitumen retention rate  $f$  based on the results from ASTM D6140. Recommended asphalt application rates for construction should be obtained from the ARI manufacturer or supplier.

The manufacturer's certificate shall state that the furnished ARI meets MARV requirements of the specification as evaluated under the manufacturer's quality control programme. A person having legal authority to bind the manufacturer shall attest to the certificate.

Either mislabelling or misrepresentation of materials shall be reason to reject those ARI products.

## **8.9 Installation**

Ensure that ARI is installed strictly in line with the manufacturer's recommendations.

Cores may be drilled through an overlay reinforced with an interlayer. The adhesion of the ARI to the existing surface and to the overlay determines whether an intact core is recovered or not.

## **8.10 References**

***Geosynthetics In Flexible And Rigid Pavement Overlay Systems To Reduce Reflection Cracking***, Report No. FHWA/TX-02/1777-1, Gregory S. Cleveland, Joe W. Button, And Robert L. Lytton, October 2002

***Draft Standard Specification for Inorganic Paving Mat for Highway Applications***, ASTM Subcommittee D35.03. This Document is not an ASTM Standard; it is under consideration within an ASTM Technical Committee but has not received all approvals required to become an ASTM Standard. ASTM Copyright. All rights reserved.

# **APPENDIX A - Selection of Reinforcement Product**

## **A.1 General Considerations**

### **A.1.1 Overlay Stress Absorption**

Asphalt Reinforcement Interlayers can dampen stress, relieve strain, and provide tensile reinforcement to the asphalt. Asphalt Reinforcement must provide increased tensile strength at a very low deformation. It must be stiffer than the material to be reinforced. The geometric configuration of an interlayer will greatly affect its reinforcement capability. The cross-sectional area must be sufficient so that it will redirect tensile stresses. The width of the product must exceed the limits of the redirected stress energy. The steeper the stress-strain curves for Asphalt Reinforcement the better.

### **A.1.2 Overlay Thickness**

The minimum recommended thickness of asphalt overlay for each type of ARI must be complied with to optimise performance.

### **A.1.3 Compatibility/Bond with Asphalt**

The opening (windows) in the mesh or grid structure must be such that optimum shear adhesion is achieved while promoting aggregate interlock and confinement. The polymer coating of the woven and warp knit grids must have high asphalt compatibility and provide protection against a wide range of chemical attack. Each fibre must be completely coated to ensure no slippage within the composite asphalt.

Asphalt gains its compressive strength through compaction. The mix aggregate is specifically selected to provide interlock and confinement within the load bearing stone structure, and bitumen is the glue that holds the particles together. The particles strike through or become embedded within the grid structure, thus becoming mechanically interlocked within the composite system. This confinement zone impedes particle movement which may result in better asphalt compaction. If this is achieved it could lead to greater bearing capacity, and increased load transfer with less deformation. This would reduce shoving as it keeps the asphalt particles confined.

The ARI must be compatible with the asphalt to provide a strong internal bond within the composite. It must be thermally stable and physically durable to withstand the rigors of the paving operation. Best performance and adhesion is achieved on a smooth, asphaltic levelling course surface.

Practical application of any reinforcement requires the ability to adapt to any paving operation. Placement must be quick and easy, and the product must remain secure during paving.

### **A.1.4 Durability and/or Corrosion**

Ideally, fibres used in the manufacture of ARIs shall not melt at temperatures below 205°C. Any threads used in the joining of ARIs by sewing or knitting shall consist of long chain synthetic polymers, and shall also be heat stable to temperatures of 205°C. They shall be formed into a stable network such that the filaments or yarns retain their dimensional stability relative to each other, including selvages (ASTM Draft Specification referenced below).

The polymer coating on the woven and warp knit grids and the nonwoven component of the composite grids must provide protection from physical abrasion and be resistant to biological attack, UV light, and weather. For long-term performance, an ARI must exhibit very little or no creep deformation or chemical breakdown over time.

### **A.1.5 Milling and Recycling**

Where recycling will be an option in the future life of the pavement then the ARI with the best recycling ability should be selected otherwise for straight milling the best fit-for-purpose ARI should be selected.

