THEORY AND PRACTICAL EXPERIENCES IN PAVEMENT REHABILITATION USING ASPHALT REINFORCEMENT GRIDS

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Abstract: *The conventional method for rehabilitation of cracked asphalt pavements is the installation of new asphalt layers. This resurfacing is often not an effective solution, as the existing cracks in the old asphalt layers can rapid propagate to the top of the new overlay. In order to delay the development of reflective cracks, asphalt reinforcement grids have shown outstanding results in addressing the issue of crack propagation, eliminating or delaying the damage caused by water intrusion. Through basic theory and practical experiences this paper will demonstrate the success and extended pavement life that can be achieved by using asphalt reinforcement grids in highway applications. Special attention is given to the performance on site, e.g. the loss of tensile strength due to the paving procedure and the importance of using alkali-resistant materials when in direct contact with concrete or cement stabilized materials. The increased pavement life achieved by the use of this technology not only prevents excessive disruption to traffic flow and local business, but it also demonstrates strong environmental and economic benefits.*

Keywords: *asphalt reinforcement grid, pavement rehabilitation, reflective cracking.*

1. INTRODUCTION

Geosynthetics have been used all over the world for more than 40 years to delay or even prevent the development of reflective cracks in asphalt layers. Using asphalt reinforcement can clearly extend the pavement service life and therefore increase the maintenance intervals of rehabilitated asphalt pavements [1, 2]. This increase in pavement life does have the positive effect that not only the maintenance costs per year but also the amount of energy used for the maintenance can be significantly reduced. The need for sustainable designs and construction methods is now appearing more and more in corporate and social responsibility statements and could eventually become a criterion for the selection of construction methods.

Therefore the use of appropriate asphalt reinforcement should ideally be considered for future maintenance and rehabilitation surfacing contracts on bound pavements, which have a history of cracking at surface. Currently there are a number of different products and systems made of different raw materials (e.g. polyester, glass fiber, polyvinyl alcohol, carbon fiber, polypropylene) available in the market. It is not disputed that each of these systems has a positive effect in the battle against reflective cracking [3, 4]. However, there are differences in the behavior and effectiveness of each system.

The objective of the paper is to provide the reader sufficient information to introduce the concepts of using appropriate asphalt reinforcement geosynthetics in the rehabilitation or maintenance of bound road surfaces. Additionally typical applications and limits for the use of asphalt reinforcement, described by basic theory and practical experiences, will be demonstrated.

2. MECHANISMS OF REFLECTIVE CRACKING

Reflective cracking consists on the propagation of cracks from a deteriorated layer to the surface of a new overlay and is the major modes of failure in rehabilitated pavements [5]. It is well known that cracks appear due to external forces, such as traffic loads combined with temperature variations. The temperature influence leads to the binder content in the asphalt becoming brittle, so that cracking starts at the top of a pavement and propagates down (top-down cracking). On the other hand, high stresses at the bottom of a pavement from external dynamic loads lead to cracks that propagate from the bottom to the top of a pavement (bottom-up cracking).

When a wheel load passes over the road construction, localized bending and shear stresses appear on the existing crack and cause the origin and further development of cracks [1, 4]. The shear action occurs twice by each load application, while the bending action occurs only once (Figure 1).

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Shear action (+) Bending action Shear action (-)

Figure 1. *Critical loading cases in a pavement crack*

A conventional rehabilitation of a cracked flexible pavement involves milling off the existing top layer and installing a new asphalt course, but cracks are still present in the existing (old) asphalt layers. As a result of the horizontal and vertical movements at the crack tip, the cracks will propagate rapidly to the top of the rehabilitated pavement.

In a similar case, deteriorated concrete pavements are typically rehabilitated by installing new asphalt layers over the old concrete slabs. The temperature variations lead to a rapid crack propagation especially at the expansion joints to the top of the new asphalt overlay. As summary, it can be stated that simple hot mixed asphalt (HMA) overlays are not cost-effective against reflective cracking [5].

In order to delay the propagation of cracks into the new asphalt layers, there are several techniques to rehabilitate cracked pavements. However, one of the most popular method among new techniques recommended is the use of interlayer systems between the old pavement and the new overlay, such as geosynthetics [6].

