PRACTICAL EXPERIENCE WITH ASPHALT REINFORCING POLYMER GRID AND COMPOSITE IN AIRFIELDS

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ABSTRACT

A conventional method for rehabilitation of damaged airfields is the installation of new asphalt layers. Due to external forces from planes and naturally temperature variations, existing cracks or joints rapidly propagate out of the old pavement into the new asphalt overlay. In order to delay this phenomenon, known as reflective cracking, polymer reinforcement grid and composite have shown outstanding results. The reinforcement grid adopts the peak stresses at the crack tip, distributes them over a larger area and thus retards the crack propagation. The composite enables additionally a stress-relieving system and a moisture barrier, eliminating or delaying the damage caused by possible 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 systems in airfield applications. Special attention is given to the performance on site and the key factors associated with the effectiveness of the reinforcing material, e.g. the loss of tensile strength due to the paving procedure, the importance of the bond-strength, and the importance of using alkali-resistant materials when in direct contact with concrete. 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 economic benefits.

Keywords: polymer reinforcement, grid, composite, airfield, resurfacing.

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 (Montestruque, 2002; Monser et al, 2010). Consequently, damaged roads and airfields can be resurfaced more cost-effectively by using stress-relieving or reinforcing systems (De Bondt, 1995).

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 products has a positive effect in the battle against reflective cracking (Vanelstraete and Francken, 1996; Norambuena-Contreras and Gonzalez-Torre, 2015). 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 pavement rehabilitation or maintenance, especially in airfields. Referring to this, required properties for asphalt reinforcement products are described according to the European standards. Additionally, some practical experiences and limits for the use of asphalt reinforcement will be presented.

2. 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 (Elseifi, 2015). 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 (Montestruque, 2002; Norambuena-Contreras and Gonzalez-Torre, 2015). The shear action occurs twice by each load application, while the bending action occurs only once (Figure 1).

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, for overlaying to become more cost effective, the speed of propagation of the existing crack to the new surface has to be reduced (De Bondt, 1995).

In order to delay the propagation of cracks into the new asphalt layers, there are several techniques to rehabilitate cracked pavements, such as modify the mechanical properties of the overlay or place a stress-relieving system. 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 (Nejad et al, 2016).

3. ASPHALT REINFORCEMENT INTERLAYERS

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 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 (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 when in fact these products serve only a separation and 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 (Asphalt Academy, 2008).

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 (2002) 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.

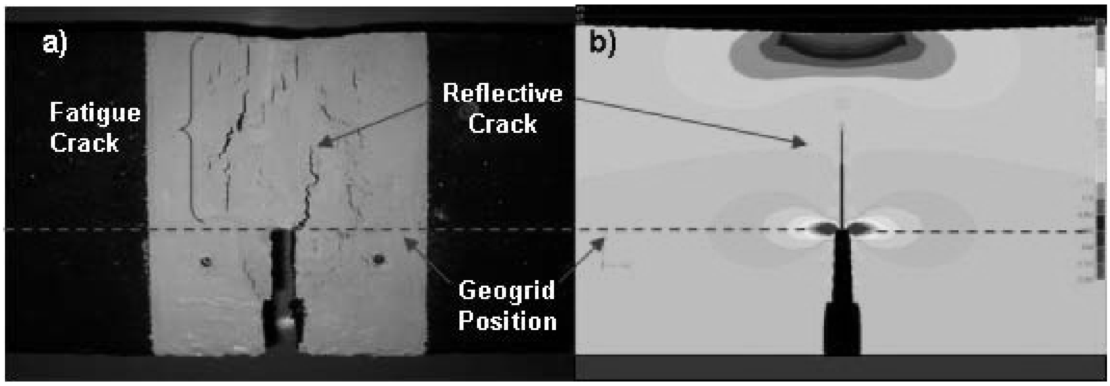

Figure 2. Comparison between laboratory and numerical simulation results (Montestruque, 2002)

Norambuena-Contreras and Gonzalez-Torre (2015) 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.

4. REQUIRED CHARACTERISTICS

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 shall be always performed on finished products.

4.2 Installation damage

According to the BS EN 15381, 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 (Sakou, 2011) 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.

