Technical Guideline:

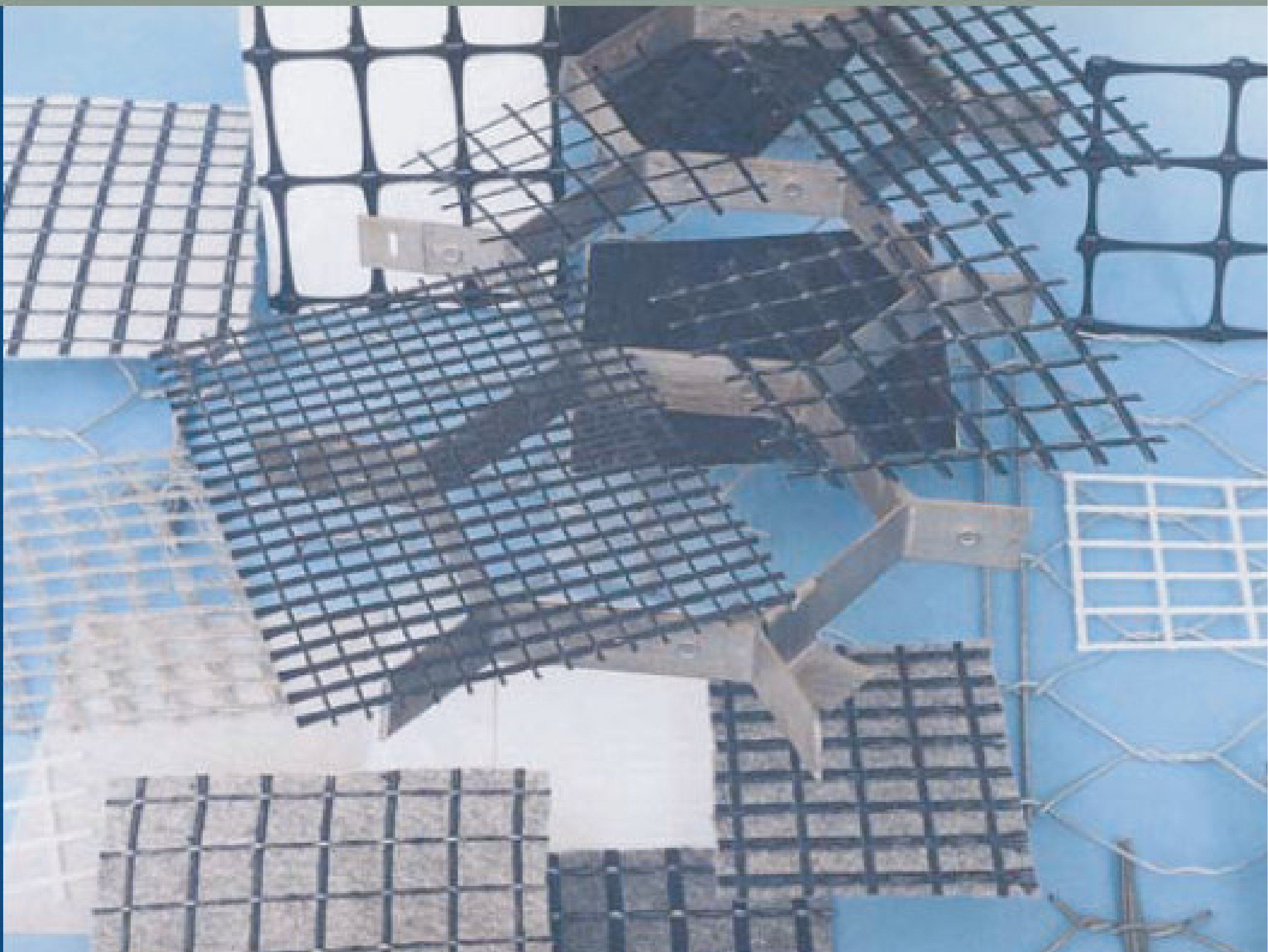
Asphalt Reinforcement for Road Construction

TG 3

First edition

November 2008

ASPHALT ACADEMY



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ABBREVIATIONS

TECHNICAL

AADT	Annual Average Daily Traffic
ARI	Asphalt Reinforcement Interlayer
CAM	Crack Activity Meters
CC-E1	Crack Sealing Cold Elastomer
CH-E1	Crack Sealing Hot Elastomer
CH-R1	Crack Sealing Hot Rubber
CTB	Cement Treated Base
DCP	Dynamic Cone Penetrometer
EN	European Norm
FWD	Falling Weight Deflectometer
HMA	Hot Mastic Asphalt
HSE	Health, Safety and Environment
HVS	Heavy Vehicle Simulator
MARV	Minimum Average Roll Value
MMLS	Mobile Load Simulator
MQA	Manufacturing Quality Assurance
PPE	Personal Protective Equipment
RQ	Riding Quality
RSD	Road Surface Deflectometer
SAMDM	SA Mechanistic Design Method
SAMI	Stress Absorbing Membrane Interface
SMA	Stone Mastic Asphalt
TMH	Technical Manual for Highways
TRH	Technical Recommendations for Highways
UTS	Ultimate Tensile Strength

ORGANIZATION

ASCE	American Society for Civil Engineers
ASTM	American Standard Test Method
COLTO	Committee of Land Transport Officials
COST	European Co-operation in the field of Scientific and Technical Research
CSIR	Council for Scientific and Industrial Research
FHWA	Federal Highways & Waterways Association (USA)
ISO	International Standards Organization
Reflex	Reinforcement of Flexible Road Structures with Steel Fabrics to Prolong Service Life
RILEM	International Union of Laboratories and Experts in Construction Materials, Systems and Structures
SABITA	South African Bitumen Association
SADC	Southern African Development Community
SANS	SA National Standards
SATCC	Southern African Transport & Communications Commission
TTI	Texas Transport Institute

Chapter 1

1. **INTRODUCTION**

2. FUNCTIONS AND BENEFITS OF ASPHALT REINFORCEMENT

3. TYPES AND SELECTION OF REINFORCEMENT PRODUCT

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5. DESIGN METHODS

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1 INTRODUCTION

1

1.1 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.

For the purpose of this study 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.

Currently there is a large amount of research being carried out in this field, but there has been very little effective dissemination of the best practice and research results in southern Africa. This has led to:

- a lack of understanding of ARI technology
- a lack of awareness of the results of research
- poor ARI technology transfer
- little or poor quality implementation of innovative ARI technology

The need for a guideline document was confirmed by the working group, in particular the need for:

- A toolbox that could assist engineers in the design and implementation of Asphalt Reinforcement.
- A best practice documented for southern African conditions.
- Guidance for new entrants into the profession.

1.2 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 TRH3 document)

However, it provides a source of comprehensive references which provide additional details and examples of local and international experience and research results.

1.3 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.

1.4 Development of Guideline

Members of the technical group consisted of representatives from the CSIR, Road Authorities, the Asphalt Industry, Producers and Engineering Consultants.

The Guideline was compiled using the accumulated knowledge and practical experience of the working group which included representatives from product manufacturers, international research organization (CSIR), road authorities, engineering consultants, asphalt industry and others who have long experience of working in the field of ARI. It was produced with inputs from key experts from European countries.

The Guideline was developed through “local” participation. As a result, it has been possible to capture and incorporate a significant amount of local knowledge in the document. The benefits of this approach include a document that:

- reflects the needs of the region
- has an emphasis on local ownership
- facilitates wider application
- improves prospects for sustainable implementation

1.5 Structure and Content

The Guideline is divided into twelve chapters as presented 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 Methods

6
Specification Of Materials

7
Surface Preparation

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Quality Assurance and Material Testing

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Database of Products

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Document Details

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Annexures

1.6 Updating

As ARI technology is continually being researched and improved, it will be necessary to update the Guideline periodically to reflect improvements in practice. The Guideline has been produced in electronic format and will be posted on the Asphalt Academy website (www.asphaltacademy.co.za)

1.7 References

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

South African Road Agency Limited, ***TRH3 - Design and Construction of Surfacing Seals***, April 2007

Chapter 2

1. INTRODUCTION

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2 FUNCTIONS AND BENEFITS OF ASPHALT REINFORCEMENT

2

2.1 Introduction

The use of reinforcement for the maintenance and rehabilitation of flexible pavements in South Africa is slowly 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.

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. However, the worldwide 'explosion' in traffic volumes, axle-loads and tyre pressures are rendering conventional pavement design methods inadequate, and reinforcement is therefore required to supplement the normal pavement structure against premature failure. It is inevitable that the use of reinforced flexible pavements in South Africa will become commonplace in the near future.

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.

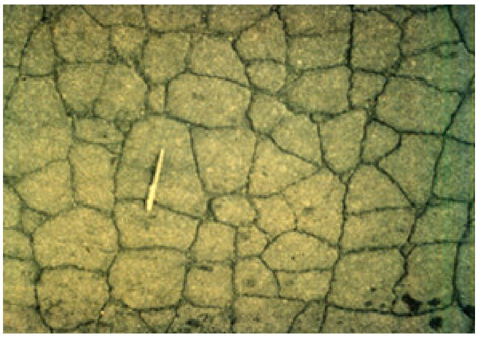


Figure 2.1: Example of asphalt pavement where reinforcement could provide a benefit

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 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.

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).

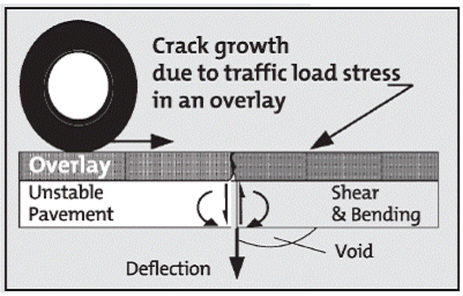


Figure 2.2: Mechanism of crack reflection

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.

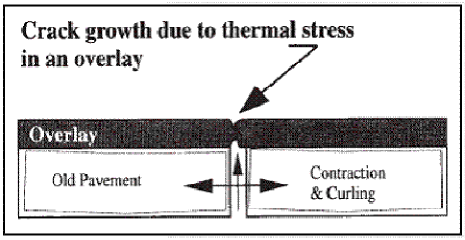


Figure 2.3: Mechanism of Thermal Induced Cracking

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.

Secondly, when an existing crack, directly below an un-cracked 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)

2.2.3 Traffic Induced Cracking

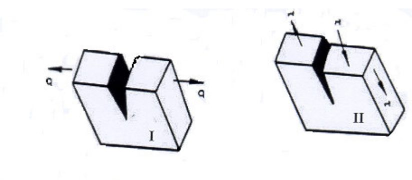


Figure 2.4: Different modes of traffic induced reflective cracking

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 the adjacent Figure 2.4.

2.2.4 Benefits of Reinforcement

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)

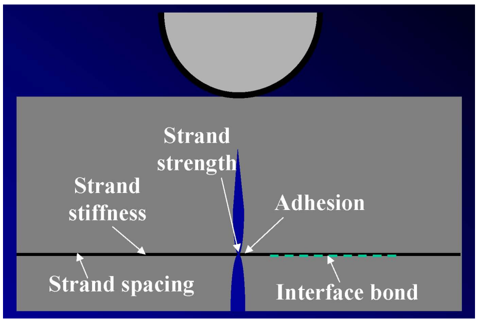


Figure 2.5: Factors affecting effectiveness of ARI

2.3 Asphalt Fatigue and Rut Resistance

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).

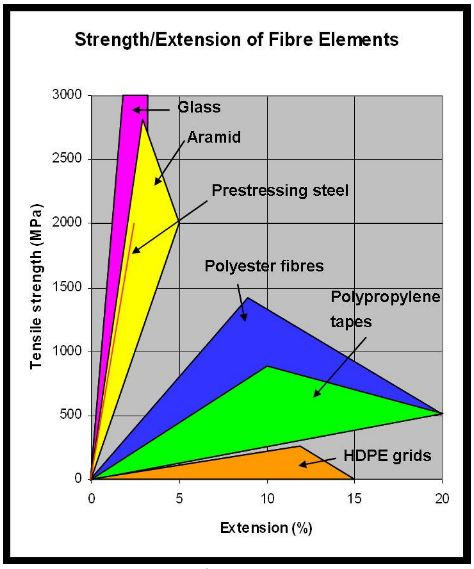
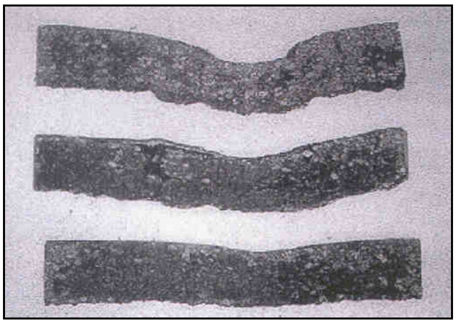


Figure 2.6: Strength Extension properties for different reinforcing materials

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 gives 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.



No reinforcement

Reinforcement at mid-depth

Reinforcement at bottom

Figure 2.7: Pavement Cross-section following 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

S.F. Brown, N.H. Thom and P.J. Sanders, ***A study of Grid Reinforced Asphalt to combat Reflection Cracking***, Association of Asphalt Paving Technologists 2001 Annual meeting, Transport Research Laboratory United Kingdom, 2001

M Elseif and I.L Al-Qadi, ***Effectiveness of Steel Reinforcing Nettings in Combatting Fatigue Cracking in New Pavement Systems***, Transport Research Board, 83rd Annual Meeting, Washington DC, January 2004

J.P.Giroud, and L. Noiray, ***Design of geotextile reinforced unpaved roads***, Proceedings from ASCE Geot.Ergrg.Div, Vol. 28, No.GT9

Maccaferri Literature Brochure on ***Asphalt Pavement Reinforced using Woven Steel Mesh***

Tensar Asphalt Brochure, ***Asphalt pavements – Reinforcing Asphalt layers in Roads and Trafficked Areas***, Tensar International, Blackburn, UK

Gregory S. Cleveland, Joe W. Button, and Robert L. Lytton***, Geosynthetics in flexible and rigid pavement overlay systems to reduce reflection cracking***, Report FHWA/TX-02/1777-1, Texas Transportation Institute, The Texas A&M University System, USA; October 2002.

Presentation on Non Standard Pavements, Dr A Collop, University of Nottingham, UK

Advanced Fiber Glass Technology for Asphalt Pavement Overlays, Technical Manual, St. Gobain Technical Textiles.