3. ASPHALT REINFORCEMENT GRIDS

The main function of geosynthetic products used in the construction and rehabilitation of roads and pavements is to reduce the amount of cracking in a new pavement or asphalt overlay. This can be achieved by reinforcement, stress relief and/or interlayer barrier [7]. Certain geosynthetics only perform a single function and others can perform several functions from a single product.

Basically, there are three types of geosynthetics designed for pavement rehabilitation: geotextiles (nonwovens), geogrids (grids) and geocomposites. While the stress relief function concerns to soft products (as nonwovens) to dissipate strain energy by deforming itself, the reinforcement function regards stiff products (as grids) to compensate the lack of HMA's tensile strength [5]. In providing reinforcement, the grid structurally strengthens the pavement section by changing the response of the pavement to loading [8]. The reinforcement increases the resistance of the overlay to high tensile stresses and distributes them over a larger area, thereby reducing the peak shear stresses at the edges of the cracks in the existing old pavement. The reinforcement also provides a normal load to the crack surfaces, thereby increasing the aggregate interlock (shear resistance) between both crack surfaces and thus increasing the resistance to reflective cracking.

Many products have been promoted as a reinforcement when in fact these products serve only a separation, moisture barrier, function. Designers should have a clear understanding of the limitations all the different asphalt interlayer products offer in terms of position and stress-strain characteristics within the pavement structure [13].

With the purpose of analyze and quantify the improvement of the crack resistance when using an asphalt reinforcement, several studies have been developed during the last decades.

Montestruque [1] performed at the Aeronautics Technological Institute in Sao Paulo in Brazil a full testing program to evaluate crack reflection potential. An asphalt wearing course was applied over an existing crack and both the bending mode and the shear mode were investigated under dynamic fatigue loading conditions. Moreover, numerical simulations were performed using the Finite Element Method (FEM) to interpret the results obtained from the tests. The results indicate that a bitumen coated polyester grid considerably delayed the through-penetration of cracks generated due to shear stresses and bending stresses. Compared to the unreinforced material, the reinforced asphalt layer was subjected to up to 6.1 times the number of dynamic loading cycles before a crack reached the surface. The crack pattern clearly shows that the reinforcement takes up and distributes the tensile forces (Figure 2). The numerical simulation allowed a better understanding of the crack propagation mechanism observed in the laboratory. The asphalt reinforcement grid absorbs part of the applied load, interrupting the propagation of the reflective crack. Once the reflective crack problem is controlled, the durability of the overlay and the appearance of new cracks became a function of the asphalt concrete fatigue characteristics.

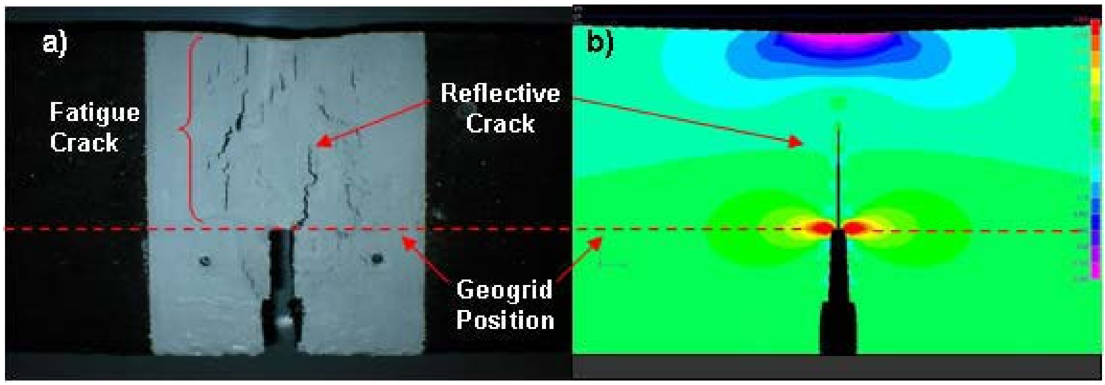

Figure 2. *Comparison between the laboratory and the numerical simulation results [1]*

Norambuena-Contreras et al. [4] tested eight different types of geosynthetics used as anti-reflective cracking systems. The reflective cracking test results showed that the use of a geosynthetic produced a reduction on the average crack opening in all cases evaluated. Nevertheless, it was found that geosynthetics that present high tensile strength do not necessarily present a high contribution on retarding the crack propagation in asphalt pavements. Additionally, it has been seen that the resistance to deterioration of materials that composes geosynthetics is a more decisive factor on their subsequent behavior than the material itself.

