Functionality, effectiveness of the asphalt reinforcement grid made of polyester and requirements of the construction sites based on project examples in Africa.

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ABSTRACT
The demand for increased mobility on the African continent has been steadily growing over the years. The heavy traffic loads plays a considerable role on the lifetime of road pavements. Influenced by the interests of increasing economic development of a region / country has resulted in significantly increased traffic volumes. This growth is noticeable not only in urban, but also in rural areas. New regions have been developed and/or have gained in economic importance, which adds additional stress to the existing road network. In addition to the higher dynamic loads, climatic influences also play an important role and contribute to the formation of cracks and deformations in the existing roads. Despite the financial constraints, the existing road network must be gradually adapted to these new increased loads and associated stresses. The maintenance/rehabilitation of the existing road network is of central importance for the extension of the usability and service life of asphalt and concrete roads.
For over more than 40 years, the use of appropriate asphalt reinforcement geogrids manufactured form polyester, has been one of the most beneficial options for the rehabilitation of existing roads.
This article provides an overview of the requirements, the functionality and the effectiveness of the asphalt reinforcement to delay and partially prevent the propagation of reflective cracks, as well as the extension of the maintenance intervals and the associated cost savings over the period of use, not to mention increased sustainability. This paper includes practical examples of construction projects in Africa and the important requirements for the correct installation of the asphalt reinforcement.

1. INTRODUCTION

Since the end of the 60´s, and in order to delay or even to prevent the development and propagation of reflective cracks, Asphalt reinforcement grids have been used in several projects over the world. A number of different products and systems made of different raw materials (e.g. polyester, glass fibre, carbon fibre and polypropylene) are available on the market. Depending on the projects conditions and respectively on the rehabilitation variant, each of these systems has a positive effect in confronting against reflective cracking. However, there are some differences in the behaviour and effectiveness of each system.

Figures 1 and 2 – Installation of Asphalt reinforcement grid "End of the 60´s"

The main positive effects of using asphalt reinforcement grids are the extension of the pavement service life and also to decrease the maintenance expense of the rehabilitated asphalt pavement (large Intervals). [Montestruque, 2002; Monser et al., 2010]. The associated effects e.g. Maintenance costs and Amount of energy can be significantly reduced. Environmental and climatic protection is gaining an ever increasing importance, the road construction industry may therefore benefit from adopting these solutions in order to assist in tackling climate change. 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.

2. REFLECTIVE CRACKS; ONE OF THE COMMON CAUSES OF ASPHALT DAMAGE

One of the major problems associated with the use of asphalt pavements is reflective cracking. This phenomenon is commonly defined as the propagation of cracks from an existing damaged pavement or base course into and through a new asphalt overlay, resulting from load-induced and/or temperature-induced stresses.

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. The shear action occurs twice by each load application, while the bending action occurs only once (Figure 3).

Figure 3 – Critical loading cases in a pavement crack

The temperature influences additionally the asphalt behaviour due to its impact on binder content, which leads start cracking at the top of a pavement and propagates downward (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).

3. ASPHALT REINFORCEMENT INTERLAYERS

In order to delay the propagation of cracks into the new asphalt layers, there are several techniques available for rehabilitation of cracked pavements, such as modify the mechanical properties of the overlay or place a stress-relieving system. However, one of the most popular methods amongst new techniques recommended is the use of interlayer systems between the old pavement and the new overlay, such as Geosynthetics (Nejad et al, 2016).

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. Certain Geosynthetics only perform a single function and others can combine several functions from a single product.

Basically, there are three types of Geosynthetics designed for pavement rehabilitation: geotextiles (nonwovens), Geogrids (grids) and Geocomposites. Compared to the stress relief function of soft products (such as nonwovens) to dissipate strain energy by deforming itself, the reinforcement function requires stiff products (such as grids) to compensate the lack of Hot Mix Asphalt's (HMA) tensile strength (Elseifi, 2015). In providing reinforcement, the grid structurally strengthens the pavement section by changing the response of the pavement to loading (Koerner, 2012). 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 while in fact these products serve only a separation and moisture barrier function. Therefore, designers should have a clear understanding of the limitations all the different asphalt interlayer products offer in terms of their function, position and stress-strain characteristics within the pavement structure (Asphalt Academy, 2008).

4. REQUIRED CHARACTERISTICS FOR EFFECTIVE ASPHALT REINFORCEMENT

In Europe, the standard BS EN 15381:2008 "Geotextiles and geotextile-related products - Characteristics required for use in pavements and asphalt overlays", 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 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 test shall be always performed on finished products.