Chapter 3

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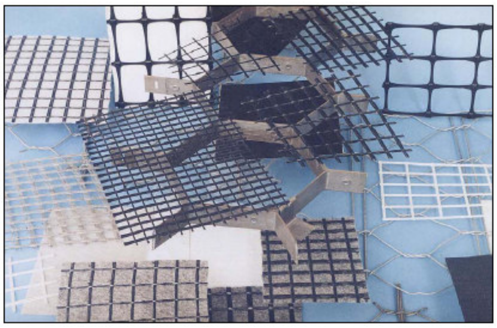
3 TYPES AND SELECTION OF REINFORCEMENT PRODUCT

3



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:

Figure 3.1: Milled surface prior to placing of ARI

- **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℃. 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 Annexure A.

3.3 References

Berwarrina, ***ALF (Accelerated Loading Facility) trial 1991 Road Traffic Authority***, Australia.

Syracuse revisited: ***Asphalt Recycling Programme eliminates concern in use of Engineering Fabrics***, Better Roads Magazine (USA), September 1981.

R.M. Koerner 1986 after Murray C.D, ***Designing with Geosynthetics***, Simulation Testing of Geotextile Membranes for Reflective Cracking. 1982.

ER Steen, ***New Road Constructions, Stress Relief of Cement Treated Base Courses***, 7th International Conference on Geosynthetics, Nice, France 2002.

RP van Zyl and JG Louw, ***Geofabric SAMI Performance to Curb Reflection Cracking in Asphalt Overlays***, 5th Conference on Asphalt Pavements for Southern Africa, Swaziland, June 1989.

Advanced Fiber Glass Technology for Asphalt Pavement Overlays, Technical Manual, St. Gobain Technical Textiles.

DJ O'Farrell, ***The Treatment of Reflective Cracking with Modified Asphalt and Reinforcement***, Reflective Cracking in Pavements, RILEM 1996.

Huesker Geosynthetic GmbH & Co. Technical Literature on ***"Roads with Cracks"***, issue 6/97 F.

Tensar Asphalt Brochure, ***Asphalt pavements – Reinforcing Asphalt layers in Roads and Trafficked Areas***, Tensar International, Blackburn, UK

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.

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*

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

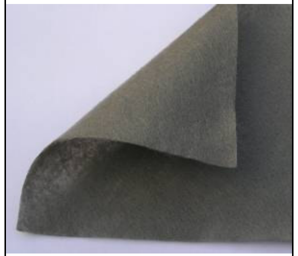
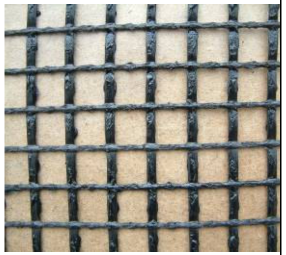
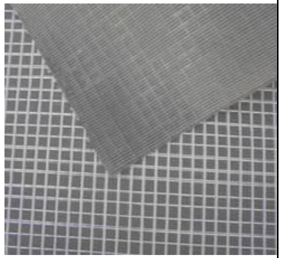
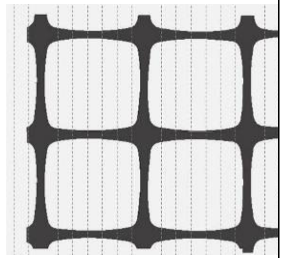
Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene [1)]	a) Glass fibre grids [2)]	b) Polyester grids [3)]	c) Steel mesh [4)]	a) Stitched or Warp knitted [5)]	b) Bonded [6)]
Photos of Typical Products						
Overlay Stress Absorption	i. Act as stress absorbing interlays ii. Prevent ingress of water into pavement layers iii. Bridge shrinkage cracks iv. Provides increased overlay performance by 20 to 40%	i. Modulus ratio of up to 20:1 over asphalt ii. High stiffness redirects crack energy iii. High stiffness resists deformation	i. Increases tensile strength of asphalt layer ii. Reduces tensile peak stress iii. Assists with asphalt fatigue iv. Reduces formation of ruts	i. Reduces peak tensile stress ii. Improves asphalt fatigue iii. Absorbs crack discontinuities iv. Good rut resistance	i. High stiffness redirects crack energy ii. Reduces peak tensile stress iii. Improves asphalt fatigue	i. Increase fatigue life of pavement with weak foundations ii. Used in above application, reduces rutting and controls reflective cracking iii. Susceptible to creep
Overlay Thickness	i. Generally 35mm but can be as little as 25mm	i. Minimum overlay thickness of 40mm ii. 25mm overlay thickness achieved under controlled conditions	i. 50mm with paver ii. 40mm manual installation	i. 50mm minimum ii. 60mm unsupervised	i. 40mm Minimum ii. 25mm used successfully in light trafficked areas with low loadings	i. Stiff bi-axial grids used in 70mm overlays ii. Thinner composite polyester grids used in 50mm overlays

Table 3.1: Summary of Issues to consider when Selecting Reinforcement Products (continued)

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene [1)]	a) Glass fibre grids [2)]	b) Polyester grids [3)]	c) Steel mesh [4)]	a) Stitched or Warp knitted [5)]	b) Bonded [6)]
Compatibility / Bond with Asphalt	i. Paving fabrics resistant to shrinkage ii. Polyesters heat resistance at 210^{O} C and perform better than polypropylenes which are sensitive at temperatures > 145^{O} C iii. Rough texture provides interlock adhesion iv. Robustness which withstands high installation damage	i. Melting point 1000^{O}C ii. Polymer modified bitumen coat of grid has good compatibility with tack coat and asphalt	i. Polyester heart resistance up to 210^{O}C ii. Good compatibility with tack coat and asphalt	i. High interlock with asphalt matrix ii. Tensioned and nailed at regular intervals to sub-structure	i. No pre-dressing or tensioning required ii. Fabric impregnated with bitumen iii. Impregnated layer provides moisture proofing iv. Non woven fleece good compatibility with tack coat and asphalt v. Check stability of reinforcement when subjected to operation heat. Glass 1000^{O}C. Polyester 260^{O}C, polypropylenes. 165^{O}C	i. No pre-dressing or tensioning required ii. Fabric impregnated with bitumen iii. Impregnated layer provides moisture proofing iv. May increase pavement life by a factor of 3
Durability and Corrosion	i. Polyesters or polypropylenes are non corrodible and resistant to most chemicals	i. Non corrodible ii. Resistant to oil and fuel spillage, biological attack, UV light, weather	i. Non corrodible ii. Resistant to oil and fuel spillage	i. Steel mesh coated by bitumen when installed ii. Heavily zinc coated (durability)	i. Non corrodible ii. Resistant to oil and fuel spillage iii. Thermally stable up to 165^{O}C	i. Non corrodible ii. Resistant to oil and fuel spillage iii. Thermally stable up to 165^{O}C

Table 3.1: Summary of Issues to consider when Selecting Reinforcement Products (continued)

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene [1)]	a) Glass fibre grids [2)]	b) Polyester grids [3)]	c) Steel mesh [4)]	a) Stitched or Warp knitted [5)]	b) Bonded [6)]
Milling and Recycling	i. Hot milling and heat scarification can cause problems ii. Cold milling does not usually present problems iii. Fabrics in excess of 150g/m^2 may interfere with milling process iv. Polyester fabrics less susceptible to hot milling v. Chisel teeth preferred over conical teeth vi. Milling speed range: 3 - 6m/min	i. Fibre broken down during milling process and easily recycled	i. Easily milled (including hot milling) by chisel teeth and recycled.	i. Increase overlay thickness to allow cover during milling operation ii. Asphalt milled off just above mesh prior to pulling out iii. No recycling capabilities	i. Cold milling does not present problems ii. Hot milling and heat scarification may cause problem where geosynthetic is present iii. Cognisance should be taken of the different behaviour of the paving fabric as opposed to the grid or mesh component iv. Chisel teeth preferred v. Milling speeds of 3 - 6m/min 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.	i. Strong plastic grids may interfere with milling operations ii. Aggressive milling required due to thick and hard extruded polymer strands. iii. Nonwovens milled as mentioned in Woven Paving Fabrics iv. Recycling unlikely as contamination of mix is high
Boundary Operating Conditions / Limitations and Constraints	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	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	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. 1st 4m securely fastened with nails or screws (1/m^2) iii. Remainder to be tensioned and fixed	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 conditions.	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

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene [1)]	a) Glass fibre grids [2)]	b) Polyester grids [3)]	c) Steel mesh [4)]	a) Stitched or Warp knitted [5)]	b) Bonded [6)]
	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.	iv. Laid glass fibre paved same day v. Sensitive to mechanical abrasion when exposed		by nailing / screws iv. Fixing in direction of paver v. Overlap by 150mm	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.	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.

Table 3.1: Summary of Issues to consider when Selecting Reinforcement Products (continued)

Issues to Consider	Paving Fabric	Paving Grids			Composite Paving Grids	
	a) Polyester or polypropylene [1)]	a) Glass fibre grids [2)]	b) Polyester grids [3)]	c) Steel mesh [4)]	a) Stitched or Warp knitted [5)]	b) Bonded [6)]
Boundary Operating Conditions / **Limitations and Constraints** (continued)	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*

Chapter 4

4 EVALUATION OF EXISTING PAVEMENT CONDITION

4

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).

Figure 4.1: Typical reflective cracking from a CTB pavement

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

Figure 4.2: Cracking adjacent to concrete pavement

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 delmination?)*
- 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.

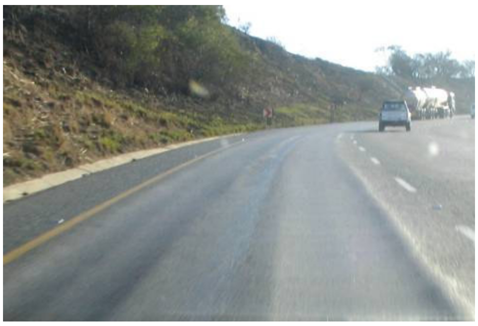


Figure 4.3: Rutting of the asphalt layer

- 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

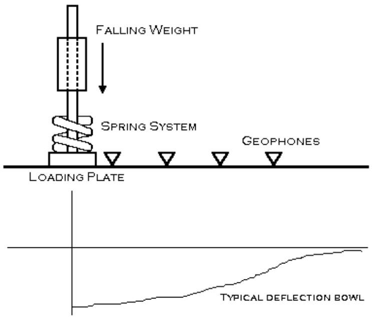


Figure 4.4: FWD Mechanism

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.

Figure 4.5: RSD

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 Treaments
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 can not 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, 6th Annual Conference on Asphalt Pavements for Southern Africa, 1994

Chapter 5

1. INTRODUCTION

2. FUNCTIONS AND BENEFITS OF ASPHALT REINFORCEMENT

3. TYPES AND SELECTION OF REINFORCEMENT PRODUCT

4. EVALUATION OF EXISTING PAVEMENT CONDITION

5. DESIGN METHODS

6. SPECIFICATION OF MATERIALS

7. PRACTICAL CONSTRUCTION ISSUES

8. QUALITY CONTROL AND MATERIAL TESTING

9. DATABASE OF PROJECTS

10. RESEARCH

11. DOCUMENT DETAILS

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5 DESIGN METHODS

5

5.1 Background

Earlier research has demonstrated that reinforcement in asphalt layers such as fabrics, grids or composites can enhance cracking and rutting resistance of the asphalt layers significantly if properly applied.

This has lead to increased use of reinforcement in asphalt layers over the past years throughout the world. The use of these reinforcement products on a large scale in South African pavements were however limited to ad hoc projects. Their use was mostly restricted to localized areas such as patches and small repair areas on projects.

The reasons for the limited use of the above-mentioned products as reinforcement in asphalt layers on South African pavements are most probably due to the following:

- The relatively high costs of the products.
- A lack of understanding the real benefits of the reinforcement.
- No detailed design procedure is currently available whereby the designer can quantify the benefits of the products and thereby justify the cost effectiveness of the reinforcement.
- The relatively thin asphalt layers constructed on the South African pavements.

The demand for the use of reinforcement in asphalt layers on South African pavements to cope with the ever increasing loading conditions will however increase in future.

The following design procedures and guidelines are proposed for use in the interim until a reliable and proven design procedure has been developed for the South African conditions.

5.2 Simplified Design Procedures

When reinforcement is considered for use in a pavement structure, the pavement design calculations should be performed as normal to check for excessive strain in the subgrade, shear stress in granular layers etc. The South African Mechanistic Design Method (SAMDM) can be used for these calculations, in conjunction with the principles provided in TRH12 and TRH4. Preliminary calculations and investigations suggest that the presence of the reinforcement does not significantly affect the manner in which stresses and strains are distributed in the pavement as a whole. This effect is due to the relatively low thickness and stiffness of reinforcement layers, which do not change the macro stress-strain patterns in the pavement, and do not appear to significantly affect the manner in which the pavement displaces under loading.

Although there are most likely some localized stress effects at the reinforcement asphalt interface, these effects cannot be modelled using routine design tools, and require specialist investigations involving Finite Element techniques. For this reason, where these specialised tools are not available it is not recommended that the reinforcement layer be explicitly included in the modelled pavement system, and design calculations should therefore be performed as normal to check the working stresses and strains in all layers.

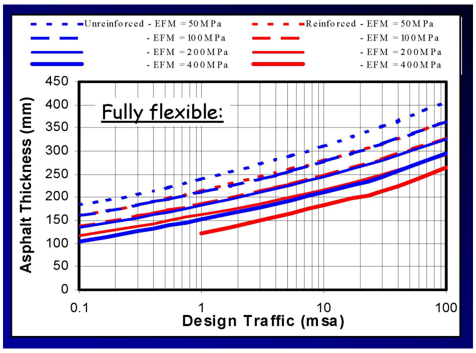

Figure 5.1: Example of Transfer Functions developed through research at Nottingham University

Since the presence of the reinforcement is believed to have a significant benefit in prolonging fatigue life and crack propagation at a given strain level, the evaluation of the asphalt fatigue life at the calculated strain level should receive special attention. If a well documented and validated transfer function exists for asphalt layers that incorporate reinforcement materials, then that transfer function can be used for evaluation of the fatigue life of the asphalt layer(s) that incorporate the reinforcement material (see Figure 5.1). Alternatively, a shift factor could be applied to the standard fatigue life calculated with traditional transfer functions for asphalt material, provided that the basis for the shift factor is clearly stated (e.g. a reference should be provided to support the basis for assuming the shift factor, and ideally relevant supporting literature should be included in an appendix).

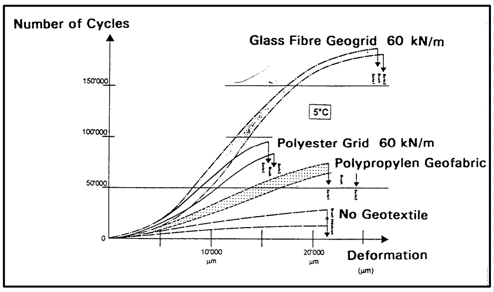

Figure 5.2: Example of Increased Fatigue Life using ARI *(ref. Jaecklin)*

An example of a shift factor is described by Dr. RM Koerner in his book “Designing with Geosynthetics” as the Fabric Effectiveness Factor (FEF).

