CONCRETE PAVEMENT REHABILITATION BY USING A HIGH MODULUS POLYESTER GRID AS ASPHALT REINFORCEMENT

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ABSTRACT

Rehabilitation of cracked concrete pavements is usually associated with high costs and complex repair techniques. A conventional resurfacing by installing a simple asphalt wearing course over the old concrete slabs is often not an effective solution, as the expansion joints can rapid propagate to the top of the new overlay. In order to delay the development of the reflective cracks, an asphalt reinforcement grid can be placed before the resurfacing. The reinforcement adopts the peak stresses at the crack tip, distributes them over a larger area and thus retards the crack propagation. The purpose of this paper is to report the positive performance of a concrete pavement rehabilitation in the southeast of Brazil by using a high modulus polyester grid as asphalt reinforcement. The high-traffic highway MG-424 was severely cracked and damaged after an unsuccessful asphalt resurfacing. In order to evaluate the pavement support conditions and to adopt a proper rehabilitation structure, a displacement measurement device called Crack Activity Meter was used. The vertical and horizontal movements between the expansion joints and large cracks were measured and analyzed in terms of Load Transfer Efficiency. Based on the deflection results and on the observed performance, it is possible to conclude that the asphalt reinforcement is an effective treatment against reflective cracking in asphalt overlays, contributing to an extension of pavement service life.

Keywords: asphalt reinforcement, polyester grid, concrete pavement rehabilitation, case study.

INTRODUCTION

Asphalt reinforcement has 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). 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 maintenance per year 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.

Currently there are a number of different products and systems made of different raw materials (e.g. polyester, glass fiber, 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 (Vanelstraete and Francken, 1996). However, there are differences in the behavior and effectiveness of each system.

This paper focuses on the performance of the high-traffic highway MG-424 in the southeast region of Brazil, which was rehabilitated in 2013. The existing concrete pavement was severely cracked and damaged after an unsuccessful asphalt resurfacing. For the rehabilitation a high modulus polyester geogrid was used as asphalt reinforcement to prevent or to reduce the risk of further propagation of cracks to the new asphalt layer. A displacement measurement device called Crack Activity Meter (CAM) was used to determine the vertical and horizontal movements between expansion joints and large cracks. According to the observed deflections, it is possible to evaluate the pavement support conditions and to select an appropriate rehabilitation method.

CREATING AN ASPHALT REINFORCEMENT OVER ALMOST 40 YEARS

The idea of a reinforcing fabric for asphalt road construction first emerged in the early 1970s. The first experiences with geogrids were in the construction of earthworks and foundations, so the idea to use them in asphalt pavements was a logical next step. The initial intention was that the embedded geotextile layer was able to pick up the tensile stresses in the asphalt and prevent cracks from forming. However, it was soon realized that this principle did not work, but the product proved very useful at delaying the formation of reflection cracks in resurfaced roadways.

Even then polyester, abbreviated as PET, was a preferred raw material because of the compatibility of its mechanical properties with the behavior of asphalt. Since then many products made from different raw materials have been developed.

BASICS: REFLECTIVE CRACKING AND ASPHALT REINFORCEMENT

It is well known that cracks appear due to external forces, such as traffic loads and temperature variations. The temperature influence leads to the binder content in the asphalt becoming brittle; 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, such as, traffic, lead to cracks that propagate from the bottom to the top of a pavement (bottom-up cracking).

A conventional rehabilitation of a cracked 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 stress concentrations at the crack tips caused by external forces from traffic and natural temperature variations, the cracks will propagate rapidly to the top of the rehabilitated pavement.

Deteriorated concrete pavements are typically rehabilitated by installing new asphalt layers over the old concrete slabs. Temperature variations lead to a rapid crack propagation especially at the expansion joints to the top of the new asphalt overlay.

In order to delay the propagation of cracks into the new asphalt layers an asphalt reinforcement comprised of high tenacity polyester can be installed. 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.

