Pavement rehabilitation by using an asphalt reinforcement grid made of high modulus Polyester

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ABSTRACT: The rehabilitation of an existing cracked pavement made of concrete slabs or asphalt can be simply done by the installation of new asphalt layers. Due to external forces from traffic and natural temperature variations, existing cracks or joints rapidly propagate out of the old pavement into the new asphalt overlay. The application of an asphalt reinforcement showed excellent results in delaying the development of reflective cracks. The installation of a high modulus polyester grid led to a considerable extension of pavement life. This paper shows typical applications and limits for the use of asphalt reinforcement in rehabilitating deteriorated pavements. This will be described through basic theory, results of laboratory investigations and our practical experiences from the last 40 years with asphalt reinforcement.

KEY WORDS: asphalt reinforcement, runway rehabilitation, geogrid, concrete

1. INTRODUCTION

Asphalt reinforcement has been used all over the world for many years to delay or even prevent the development of reflective cracks in asphalt layers. Using asphalt reinforcement can clearly extend the fatigue life and therefore the maintenance intervals of asphalt pavements. Currently there are a number of different products and systems made of different raw materials (e.g. Polyester, Glass, Carbon, Polypropylene...) available in the market. It is without disputed that all these systems have a positive effect, however there are differences in the behaviour on site and the degree of effectiveness.

2. BASICS REFLECTIVE CRACKING AND ASPHALT REINFORCEMENT

As is well known, cracks appear due to external forces, such as traffic loads and temperature variations. The temperature influence leads to the fact that the binder content in the asphalt is 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 loads like traffic or landing airplanes, lead to cracks which propagate from the bottom to the top of a pavement (bottom-up cracking).

A typical rehabilitation of a cracked pavement involves milling off the existing top layer and installing a new asphalt course. Due to stress concentrations at the crack tips, the existing cracks will propagate rapidly to the top of the rehabilitated pavement.
Deteriorated concrete pavements are often rehabilitated by installing new asphalt layers over the old concrete slabs. Due to temperature variations the expansion joints of the concrete slabs and the existing cracks will rapidly propagate to the top of the new asphalt layer. In order to delay the propagation of cracks into the new asphalt overlay the answer is to install a high modulus polyester grid. The asphalt reinforcement attracts the vertical forces, at the peak of a crack, and distributes them over a larger area. This results in delaying the propagation of the existing cracks into the new asphalt overlay and therefore it can extend the fatigue life and thus the maintenance intervals of a pavement.

3. CREATING AN ASPHALT REINFORCEMENT OVER ALMOST 40 YEARS

The idea of a reinforcing fabric for road construction first emerged at the end of the 1960s. The initial aim was to develop a product to reinforce asphalt. The embedded geotextile layer was intended to pick up the tensile stresses in the asphalt and therefore prevent cracks from forming, however, it was soon realised that this principle did not work, but it was found that the product proved very useful at delaying the formation of reflection cracks in resurfaced carriageways. Even then polyester was the preferred raw material because of the compatibility of its mechanical properties with the stress-strain behaviour of asphalt.

Working in close cooperation with a manufacturer of polyester yarns and a weaving mill for technical yarns, HUESKER came up with the reinforcement grid HaTelit®, at the start of the 1970s, as a grid of polyester fibres with a 20mm mesh size.

After a few years of experience and continuous development it became clear that the bond between the grid and the asphalt layers was one of the most important factors in the successful functioning of asphalt reinforcement. The mesh size of the grid was increased from 20mm to 30mm, and a bituminous coating was added to achieve a better bond and interlock with the asphalt-aggregate matrix, HaTelit® 30/13 was created. Many of the influencing factors that are considered self-evident today were completely unknown in those days; there were no comparable products that HUESKER could use for comparison.

Further product improvements were followed by the development of a completely new product in the mid-1990s in which an ultra-light nonwoven was added to the grid to ease installation. It was found that the increased mesh size of 40mm seems to be ideal for an excellent interlocking between the asphalt layers. To continuously ensure a good bond between the asphalt layers, the very light nonwoven was, like the grid, bituminous coated. The current product seems to be ideal for asphalt reinforcement.

Figure 1 / 2: First use of asphalt reinforcement at the end of the 1960s
4. WHY POLYESTER

Polyester as asphalt reinforcement is chosen because of the high compatibility of its mechanical behaviour to the modulus of asphalt. Compared to other products with stiffer and more brittle raw materials, polyester is very resistant to installation damage [1] and shows an excellent behaviour under dynamic load caused by high traffic and landing aircrafts [2+4]. This became apparent as a result of a research project on “Georeinforcements” of the Helsinki University of Technology [2], in this research Periodic Load Tests were carried out which revealed that polyester grids have a much better behaviour under dynamic load than grids with a brittle raw material. The long term interaction of the reinforcement and the asphalt layers is crucial to the proper functioning of asphalt reinforcement. Furthermore the reinforcement must resist as much damage as possible from the stresses and strains applied during installation and overlaying / compaction of the asphalt. Even during installation the reinforcement may be subjected to high load when trafficked by tracked pavers or “blacktop” trucks. Very high forces can also be applied to the individual strands of the reinforcement by aggregate movement in the hot blacktop during compaction.

5. RESULTS OF RESEARCH

5.1 Prevention of Reflective Cracks in Asphalt Layers (Belgian Road Research Centre)

As already mentioned above, cracks from old asphaltic layers reflect through the new surface due to daily temperature variations, but especially due to frost-thaw cycles. In order to simulate thermally induced reflective cracking, the Belgian Road Research Centre (BRRC) developed a test method at the beginning of the 90’s (see Figure 3) to investigate the effect an asphalt reinforcement has on the reduction of cracks.