As found by De Bondt [12], the bonding of the material to the surrounding asphalt plays a critical role in the performance of an asphalt reinforcement. If the reinforcement is not able to sufficiently adopt the high strains from the peak of a crack, the reinforcement cannot be effective. In his research, de Bondt determined an equivalent "bond stiffness" in reinforcement pull-out tests on asphalt cores taken from a trial road section. The equivalent bond stiffness of a bituminous coated polyester grid was found to be the best of all the commercial products investigated.

4. BS EN 15381 AND REQUIRED CHARACTERISTICS

The European Standard BS EN 15381 *"Geotextiles and geotextile-related products - Characteristics required for use in pavements and asphalt overlays"* [7], specifies the relevant characteristics of a geosynthetic for the Declaration of Performance (DoP) and CE-marking. According to the function of the product – reinforcement, stress relief or interlayer barrier – specific characteristics have to be declared. This standard can also be used by designers to define which product functions and conditions of use should be considered in the project, when using asphalt reinforcement grids.

4.1. Tensile strength

The BS EN 15381 [7] specifies that the tensile strength of asphalt reinforcement grids should be carried out according to the EN ISO 10319 *"Geotextiles – Wide-width tensile test"*. If this method is not suitable for a certain product type, it can be tested using a different standard. However, the tensile strength shall be always performed on finished products.

4.2. Installation Damage

According to the BS EN 15381 [7], damage during installation of an asphalt reinforcement grid is influenced by the paving procedure and by the compaction of the asphalt. After an asphalt reinforcement product is placed, many asphalt delivery trucks may have to pass over the grid. Additionally there is the compaction of the hot mix asphalt, during which the individual filaments or strands of the asphalt reinforcement are largely influenced by the movement of aggregates, in particular of coarse and sharp-edged aggregates. Next to the reinforcement characteristics (flexible or brittle raw materials), the degree of installation damage by roller compaction not only depends on the number of passes and the type of compaction (e.g. rubber tired, static, dynamic). The degree of installation damage is additionally influenced by the weight of the compactor and the condition of the base layer (e.g. smooth, rough or milled).

To successfully counteract reflective cracking, placed reinforcement products must resist the installation influences without damage and as much as possible without serious loss of strength. A detailed research was carried out by the RWTH Aachen University in Germany [9] to analyze and quantify the residual tensile strength of asphalt reinforcement grids after the influence of installation damage. Site tests were performed and two asphalt reinforcement products with different raw materials (polyester and glass fiber) were tested.

The results showed, that the potential of installation damage on asphalt reinforcement materials can vary depending upon the adopted product (Figure 3). The polyester grid lost max. 30% of its tensile strength after loading from truck passes and asphalt compaction. In contrast to this the glass fiber grid showed a loss of strength up to approx. 90%. This revealed that brittle raw materials can be damaged significantly more compared to a polymer grid reinforcement.

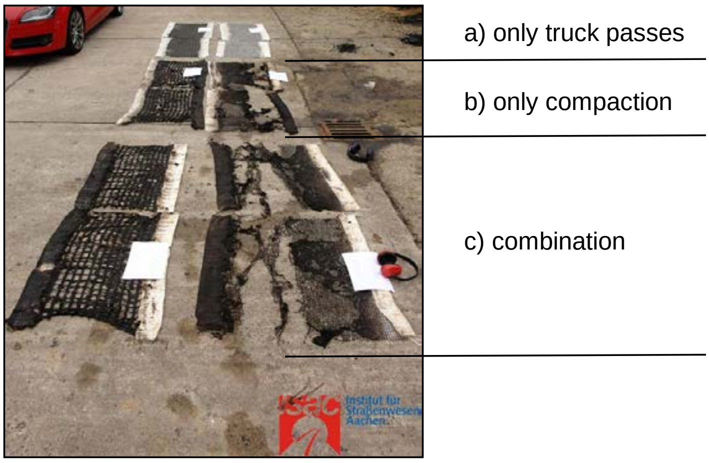

Figure 3. *Results of installation damage test (left: polyester grid; right: glass fiber grid)* [9]

Due to this good resistance to mechanical influences, polymer materials can be installed directly on milled surfaces. In contrast, fiber glass grid products usually require an asphalt levelling layer before the installation.