4.2 RESISTANCE TO INSTALLATION DAMAGE

According to Norambuena-Contreras and Gonzalez-Torre (2015), resistance of geosynthetic asphalt reinforcing materials to deterioration and installation damage is the most decisive factor on their subsequent behaviour in the pavement rehabilitation.

It is detailed in the BS EN 15381 that the damage during installation of an asphalt reinforcement geosynthetic is induced 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 paving and 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 have the characteristic to resist the installation influences without damage and as much as possible without serious loss of strength. This highlights the importance of the choice and evaluation of material, from which the reinforcing geosynthetics are made. Various materials have different mechanical properties which determine the end product's ability to resist the installation damage. For example, polyester polymers, abbreviated as PET, are flexible and durable polymers, whereas glass fibres are known to be brittle.

A detailed research was carried out by the RWTH Aachen University in Germany (Sakou, 2011) to analyse 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 fibre) were tested.

The results showed, that the potential of installation damage on asphalt reinforcement materials can vary depending upon the adopted product (Figure 4). The polyester grid lost max. 30% of its tensile strength after loading from truck passes and asphalt compaction. In contrast to this, the glass fibre 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.

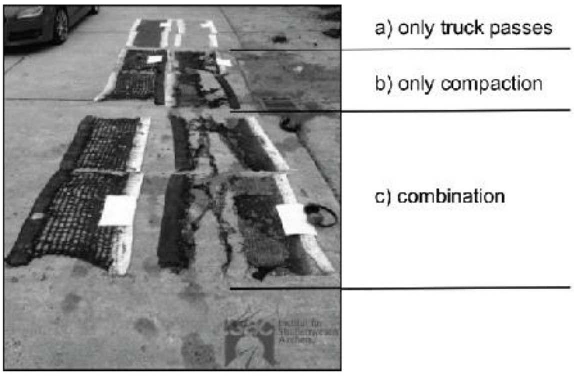

Figure 4 – Results of installation damage test
(left polyester grid, right glass fibre grid (Sakou, 2011)

Due to this good resistance to mechanical influences, polymer materials can be installed directly on milled surfaces. In contrast, fibre 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 to evaluate the performance. Installation damage can be simulated by the use of the testing procedure detailed in BS EN ISO 10722:2007.

5. PROOF OF EFFECTIVENESS BY RESEARCH: PET POLYMER REINFORCMENT GRID

For the purpose of analysing and quantifying the improvement of crack resistance when using an asphalt reinforcement, several studies have been developed in the last decades.

A full testing program evaluating crack reflection potential has been conducted by Montestruque (2002) at the Aeronautics Technological Institute in Sao Paulo in Brazil. As part of the study, 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 times the number of dynamic loading cycles before a crack reached the surface (Figure 5b). The crack pattern clearly shows that the reinforcement takes up and distributes the tensile forces (Figure 5c). 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 5.a – Test set-up

Figure 5.b – Comparison of cracks with and without reinforcement and the number of cycles conducted before the cracks reached the surface (Montestruque, 2002)

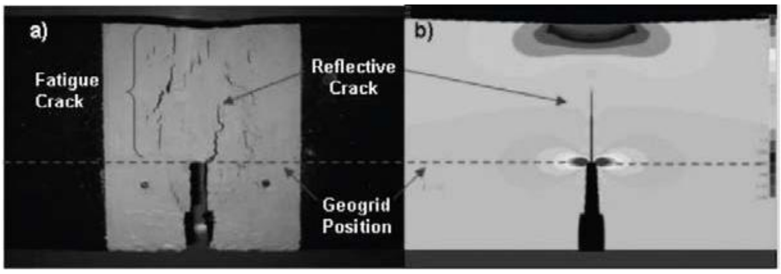

Figure 5.c – Comparison between laboratory and numerical simulation results (Montestruque, 2002)

6. PRACTICAL EXPERIENCES

The following projects shall provide an example of the successful use of polyester asphalt reinforcement.

6.1 INTERNATIONAL AIRPORT DOUALA (CAMEROON)

In March 2016, the international Airport of the economic capital of Cameroon, Douala, was closed for an extensive rehabilitation program of the aircraft parking area and the airstrip. The runway with a length of 2860 m was built forty five years ago and suffered many degradation during the time. During the period of full closure of Douala International Airport, all flights and passengers to and from Cameroon were made from Yaoundé Nsimalen Airport. This situation has made it possible to boost the planned rehabilitation works. According to the aeronautical authority in Cameroon, 43% of the domestic passenger traffic and 72% of the international traffic are ensured by the airport of Douala, compared with 37% of domestic traffic and 27% of international traffic for Yaoundé Nsimalen. As all managers, airport infrastructure operators strive to reduce the costs and to optimize the operation processes.