High modulus polyester is a flexible raw material with a maximum tensile strain less than 12%. The coefficients of thermal expansion of polyester and asphalt (bitumen) are very similar. This leads to very small internal stresses between the PET fibers and the surrounding asphalt (similar to reinforced concrete). For this reason Polyester does not act as an extrinsic material in the asphalt package, however at this point it should be mentioned that the aim of a PET-grid as asphalt reinforcement is not to reinforce asphalt in such a way as one reinforces concrete. The installation of a PET-grid as asphalt reinforcement improves the flexibility of the structure and avoids peak loads over a cracked existing layer into the overlay and through this mechanism reflective cracking is delayed.

As found by De Bondt (1999), 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 PET-grid was found to be, by far, the best of all the commercial products investigated.

CASE STUDY: HIGHWAY MG-424, MINAS GERAIS, BRAZIL

The MG-424 is a public dual carriageway, which begins at an intersection with the MG-010 in the metropolitan region of Belo Horizonte, capital of the state of Minas Gerais. This highway has heavy traffic loads and is an important connection in this state. The existing pavement consists of concrete slabs (PCC – Portland Cement Concrete), which over the years received an asphalt resurfacing (Figure 1).

(a) (b)

Figure 1: Joints and cracks of the concrete slabs propagated to the surface (December 2012)

As can be seen in Figure 1, the pavement, in 2012, was severely damaged, and the joints and cracks of the rigid pavement had propagated through the asphalt overlay. This is a natural and expected phenomenon, especially concerning the thermal stress arising from temperature changes and different coefficients of thermal expansion from concrete and asphalt (Vanelstraete and Francken, 1996). Moreover, the relationship between the longitudinal and transverse lengths of PCC plates were not sufficient to minimize the horizontal movements of the slabs.

With the objective of evaluating the subgrade support condition, and consequently the potential for crack reflection after a new rehabilitation operation, measurement of vertical and horizontal relative movements of the crack walls against each other was done by using a special device, called Crack Activity Meter (CAM).

Crack Activity Meter Analysis

The CAM was developed by the National Transport Institute of South Africa, and allows the measurement of differential displacements of each side of one specific crack along the passage of a wheel (De Bondt, 1999). Two displacement measurement devices type LVDT (Linear Variable Differential Transformer), one positioned horizontally and the other vertically, register, respectively, the increment on the aperture of the crack and the relative vertical displacement (shearing displacement) of the crack walls (Figure 2).

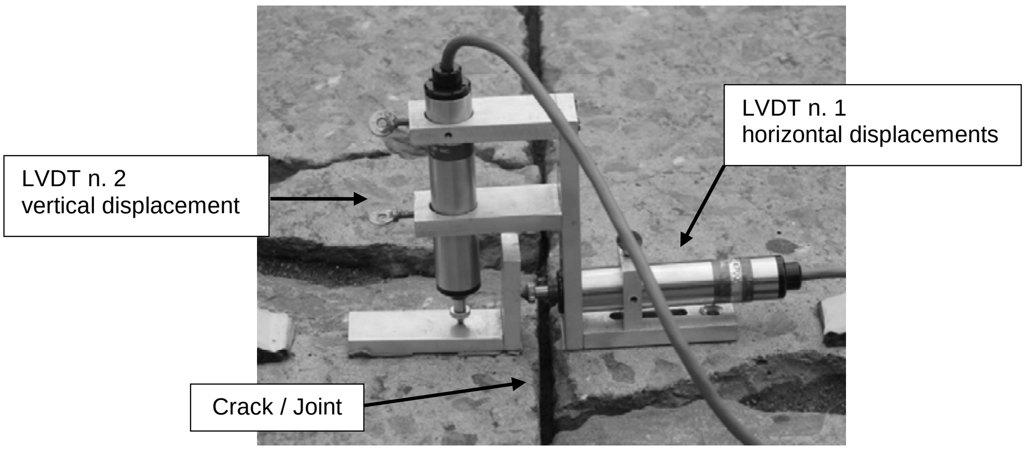
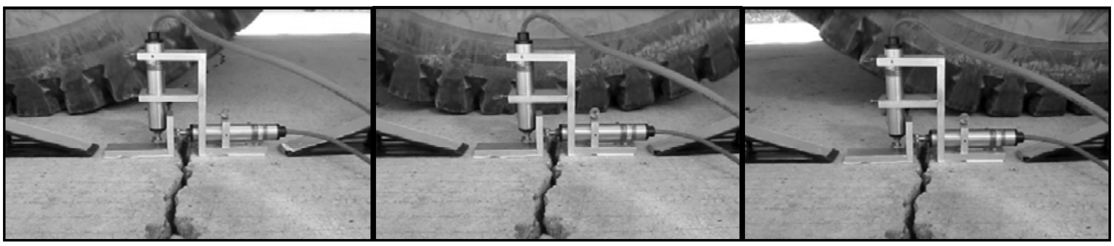