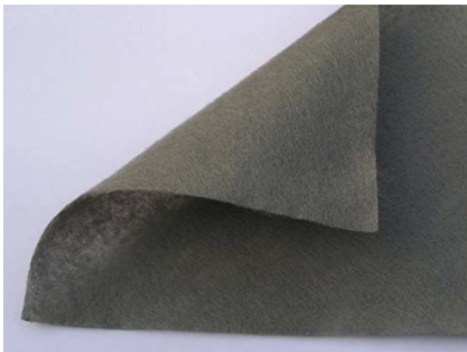
### **A.1.6 Boundary Operating Conditions/Limitations/Constraints**

Most ARIs in some form or another will have certain boundary operating conditions and limitations peculiar to their structure and make-up and careful consideration should be given to the manufacturer's recommendations. Experience has shown that the existing pavement section must show no signs of pumping, excessive movement, or structural instability. To maximise the benefits of specialist, high strength ARIs, pavements must be structurally sound. If a pavement is structurally unstable, the Engineer should design to first address the structural problem, then the reflective cracking problem.

Field evaluation should include a visual distress survey in accordance with accepted methodology and deflection testing, such as a falling weight deflectometer (FWD). This data should be used to determine the effective modulus of the existing pavement section.

Three main types of ARI with variations thereof are covered in this guideline, namely, paving fabrics, paving grids (steel, glass fibre and polymeric) and composites thereof. They are described according to the abovementioned general considerations highlighting their benefits.

## **A.2 Paving Fabrics**



They generally comprise nonwoven continuous filament polyester or polypropylene geotextiles that are bonded mechanically (needle punching or stitching) or thermally.

### **A.2.1 Overlay Stress Absorption**

Paving fabrics act as stress absorbing interlayers and prolong fatigue life of the overlay when the structural layers are weak and susceptible to rutting or shrinkage cracking. Surfacing lifetime can be prolonged by a factor of 2.

Paving fabrics prevent the ingress of water into the pavement layers by providing a more flexible, homogeneous waterproof layer, thereby stabilising pavement moisture content and curbing pumping through block cracks.

Paving fabrics bridge shrinkage cracks retarding their propagation up through the surfacing and allow larger deflections of the order of 2–3 mm to take place.

The required overlay thickness is reduced by the passage of cracks being retarded through the asphalt layer by the paving fabric.

The paving fabric system gives additional overlay performance equivalent to increased overlay thickness of 20 to 40% with an average performance equivalence of approximately 32% (GMA, 1997).

Improved dynamic cycle life factors of 3 to 5 have been reported with paving fabrics.

### **A.2.2 Overlay Thickness**

Depending on the traffic volumes the thickness of overlay can be as little as 25 mm, but generally at least 35 mm is the norm. Success has been achieved beneath ultra-thin friction courses of 15 mm but this would be dominated by the waterproofing benefit more than the stress relieving aspect due to the thinness of the overlay.

### **A.2.3 Compatibility/Bond with Asphalt**

Paving fabrics are resistance to shrinkage due to the hot asphalt, particularly for a paving fabric which is manufactured from polyester, which has a heat resistance of 210°C, compared to polypropylene, which is sensitive to temperatures in excess of 145°C.

The nonwoven texture of paving fabrics provides interlock adhesion as well as being conformable to irregular surfaces (e.g. milled surfaces).

Paving fabrics have robustness and can withstand rough installation conditions (can be trafficked after installation).

### **A.2.4 Durability and/or Corrosion**

Paving fabrics manufactured from polyester or polypropylene are non-corrodible and so are not affected by spillage oil or fuel. They are resistant to most chemicals.

### **A.2.5 Milling and Recycling**

A few problems have been reported when recycling pavements containing a geosynthetic interlayer. Hot milling and, particularly, heater scarification can cause problems when a geosynthetic is present; however, cold milling does not usually present problems. The cold pavement holds the geosynthetic while the milling machine tears it out in small pieces. Thick fabrics may interfere with any milling process. A typical 150 g/m<sup>2</sup> polymeric fabric milled with HMA does not normally have a significant effect on mixture properties, construction operations, or mix plant stack opacity.

Polyester paving fabrics with a melting point of >200°C are less susceptible to hot milling than the polypropylene paving fabrics with melting temperatures of <160°C.

Chisel teeth are preferred over conical teeth because smaller pieces of paving fabric are generated permitting easier recycling and re-introduction into the new mix design. Milling speeds of 3-6 metres per minute are preferred rather than faster speeds. Paving fabric pieces of between 20 mm width and 40 mm length can be achieved using the preferred method.

It has been reported that recycling can be achieved into asphalt mix designs containing up to 0.5% paving fabric pieces by weight.