The choice of the appropriate rehabilitation method depends on several factors. An increase of the rehabilitation intervals, an extension of the service life and a long-term reduction in maintenance costs. The local conditions, the technical and economic requirements play also an important role. After a comparative and detailed study, incorporating the problem of advanced cracking of the landing runway, Asphalt reinforcement grid type anti-cracking system made of polyester was chosen for the rehabilitation of the International Airport of Douala (MEDOU-Info 14-2016).

6.1.1 PREPARATION OF THE EXISTING SURFACE

The PET - Asphalt reinforcement grid have to be installed between two bituminous layers. In the case of Douala International Airport, the bituminous existing surface was milled and cleaned for the installation of the Asphalt reinforcement grid (PET). Thanks to its high resistance against mechanical damage, the used PET-Grid could be placed directly on the milled surface. Important irregularities were either reshaped or milled. Local cracks less than 3 mm width have been not treated. Cracks with a width of more than 3 mm have been filled, after cleaning with high compressed air, with a bituminous sealant (Figure 6a).


Figures 6a und 6b: Surface preparation after milling works

6.1.2 SPRAYING OF THE BITUMEN EMULSION

The prepared surface have been sprayed uniformly using spraying vehicle with a homogeneous bituminous bonding layer with a minimum of 0.6 kg/m² of a 70% cationic bitumen emulsion to ensure a good bonding between the asphalt layers (Figures 7a and 7b). In cases of rough and open-pore surfaces, the minimum amount of the bitumen emulsion should be increased up to 1.0 - 1.2 kg / m². The applying of bitumen emulsion with a 60% bitumen content is also possible, the minimum amount of the emulsion have to be adjusted. The emulsion must be fresh or partly-broken before the PET- asphalt reinforcement grid is applied so that the residual water and solvents can be evaporated. Breaking the emulsion results in a change of colour from brown to black.


Figures 7a and 7b: Spraying of bitumen emulsion

6.1.3 INSTALLATION OF THE ASPHALT REINFORCEMENT GRID

Asphalt reinforcement grid (PET) should be generally unrolled on a flat surface (Figures 8a and 8b). The process is carried out using a conventional unwinder. Within the Douala International Airport project, the installation was done manually and using a vehicle. Traffic, other than construction and service vehicles, was prohibited on the grid before the application of the bituminous mix. The covering of the edges was done with approximately 10-15 cm in the longitudinal and 20-25 cm in the transverse direction.

Figures 8a and 8b: Installation of PET Asphalt reinforcement grid

6.1.4 OVERLAYING WITH ASPHALT

The use of a reinforcing grid requires the application of a good bituminous mixtures according to the rules of the art in order to produce a high-quality asphalt layer. The Asphalt cover have to be overlaid with a minimum thickness of 4cm (compacted). The laying of the asphalt have to follow quickly (after completion of the breaking process of the bitumen emulsion) the laying of the grid (Figure 9a). The formation of waves or folds in the grid should be avoided. However, a slight wave formation in front of the finisher does not disturb the functioning of the finisher. The joints of the asphalt layers must not coincide with the coverings of the grids. Finishers and other supply vehicles should be driven smoothly and carefully to avoid tensions in the grids. When accelerating the finisher, acceleration, sudden steering changes and truck braking must be avoided.

Figures 9a and 9b: Overlaying with asphalt incl. compaction

6.2 KAMPALA – JINJA ROAD (UGANDA)

6.2.1 SITE DESCRIPTION AND CURRENT SITUATION

The Kampala-Jinja Road is one of the main arteries of Uganda´s road system. This section (ca. 76 km) is a busy and heavy trafficked road and forms a section of road network that connects some East African countries (e.g. Burundi, Rwanda, Democratic Republic of the Congo) to Kenya and ultimately to the Kenyan port of Mombasa (Figures 10 and 11). It is therefore a vital commercial link to the outside world with high social and economic value for this region. The rehabilitation works in this section were already advanced.