Figure 2: Crack activity meter

The CAM should be placed and fixed in a location where the crack considered in the study remains in between the two fixing plates. The truck used for the tests has a double-axle which was calibrated to 8.2 ton/axle. As soon as the wheel loads are imposed on to the crack, bending and shear stresses are induced (Figure 3). The shear action occurs twice by each load application, while the bending action occurs only once. The data acquisition system comprises electronic equipment capable of registering the complete curves of displacements.



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

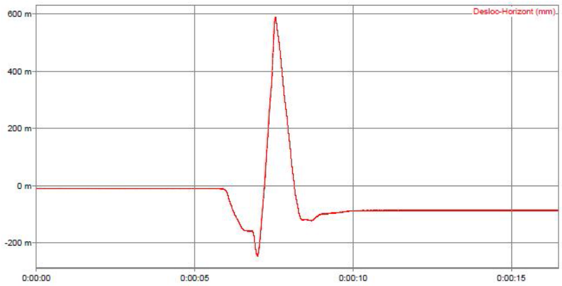
Figure 3: Wheel load stresses in a crack

The relative vertical movement between the walls of a crack is an important parameter used to characterize the condition of the concrete slabs. According to its magnitude it is possible to detect voids under PCC slabs, helping to decide if a slab should be repaired (grouted), fractured or even removed.

The displacement measurements indicated that the existing concrete pavement presented sections in better and others in worse condition. At the station 163, for example, large cracks and corner breaks could be observed, indicating a possible loss of pavement support (Figure 4).

Figure 4: Crack and corner break at station 163

As can be seen in Figure 5, very high vertical and horizontal displacement were measured in this station, confirming the loss of support and evidencing the presence of voids below the concrete slab.



Vertical displacement: 1.57 mm　　Horizontal displacement: 0.919 mm

Figure 5: Vertical and horizontal displacement – station 163

Deflection Evaluation

In order to choose a proper rehabilitation solution and to identify, if pretreatments are required, the load transfer efficiency (LTE) at the cracks or joint was determined. The LTE is presented in a technical report of the Federal Highway Administration (FHWA, 2006), and can be expressed as follows:

$$LTE = \frac{W_2}{W_1} \qquad (1)$$

where:
W_1 = deflection on the slab where the load is applied;
W_2 = deflection on the adjacent slab (other side of the joint/crack).

The LTE is often defined as the ratio of the deflection of the unloaded side to the deflection of the loaded side. Figure 6 illustrates the presented concept of deflection load transfer (approach 1 according to FHWA, 2006):

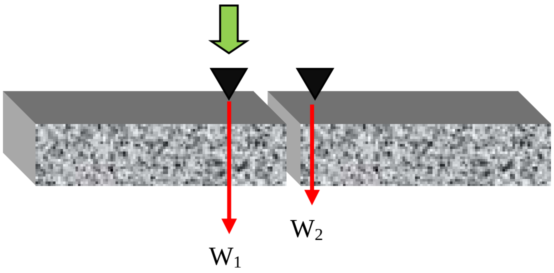


Figure 6: Load and sensors position for approach 1

The LTE values may range from 0 percent (no load transfer) to 100 percent (full load transfer). The load transfer rating as related to the LTE is presented in Table 1. For joints or cracks with LTE rated below fair, joint replacement or subgrade improvement is recommended before placing the new asphalt wearing course. According to Asphalt Institute (2001), pavements with poor LTE should be considered candidates for grouting, cracking and seating, or rubblizing prior to overlay. The appropriate repair option will normally depend on the condition of the slab, though.