To summarize, all asphalt reinforcement undergoes installation damage caused by the combination of different activities during the pavement construction. This damage has the effect of reducing the available post-construction strength of the reinforcement and, subsequently, it is important to know the residual strength of a product. Installation damage can be simulated by the use of the testing procedure detailed in BS EN ISO 10722 [10].

4.3. Durability

The durability of an asphalt reinforcement grid, i.e. its resistance to chemical degradation, will depend mostly on the type of raw material that is used and on the environment conditions. The standard BS EN 15381 [7] specifies some important durability aspects, such as weathering, alkaline resistance and melting point, which should be considered when using asphalt reinforcement grids.

If a product is to be used in direct contact with an unprotected concrete or cement stabilized surface, alkaline resistance is needed. For example, grids made of polyvinyl alcohol (PVA) have a high strength and stiffness and a good resistance to alkalis, lower concentrations of acids, and oils. Otherwise, glass fiber grids are sensitive to hydrolysis and when exposed to concrete, progressive loss of stiffness and weakening of the grid can be expected [11].

Regarding the material stability, polymer products must have a higher melting point than the temperature of the installed asphalt. According to Norambuena-Contreras et al. [4], the resistance to deterioration and installation damage of materials that composes geosynthetics is the most decisive factor on their subsequent behavior in the pavement rehabilitation.

5. PRACTICAL EXPERIENCES

The following projects shall give an example of the successful use of asphalt reinforcement in roads.

5.1. Municipal Road Rosenstrasse, Ochtrup (Germany)

The municipal road Rosenstrasse is located in the northwest German town of Ochtrup and is a highly trafficked road. The majority of vehicles are trucks, because the road is one of the main connections to the nearby border of the Netherlands. In 1996, before rehabilitation, the road revealed severe alligator cracking, longitudinal and transverse cracking in large scale. The original design, and budget, called for milling the surface, approx. 50 mm, and installation of a new 50 mm asphalt surface course. Due to the problematic condition of the existing base the expected lifetime of the new surface was just 2 years (Figure 4).

The more durable (but also more expensive) solution was to take up the cracked binder and base course. An alternative solution to the foresaid was the installation of a high modulus polyester grid as asphalt reinforcement over the cracked binder course, in which the thickness of the new wearing course should remain 50 mm. Hence, the economic advantage had to be proven by a longer lifetime, which should be the main goal in most of the applications. The layers shall have the standard thickness, the economic advantage then results from the longer lifetime of the surface over the old cracked area.

After milling off the 50 mm surface course a polyester grid as asphalt reinforcement was installed, and covered again with a 50 mm 0/11 AC asphalt layer. The whole project was finished in summer 1996. In the years 2002, 2009 and in context of a masters-thesis in 2013, a visual assessment of the road condition was carried out.

5.1.1 Assessment in June 2002

Six years after the repairs were carried out, the Steinfurt District's Chief Executive was asked for a condition report on the Rosenstrasse. In his answer, the responsible clerk commented as follows: "(…) I'm happy to inform you that the repairs at the time to Kreisstrasse 57, Rosenstrasse, using HaTelit® have fully stood the test of time. The use of the asphalt-reinforcement system under the 0/11 asphalt layer has meant that, to this day, no cracks have appeared in the asphalt-concrete surface. This method was chosen at the time to avoid the necessity for replacing the cracked binder and base course (...)"

5.1.2 Assessment in September 2009

With the permission of Ochtrup municipality, the TÜV Rheinland LGA Bautechnik GmbH was commissioned to record the cracking and assess the condition of Rosenstrasse along the length repaired in 1996. The appraisal also compared the current condition with the condition that existed before repairs were carried out in 1996. This comparison permitted conclusions to be drawn about whether the use of the asphalt-reinforcement system was able to delay the occurrence of cracks propagated from the lower courses.