### **A.2.6 Boundary Operating Conditions/Limitations/Constraints**

De-lamination of the paving fabric from the asphalt could occur if:

- Water is present in the base.
- Insufficient tack coat and/or saturation of paving fabric leaving areas of the paving fabric porous thus allowing water ingress into the pavement layers.
- The paving fabric is laid in the rain or wet conditions.
- Fuel leakage or contamination occurs between applications of paving fabric and the overlay.

Mechanical failure of the paving fabric could occur if:

- The vertical crack movement is excessive and tears the paving fabric.
- There is insufficient or no overlap between full width applications.
- It is laid at intersections where braking is excessive causing extreme shear stresses to be imposed on the interlayer intensifying the risk of tearing thereof.
- Potholes are not repaired or cracks larger than 7 mm are not pre-filled prior to the paving fabric placement.

Shoving or heaving could occur:

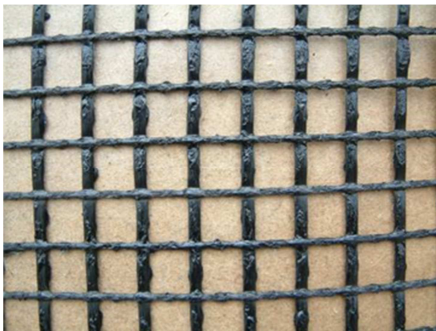
- At intersections or on sharp bends.
- Due to slippage on a smooth surface.

Bleeding of binder through the asphalt could occur if:

- Too much binder has been applied on the paving fabric.
- Cutback or winter grade bitumen is used and the volatiles are not allowed to escape before applying the overlay. If the climate conditions require a cutter to be added to the bitumen for the overlay, it is preferable that the tack coat placed prior to placement of the paving fabric is not cut back. The reason for minimising the use of the cutter is that it otherwise gets locked in the paving fabric structure and the volatiles try to escape/evaporate during hot weather, softening the bitumen. This results in bleeding through and/or slippage of thin overlays on the paving fabric.

Manufacturer's installation guidelines should be strictly adhered to.

## **A.3 Paving Grids**



These comprise:

- Coated, multi-filament woven or warp knit glass fibre grids.
- Coated, multi-filament woven or warp knit polyester grids.
- Double twist steel wire mesh manufactured from galvanised steel and transversely reinforced at regular intervals with steel wires.

### **A.3.1 Glass Fibre Paving Grids**

The glass fibre grids are composed of high modulus fibre glass strands connected together by a special weaving or warp knitting process to form an open mesh structure. These grids are coated with a modified polymer and generally are supplied with a pressure sensitive adhesive backing.

#### **A.3.1.1 Overlay stress absorption**

High modulus fibre glass exhibits a tremendous strength to weight ratio and is kilogram for kilogram stronger than steel. With a modulus ratio up to 20:1 over asphalt (20°C), glass fibre grids provide

the stiffness required to redirect crack energy. The stress-strain diagram for glass is virtually a straight line of nearly vertical slope. This indicates that the material is very stiff and resists deformation.

These grids are manufactured to strengths ranging from 50 x 50 to 200 x 100 kN/m. Glass fibre grids should exhibit less than 5% elongation at break. Polymeric Asphalt Reinforcement although initially stable, exhibits creep deformation due to constant loading over long periods of time. Fibre glass reinforcement exhibits no creep thus assuring long term performance under constant, high strain conditions.

#### **A.3.1.2 Overlay thickness**

Glass fibre grids usually require a minimum overlay thickness of 40mm. Under strictly controlled conditions success may be achieved with overlay thicknesses of 25 mm where traffic volumes and loadings are light and the section is straight and relatively flat.

#### **A.3.1.3 Compatibility/bond with asphalt**

The melting point of fibre glass is 1000°C. This insures stability when subjected to the excessive heat of a paving operation. The polymer modified bitumen coating of the glass fibre strands has good compatibility with the bitumen tack coat and the asphalt and enhances adhesion within the composite asphalt overlay.

The grid structure is protected from physical abrasion by the coating.

#### **A.3.1.4 Durability and/or corrosion**

Glass fibre paving grids are non-corrodible and are resistant to spillage of oil and fuel, biological attack, UV light, and weather.