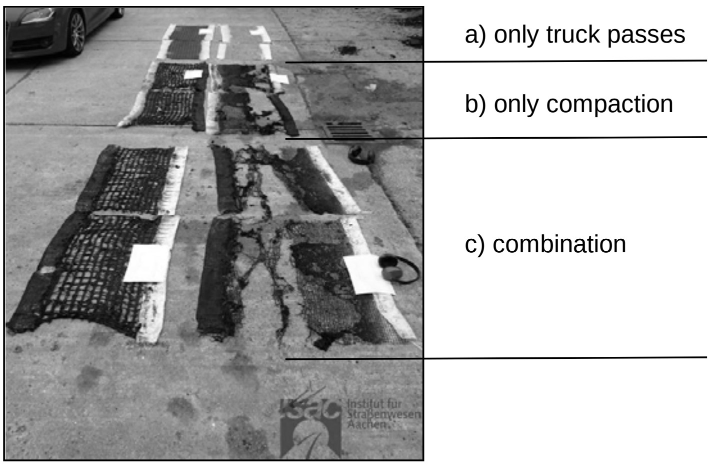

Figure 3. Results of installation damage test (left polyester grid, right glass fiber grid (Sakou, 2011)

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 10722:2007.

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. BS EN 15381 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 (CUR, 2012).

Regarding the material stability, polymer products must have a higher melting point than the temperature of the installed asphalt. According to Norambuena-Contreras and Gonzalez-Torre (2015), 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 Rehabilitation of Brussels Airport at the end of the 1970s

The 45 m wide existing concrete runway at Brussels Airport was showing damage to such a serious extent that a complete refurbishment was considered essential. This was the first time that asphalt reinforcement was used to delay the propagation of cracks at the expansion joints, and in the concrete slabs themselves, through to the surface of an overlay.

Firstly 10 mm existing asphalt were milled off the runway surface, then any holes broken out of the concrete slabs were in-filled and a bituminous regulating course was applied. Then, an asphalt reinforcement made of high modulus polyester was installed on top of the regulating material (Figure 4).

As the highest loading from landing aircraft occurs in the centre of the runway, just the central 25 m wide strip of the runway was reinforced. The 10 m wide edge zones remained unreinforced. The whole of the runway surface was then overlaid with a 50 mm binder course and a 50 mm surface course. The resurfacing works were only required to preserve the use of the runway for two years.

Three years later in 1983, when the first formal assessment took place, it was found that in the unreinforced zones virtually all the expansion joints between the concrete slabs had propagated through to the blacktop surface. In the polyester grid reinforced zone no individual cracks could be seen, even with the highest loads in these sections. The last assessment took place in 1990 (10 years later), the runway was still in excellent condition. Apart from some minor surface treatment, up to then, no further measures had been necessary. According to Knappenberg (1983) the refurbishment of the runway using a high modulus polyester grid had been a complete success.

Figure 4. Installation of the polyester reinforcement at Brussel Airport in 1979

5.2 Salgado Filho Airport, Porto Alegre (Brazil)

In 2001 the existing access to an aircraft maintenance hangar (used by aircraft as large as the Boeing 777, with a weight over 250 tons) had to be resurfaced after more than 40 years of use. The existing pavement was made of 5.0 × 3.5 m concrete slabs, 250 mm thick. The slabs were resting on a layer of gravel.

The rehabilitation design involved the installation of an asphalt leveling layer first. In order to prevent the propagation of the expansion joints from the concrete slabs into the new surface, an asphalt reinforcement made of high modulus polyester was to be installed. A 50 mm asphalt surface course was installed on top of the polyester reinforcement.

Because it was not possible to block the access for an extended period of time, the rehabilitation work had to be finished in just one night. In order to stay within this very tight time frame, it was decided to only reinforce the heavily loaded inner portion of the pavement. The outer portions, which are not typically subjected to the heavy loading of aircraft traffic, were left unreinforced.

What initially was thought to be a purely practical solution developed into an ideal demonstration of the effectiveness of an asphalt reinforcement grid. By only reinforcing a portion of the pavement and leaving the remainder unreinforced, a direct side-by-side comparison of the performance of the reinforced and unreinforced sections was possible.