On August 24th 2009, a visual inspection was undertaken in accordance with Working Paper No. 69 by the “Forschungsgesellschaft für Straßen und Verkehrswesen” (FGSV: Research Association for Road and Transport in Germany). The LGA used the image documentation of the construction measures prepared in May 1996 as the basis for its assessment. The District's Chief Executive employed by the Steinfurt District at the time also provided additional necessary information.

After 13 years of use, the cracking condition value (ZWRIS) for the section of the road repaired with the polyester asphalt reinforcement in 1996 was determined as being excellent. According to the LGA, the visual inspection of the road surface revealed almost no damage to the substance. Two repair sites were recorded over the entire section; these, however, were due to work carried out on the drainage system. Only a few lateral cracks were discovered on the outer edge of the built-up road.

5.1.3 Site investigation and assessment in March 2013

In context of the visual assessment in 2013, cracks and settlements in the border area of the road and at some manholes and gullies have been identified (Figure 6). The cause of the cracking lies most likely in the fact that the compaction of underlying layers has not been properly carried out. The redensification of these areas by the traffic loads has led to the cracks at the road surface (Figure 7).

To further investigate the condition, two drill cores have been taken. At one core, the interlayer bond according to Leutner had been checked. Between the asphalt bearing course - Polyester reinforcement - and upper asphalt layer a maximum shear force of 24 kN was measured. The German guideline for asphalt works – ZTV Asphalt-StB 07 – demands a minimum value of 12 kN, so this demand had been fulfilled. After evaluating the whole data record of the Rosenstrasse it was found, that the condition, after a lifetime of 17 years, was still very good (Figure 5).

Figure 4. *Condition after milling in May 1996*

Figure 5. *Condition in March 2013*

Figure 6. *Cracking resulting from road works*

Figure 7. *Repair works at the road edge in 1996*

5.2. E75 Rehabilitation, Belgrade (Serbia)

The dual carriageway E75 is one of the most important highways of Serbian road infrastructure. In 2010, the asphalt overlay of a section in Belgrade had become damaged by reflective cracking, likely caused by the cracking of the cement stabilized base (Figure 8). Cement stabilized layers provide excellent support for asphalt surfaces, however, it can lead to shrinkage cracks, which reflect through the asphalt surface.

Figure 8. *Reflective cracking from cement stabilized base*

For this reason, the rehabilitation works designer specified an asphalt reinforcement grid to be incorporated into the new bituminous layers to mitigate any future propagation of reflective cracks through the new asphalt layers. The chosen reinforcement material was a polyester grid.

The exisiting pavement comprised of base, binder and wearing courses. The top two layers were removed to a depth of approximately 150 mm by milling. The milled surface was then brushed clean and a polymer modified emulsion was evenly sprayed onto the milled surface (in accordance with the manufacturer's installation guidelines). After the emulsion had been left to 'break' the installation of the polyester grid was carried out by unrolling the material over the emulsion and then rolling with a light tandem roller. After this the new asphalt layer could be placed directly onto the asphalt reinforcement grid (Figure 9). The road rehabilitation was carried out in July 2010.

Figure 9. *Asphalt placement on HaTelit*

Figure 10. *E75 pavement condition in 2016*

Almost six years after the rehabilitation, the reinforced area in the highway E75 still does not show any indication of cracking (Figure 10). The use of a polyester grid prevented the propagation of reflective cracks developing from the cement stabilized base, proving to be an effective solution. The technique of introcucing a polymeric reinforcement into bituminous pavements has been demonstrated to extend the working life of asphaltic pavements by up to three times. It is therefore anticipated that a similar benefit is expected to be achieved on this project. This will help to minimise any traffic diversions and disruption caused by this type of remedial work, as well as reducing future maintenance costs.

6. LIMITS IN USING A REINFORCEMENT GRID

There are limits in using asphalt reinforcement, with no system available on the market able to increase the bearing capacity. In most cases, the expectation of strength or bearing capacity improvements from the use of these materials is unrealistic [13]. The pavement structure must have sufficient bearing capacity to carry the future traffic loading, alternatively it has to be replaced or strengthened. When having a poor quality subgrade, it is necessary to carry out other measures, e.g. base reinforcement or increasing the pavement thickness. Morevoer, the integrity of the surfacing must be adequate to support the asphalt reinforcement without disintegrating.