FEF = N_r / N_n

Where

FEF = Fabric effectiveness factor
N_r = Number of load cycles to cause failure in the ARI option
N_n = Number of load cycles to cause failure in the non ARI option

Research has shown that FEF values can vary between 3 and 5. However care should be taken not to reduce asphalt overlay thickness below that required for structural capacity.

5.3 Practical Design Guidelines

The following practical design guidelines are proposed for use of reinforcement in asphalt overlays:

- **Overlay Thickness**

The asphalt overlay thickness should be determined as if the reinforcement is not present. The determined thickness of the asphalt layer can be reduced based on the contribution of the reinforcement. The reduction factor can vary significantly depending on the type of reinforcement to be used and whether it is introduced to reduce reflective cracking or enhance rutting resistance. Research in the UK and USA indicated reductions in layer thickness of up to 30% when grid reinforcement is employed provided that the thickness is not reduced below that required for structural capacity.

Alternatively the use of an ARI can lead to an increase in the design lifetime of the overlay using the same overlay thickness as would be used without an ARI.

The minimum recommended thickness of the supplier must be complied with but it is recommended that the thickness of reinforced asphalt should not be less than 50mm if grids or composites are used as reinforcement and not less than 40mm if fabric is used. If a fabric is used under an asphalt overlay to provide an impermeable membrane thinner asphalt overlays can be used. It is however recommended that the asphalt overlay thickness be not less than 25mm.

- **Overlay Type**

Only dense-graded, well compacted, low permeability asphalt mixes should be used as overlays over the reinforcement. A permeable asphalt mix over a waterproofing fabric or composite can trap and hold water. Retained water can cause rapid failure of the overlay due to stripping of the asphalt.

- **Pavement Condition**

Reinforcement should only be used over sound pavements. There should be no evidence of severe load associated distress i.e. crocodile cracking, no deep ruts as pavement failures. If failures do occur in localized areas it should be repaired before the reinforced overlay is constructed.

5.4 Selection of Design Models – COST 348

- **Overview**

COST 348 is one of the actions supported by the COST Research part of the European Commission - Research DG (See section 10.3.1). The memorandum of understanding of COST-action 348 describes the contents of Work Package 4 as follows:

The selection of design models for the structural design of roads with reinforcement products, depending on the type of damage and the loading conditions. The design procedures cover reinforcement applications for pavement coating (SAMI), pavements, base and sub-base layers and road widening.

Work Package 4 is included as Annexure B in this document for easy reference. It provides an overview of available design models and software packages that can be used for more sophisticated analysis of reinforced asphalt pavements.

- **Conclusions and Recommendations**

From the work carried out by the COST-members, it can be concluded that:

- a (small) number of methods / procedures exist for the design of pavements with steel meshes / geosynthetics in the unbound granular base layers and/or in the asphalt layers.
- no generally accepted design method / procedure is available, which is accessible for everyone; this is however also true for so-called reference pavement structures (without steel mesh / geosynthetic).
- no design method / procedure has been found yet, which is covering all types of loading, can do predictions for all cases which can occur in the field and which has been validated to the extent, which is required (with long-term field data).
- steel meshes and geosynthetics have proved to work in the long run

(based on field experience of up to roughly 15 years). Depending on the nature of the product, the effectiveness is due to different functions: separation, barrier (for water penetration), stress-relief and reinforcement.

It is recommended:

- to put more scientific effort into creating and testing user-friendly generic design tools.
- to start collecting much more long-term field data. This should then be performed in a more uniform way and detailed enough so that the data can be utilized for the validation of future (analytical) design tools.
- to build instrumented roads, in order to avoid the necessity to also build reference sections without steel mesh / geosynthetics. The latter is often not possible from the road owner's responsibility point of view.
- to bring into (daily) pavement engineering practice the design tools which have become available recently; e.g. via (COST) seminars. This will stimulate road authorities and consultants to select more often cost-effective solutions with steel meshes or geosynthetics, rather than always going for the traditional approach.

5.5 Other Design Models

Chapter 10 (Research) provides further information on research into design models for reinforced asphalt pavements.

5.6 References

De Bondt A, et al, COST Action 348 - ***Reinforcement of pavements with steel meshes and geosynthetics,*** January 2006

Presentation on Non Standard Pavements, Dr A Collop, University of Nottingham, UK

FP Jaecklin and J Scherer, ***Asphalt Reinforcing using Glass Fibre Grid "Glasphalt"***, Reflective Cracking in Pavements, RILEM 1996.

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6 SPECIFICATION OF MATERIALS

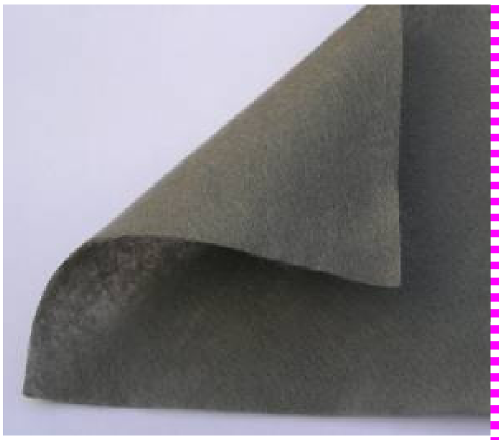
6

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

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.

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 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	^{o}C	260	ASTM D276

Bitumen:
As per specifications for conventional surfacings.

Asphalt:
As per specifications for conventional surfacings.

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.

Construction Methods / Requirements

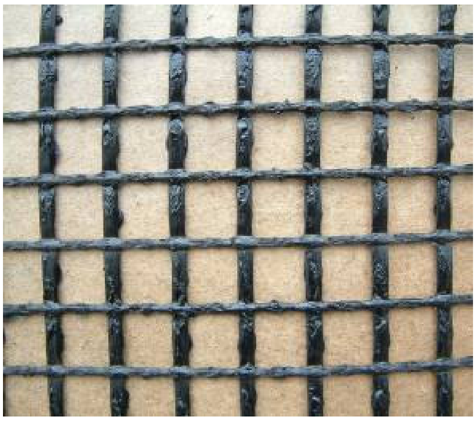
The manufacturer or their representative supplier's recommended installation procedures for crack sealing and full width sealing shall be strictly adhered to.

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^2)
Narrow paving geotextile strips	Unit:	Linear metre (m)



6.3 Paving Grids

Scope

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

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 Specification for Paving Grids

Property		Units	Type 1	Type 2	Type 3	Test Method
Mass	Nominal	g/m^2	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.	$^{\circ}C$	>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.

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.

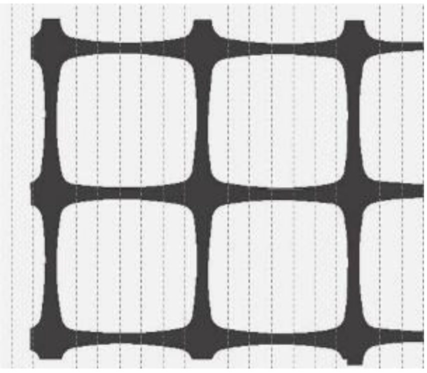
Construction Methods / Requirements

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.

Measurement and Payment

Computation of Quantities:
The paving grid shall be measured in square metres.

Schedule items:
Paving grid Unit: Square metre (m^2)



6.4 Composite Paving Grids

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.

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.

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.

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 Specification for Composite Paving Fabrics

Property		Unit	Require-ment	Test Method
Grid		Fibre glass reinforced or polymeric grid pattern Grid dimensions: 15mm x 15mm		
Tensile Strength	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		
Melting Point		°C	>265	ASTM D276
Penetration Load	Penetration Load	kN	2	
	Elongation	%	32	SANS 10221-07
Trapezoidal Tear Strength	Machine	N	215	ASTM D 4533
	Across	N	188	
Grab Strength	Machine	N	390	ASTM D 4632
	Across	N	420	
Puncture Resistance	Diameter of Hole	mm	28	EN 13433
Bitumen Retention ** See Explanation Below	Bitumen Retention	l/m^2	≥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.				

Measurement and Payment

Computation of Quantities:
The composite paving grid shall be measured in square metres.

Schedule Items:
Composite paving grid Unit: Square metre (m²)

6.5 Steel mesh

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.

Materials

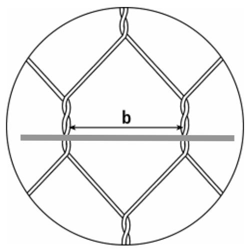
The transversally reinforced hexagonal woven double twist heavily galvanized mild steel mesh should conform to the specifications tabulated in Table 6.4. Type 1 is for asphalt reinforcement applications.

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^2 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
MESH TOLERANCE The tolerance on the opening of mesh "b" being the distance between the axis of two consecutive twists according to SANS 1580:2005			

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.

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.

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.

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 (m²)

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

Chapter 7

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7 PRACTICAL CONSTRUCTION ISSUES

7

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.

a) 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.

b) 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.

c) 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.

d) 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 71^{o}C, 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.

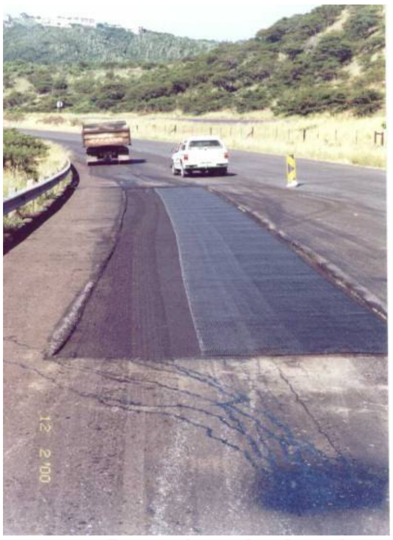

Figure 7.1: Placed, tacked and saturated ARI prior to paving

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 5ºC and 60ºC.
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 coat should be applied to improve bonding of the layers, but it can cause complications with the adhesion of the ARI.
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.

Figure 7.2: Glass fibre grid placed on levelling layer prior paving

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

Figure 7.3: Delivery of steel mesh grids to site

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

Figure 7.4: Placing of steel mesh grids on prepared surface

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/m2.

Figure 7.5: Fixing of steel mesh grids

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 asphalting 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

Figure 7.6: Applying tack coat prior to paving

a) Tack coat should be applied to improve bonding of the asphalt to the existing surface.
b) Tack should be sprayed after the steel ARI mesh has been placed.
c) 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

Figure 7.7: Final paving operations

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. 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

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8 QUALITY ASSURANCE AND MATERIAL TESTING

8

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 to 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 10319 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.*

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9 DATABASE OF PROJECTS

9

9.1 Introduction

As one part of the strategy to investigate the use and develop guidelines for the use of asphalt reinforcement products in South Africa, it was decided to develop a database of existing applications of these products. The objective of this database is to compile the available information (on both successful projects and failure projects) with as much information on each of the projects and applications as available, to ensure that it can be used as a learning tool for the use of asphalt reinforcement.

The initial database was developed to contain information on the project, the conditions before construction, reasons for using asphalt reinforcement and data from any follow-up investigations performed on the project.

This database is developed and populated with information from more than 27 projects (August 2007). However, most of the information focuses on simple project related data and not much pavement performance data have been collected as yet.

The objective is to use the data from the populated database to start developing an understanding of situations and applications where the various types of asphalt reinforcement were both successful and not successful.

9.2 System Used

The database was developed using Microsoft Access 2002. It consists of seven sheets containing the following information:

- Project background;
- Project details;
- Pre-construction information;
- Reinforced section information;
- Pavement before data;
- Pavement after data, and
- Pavement additional data.

There are also a number of photographs referenced on some of the projects.

The detailed layout of each of these sheets is provided in Figures 9.1 to 9.3. These data are collected through Microsoft Excel spreadsheets that are completed by the project staff and then compiled into the database.

As a standard feature of the database various searches can be performed on the data. These include searches for any of the relevant fields such as project name, traffic levels, age, type of asphalt reinforcement, area of asphalt reinforcement etc. Some standard searches have been programmed in the database.

The functionality of this database is directly linked to the amount of data that it was populated with.

9.3 Current Information

The August 2007 version of the database contains data from 27 projects. These projects represent 4 types of products and the projects were constructed in the period between 1980 and 2004. Traffic levels on the projects range from an AADT of 800 to 57 000 with between 2 per cent and 21 per cent heavy vehicles.

Unfortunately, approximately 50 per cent of the basic data for these 27 projects that have not been captured, and limited pavement performance data is available for only one of the projects. In order to increase the potential benefit and functionality of the database, attention should be focused on both increasing the number and diversity of projects on the database as well as the detailed information on each of the projects.

ASPHALT REINFORCEMENT LEVEL 2 (Additional information)			
Pavement data (indication of available data i.t.o instrument, date, density, location, etc)			
	Before	**After**	**Additional measurements**
Visual data			
Deflection data (Average SCI)			
Rutt depth (2m straight edge)			
DCP data (DN800)			
Riding quality data (Average IRI)			
Other (Specify)			
Additional information on Pavement structure (not noted on Level 1)			
Reinforcement information - Any special information not noted before on Level 1 (i.e. special installation instructions, trial section, non-standard installation etc)			
Drainage information (both surface and subsoil where applicable)			
Description of drainage			
Adequacy of drainage			
Cost information (i.e. reinforcement, asphalt, preparations etc)			
Photographic record (reference to locations and typical available photographs)			
Failure information			
Any identified failures?			
Age when occurred			
Possible reasons for failures			
Maintenance / rehabilitation actions			

Figure 9.2: Information collected for the Pavement before and Pavement after sheets of the database.

ASPHALT REINFORCEMENT - LEVEL 3 (Time related performance) Monitoring of pavement data (indication of available data i.t.o instrument, date, density, location, etc)											
Condition data	Time of Inspection (Months)										
	Existing	3	6	12	18	24	30	36	48	60	72
Longitudinal Cracking (m)											
Control											
Reinforcement											
Transverse Cracking (m)											
Control											
Reinforcement											
Crocodile cracking (m^2)											
Control											
Reinforcement											
Deflection data (Ave. SCI)											
Control											
Reinforcement											
Rutt depth (2m straight edge)											
Control											
Reinforcement											
DCP data (DN800)											
Control											
Reinforcement											
Riding quality (Average IRI)											
Control											
Reinforcement											
Other?											
Control											
Reinforcement											

Figure 9.3: Information collected for the Pavement additional data sheets of the database.