#### **A.3.1.5 Milling and recycling**

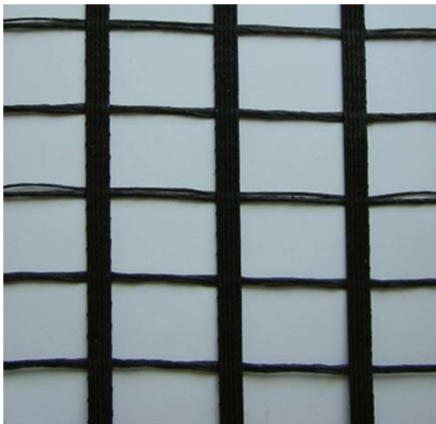
The milling process will break the glass fibre into short strands that can be easily mixed into the new asphalt design in the recycling process.

#### **A.3.1.6 Boundary operating conditions/limitations/constraints**

Glass fibre paving grids with an adhesive backing cannot be applied to a wet surface (water or bitumen). The surface must be dry. The tack coat applied prior to placement must be cured. Glass fibre is a skin irritant so the workers installing the grid must wear gloves.

Laid glass fibre grid should be paved over on the same day to avoid traffic abrading the exposed grid. Glass fibre is sensitive to mechanical abrasion when exposed. Manufacturer's installation guidelines should be strictly adhered to.

### **A.3.2 Polyester Paving Grids**



Usually these grids are a flexible reinforcement made of high modulus polyester filaments which are connected to each other by a special weaving or warp knitting process so that an open mesh structure results. These grids are coated with a bituminous material that is compatible with asphalt.

#### **A.3.2.1 Overlay stress absorption**

Polyester paving grids increase the tensile strength of the asphalt layer and they take up a significant proportion of the horizontal tensile stresses within the asphalt overlay to

ensure a uniform distribution of these stresses over a larger area. This reduces tensile stress peaks and the associated risks of pavement overloading. This load-distribution effect also reduces the formation of ruts in areas of high traffic loading.

The grid reinforced asphalt layer can tolerate higher dynamic loads and resist fatigue more effectively. Polymeric Asphalt Reinforcement although initially stable, exhibits creep deformation due to constant loading over long periods of time. In terms of creep, polyester grids show a reduction in ultimate tensile strength (UTS) of up to 40 %. The polyester grids range between bi-axial strengths of 30 x 30 and 100 x 100 kN/m at between 10 and 14 % strain at break and thus mobilise less strength at very low strains than glass or steel.

#### **A.3.2.2 Overlay thickness**

Generally these grids are used to reinforce asphalt layers at least 50 mm thick with a paver installation. In manual installation the asphalt layer can be reduced to 40 mm thick.

#### **A.3.2.3 Compatibility/bond with asphalt**

The polymer modified bitumen coating must have good compatibility with the bitumen tack coat and the asphalt. The coating of each fibre must ensure no slippage within the composite asphalt overlay. Protection from abrasion is also afforded by the coating.

Polyester grids have a heat resistance of up to 210oC.

#### **A.3.2.4 Durability and/or corrosion**

Paving fabrics manufactured from polyester are non-corrodible and so are not affected by spillage oil or fuel. They are resistant to most chemicals.

#### **A.3.2.5 Milling and recycling**

Polyester grids can be milled and recycled because in confinement between asphalt layers the highly mechanical, abrasive action of the chisel teeth snap the strands into relatively short lengths enabling their use in base re-construction. Their high heat resistance of 210°C allows hot milling and recycling.

#### **A.3.2.6 Boundary operating conditions/limitations/constraints**

The bitumen tack coat must be applied to a clean, dry substructure.

Polyester is the least resistant polymer to creep but compared to glass and steel allowance should be made for a creep reduction factor to be applied to the Ultimate tensile strength of the polyester grid.

Manufacturer's installation guidelines should be strictly adhered to.

### **A.3.3 Steel mesh**



Usually a double twist steel wire mesh manufactured from heavily galvanised steel and transversely reinforced at regular intervals with steel rods.

#### **A.3.3.1 Overlay stress absorption**

The double twist steel mesh absorbs crack discontinuities or carries the stress at the crack tip without de-lamination of the adjacent pavement layers and with some reduction in the load

transfer between the layers, which inadvertently improves the fatigue life of the overlying layer.

#### **A.3.3.2 Overlay thickness**

The absolute minimum overlay thickness is 50mm. The recommended overlay thickness without supervision is 60mm.