It is generally difficult to prevent crack propagation resulting from large vertical movements (e.g. concrete slabs which are not stable in their position, frost heave), even when using an asphalt reinforcement system. At some point a reinforcement can become unnecessary. In such cases it is therefore necessary to eliminate, respectively minimize, the movements prior the installation of a reinforcement grid and the new asphalt layers (e.g. undertake injection below the slabs, or “crack and seat” the slabs to achieve a stress relief).

Although there are a number of laboratory tests, research modeling and trials showing the effectiveness of asphalt reinforcement grids, it is important to understand the possible causes of existing cracks and other pavement distress. Maintenance or rehabilitation should only be instituted once the correct mechanisms that lead to failure / distress have been identified.

7. CONCLUSIONS

Reflective cracking can occur in cracked pavements rehabilitated with a simple asphalt overlay. To delay the development of reflective cracks, an asphalt reinforcement grid can be placed before the new asphalt wearing course. In order to choose the proper product for a road rehabilitation, construction conditions and material characteristics must be chosen taking into account.

The presented case studies have showed that the use of an asphalt reinforcement in pavement rehabilitation can be advantageous. Based on the observed performance, it is possible to conclude that the asphalt reinforcement is an effective treatment against reflective cracking in asphalt overlays, resulting in an extension of the service life of a rehabilitated pavement.

References

[1] Montestruque, G. E., 2002. *Contribuição para a Elaboração de Método de Projeto de Restauração de Pavimentos Asfálticos Utilizando Geossintéticos em Sistemas Anti-Reflexão de Trincas* (in portuguese). Ph.D.-thesis, Technological Institute of Aeronautics, São José dos Campos, Brazil.

[2] Monser, C. A., Montestruque, G. E., Silva, A. E. F., 2010. Evaluation of an airport pavement after almost 8 years of overlay rehabilitation with a polyester geogrid asphalt reinforcement. Proceedings of the 9th International Conference on Geosynthetics, Brazil.

[3] Vanelstraete, A., Francken L., 1996. Laboratory testing and numerical modelling of overlay systems on cement concrete slabs. Proceedings of the Third International RILEM Conference, Maastricht, Netherlands.

[4] Norambuena-Contreras, J., Gonzalez-Torre, I. 2015. Influence of geosynthetic type on retarding cracking in asphalt pavements. Construction and Building Materials, 78: 421-429.

[5] Elseifi, M. 2015. Presentation 2: Mitigation strategies for reflective cracking in pavements. TRB Webinar – Mechanisms and Mitigation Strategies for Reflective Cracking in Rehabilitated Pavements (August 24, 2015).

[6] Nejad, F. M., Asadi, S., Fallah, S., Vadood, M. 2016. Statistical-experimental study of geosynthetics performance on reflection cracking phenomenon. Geotextiles and Geomembranes, 44: 178-187.

[7] BS EN 15381:2008. Geotextile and geotextile-related products – Characteristics required for use in pavements and asphalt overlays.

[8] Koerner, R. M. 2012. Designing with Geosynthetics. Xlibris Corporation.

[9] Sakou L., 2011. *Überprüfung der Wirksamkeit von Asphaltbewehrungssystemen unter Berücksichtigung der Einbaubedingungen* (in german). Diploma Thesis, RWTH Aachen, Institute of Road and Traffic Engineering.

[10] BS EN ISO 10722:2007. Geosynthetics. Index procedure for the evaluation of mechanical damage under repeated loading. Damage caused by granular material.

[11] CUR Building and Infrastructure, 2012. Durability of geosynthetics – Publication 243. Netherlands.

[12] De Bondt, A.H., 1999. *Anti-Reflective Cracking Design of (Reinforced) Asphaltic Overlays*, Ph.D.-thesis, Delft, Netherlands.

[13] Asphalt Academy, 2008. *Technical Guideline: Asphalt Reinforcement for Road Construction*. TG 3, First Edition, South Africa.