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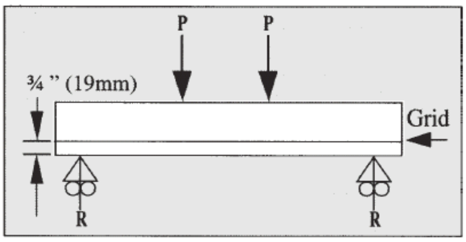
10 RESEARCH

10

10.1 Background

Schematic Diagram of the Beam Fatigue Test

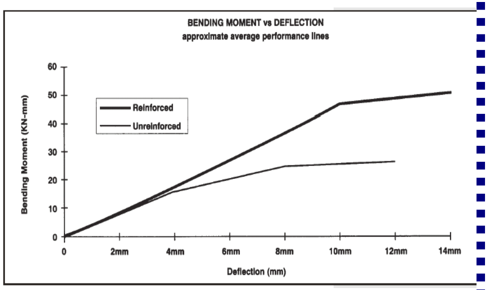


The field of Asphalt Reinforcement Interlayers has been subjected to wide research over the past two decades. This section provides an overview of some of these research projects with details of the institutions where research on ARI has been undertaken. The information provided refers to:

- Institutions (e.g. universities) that are known for their research work on ARIs.
- Specific national or international research projects (e.g. COST 348) that were established specifically for ARI research.
- Conferences where the subject of ARI features significantly.

10.2 Universities

10.2.1 Texas Transport Institute – Texas A&M University (USA)



The TTI has been involved in numerous research projects in the field of ARI. The research has mostly been under the direction of Dr Robert Lytton, J Button and J Epps. Laboratory and field tests are ongoing and international publications and journals should be monitored for publication of more results. Publications by these researchers are included as references in the various chapters.

10.2.2 University of Nottingham (UK)

Under the guidance of SF Brown, NH Thom and PJ Sanders, the university investigated the effectiveness of different interlayer systems (geogrid, steel reinforcement and fibreglass grids) in preventing the reflection of cracks in HMA overlays. Their findings and other research work has been published in a number of papers. Also see Annexure B.8.4.

10.3 National / International Research Projects

10.3.1 Cost 348

COST 348 is one of the actions supported by the COST Research part of the European Commission - Research DG. Following a proposal, COST348 was initiated in 2001. Since 2002 it has been run by the management Committee, a group of scientific and technical experts, to enhance the process of material assessment and design, as well as to develop appropriate structural design methods and measurement techniques in order to reach for this technology the status of a generally accepted alternative in road constructions. The COST348 action will also facilitate an exchange of experiences between different European countries.

COST Committee 348 was organized to develop guidelines for the structural design and construction of pavement structures reinforced with steel meshes and/or geosynthetics. Guidelines will be developed for inclusion of reinforcement in any component of the pavement structure.

The goal is to provide a new set of design models and working procedures, at first and primarily intended to cover the European countries within this Cost Action 348 programme, but with the perspective that they can be shared worldwide on a later stage. Particular objectives are:

- To enhance the process of material assessment and design, as well as
- To develop appropriate structural design methods and measurement techniques in order to reach (for this technology) the status of a generally accepted alternative in road constructions.
- To enhance reinforcement technologies
- To stimulate contacts and transfer of knowledge,
- To produce material testing methods.

The COST348 action was approved for the period of three years: 2003 to 2005. More information about the COST 348 can be found on http://www.cordis.lu/cost-transport/home.html.

10.3.2 Reflex

REFLEX is the acronym for “Reinforcement of Flexible Road Structures with Steel Fabrics to Prolong Service Life”. The project was started in March 1999 and completed in 2002. It was co-ordinated by the Swedish National Road and Transport Research Institute. Project was funded by the European Community Under the Industrial & Materials Technologies Programme (Brite-EuRam III).

The main objective of the REFLEX project is to develop a new methodology of road construction and rehabilitation with the use of steel reinforcement fabrics in order to make road structures more cost effective by improving the lifetime. The method is presumed to give thinner road structures and/or longer life cycles, which will lead to a reduction in the use of natural resources. Further, reduction of the need for maintenance, reduction of congestion, redaction of accidents, improvement of safety of road traffic can be expected.

RELEX produced a number of reports as listed below:

a) Investigation of material specification of steel and the configuration of steel fabric.
b) Experimental activity required for the input to the theoretical modelling and for the planning of accelerated tests and roads.
c) Laboratory studies on asphalt - steel net compound system and unbound granular material - steel net compound system.
d) Full Scale Accelerated Tests
e) Performance of Existing Reinforced Roads
f) Design and Construction of Full Scale Test Roads

g) Performance Of Full Scale Test Roads
h) Performance of Full Scale Test Roads
i) Modelling of Flexible Pavement Reinforced by Steel Net
j) Final Report - Economical and environmental aspects
k) Final Report – GUIDELINES

More information can be obtained from http://www.vti.se/reflex

10.4 International Conferences

10.4.1 RILEM

The first RILEM conference on reflective cracking in pavements was held in 1989 and was intended as a single event. Due to the interest shown in this subject it has grown into an International Conference that is held every four years with the latest one in 2004 in France.

The seven main topics selected for the conference were:

- Modelling and validation
- Initiation and propagation of cracks
- Construction and maintenance techniques to inhibit pavement cracking
- Long-term performance of crack inhibition, crack preventive techniques and pavement service life prediction.
- Influence of construction approaches on cracking
- Experimental studies: laboratory and field
- Testing techniques and effectiveness of evaluation approaches

More information is available from http://www.rilem.net/index.html

10.4.2 Geosynthetics

The geosynthetics conferences are held every 4 years and commenced in 1979.

7th International Conference on Geosynthetics

The 7th International Conference on Geosynthetics was held in September 2002 in France. Volume 3 - Transportation and hydraulic engineering, had the sub-section Pavements. The following papers are highlighted:

- ***Analytical modeling and field performance testing of geocomposite membrane in flexible pavement systems***, *I.L. Al-Qadi & M.A. Elseifi, p* 907
- ***The proper use of geosynthetics in flexible pavements***, *I.L. Al-Qadi, p* 913
- ***The effect of glass-sheet reinforcement on crack resistance of asphalt concrete***, *S.D. Cho, D.Y. Lee, S.K. Han, N. Kim & T-B. Ahn, p* 917
- ***Research on the mechanical performance of the asphalt concrete reinforced with geosynthetics***, *Z. Guo, Y. Huang & C. Chen, p* 927
- ***The use of geosynthetics in paving applications – Factors influencing the reflective cracking***, *R.G. Lugmayr, E.K. Tschegg & J. Weissenböck, p* 935

- ***Design of geosynthetic reinforced flexible airfield pavement***, *J.N. Mandal & N.N. Chaudhury, p* 939
- ***Geogrid efficiency in a push test***, *M. Matys & R. Baslik, p* 943
- ***Mechanistic-empirical models for reinforced pavements***, *S. Perkins, E.V. Cuelho, G. Eiksund, I. Hoff, G. Svano, A. Watn, C.W. Schwartz & B. Christopher, p* 951
- ***New road constructions, stress relief in cement treated base courses***, *E.R. Steen, p* 959
- ***The effect of geosynthetics materials in preventing asphalt pavements from reflective cracking***, *Z-G. Zhou & J-L. Zheng, p* 963

8th International Conference on Geosynthetics

The 8th International Conference on Geosynthetics was held in September 2006 in Japan and included a similar section on Road and Transport:

Geotextile paving fabric for airport rehabilitation works: The Philippine field experience, Lim, L.K., Renato Jr., D.T, Antonio M.N & Librado, P.G. and Chew, S.H.

A finite element study on optimum location of geogrid layer installation in asphalt overlay, Moghadasnejad, F. and Toolabi, S.

10.5 References

7th International Conference on Geosynthetics, Nice, France, September 2002 - Delmas, Gourc & Girard (eds) © 2002 Swets & Zeitlinger, Lisse ISBN 90 5809 523 1

8th International Conference on Geosynthetics, Yokohama, Japan, September 2006, Millpress Science Publishers, Rotterdam, Netherlands, ISBN 90 5966 044 7

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11 DOCUMENT DETAILS

11

Client:	South African National Road Pavement Forum
Project:	Develop guidelines for the use of Asphalt Reinforcement in southern Africa
Report Title:	Asphalt Reinforcement Guideline
Revision:	August 2008
Committee:	Asphalt Reinforcement Working Group
Project Manager:	Philip Joubert, (SSI)
Contributors:	Garth James, (Kaytech) Marco Pauselli, (Maccaferri SA) Mias Wiese, (SANRAL) Cobus Venter, (Tensar) Joe Grobler, (Vela VKE) Wynand Steyn, (CSIR) Julian Wise, (Zebra Bituminous Surfacing)
Date:	August 2008

12 ANNEXURES

12

ANNEXURE A

A. Selection of a 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 curve 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℃. 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℃. 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

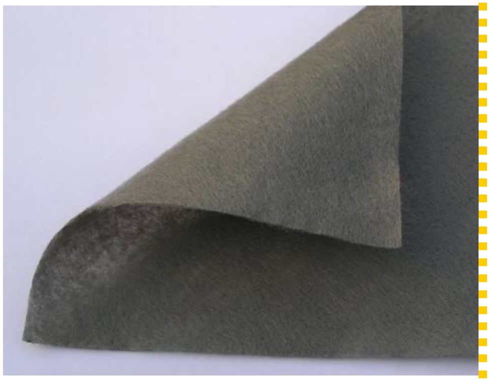
Where recycling will be an option in the future life of the pavement then the ARI with the best recycling ability should be selected otherwise for straight milling the best fit-for-purpose ARI should be selected.

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 210ºC, compared to polypropylene, which is sensitive to temperatures in excess of 145ºC.

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^2 polymeric fabric milled with HMA does not normally have a significant affect 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 is applied 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:

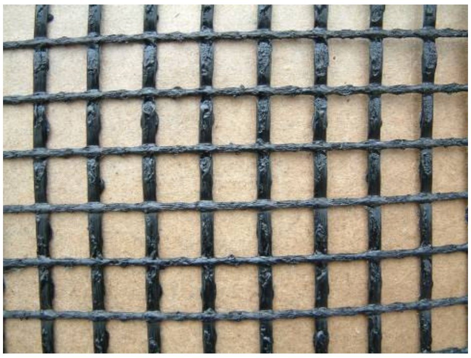
- At intersections or on sharp bends.
- Due to slippage on a smooth surface.

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



They 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

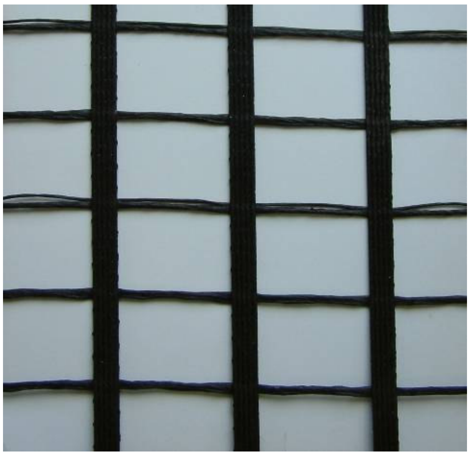
The milling process will break the glass fibre into short strands that can be easily mixed into the new asphalt design in the recycling process.

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.3.2.2Overlay 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.3.2.3Compatibility/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 210^{o}C.

A.3.2.4Durability 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.3.2.5Milling 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 210ºC allows hot milling and recycling.

A.3.2.6Boundary 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/ m^2. 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

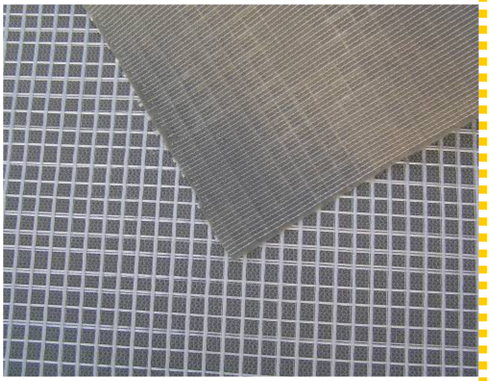
As opposed to the paving grid on its own these composites combine the positive effects of a nonwoven paving fabric and the high strength, high modulus, low creep of paving grids.

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 165ºC 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 >200ºC are less susceptible to hot milling than the polypropylene paving fabrics with heat resistance at temperatures <160ºC.

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 saturation of the paving fabric component is applied 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.

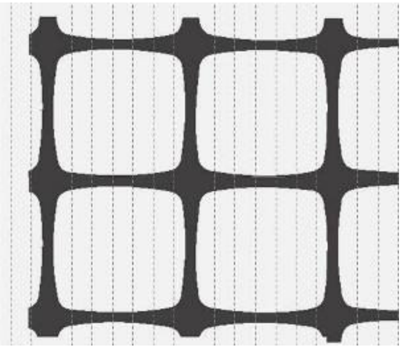
Shoving or heaving could occur:
- At intersections or on sharp bends.
- Due to slippage on an old, rich surface.

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 stitchbonded 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.4.2.1Overlay 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.4.2.2Overlay 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.4.2.3Compatibility/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.4.2.4Compatibility/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 165ºC 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 210ºC 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

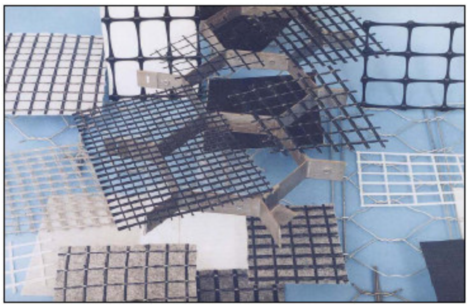
The bonding of the composite to the road surface is critical to the performance of these types of reinforcing interlayers.

De-lamination could occur if:
- Water is present in the base due to the absence of sub-soil drainage.
- Insufficient tack coat and/or saturation of the paving fabric component is applied 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.



ANNEXURE B

B. Cost Action 348

Reinforcement Of Pavements with steel Meshes and Geosynthetics

Extracts from Cost 348, Work Package 4: Selection of Design Models and Design Procedures (Arian de Bondt – 03/01/06**)**

B.1 Foreword to Cost Action 348, Work Package 4

The memorandum of understanding (MoU) of COST-action 348 describes Work Package 4 as follows:

The selection of design models for the structural design of roads with reinforcement products, depending on the type of damage and the loading conditions. The design procedures cover reinforcement applications for pavement coating (SAMI), pavements, base and sub-base layers and road widening.

When the project was in its starting phase, the COST-participants decided that the end result of Work Package 4 should give a clear picture on what is available or what should become available in future with respect to design models and design procedures for steel meshes and geosynthetics in pavements; this when applied in the top of a pavement structure (the asphaltic layers) or deeper (the unbound layers). The report should also provide an overview of the required steps which need to be taken during the design process of pavement layers with these type of materials as well as guidelines for the collection of long-term field data.