#### **A.3.3.3 Compatibility/bond with asphalt**

The 3D mesh open structure achieves interlock with the asphalt aggregate matrix, resulting in high shear resistance at the interface of the reinforcement and the asphalt. The interlock improves the load transfer to the reinforcement. The open mesh structure of the mesh allows each wire strand to integrate itself into the surrounding asphalt, and therefore effectively act as a piece of continuous aggregate with the stone matrix, which constitutes approximately 40% of the composition in a continuously graded asphalt mix.

#### **A.3.3.4 Durability and/or corrosion**

The steel mesh when installed becomes coated by bitumen, as would be the case for a piece of aggregate thus inhibiting corrosion. Experience has shown that no additional bitumen is required for the asphalt, since the bitumen coated surface area of the asphalt displaced by the steel mesh is higher than the coated surface area of the steel mesh. Once the crack propagates, the salts or chemicals may penetrate into the crack, and affect only the localised contact with the mesh, if the bitumen coating becomes compromised. This in no way compromises the performance of the mesh, since the nature of the double twisted mesh is such that should one of the strands be compromised, then the load will be transferred to adjacent strands. This can be seen by cutting a strand of wire and trying to pull the mesh apart. The mesh does not unravel.

#### **A.3.3.5 Milling and recycling**

If the wearing course needs to be milled at the end of a maintenance design period, then the thickness of the overlay should be increased accordingly, at the design stage, to allow sufficient cover over the mesh to prevent the mesh from being affected during the milling process. However, the mesh can be milled with some minor effort and requires manual intervention at regular stretches to remove rolled mesh from cutting teeth.

#### **A.3.3.6 Boundary operating conditions/limitations/constraints**

Installation is achieved with the nailing down. Once the mesh is unrolled and the inherent curvature is removed with the aid of a rubber tyred roller fixing follows. The first 4m of each roll is securely fastened to the existing road surface with nail or screw anchors installed 1/ m2. Thereafter the steel mesh is taut and secured to maintain good contact with the road pavement surface. Clips with nail or screw anchors are determined by the condition of the existing road surface. Fixing must take place in the direction of the paver. Allow for 150mm overlap between adjacent mesh rolls.

No recycling capability.

Manufacturer's installation guidelines should be strictly adhered to.

### **A.4 Composite Paving Grids**

As opposed to the paving grid on its own these composites combine the positive effects of a nonwoven paving fabric and the high strength, high modulus, low creep of paving grids.

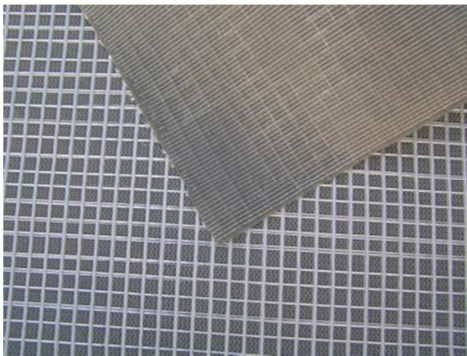
The reinforcing effect of the high strength, low strain component in combination with the sealing, stress relieving and uniform adhesive bonding properties of the nonwoven paving fabric fleece leads to a dramatic reduction of reflective cracking. These composite paving grids should be used when

exceptionally high stresses could occur, caused by temperature or high daily traffic volumes and where the ingress of water cannot be tolerated.

The physical potential of high modulus grid material affects longevity and performance.

Asphalt beams reinforced with a composite of glass fibre grid and a nonwoven paving fabric indicate a greater life expectancy of about 7 to 8 times than that of a unreinforced asphalt; about 2.5 times that for a paving fabric reinforced asphalt; and about 2 times than for a polyester geogrids (ref Jaecklin).

Longevity in terms of load cycle capacity shows that, although polyester grids significantly increase load cycle capacity, the glass fibre grid composite may start deforming similarly to polymers, yet many more cycles are acceptable without significant additional cracking much like the behaviour of steel reinforcing.



#### **A.4.1 Stitched or Warp Knitted Paving Grids**

These include the following fabrics:

- Woven roving glass fibre (either warp (machine),
- weft (cross) or bi-axial oriented) stitch bonded (polyester yarn) to a needle punched nonwoven paving fabric (polyester or polypropylene) or
- a warp knit glass or polymer fibre grid type

structure attached to a fleece (nonwoven paving fabric) insertion.