In October 2007, approximately 7 years after the rehabilitation, the first assessment of the pavement took place. At that time the designer, the technical manager of the airport, and an employee of the reinforcement manufacturer were present. The expansion joints in the concrete beneath the unreinforced pavement areas had already propagated to the top of the surfacing. The vegetation, visible in the developed cracks, led to the conclusion that these cracks had existed for some time. In contrast, the PET-grid reinforced areas did not show any indications of cracking (Figures 5 and 6).

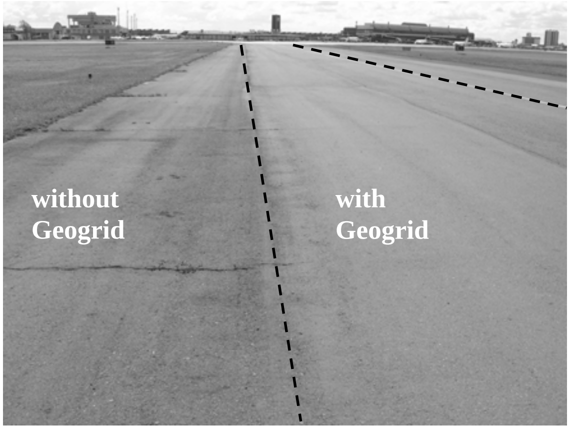

Figure 5. Overview of the studied section: view from the dockyards to the terminal

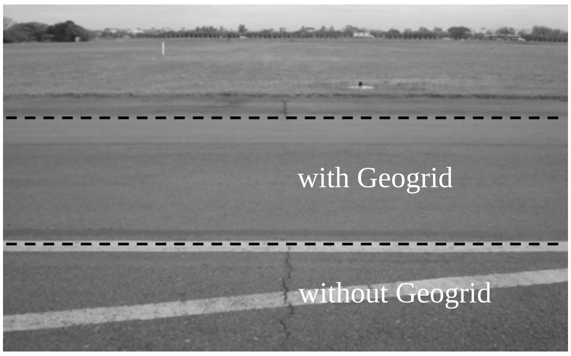

Figure 6. Joints of the concrete slabs reflect in the area where no reinforcement was used

Because the unreinforced section was not subjected to aircraft traffic, the propagation of the expansion joints in these areas can be conclusively attributed to the horizontal stresses that resulted from changes in temperature. The areas reinforced with the polyester grid were subjected to both temperature-induced and aircraft traffic-induced stresses. For further details the reader is referred to a paper prepared by Monser et al (2010).

5.3 Melbourne Airport (Australia)

In 2012, due to existing pavement failures, the 40 years old taxiway Alfa north of Runway 27 (the only taxiway to holding point Bravo) required a maintenance treatment that could achieve 5 to 10 years usable service life with allowance for some ongoing maintenance.

The existing pavement consisted of 7.5 m x 7.5 m concrete slabs, which were 430 mm thick. The pavement under the concrete slabs was a crushed rock base variable in depth, placed over improved subgrade. Since concrete slab replacement was not feasible at this point, 100 mm asphalt overlay was proposed as part of the maintenance treatment to alleviate FOD risk and extend the lifetime of the pavement. The overlaying process involved placement of two no. 50 mm asphalt layers.

Additionally, in order to mitigate the propagation of the existing concrete pavement failures into the new asphalt surface, an asphalt reinforcement made from high modulus polyester was installed between the two 50mm AC layers as seen in Figure 7. Works were completed at night between 10 p.m. and 6 a.m. The treatment area was 100 m in length across the full taxiway width.

In 2016, approximately 4 years after the rehabilitation, the airfield manager of the airport verbally reported that a good mitigation performance by the polyester asphalt reinforcement has been achieved with a substantial reduction rate in pavement failure, despite the increased amount of traffic, and types of aircraft using the airport. The taxiway pavement is still in service and is performing well; a future capital decision on this project is yet to be made.

Figure 7. Laying asphalt over polyester asphalt reinforcement

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 (Asphalt Academy, 2008). 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.

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