The information which is given in this document has been composed by using individual contributions from the participants of COST348. The list of participants and the report is downloadable from the official website of COST-action 348 (http://cost348.zag.si).

B.2 Foreword to Annexure B

Annexure B only contains extracts from Work Package 4 relating to asphaltic layers. Work Package 4 also covers unbound granular bases which are not considered in this guideline document.

B.3 Scope and Definitions

In order to stimulate routine design with steel meshes and geosynthetics in pavement structures, one should, when introducing such a relatively new concept on a large scale, stick as much as possible to the way in which pavements without steel meshes and geosynthetics are treated in the design process.

Depending on the country, routine pavement design (so without steel meshes and geosynthetics) is of an empirical or semi-empirical nature. Empirical pavement design methods often consist of tables in which, depending on the traffic class and subsoil conditions, standardized compositions are given, which have been found to perform well under normal conditions. In case of a semi-empirical procedure, a computational tool is used to compute stresses and strains at critical pavement locations. Once these are available, so-called transfer functions are applied to relate pavement distress (in terms of e.g. % cracking or mm rut depth) to computed stresses and strains. These transfer functions are obtained by means of long-term field testing and/or accelerated loading facilities.

It is obvious that introducing new products in empirical design methods takes a lot of time and financial resources, because for all kind of circumstances trial sections need to be laid down and monitored for a long period and/or a lot of accelerated loading tests are needed. The disadvantage of this is also, that producers have to wait too long, before they can see any potential benefit from investments in product developments. This could lead to the peculiar situation, that when a product has been approved after say e.g. a 15-year trial period, it does not exist anymore. Another disadvantage is that the road community is using “old-fashioned” materials too long.

From the foregoing, it can be concluded that the only way to bring in new products into the road construction industry, is by means of sticking to the semi-empirical approach or using an entirely analytical approach. The problem with the latter is however, that this approach does not even exist for the traditional materials, so it becomes very costly and time-consuming. Also, without verification in practice, it is difficult to get confidence in the output of analytical methods.

In this COST WG4-report an overview is given of the important aspects of design methods and design procedures for steel meshes and geosynthetics. Steel meshes are defined here as products consisting of steel bars or wires in the shape of a grid, net, netting or fabric, with the purpose of taking loads (transferring forces). The terminology geosynthetics (and related products) is utilized in this report for all synthetic or natural materials (e.g. polymers, glass, carbon fibre, etc.), which are currently applied in the field of road construction in order to improve the performance of granular bases and/or asphaltic layers via the function reinforcement, stress-relief, barrier or separation; see [1], [2] and [3] for a definition of these functions.

Given the fact that steel meshes and geosynthetics are functioning in different ways when applied in a granular base layer or in an asphalt concrete layer, it is logical that they have to be treated differently. This is why chapter 2 describes the use in unbound granular bases and chapter 3 the use in asphaltic layers. Conclusions and recommendations are found in chapter 4.

B.4 Introduction to Asphaltic Layers

In case of asphaltic layers, geosynthetics are applied for new construction as well as for maintenance. This almost always to tackle cracking problems [9], since rutting can very often be treated in a easier (more cost-effective) way by means of improving the asphalt mixture constituents. Below, first of all more background on the mechanisms of rutting and cracking in asphaltic layers is given.

B.5 Rutting in Asphalt Layers

Long-term field experience as well as extensive wheel tracking tests have shown that the rutting which is visible at the surface of asphaltic layers can be caused by:

a) shear deformation (up to failure) within the bituminous mixture itself (especially at low traffic speeds or high temperatures)
b) and/or plastic deformation in the underlying unbound layers (foundation, subsoil, etc.).

The latter mechanism has been discussed in Work Package 4, chapter 2 – Chapter on Unbound Granular Bases.

It is obvious that depending on the geometrical nature of a steel mesh or geosynthetic, it is possible to lock the aggregate particles of a mixture in such a way that the well-known shear type failure (often called flow rutting) cannot take place. It is also clear that this interlocking effect depends on the vertical distance to these products. This implies that the steel mesh or geosynthetic should be located in the critical region in the pavement; for most loading applications (e.g. truck traffic) this is the top 100 mm of the pavement.

B5.1 REFLEX approach

Because of their visco-elastic and visco-plastic behaviour permanent deformations in the asphalt layers are induced. Some pavement design models try to calculate the rutting rate of a pavement system, but until now no generally (worldwide) accepted method to calculate rut depth has been developed.

Linear-elastic multilayer programs such as e.g. BISAR are able to calculate the values and vectors of stress and strain tensors, the principal stresses and strains and the corresponding principal directions, the maximum shear stresses / strains and displacements in x-, y- and z directions. Therefore the stress tensor and the deformation tensor D can be determined.

Laboratory tests showed that after a certain period of post-compaction there is no change of volume during rutting. Therefore the part of the deformation tensor, which describes a deformation with constant volume has to be determined. By splitting off the hydrostatic part from the deformation tensor, one gets the deformation deviator D’. This deviator describes the modification of the shape at constant volume. Hilmer [10] and Neumann [11] adopted these thoughts and wrote a program which is splitting off the hydrostatic part from the deformation tensor calculated with

BISAR. Then the horizontal and vertical deformations can be calculated (Modified BISAR – program). In case of reinforced asphalt pavements, the reinforcement was substituted by an equivalent layer under the load.

The way of modeling, which was applied in the REFLEX-project, is illustrated in Figure B1, whereas Figure B2 shows the effect of the presence of the steel mesh. Via the finite element analyses (FEM), it can be deduced that the steel mesh is capable of reducing the shear stress by roughly 30%.

For details, see http://www.vti.se/reflex (status December 2005).

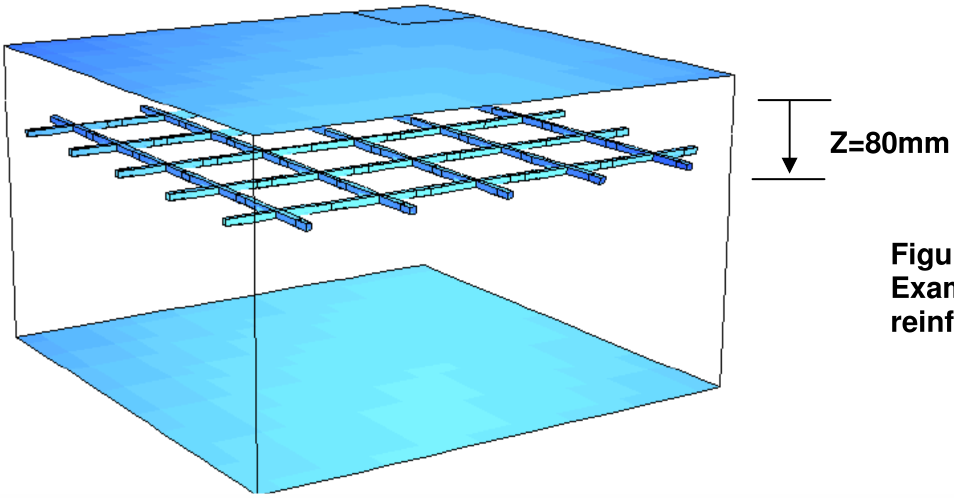


Figure B1:
Example – FEM model with reinforcement at z = 80mm

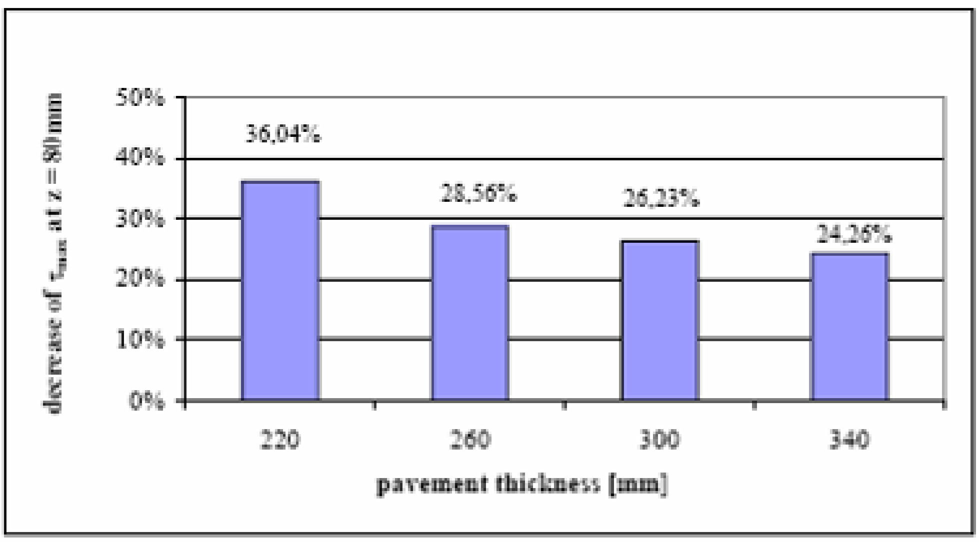


Figure B2:
Decrease of Shear in Asphalt due to Reinforcement

It is noted that the intention of the REFLEX-approach was to create a development and analysis tool, in order to get a better understanding of the measured rutting performance in the laboratory (large wheel tracking tests); this with and without steel meshes. This approach was not meant as a routine tool for the design of reinforced pavement structures on the criterion rutting.

B.6 Mechanisms of Cracking in Asphaltic Pavements

Asphaltic pavements are defined here as pavement structures with at least one bituminous bound layer at the surface. In order to be able to evaluate the effect of steel meshes and geosynthetics versus cracking it is necessary that first of all the phenomenon of cracking in asphaltic layers is well understood.

Cracking of asphaltic pavements can be caused by three different mechanisms, as described by de Bondt [12]:

- traffic,
- temperature variations in time and
- uneven soil movements.

The latter can be downwards e.g. uneven settlements (road widening!) or upwards e.g. frost heave, or a combination of these.

In general, two phases during the cracking process of asphaltic pavements/mixtures can be discerned [12],[13]:

- initiation and
- propagation.

Which one of the two is predominant on a specific site for the interval period between construction/maintenance measures, depends on the mechanism which is active.

The type of damage mechanism which is causing the cracks to appear at the pavement surface depends on

- the properties and nature of the pavement structure (thicknesses, stiffnesses),
- the quality of the underlying soil,
- the traffic characteristics,
- the climatic conditions and also
- if the situation is new construction or maintenance in the form of relatively thin asphaltic overlays. In the latter case the severity of cracking in the existing pavement structure plays an important role.

It is crucial to be sure about the mechanism and cracking phase which is critical at a specific site, because the effectiveness of using steel meshes / geosynthetics depends on this. The table below presents an overview of the dominant cracking phases [14],[15]. In case of uneven soil movements, no general information can be given, since this is case dependent.

Table 1: Overview of Dominant Cracking Phases in Asphaltic Pavements

Dominant Cracking Phase in Asphaltic Pavements		
Damage Mechanism	**Crack Initiation Phase**	**Crack Propagation Phase**
Traffic Loading	X	X
Temperature Cycles	X	
Uneven Soil Movements	Case Dependant	Case Dependant

It is clear that steel mashes / geosynthetics can only be applied cost-effectively if they are specified/utilized in such a way that they tackle the dominant cracking phases given above. The required design model/procedure should cope with this.

B.7 Requirements for Design Methods and Procedures

Since the beneficial effect of a given steel mesh / geosynthetic highly depends on the type of cracking mechanism which is dominant on a particular jobsite and is also extremely case dependent (especially the quality of the soil plays an important role), proper design based on (extrapolated) laboratory experiments and/or accelerated load testing data is not possible. The requirements for any design model or procedure for a steel mesh / geosynthetic in asphaltic pavements, which is meant to be used for routine purposes, can be summarized as follows:

- it should tackle the right mechanism at the jobsite which is analyzed (see section B4)
- if relevant, the traffic characteristics (number, type of vehicles, speed) specific for the jobsite need to be taken into account
- if relevant, the temperature variations in time specific for the jobsite have to be incorporated
- the pavement and soil properties relevant for the jobsite should be used
- in case of maintenance, the existing condition of the pavement has to be one of the input parameters
- the mechanical properties of the steel mesh / geosynthetic (stiffness / strength) must be incorporated in sufficient detail
- the interaction between steel mesh / geosynthetic and surrounding asphalt mixtures has to be taken into account
- the computational engine (procedure), which is behind the method should be described in such a way that it can be evaluated (judged) by third parties
- the method should have been validated with long-term monitoring field data
- life-cycle costing analyses should be possible in an easy way
- for an average jobsite the (user-friendly) design process should not take longer than one afternoon for an average skilled pavement engineer. The latter implies familiar with the mechanistic-empirical approach.
- the end result of the design process should be tender

specifications and a sketch of the laying plan of the steel mesh / geosynthetic. The tender specifications should be in a generally accepted format, where product description is according to international standards (e.g. CEN).

Furthermore, it recommendable if parameters which give an indication about road user costs and driving comfort are outputted. This because it is interesting for clients to know the effect of maintaining the pavement with a steel mesh / geosynthetic on well-known parameters such as PSI or IRI.

B.8 Currently Available Design Methods and Procedures

From the questionnaire performed by the COST-countries (Work Package 2), it is clear that only a small number of design models and procedures are available, of which no one really meets all the requirements which are mentioned above. This is also caused by the fact that the design of maintenance treatments for cracked pavement structures, in which no steel mesh / geosynthetic is included, is a subject which has had hardly any attention in the road construction community in the past. In almost all cases the selection of e.g. the mixture properties and the thickness of an asphaltic overlay are based on empirical knowledge. This implies that relatively new options (such as e.g. steel meshes / geosynthetics) need a very long waiting period before they can be judged, which is unacceptable from an economical point of view.

Design models and procedures which have been found to be used in practice at the moment or have just become available, are discussed in detail in the following sections.

B.8.1 ARCDESO®

A wide range of possible solutions for reflective cracking exist:

- mill and fill (and overlay),
- application of thick asphaltic overlays,
- the use of modified asphaltic mixtures (e.g. high bitumen content,
- elastomer modified bitumen or composed in such a way that a porous nature is created),
- the application of stress-relieving systems or
- the incorporation of reinforcement.
- Combinations of these solutions are of course also possible.

During the design phase of a project, each solution needs to be assessed, in terms of cost and benefit to life expectancy, before deciding about the most appropriate maintenance option and implementing it. Given the nature of reflective cracking, complex analyses are required to compute the number of load repetitions (not necessarily traffic cycles), which are needed for a crack to propagate into and through an asphaltic overlay. It is obvious that it is impossible to do this labor intensive work for each project for all combinations of maintenance options listed above. Furthermore, the current pavement designer is technically not capable of performing these type of computations. It is therefore ideal if a tool existed, which could analyze several thousand maintenance options within the typical period of time, that is available for the computational part of an asphaltic overlay design procedure, which is roughly one afternoon.