##### **A.4.1.1 Overlay stress absorption**

The glass fibre filaments have a very high tensile modulus enabling them to mobilise significant strength at low strain. These composites are suitable to absorb sustained loading such as that caused by soil swelling tension stresses, or by temperature induced joint movements.

High modulus glass fibre exhibits a tremendous strength to weight ratio and is kilogram for kilogram stronger than steel. With a modulus ratio up to 20:1 over asphalt (20° C), glass fibre grids provide the stiffness required to redirect crack energy. The deformation modulus of the glass fibre grid component is about ten times higher than polymer geogrids, thereby absorbing more of the stresses that would otherwise affect asphalt. This reduces stress peaks and asphalt deformations, which in turn reduces crack potential. The stress-strain curve for glass is virtually a straight line of a near vertical slope. This indicates that the material is very stiff and resists deformation exhibiting less than 5 % elongation at break. Glass fibre exhibits no creep. This assures long-term performance under constant, high strain conditions.

##### **A.4.1.2 Overlay thickness**

These composites are used to reinforce asphalt overlays with a minimum thickness of 40mm but success has been achieved with overlay thicknesses of 25 mm where traffic volumes and loadings are light and the section is straight and relatively flat. Tack coats are required for composite fabrics for the purposes of adhesion to the prepared surface.

##### **A.4.1.3 Compatibility/bond with asphalt**

No pre-dressing and tensioning prior to mechanical paving is required. Once impregnated with bitumen, the fabric bonds to the prepared surface ready for machine or manual paving. This

impregnation also provides the additional benefit of acting as a moisture-proofing barrier during service life.

The nonwoven fleece must have good compatibility with the bitumen tack coat and the asphalt. The coating of each fibre must insure no slippage within the composite asphalt overlay. Stability of the Asphalt Reinforcement must be ensured when subjected to the excessive heat of a paving operation. The melting point of glass fibre is 1 000° C, polyester is 260°C and polypropylene is 165°C.

#### **A.4.1.4     *Durability and/or corrosion***

These composites are non-corrodible so will not be affected by spillage of oils and fuel. They are also thermally stable and can be safely installed within asphalt at 165°C without significant change in geometry and physical properties.

#### **A.4.1.5     *Milling and recycling***

A few problems have been reported when recycling pavements containing a geosynthetic interlayer. Hot milling and, particularly, heater scarification can cause problems when a geosynthetic is present; however, cold milling does not usually present problems. The cold pavement holds the geosynthetic while the milling machine tears it out in small pieces.

One must be cognisant of the difference in behaviour of the paving fabric component as opposed to the grid or mesh component. Polyester paving fabrics with a heat resistance of >200°C are less susceptible to hot milling than the polypropylene paving fabrics with heat resistance at temperatures <160°C.

Chisel teeth are preferred over conical teeth because smaller pieces of paving fabric are generated permitting easier recycling and re-introduction into the new mix design. Milling speeds of 3-6 metres per minute are preferred rather than faster speeds. Paving fabric pieces of between 20 mm width and 40 mm length can be achieved using the preferred method.

Recycling can be achieved into asphalt mix designs containing up to 0.5% paving fabric pieces by weight. The milling process will break the glass fibre component into short strands that can be easily mixed into the new asphalt design in the recycling process but the paving fabric component will determine the recycling mix design as mentioned above.

#### **A.4.1.6     *Boundary operating conditions/limitations/constraints***

The bonding of the composite to the road surface is critical to the performance of these types of reinforcing interlayers.

De-lamination could occur if:

- Water is present in the base due to the absence of sub-soil drainage.
- Insufficient tack coat and/or incomplete saturation of the paving fabric component thus allowing water ingress.
- The composite paving grid is laid in the rain or wet conditions.
- Fuel leakage or contamination occurs between applications of the composite paving grid and the overlay.

Shoving or heaving could occur:

- At intersections or on sharp bends.

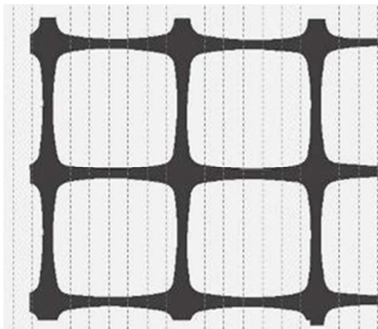
- Due to slippage on an old, rich surface.