Table 1: LTE rating (FHWA, 2006)

Load Transfer Rating	LTE (%)
Good	> 80
Fair	60 – 80
Poor	< 60

According to the obtained displacements with the Crack Activity Meter and the deflection analyses using the LTE concept, the old concrete pavement was classified between fair and good. That means most of the joints and cracks presented a good load transfer, indicating a sufficient bearing capacity of the subgrade. At station 160 for example, where large cracks and corner breaks were observed, low displacements were observed and a good load transfer rating was obtained. The concrete slabs were stable in their positions and replacement or ground improvement was not necessary before the asphalt resurfacing.

On the other hand, some slabs presented high vertical displacement, as for example at station 163. In this case, a poor load transfer rating was obtained and other pretreatments before the rehabilitation were required. In such cases, the slabs were removed or reseated with a heavy roller, in order to eliminate or minimize the vertical movements.

Pavement Rehabilitation

The rehabilitation design involved first milling off the existing asphalt layer and placing a 40 mm asphalt leveling layer. Then an asphalt reinforcement made of high modulus polyester should be installed to reduce the risk of propagation of any crack or expansion joint from the concrete slabs into the new surface. Finally, a 50 mm asphalt surface course should be laid on top of the polyester grid.

In the beginning of 2013 the highway MG-424 was rehabilitated. After milling off the existing asphalt, the 40 mm placed asphalt levelling course was not immediately covered by the following planned layers. Almost two months after its installation, some thermal cracks could be already observed in the surface (Figure 7). The expansion joints from the concrete slab had reflected through this new asphalt overlay. This fact demonstrated the importance of using a reinforcement, in order to prevent an early development of reflective cracks in the new asphalt layer.

Figure 7: Early reflective cracking (March 2013)

On April 2013, a polyester grid as asphalt reinforcement was then installed full width in accordance with the manufacturer's installation guidelines (Huesker, 2015) on the levelling layer, and was covered with the planned 50 mm asphalt surface course (Figure 8).

Figure 8: HaTelit® asphalt reinforcement

Almost two years after the rehabilitation, the reinforced area in the highway MG-424 still does not show any cracking (Figure 9). The use of a polyester grid prevented the propagation of reflective cracks developing from the expansion joints of the concrete slabs, proving to be an effective solution.

Figure 9: Highway MG-424 two years after rehabilitation

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). When having a poor quality subgrade, it is necessary to carry out other measures, e.g. base reinforcement or increasing the pavement thickness.

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).

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 (Asphalt Academy, 2008).

CONCLUSION

Reflective cracking occurs in concrete 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. High tenacity polyester as a raw material is often chosen because of the high compatibility of its mechanical behaviour to the modulus of asphalt and its good behavior under dynamic loads.

The presented case study has showed that the use of an asphalt reinforcement in concrete pavement rehabilitation can be advantageous. The use of a polyester grid has to date prevented the propagation of expansion joints and cracks through the new asphalt overlay in a high-traffic highway. However, before choosing the appropriate repair solution, it is important to know the structural conditions of the existing pavement, if there are signs of pumping, excessive vertical movements or weak subgrade, for example. In the presented case study, vertical and horizontal relative movements were measured, so that the subgrade support condition and the slabs stability could be estimated. 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 concrete pavement.

AKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance and support of Eng. G. Scarpone Salem (DER-MG) and Eng. M.T. de Carvalho (TORC – Terraplenagem, Obras Rodoviárias e Construcoes Ltda).

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