The Anti-Reflective Cracking Design Software which has been developed meets the challenge described above. The first version of this innovative Internet based program (denoted as ARCDESO® 1.0) is capable of dealing with the mechanism temperature variations in time; this for rigid, semi-rigid (composite) as well as flexible pavement structures. Practical experience has shown that in the majority of cases this phenomenon is dominant (or it is worthwhile to use some form of reinforcement). The user-friendly program has been developed for Saint-Gobain Technical Fabrics / Ooms Nederland Holding within a research project carried out by the department of Research & Development of Ooms Nederland Holding. Distributors of GlasGrid® have access to this program.

The software includes typical aspects which are of importance for the assessment of the effectiveness of reinforcement versus reflective cracking, such as:

- reinforcement stiffness under creep conditions,
- resistance versus damage during installation,
- anchorage length,
- pullout resistance,
- tack coat characteristics (spray rate and quality),
- incorporation of in-situ climatic conditions / existing pavement properties (including crack spacing variability) [16].

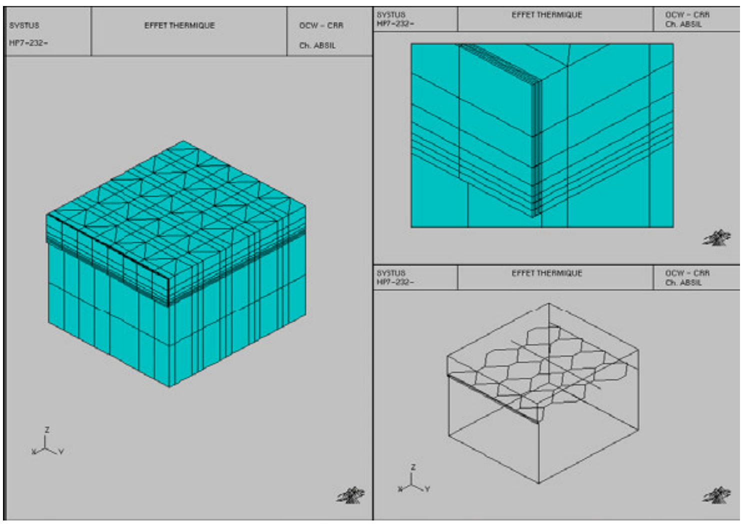
Furthermore, a database with asphalt overlay mixtures is available, including their thermal as well as mechanical characteristics (including healing potential). Finally, the crack predictions can be analyzed and evaluated in different ways. Figure B3 shows an example of the computational output.

Figure B3: Example of Computational Output of ARCDESO® [16]

B.8.2 Bitufor®

It is well-known that the classical multi-layer design models are unable to describe the local stress concentrations encountered around cracks or discontinuities in roads. Different finite element simulations of cracked road structures in which interlayer systems are described as continuous homogenous layers were found not to be satisfactory to provide the real reinforcement effects of geogrids and steel nettings. The structural design model which was developed, is based on a three dimensional finite element analysis of road structures containing a discontinuity or a crack and in which an exact modeling of the Bitufor® steel reinforcing net is introduced, with its real geometry and mechanical characteristics (as illustrated in figure B4).

The aim of the program [17],[18] is to compare the lifetime for crack initiation with the use of a steel netting to that of a system without interface system and to determine the "gain" in asphalt layer thickness with the use of this system.



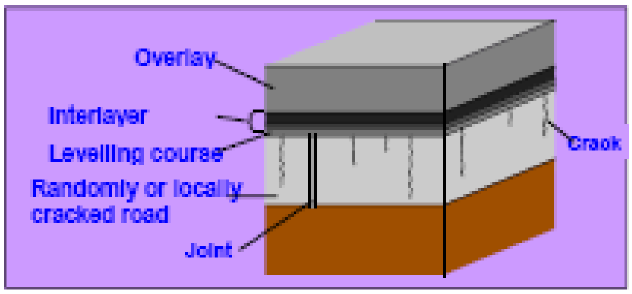


Figure B4: *Finite Element Representation of the Steel Netting*

The model is used for the simulation of asphalt overlays with a steel netting on transversal cracks or joints in rigid pavements, in semi-rigid pavements and in flexible pavements. Also on longitudinal cracks in cement concrete structures. In the case of traffic loading, both the effect on the vertical differential displacements at slabs ("slab rocking"), as well as the effect on the bearing capacity are examined. Also different overlay thicknesses can be considered.

The database of the design software can be described as follows:

- the database contains the parameters which characterize the materials, climate and traffic. This data is collected per country or region for which they are defined.
- materials: the materials are described as those ones which are listed in the general tender specifications: asphalt, concrete, lean concrete, road base / subbase material (each material is described by means of an E-modulus and a Poisson's ratio).
- climate: average air temperature and frost index
- traffic: the elementary histograms and weight-in-motion data.

The design is performed with the data (see above) which are standard or modified by the user. The design method makes use of the mechanics of continuous media and the theory of strength of materials. The calculation models of the software give the values of stresses and strains in the structure when they are subjected to traffic loading under given climatic conditions.

B.8.3 REFLEX

According to the REFLEX-team [19], for the investigation of the behaviour of steel nets in flexible pavements, generally two computation methods are possible:

- the multi-layer theory, which is applied in most commonly used design programs,
- the finite element method, which enables the calculation of particular problems, but is (in its direct form) not suitable for the daily practical use.

One important assumption of the multi-layer theory is, that the layers have to be homogeneous. Therefore it is not possible to compute a composite system of steel reinforcement and asphalt. One way to solve this problem is to introduce an equivalent layer (EL) for the reinforcement (see also section 2 of Work Package 4 – Unbound Granular Layer). The mechanical parameters needed as input for the different layers are the thickness, the modulus of elasticity and the Poisson's ratio. The modulus of elasticity of the EL can be determined by means of different equations, based on axial stiffness or moment of inertia [19],[20]. The formulas show different evaluations concerning the expected influence of reinforced layer thickness (between linear and power three). Assuming that the diameter of the steel bar can be directly used as the thickness of the equivalent layer, the calculation is not dependent on the thickness evaluation and can be simplified further [19],[20]. The cross-section of the steel bar is then converted into a square section first.

The FEM-computational model used within the REFLEX-project is based on a three-dimensional finite element analysis with the program SOFiSTiK. The following assumptions are used:

- linear-elastic material behaviour,
- the cross-section of the steel is assumed to be quadratic instead of round,
- the single bars are not lying one upon the other, but intersect in one level,
- full friction between steel and asphalt elements is assumed.

To examine the influence of the steel net, the reinforced system was compared with the unreinforced one. For the unreinforced system the material of the elements describing the reinforcement was set equal to the one of the surrounding asphalt. For the reinforced system the material characteristic of steel was assigned to the corresponding elements. It must be taken into account that because of the assumption of full friction, the steel elements transmit high stresses to the adjoining asphalt elements. Therefore the stresses of the asphalt elements next to the steel elements are relatively high.

This effect must be taken into account during the evaluation.

To summarize, the results of the overall REFLEX-project are first of all, that procedures for laying of steel fabrics have been optimized and tested in the field. Furthermore, a first step towards a design procedure for steel meshes has been made.

B.8.4 University of Nottingham

This design approach [21] deals with reflective cracking, with and without grid reinforcement. The design case considered is a regularly cracked existing pavement (or cement treated base). The method estimates the growth of a crack under the three modes shown in figure B5.

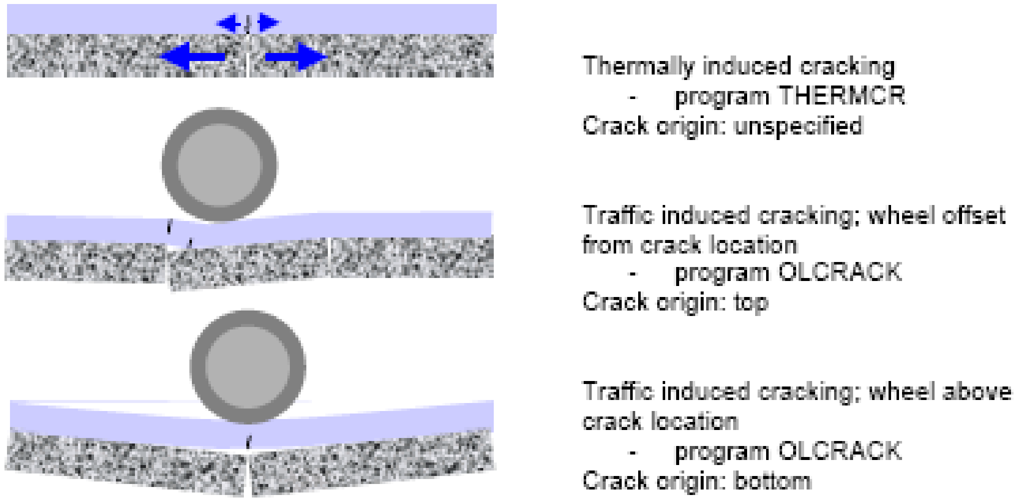


Figure B5: *Schematic of the University of Nottingham Model [22]*

Characteristics of the approach are:

- linear-elastic or linear-viscous material properties
- viscous tack coat assumed in THERMCR
- THERMCR traces a 24 hour temperature cycle
- calibration required according to temperature variation through year
- in THERMCR, the grid is assumed to be elastic and non-plastic
- tack coat tensile adhesion ignored in OLCRACK
- key parameter in OLCRACK is load transfer efficiency
- OLCRACK basic analysis 2D; correction -> 3D
- crack propagation law used (both programs): $dc/dN = A\ \varepsilon^n$
- twenty increments of crack growth considered in OLCRACK
- in OLCRACK the grid ties the crack faces together
- OLCRACK and THERMR are independent methods

OLCRACK and THERMCR are predictive programs for overlay design and have been developed by Nottingham University in conjunction with a number of pavement reinforcement product manufacturers. They are capable of replicating test results from beams on semi-continuous support and from the pilot scale pavement at Nottingham University. The input data is determined primarily from the results from FWD testing and is based on the thickness, stiffness and condition of the various layers in the existing pavement and on the thickness and stiffness of a proposed asphalt overlay. It has been used to allow reductions in the pavement thickness on specific projects.

B.8.5 Design with Paving Fabrics

The paving fabric system, developed and being in use since 1965, consists of a needle-punched delaminating free non-woven fabric treated by heat on one side only. The treated side is turned upwards against the passing wheels or tracks from the paving machinery in order to allow for the necessary trafficking on the fabric. The fuzzy side is down into the sprayed bituminous tack coat, as the fuzzy surface of the fabric enlarges the bonding between the sprayed bituminous tack coat and the paving fabric. When placed between the pavement layers, saturated with bituminous tack coat, the paving fabric system becomes an integral part of the road pavement, forming a barrier to surface water intrusion and a stress-relieving interlayer reducing reflective cracking of the new asphalt overlay.

The inclusion of a paving fabric system significantly improves the performance of asphalt overlays and gives additional performance equivalent to increased asphalt overlay thickness of 20 to 40% or in other words; saving of up to 2’’ (51 mm) of asphalt overlay thickness is achievable according to [22]. The saving of up to 2’’ of asphalt overlay is found when compared to the traditional paving with 4’’ (102 mm) of asphalt overlay in the research area. The structural improvement is due to the waterproofing and stress-relieving function of the bitumen saturated paving fabric. The preventing of surface water intrusion achieves the same result as effective base drainage. By maintaining lower moisture content in the road base materials, the effective strength or support is improved and provides up to 2½ times the pavement support of poorly drained bases and provides from 25 to 50 % increase in service life, as stated in [22]. The stress-relieving function allows for slight differential movements between the slabs, essential in rigid pavements, e.g. concrete pavements or pre-cracked cement stabilized surfaces.

If the possible reduction of asphalt overlay thickness is not utilized when using the paving fabric system, a lifetime extension of 100% is achievable. Holding this up against the investment costs of a paving fabric system, where the cost of paving fabric and installation - all included - is found to correspond to approximately 1 cm of extra asphalt overlay thickness [23], a proper installed paving fabric system is found to have very cost beneficial long-term savings.

As a short summary of the paving fabric system, it can be mentioned, that in 1984 the USA Federal Highway Administration assigned a joint AASHTO-AGC-ARTBA Committee with the task of developing standard guidelines for the selection of geotextiles for specific end uses, Called Task Force 25. This pamphlet also included the guidelines for the selection of paving fabrics. The Task Force 25 specifications for paving fabrics can e.g. be found in a paper from Vicelja [24], where the period from the very beginning until 1989 is described.

Nowadays, the American provisional TASK FORCE 25 specs have been replaced by the AASHTO M-288 standard specification for highway applications, and include the use of paving fabrics. The specification for the paving fabrics shown in the AASHTO M-288, however, is still identically with the provisional TASK FORCE 25. In lack of national or European requirements for paving fabrics, the American findings have been replicated and used as description and requirements for paving fabrics over the last 30 years over the most of Europe.

B.8.6 Validation

There are two ways in which design methods for asphaltic pavements with steel meshes / geosynthetics can be validated. First of all, instrumented pavement sections can be monitored for a sufficiently long time, see e.g. [25],[26]. In this case it is not needed that so-called reference sections (= sections without steel meshes / geosynthetics) are available. In most cases however, it is too complicated to install displacement sensors, strain gauges, etc. In such a situation, where the monitoring is limited to periodic crack mapping, it is certainly required that (equally loaded) sections with and without steel mesh / geosynthetic are available.

From the previous sections it is obvious that more long-term field data is needed to extend the degree of validation of the methods which were described above (and future methods). In order to support this (future) work and make this data also available for design methods which are under development, an overview of existing and ongoing long-term field monitoring of the participating COST countries is discussed in the next section.

B.8.6 Overview of Long-Term Field Data

Since instrumented sections are very seldomly possible in practice, it is obvious that always data is required from equally loaded pavement sections with and without steel meshes / geosynthetics. Before a listing of output from monitoring projects is given, it is useful to realize what kind of data (quality and extent) is needed so that design methods and procedures can be validated. This will be done in the form of a check-list. It is of course recommended to gather as much information as possible at the start of the project.

- bearing capacity measurements (including when and how performed)
- type of foundation soil and type of soil used in different layers with its physical-mechanical properties (soil classification, water content, stiffness, strength, permeability, capillary potential, etc.), for which the following standards should be used:
    - a) CEN ISO/TS 17892-1 (2, ... 9): 2004 – Norms for Laboratory Testing of Soils for Geotechnical Purposes,
    - b) prEN ISO 22745-1:2003: Geotechnical investigation and testing – Sampling by drilling and excavation methods and groundwater measurements – Part 1: Technical properties for execution (ISO/WD 22745-1),

and/or

- c) ENV 1997-3: 1999 Eurocode 7: Geotechnical Design – Part 3: Design assisted by field testing. All the collected data describing soil properties are supposed to be statistically analyzed in order to achieve a characteristic value to be used for design.