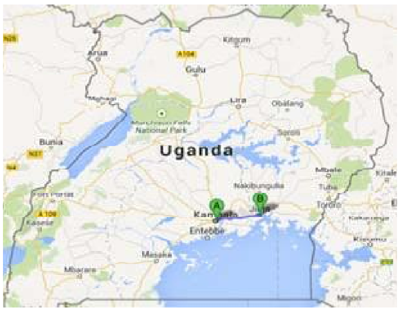

Figure 10: Project map

Figure 11: Heavy load traffic

The ongoing rehabilitation of the section in Mukono had already started. After a short time, reflective cracks coming out from the old cracked surface through the new installed asphalt layer are already visible (Figures 12a and 12b).

Figures 12a and 12b: Reflective cracks in a new rehabilitated road section after 5 months

6.2.2 Current situation of the section that to be rehabilitated with Asphalt reinforcement grid

The existing surface of the Kampala-Jinja road has several damages. Fatigue cracks form the main damage cause. Due to the heavy load traffic and to the climate conditions in this region, the cracks spreads faster.

Figures 13a and 13b: Cracked existing surface

6.2.3 REHABILITATION SET-UP - DIRECTION JINJA TO KAMPALA: CRACKED SURFACE + 2 CM LEVELLING LAYER + PET ASPHALT REINFORCEMENT GRID + 5 CM ASPHALT LAYER.

For the installation of the Asphalt reinforcement grid (PET), the existing bituminous surface was cleaned with high compressed air. Existing cracks have been filled with a bituminous sealant. The prepared surface was sprayed uniformly with a homogeneous bituminous bonding layer with a minimum of 0.6 kg / m² of a 60% cationic bitumen emulsion.

Subsequently, the surface of the levelling layer was sprayed with ca. 0.6 kg/m^2 of the same bitumen emulsion as before. Subsequently, the installation of the PET asphalt reinforcement grid was done manually. The laying of the asphalt follows immediately the laying of the grid.



Figures 14a, 14b and 14c: Work steps; spraying of bitumen emulsion, installation of polyester asphalt reinforcement grid and overlaying with 5cm asphalt

6.2.4 REHABILITATION SET-UP - DIRECTION KAMPALA TO JINJA: CRACKED SURFACE + PET ASPHALT REINFORCEMENT GRID + 7 CM ASPHALT LAYER.

In the other roadway direction (Kampala to Jinja), a different rehabilitation set-up was chosen. Here, the levelling layer was omitted, instead, a higher thickness of the asphalt top layer with 7cm was chosen to be able to connect to the level of the already rehabilitated lane (Jinja to Kampala). Further work has been carried out similarly to the first variant. Only the amount of the emulsion was increased (0.7 kg/m2) due to the surface texture of the old roadway.



Figures 15a and 15b: Spraying of bitumen emulsion 0.7 kg/m2, installation of polyester asphalt reinforcement grid and overlaying with 7cm asphalt

6.2.5 Performance of the PET asphalt reinforcement after 1 year.

As part of the monitoring of the road, the rehabilitated sections were examined after 1 year. Despite the higher traffic and especially heavy load traffic, no cracks or deformations were detected. In turn, the rehabilitated areas without the use of an asphalt reinforcement grid show clearly the first cracks.

Figure 16a: Reinforced section after 1 year

Figure 17: Unreinforced section after 1 year

7. CONCLUSIONS

Reflective cracking can occur, easily and rapidly, in cracked pavements rehabilitated using a simple asphalt overlay. In order to delay the development of reflective cracking, an asphalt reinforcement grid can be placed before the new asphalt wearing course. When choosing the suitable product for a particular pavement rehabilitation, construction conditions and material characteristics must be taken into consideration.

The presented laboratory results, as well as case studies have shown that the use of a polyester polymer asphalt reinforcing grid in pavement rehabilitation can offer significant advantages. Based on the observed performance, it is possible to conclude that asphalt reinforcement is an effective treatment against reflective cracking in asphalt overlays, resulting in an extension of the service life of a rehabilitated pavement and reduced the maintenance costs.

REFERENCES

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

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

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

CUR Building and Infrastructure, 2012. *Durability of Geosynthetics.* Publication 243. Netherlands.

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

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.

Knappenberg, F. 1983. *Report on Bruxelles/Saventen Runway reinforcement.*

Koerner, R. M. 2012. *Designing with Geosynthetics.* Xlibris Corporation.

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.

Monteith, R. 2010. *Presentation: Australian Experiences with the Use of HaTelit in Aircraft Pavements.*

MEDOU INFOS Nr. 14-2016. *Bulletin d'information trimestrielle du Cabinet MEDOU Bureau d'études techniques*

Huesker International Partners Meeting, *Garmish Partenkirschen, Germany.*
January 2010.

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.

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.

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

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

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.