Bleeding could occur if:

- Too much binder has been applied as a tack or saturation coat.
- Cutback or winter grade bitumen is used and the volatiles are not allowed to escape before applying the overlay. If the climate conditions require a cutter to be added to the bitumen for the overlay, it is preferable that the tack coat placed prior to placement of the paving fabric is not cut back. The reason for minimising the use of the cutter is that it otherwise gets locked in the paving fabric structure and the volatiles try to escape/evaporate during hot weather, softening the bitumen. This results in bleeding through and/or slippage of the wearing course on the paving fabric.

Manufacturer's installation guidelines should be strictly adhered to.

#### **A.4.2 Bonded Paving Grids**



Nonwoven stitch bonded or nonwoven paving fabric (polyester and/or polypropylene) heat bonded to a stiff, rigid, bi-axial oriented polypropylene grid or a light, spunbond nonwoven fabric (polyester and/or polypropylene) attached to a polyester grid.

##### **A.4.2.1 Overlay Stress absorption**

These products are suitable for increasing the fatigue life of pavements with weak foundations, reducing rutting and controlling reflective cracking.

The polyester and polypropylene grids range between 8 and 12 % strain at break. In terms of creep, polyester grids show a reduction in ultimate tensile strength (UTS) of up to 40 %, whereas polypropylene grids are up to 80 % reduction in UTS.

##### **A.4.2.2 Overlay thickness**

The stiff, rigid, bi-axial orientated composite grids are used to reinforce asphalt overlays with a minimum thickness of 70 mm. The thinner polyester composite grids may be used in overlays of 50 mm thickness.

##### **A.4.2.3 Compatibility/bond with asphalt**

No pre-dressing and tensioning prior to mechanical paving is required. Once impregnated with bitumen, the fabric bonds to the prepared surface ready for machine or manual paving. This impregnation also provides the additional benefit of acting as a moisture-proofing barrier during service life.

These composites are reported to increase the fatigue life of pavements with weak foundations by up to a factor of ten, reduce rutting by up to 70% and reduce reflective cracking in overlays. Real cost benefits by lengthening the maintenance cycle are provided or increased pavement life by a factor of 3. Asphalt overlay thickness may be reduced by up to 35% compared to un-reinforced overlays.

#### **A.4.2.4     *Compatibility/bond with asphalt***

These composites are non-corrodible so will not be affected by spillage of oils and fuel. They are also thermally stable and can be safely installed within asphalt at 165°C without significant change in geometry and physical properties.

#### **A.4.2.5     *Milling and recycling***

Milling techniques would have to vary for these two different types of composite paving grid. Strong plastic grids may interfere with any milling process. The stiff, rigid composite grid would require aggressive milling techniques using sophisticated equipment because the strands of the extruded polymer constituting the grid are relatively thick and hard compared to other paving grid types. The attached nonwoven would mill the same way as indicated under the previously mentioned paving fabrics section.

Recycling of this composite paving grid is unlikely and contamination of the mix will be too high. Polyester grids can be milled and recycled. Their heat resistance of up to 210°C allows hot milling and recycling. The light, nonwoven attached to the grid to facilitate bonding to the pavement with a bitumen tack coat will be broken up into small pieces in the milling process but the maximum allowable content of fabric and grid fragments will be determined by the mix design.

#### **A.4.2.6     *Boundary operating conditions/limitations/constraints***

The bonding of the composite to the road surface is critical to the performance of these types of reinforcing interlayers.

De-lamination could occur if:

- Water is present in the base due to the absence of sub-soil drainage.
- Insufficient tack coat and/or incomplete saturation of the paving fabric component thus allowing water ingress.
- The composite paving grid is laid in the rain or wet conditions.
- Fuel leakage or contamination occurs between applications of the composite paving grid and the overlay.

Shoving or heaving could occur:

- At intersections or on sharp bends.
- Due to slippage on an old, rich surface.

Bleeding could occur if:

- Too much binder has been applied as a tack or saturation coat.
- Cutback or winter grade bitumen is used and the volatiles are not allowed to escape before applying the overlay. If the climate conditions require a cutter to be added to the bitumen for the overlay, it is preferable that the tack coat placed prior to placement of the paving fabric is not cut back. The reason for minimising the use of the cutter is that it otherwise gets locked in the paving fabric structure and the volatiles try to escape/evaporate during hot weather, softening the bitumen. This results in bleeding through and/or slippage of the wearing course on the paving fabric.

Manufacturer's installation guidelines should be strictly adhered to.