- ground water level; what are the variations during the seasons?
- thicknesses and materials of the existing pavements, with relevant mechanical and thermal properties
- pavement condition before overlaying (degree and severity of cracking); do the different existing pavement sections e.g. have a similar quality?
- traffic characteristics (number, type of wheels, weight distribution, speed, degree of wander)
- climatic conditions (representative temperature data, freezing cycles, etc.)
- mechanical and thermal properties of the overlay (stiffness, failure strain, etc.)
- the properties of the steel mesh / geosynthetic; details such as the production label, the type of constituent material (e.g. the polymer or steel type classification), the form (geometry) of the reinforcement product (aperture size, junction strength, filament geometry) and the physical and durability properties (e.g. stiffness / strength values for representative temperatures and strain rates)
- tack coat details (spray rate, type of material, bitumen quality, was the surface clean?)
- installation details steel mesh / geosynthetic; issues such as weather conditions (temperature, relative humidity), skillfulness contractor (is the product laid down flat, without wrinkles?), locations of overlap and joints, damage during installation, clean surface?
- installation details pavement itself: quality of compaction, layer thicknesses, etc.
- any intermediate small maintenance being carried out
- long-term crack mapping data (known as crack counting) for sections with and without steel mesh / geosynthetic + registration of any other damage; this includes details, such as when during the season were the cracks recorded, what is the length of the cracks at the surface (e.g. along the entire pavement width), how deep are they and do they grow from the pavement surface down and/or from the bottom-up?

The questionnaire which was carried out by the COST-countries finally resulted into the following list of projects where appropriate data for model validation is available or becomes available in the coming years.

B.8.6.1 Belgium

The paper with basic details [27] describes the results of a long-term evaluation of two experimental roads and five individual projects of overlays on cement concrete slabs, where different interface systems were meant to be used for the prevention of reflective cracking. The follow-up of an experimental road during 10 years where several sections with/without steel reinforcing nettings and with/without crack and seating, showed that crack and seating on one hand and steel reinforcing nettings on the other hand, are both effective against reflective cracking. This pavement consists of an asphalt overlay of 40 mm SMA (laid down in 1995) on concrete slabs.

The follow-up during 7 years of an experimental road, where different interface systems (SAMI[1], non-woven, grid, steel reinforced netting) were applied, showed less reflective cracking on the sections with interface systems than on the reference section without interface product (see figure B6). This pavement exists of an asphalt overlay of 50 mm SMA (laid down in 1998) on concrete slabs. As prior repair before overlaying, the concrete slabs were injected to prevent as much as possible severe slab rocking. Slab rocking deflection measurements showed stabilisation of the slabs.

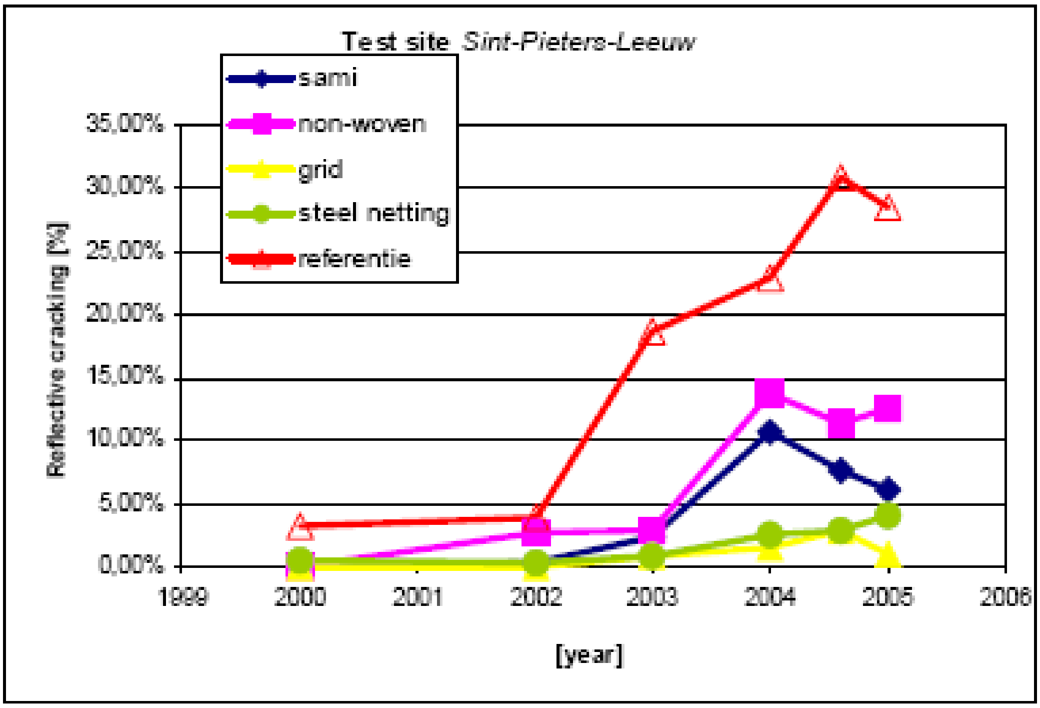


Figure B6 : *Observed Long-Term Field Performance in Belgium*

The follow-up of several individual projects, all asphalt overlays on (existing) concrete slabs, with interface systems confirm the earlier mentioned observations:

- the overlay thickness remains one of the predominant factors for what concerns reflective cracking, even with the use of an interface system.
- crack and seating the concrete slabs before placing the overlay system showed to be highly efficient.
- the projects with steel reinforcing nettings where all rules mentioned above have been respected, performed very well even after more than ten years after repair.

For the monitoring of the long-term performance of the reinforced roads, visual inspection was done once or twice a year. The transverse length of the cracks was noted and the location of the cracks was related to the presence of joints or cracks in the concrete slabs underneath. It is important that the temperature during successive inspections is more or less equal.

B.8.6.2 Germany

Flow rutting

Within the frame of maintenance measures, a bus-stop in the city of Munich has been equipped with a steel reinforced asphalt pavement at the end of 1996 [19],[28]; the length was about 40 m. The pavement consists of 65 mm SMA 0/11 S including the steel net, on in total 260 mm of asphalt binder course layers. Each steel mesh (net) had a length of 6.45 m, a width of 2.95 m and a bar-diameter of 5 mm. It had been designed especially for this jobsite. The size of the mesh was 50 mm x 50 mm within the area of the wheel tracks and 100 mm x 100 mm for the “unloaded” sections, which meant a bar assembly in three layers. To ensure a sufficient depth of coverage of the steel net (total height of net is about 15 mm), the thickness of the surface layer was increased to 65 mm.

The installation of the net and the asphalt paving was done without any problems. After more than 8 years no damage has been observed, which might be due to the installation of the steel nets. From 1999 to 2001, measurements concerning the depth control of the reinforcement and repeated profile measurements to control the flow rutting development have been performed. The bus-stop is being frequented by about 140 line-operating busses per day. A scanning device usually used for steel reinforcement within conventional concrete structures has been calibrated on steel reinforced asphalt test specimens and has been used to control randomly the in-situ distance between asphalt surface and top edge of the steel nets. A mean value of 53 mm of coverage has been determined in which the minimum value was 30 mm. These results were verified by core samples, which additionally are showing a sufficient embedment of the steel mesh within the SMA wearing course. Only small voids have been visible at the cross-over points of the longitudinal and transversal steel bars of the net. The first measurements of the transversal profiles during the summer of 2000 resulted in a maximum depth caused by flow rutting of 7 mm, which was increased up to 9 mm as shown by the next measurement at the beginning of 2002.

Reflective cracking (road widening)

One section of the county road K80 near Trier was rehabilitated using the existing pavement. Improvement of the alignment was planned to be carried out by one-way or two-way widening measures. The old pavement is contaminated by tar (pitch) containing binders. This material had to remain within the existing pavement and was therefore covered by a steel reinforced asphalt overlay, including the road widening sections. The aim was to reduce costs and construction time at this county road, which is partly bordering a water protection zone. The test section with a total length of 3140 m has been built in the summer of 2001. A part with a length of 2300 m has been equipped with a steel net reinforcement and an unreinforced section with a total length of 840m had been placed for comparison reasons (to serve as a reference). On top of the cleared existing surface, the following layers were laid:

- 40 mm wearing course 0/11 S
- 40 mm binder course 0/16
- steel net reinforcement
- 100 mm asphalt base course 0/32 C

Details of the steel net reinforcement are:

- bar diameter 6.0 mm (BST 500 M)
- quadratic meshes 100 mm (weight of net: 56.3 kg/unit)
- length of net 2.3 m
- overlap about 0.3 m
- width of net 5.9 m

In total 1170 steel nets were installed. A first trial to pave the 40 mm thick binder course which is covering the steel net reinforcement by a 6 m wide paver equipped with tracks was not successful. After exchanging this machine by the originally foreseen 3 m wide wheel tracked paver no major problems occurred anymore. Cores which were taken within the regular quality control procedure showed proper bond. Below the knots (crossings of longitudinal and transversal bars) small cavities have been identified. During about 4 years of service life no unfavourable changes or distresses have been observed which might be connected with the usage of the steel nets.

B.8.6.3 Italy

The first experience with reinforcement of asphalt was obtained during the execution of the extraordinary works in 1998, to repair the Salmastro provincial roadway in the north-east of Italy. The underlying soil showed a very poor bearing capacity, also due to the increased weight of vehicles, compared to the original design, which caused differential settlements of the road and, in certain instances, could have meant unsafe traffic conditions. In the experimental phase, four different types of reinforced paving techniques were chosen: steel mesh (547 m), fibreglass mesh (498 m), polyester mesh (547 m) and finally a reference with no reinforcement. Due to the low bearing capacity of the underlying soil, the monitoring results showed an accelerated process of degradation: the reference section had to be repaired after one year. The sections with glass and organic meshes lasted without repairs for 4 years, while the steel reinforced section is still in good condition after 6 years. Monitoring will continue for the steel mesh section [19].

A significant highway section with medium-high traffic volumes in the north-eastern Italian network, the A23 (E55) from Palmanova to Udine shows a mean daily traffic of 15000 vehicles for each direction, 80% of the entire traffic takes place on the slow lane with values up to 95% for commercial and heavy vehicles. In 1999, the total length of test trial of about 600 meters was rehabilitated, split into three sections of about 200 m. In the first two sections the renewed base layers were reinforced with REFLEX-technology (at the bottom and in the middle of them), while the third section is unreinforced, for comparison purposes. Several measurements were performed with FWD and HWD-equipment, under different climatic conditions [19]. This span of time is of course not enough to evaluate the behaviour of the steel reinforced asphalt with respect to the increase of bearing capacity and the fatigue resistance; all sections still showed a good bearing capacity. In September 2004, five years after construction, the wearing course had to be renewed; this is common practice in this area. Apart from smoothness of the surface, no other defects were detected like cracking or rutting, so the decision was taken to lay the new wearing course directly on the existing road surface without any work in advance. Monitoring of this road will continue.

B.8.6.4 The Netherlands

The Dutch Road Administration (Rijkswaterstaat) decided to construct test sections using several types of reinforcement in the overlay of the motorway A50 in the summer of 1992. The 3.2 km long stretch of this 2x2 lane motorway (including emergency lane) showed extensive transverse reflective cracking. The road has a 400mm thick base consisting of cement stabilized sand (28-days compressive strength of about 8 MPa), which is resting on a sand subbase/subgrade. The pavement was constructed in 1971, using 160mm of asphalt surfacing on the cement treated base. The pavement was overlaid for the first time in 1981 by a 45mm thick overlay. The overlay of 1992 had a thickness of 50mm. The aim of the Regional Office Friesland of the Dutch Road Administration with the trials was to get an understanding of the effectiveness in the field of several (in total 5) new or commercially already available reinforcement products/systems which were claimed to delay or arrest crack propagation through a relatively thin asphaltic overlay (50mm). Before the construction of the overlay in 1992, an extensive set of measurements on crack movements (traffic as well as thermally induced), as well as very detailed crack inspections was carried out [12],[29]. From this work, it could be concluded that on this site reflective cracking due to temperature cycles was the dominant factor.

Figure B7 presents an overview of the long-term data as was available in 2005; 13 years after construction [30].

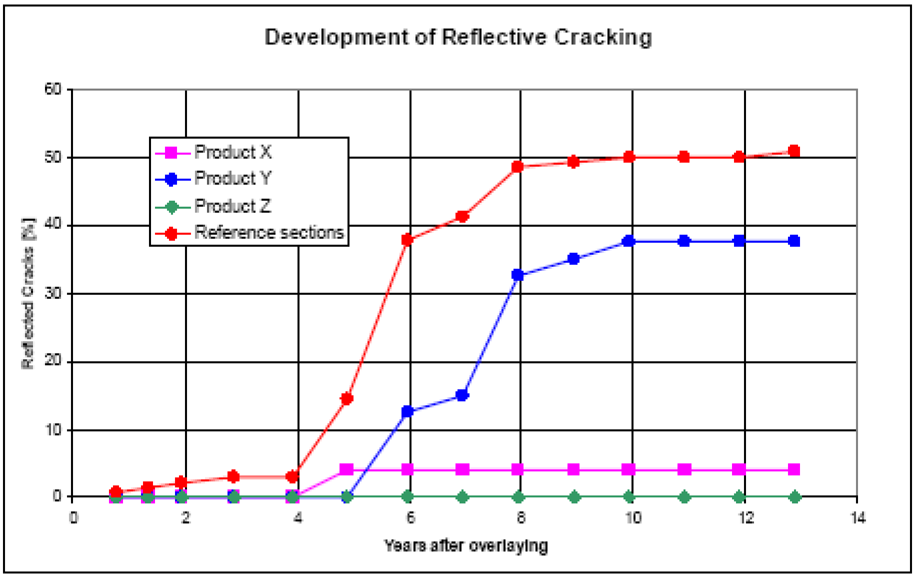


Figure B7: *Overview of Results Long-Term Crack Mapping Data [30]*

It can be observed that some reinforcement products/systems (all are grids) are more effective than others. This has to do with the reinforcement stiffness (in this case also under creep conditions) and the degree of pullout resistance. It is important to bear in mind that direct (1 to 1) use of this field data for other situations is only valid for cases where the type of loading is similar (see section 3.3); effect of temperature cycles dominant. Monitoring will continue on this site and the data will be utilized in future for the validation of computational tools. For this purpose extensive material characterization will be performed, so proper input for the simulations becomes available.

B.8.6.5 Sweden

Since the middle of the eighties of the past century, several test roads including steel fabrics have been constructed in Sweden within rehabilitation or maintenance schemes. In most cases the existing damage of these roads were cracks induced by frost heave. In the autumn of 1999, the Swedish National Road Administration started measuring the bearing capacity of some of these test trials by using an FWD. On some of these trials, the surface cross profiles were also measured with laser equipment. The objectives of the steel reinforced bituminous test sections were to increase the bearing capacity and to reduce flow rutting / frost cracking. All of the test roads have reference areas without reinforcement as a comparison [19]. The trials are situated at the E6 at Ljungskile (constructed in 1999), Road 600 at Sundom (constructed in 1999), the E6 at Fastarp-Heberg (constructed in 1996), Road 348 at Moliden (constructed in 1995), Road 771 at Hysta-Arkhyttan (constructed in 1992) and Road 42 at Koberg (constructed in 1989).

The comparison, with respect to bearing capacity, between a reinforced structure and a traditionally composed road structure is of particular interest in amongst others economical evaluations. Appropriate parameters for this kind of evaluation are essential for the cost-benefit analysis. The following was stated in the Swedish study [19]:

- experiences from field evaluations have shown that reinforcement of pavement layers is a very effective method to counteract frost heave cracks.
- the bearing capacity of the reinforced structure can be prolonged in comparison to the unreinforced structure when reinforcement is used in the appropriate way; this is in the lower part of the

- bound layers or in the unbound layers. Measured strains in the field are lower for the reinforced structures.
- results from FWD-measurements might not provide reliable results in measuring the bearing capacity of a reinforced structure; at least shortly after construction.
- in several test sections it was observed that rut developments are smaller in structures with the steel fabric than in the reference structures.

In-situ strain measurements were carried out at a highway road section on E6 at Ljungskile in the Southwest of Sweden [25]. This road was seriously damaged due to a low bearing capacity. A trial has been made to design the road structure with steel fabric reinforcement in the asphalt concrete. Three full-scale, 100-meter long test sections were built. Two test sections were reinforced with steel fabrics and one section without reinforcement as a reference road section. These sections are instrumented with strain gauges. Strain measurements at the bottom of the asphalt overlays, strain on the steel bars, unevenness/rut depth measurements and manual distress surveys were conducted. The objective is to evaluate the long-term performance of rehabilitated road structures reinforced with steel fabric.

Figure B8 shows the average of the results from the strain measurements at a load level of 30, 50 and 63 kN in the autumn of 2003. Strain measurements at the bottom of the asphalt layers are showing much lower tensile strains in the reinforced test sections than in the reference section. The differences are increasing with increasing load level.

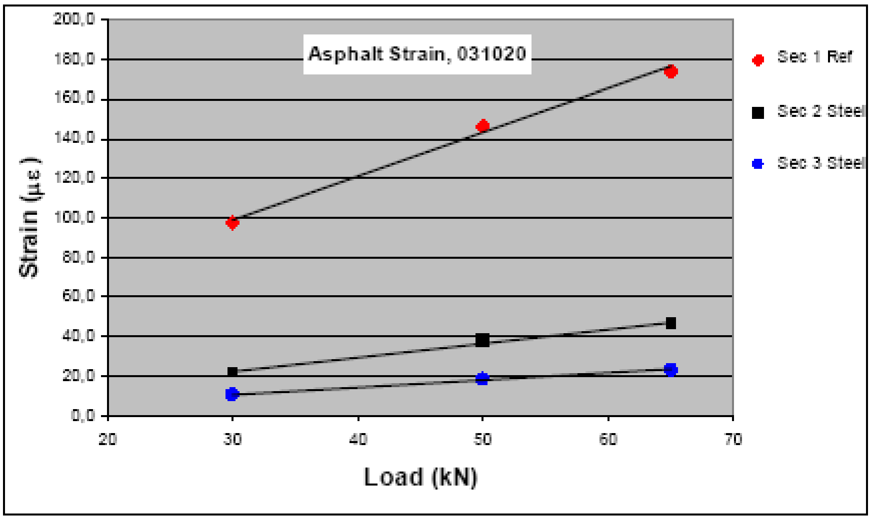


Figure B8: *Measured Strains in Asphalt at different Load Levels in the Field [25}*

Figure B9 shows the average of the results from the strain measurements relative to the strain in the reference section at a load equal to 30 kN. It can be observed that the differences between the reinforced and the reference sections are increasing with time, which indicate that the effectiveness of the steel fabric in improving the bearing capacity of the road is increasing in time.

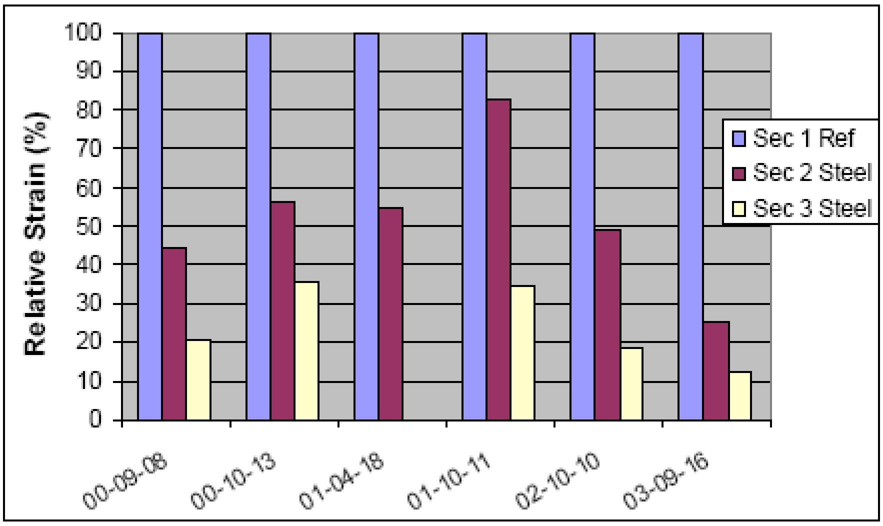


Figure B9: *Development in Time of Measured Effect of Presence of Steel on Strains [25}*

B.9 Steel Mesh / Geosynthetic Benefits in Literature

In order to complete the recent (up-to-date) picture given above, a literature survey has been carried out by de Bondt [31], by going through the proceedings of the different RILEM Conferences on Reflective Cracking [9], with the goal to find (old) long-term field performance data.

Below the results are summarized:

1989 Liège:
Page 249: After 6 years a new asphalt overlay on a road with a geotextile in Montreal showed 11 % reflective cracking, whereas the reference structure (without geotextile) showed 21 % cracking.
Page 436: In a study in France on the behaviour of semi-rigid pavements (asphalt on cement treated bases), it was found that the geotextile section showed 25 % reflective cracking after 6 years,

whereas the reference sections showed 50 % cracking.

1993 Liège:

Page 353: After 4 years the asphalt overlay on this French semi-rigid pavement, which included a geotextile showed 15 % reflective cracking, whereas on the reference structure 35 % of the old cracks were visible.
Page 360: After 5 years crack counting on a UK semi-rigid pavement, 35 % of the cracks in a reinforced section (polypropylene geogrid) were present and 60 % in the reference section.
Page 413: Ten years after overlaying a semi-rigid pavement in France, the section with the geotextile showed 40 % reflective cracking and the control section 65 %.

1996 Maastricht:

Nothing reported.

2000 Ottawa:

Page 537: In a Portuguese study it was found that 10 years after construction of a semi rigid pavement, the geotextile section showed only 1/5 of the transverse cracking of the control section.

2004 Limoges:

Page 435: Field investigations at two sites in the USA showed that after 6 years, fibreglass (100 kN/m strength) reinforced semi-rigid (composite) pavement sections showed 5, respectively 10 % reflective cracking, whereas the corresponding control sections showed 38, respectively 28 % cracking.

Conclusion

The application of geotextiles in asphalt overlays implies in the long run a reduction of the degree of reflective cracking by a factor of roughly 2. In case of reinforcing grids the effectiveness is higher. However, quantifying this effect is not yet really possible, because there are lots of products which differ enormously and a widespread database with long-term data is not available (yet).

B.10 Conclusions and Recommendations

From the work carried out by the COST-members, it can be concluded that:

- a (small) number of methods / procedures exist for the design of pavements with steel meshes / geosynthetics in the unbound granular base layers and/or in the asphalt layers.
- no generally accepted design method / procedure is available, which is accessible for everyone; this is however also true for so-called reference pavement structures (without steel mesh / geosynthetic).
- no design method / procedure has been found yet, which is covering all types of loading, can do predictions for all cases which can occur in the field and which has been validated to the extent, which is required (with long-term field data).

- steel meshes and geosynthetics have proved to work in the long run (based on field experience of up to roughly 15 years). Depending on the nature of the product, the effectiveness is due to different functions: separation, barrier (for water penetration), stress-relief and reinforcement.

It is recommended:

- to put more scientific effort into creating and testing user-friendly generic design tools.
- to start collecting much more long-term field data. This should then be performed in a more uniform way and detailed enough so that the data can be utilized for the validation of future (analytical) design tools.
- to build instrumented roads, in order to avoid the necessity to also build reference sections without steel mesh / geosynthetics. The latter is often not possible from the road owner's responsibility point of view.
- to bring into (daily) pavement engineering practice the design tools which have become available recently; e.g. via (COST) seminars. This will stimulate road authorities and consultants to select more often cost-effective solutions with steel meshes or geosynthetics, rather than always going for the traditional approach.

References

1. ISO/FDIS 10318:2005 (final draft) Geosynthetics – Terms and their definitions.
2. IGS: Recommended Descriptions of Geosynthetics – Functions, Geosynthetics Terminology, Mathematical and Graphical Symbols, version August 2000 (downloadable via http://www.geosyntheticssociety.org).
3. Geotextiles and geotextile-related products - Requirements for use in pavements and asphalt overlays. Draft of CEN-TC189 WG1a, February 2004.
4. J. Steward, R. Williamson and J. Mohney. "Guidelines for Use of Fabrics in Construction and Maintenance of Low-Volume Roads". USDA Forest Service, Portland, Oregon, June 1977.
5. P. Kolisoja, et al. "Use of Steel Reinforcement in Unbound Pavement Layers" BCRA'02.
6. S. Perkins, B. Christopher, E. Cuelho, G. Eiksund, I. Hoff, C. Schwartz, G. Svanø and Watn. "Development of Design Methods for Geosynthetic Reinforced Flexible Pavements". FHWA, Report Number DTFH61-01-X-00068, 2004.
7. NCHRP (2003), "Development of NCHRP 1-37A Design Guide, using Mechanistic Principles to Improve Pavement Design", http://www.trb.org/mepdg.
8. G. Eiksund. "Overview of Reinforcement Benefits in Unbound Granular Bases", 2004.
9. RILEM Conferences on Reflective Cracking, 1989/1993/1996/2000/2004.
10. A. Hilmer. "Einfluss der Radlasten und Reifeninnendrücke auf die Spurrinnenbildung an Asphaltstraßen" (in German). Mitteilungen des Prüfamtes für Bau von Landverkehrswegen der Technischen Universität München, Heft 43, 1984.

11. U. Neumann. “Auswirkung unterschiedlicher Bereifung von Nutzfahrzeugen auf die Spurrinnenbildung von bituminösen Decken” (in German). Mitteilungen des Prüfamtes für Bau von Landverkehrswegen der Technischen Universität München, Heft 63, 1991.
12. A. de Bondt. “Anti-Reflective Cracking Design of (Reinforced) Asphaltic Overlays”. Ph.D.-Thesis, Delft University of Technology, 1999 (see http://www.ooms.nl/adebondt/adbproef.html).
13. M. Jacobs. “Cracking in Asphaltic Mixes”. Ph.D.-Thesis, Delft University of Technology, 1995.
14. A. de Bondt. “Effect of Reinforcement Properties”. 4th RILEM Conference on Reflective Cracking, Ottawa, 2000.
15. T. Brooker, M.D. Foulkes and C.K. Kennedy. “Influence of Mix Design on Reflection Cracking Growth Rates through Asphalt Surfacings”. 6th International Conference on the Structural Design of Asphalt Pavements, 1987.
16. A. de Bondt, J. Schrader, W. van Bijsterveld and D. Long. “Scientific Background of ARCDESO® - version April 2005”. Internal Report - Ooms Nederland Holding.
17. A. Vanelstraete, D. Leonard, J. Veys. “Structural Design of Roads with Steel Reinforcing Nettings” - RILEM pro11, Ottawa, 2000.
18. BRRC - Research reports EP5035/3544-3560-3744-3239.
19. Final Report REFLEX EU-project: http://www.vti.se/reflex (status December 2005).
20. S. Nesslauer. “Untersuchungen zum Verformungs- und Tragverhalten bewehrter Asphaltstraβen” (in German). Mitteilungen des Prüfamtes für Bau von Landverkehrswegen der Technischen Universität München, Heft 77, 2003.
21. N. Thom. “A Simplified Computer Model for Grid Reinforced Asphalt Overlays” – RILEM pro11, Ottawa, 2000.
22. Geosynthetic Materials Association - USA, Handbook of Geosynthetics, January 2002, website: www.gmanow.com.
23. E. Steen. “Stress-Relieving Function of Paving Fabrics when used in New Road Constructions”, 5th RILEM Conference on Cracking in Pavements, Limoges.
24. J. Vicelja, “Pavement Fabric Interlayers, Benefits – Construction - Experience”, 1st RILEM Conference on Reflective Cracking in Pavements, Liège, 1989.
25. S. Said, H. Zarghampour, S. Johansson, H. Hakim and H. Carlsson. “Evaluation of Pavement Structures Reinforced with Steel Fabrics”, BCRA Conference 2002, Lisbon.
26. W. van Bijsterveld and A. de Bondt. “The Jointless Transition Overlay”, 2005.
27. A. Vanelstraete and J. de Visscher. “Long-Term Performance on Site of Interface Systems”. RILEM Conference on Cracking, Limoges, 2004.
28. G. Rubner. “Bewehren von Asphaltdecken” (in German). VSVI-Seminar, 1998 - München.
29. A. de Bondt and K. Saathof. “Movements of a Cracked Semi-Rigid Pavement Structure”. 2nd RILEM Conference on Reflective Cracking, Maastricht, 1996.
30. A. de Bondt, A. Wierda, H. Schotanus, K. Saathof and W. van Bijsterveld. “Long-Term Performance of the A50 (A6) Reinforcement Trial Sections”, 2006/2007 (under preparation).

31. A. de Bondt. “Review RILEM-Proceedings on Reflective Cracking”, 2005.

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