For the test, a 65 mm thick layer of asphalt is installed over a pre-cracked surface. The simulated crack is 4 mm wide and is widened by 1 mm per cycle then returned to a 4 mm width. The opening of the crack by 1 mm per cycle corresponds to the expansion volume of water which exists in a crack. This test method has now become so well established that nearly all products and systems which are available on the market have been tested. The reinforcement products differ mainly by the choice of the raw material and the use of a bituminous coating. The tested products
which are available on the market consist of glass, carbon, polypropylene (PP), steel and polyester (PET). Several results are shown in Table 1.

The reference test without interlayer (0) shows that the crack reached the surface after very few cycles. The asphalt interlayer systems clearly show differences in their effectiveness, with the bituminous coated PES-grid (6, 7) completely preventing reflection cracks. Even after completion of the tests, no cracks had been initiated, whereas all other systems made of other raw materials (with or without coatings) indicated cracks, many of which soon reached the surface. This clearly demonstrates that reinforcement stiffness must be matched to the total asphalt package (i.e. if the reinforcement is too stiff it will not interact with the surrounding asphalt matrix).

The high modulus polyester grid which is covered with a protective bituminous coating suggests that it seems to be the ideal raw material for asphalt reinforcement, with the high bond ensured by the bituminous coating, considered to be an important parameter. Only when a good bond is obtained with the surrounding asphalt layers can the tensile forces be transferred to the entire system.

5.2 Dynamic Fatigue Tests from the Aeronautic Technological Institute, Sao Paolo

5.2.1 Fatigue Test

In order to determine the influence of dynamic loads, the Aeronautic Technological Institute in Brazil carried out dynamic fatigue tests. In these tests beams of asphalt concrete with dimensions of 75mm x 150mm x 460mm were cast in the laboratory and were pre-cracked with openings of 3mm, 6mm and 9mm. The geogrid was positioned exactly over a pre-crack. The geogrid used in this test was a high modulus polyester grid incorporating an ultra-light nonwoven with a bituminous coating, a mesh size of 40 x 40 mm and a nominal tensile strength of 50 kN/m, at 12% strain.
The type of loading was sinusoidal and the applied pressures were 330, 425 and 550 kN/m\(^2\) changing the load position in relation to the crack, for bending and shear conditions. Between the steel plate and the asphalt concrete beam, a rubber pad was installed in order to minimize the concentration of stresses related to the stiffness of the steel plate. The appearance of the first visible crack at the surface provided the termination criterion of the test.

5.2.2 Results of Fatigue Test

In beams without a geogrid, the reflective crack appeared after a few load cycles. Its growth, in bending and shearing mode, was fast and practically vertical, following the face of intersected aggregate (Figure 5). When the reflection crack reached the top of the asphalt beam (75mm) it ruptured and the test was ended.

For the beams reinforced with a geogrid, this vertical growth occurred up to 20mm and 30mm, respectively for the less severe case (pre-crack opening 3mm) and more severe case (pre-crack opening 9 mm), thus the geogrid reinforcement stops the propagation of the reflective crack. After more load cycles, micro cracks started becoming more and more visible, and interconnecting with each other, leading to the formation of new cracks of less severity, spread over a greater volume of asphalt concrete (Figure 6). This fact was observed for the bending load position as well as for the shearing load position. In beams with reinforcement, the test was concluded when only one crack of less severity reached the surface.
In the unreinforced specimen, with a pre-crack of 3mm, the crack reached the top of the beam after just 79,884 load cycles, whereas the reinforced specimen could resist 477,150 load cycles. From these results a factor of effectiveness was calculated. For the reinforced specimen, with a 3mm pre-crack, it was calculated as 6.14. More detail may be obtained from the full version [4].

6. PRACTICAL EXPERIENCE

6.1 Rehabilitation of Brussels Airport at the end of the 1970s - A first challenging project

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 10mm 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. HaTelit® 30/13 was then installed on top of the regulating material.

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 50mm binder course and a 50mm 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 PES-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. As reported in [5] the refurbishment of the runway using a high modulus polyester grid had been successful!

Figure 7 / 8: Installation of the polyester reinforcement in 1979
6.2 Project: "Rosenstrasse", Germany

The project reference presented herein shall give an example of the successful use of asphalt reinforcement in roads. The project is located in the Northwest German town of Rosen- dahl. The road 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. Before rehabili- tation the road revealed severe alligator cracking, longitudinal and transverse cracking in large scale. The original design (and budget) called for milling the surface (approx. 5 cm) and installation of a new 5 cm asphalt wearing course. The expected lifetime of a new surface was just 2 years.

The more durable (but also very expensive) solution was to take up the cracked binder and base course. An alternative solution to the foresaid was the installation of HaTelit® as asphalt reinforcement over the cracked binder course, in which the thickness of the new wearing course should remain 5 cm. Hence, the economical 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 economical advantage then results from the longer lifetime of the surface over the old cracked area.

After the milling process the found surface was a very thin layer of bituminous bound gravel (Figure 9). In local spots the bonding was almost not present, but still the result was satisfac- tory.

![Figure 9: Surface after milling](image1)

![Figure 10: Condition of the road in 2009](image2)

On top of this layer a polyester grid as asphalt reinforcement was installed. Under such circum- stances a controlled and carefully organised installation is very important.

The whole project was finished in summer 1996. Regular inspections, with a last one taking place in April 2009 showed, that the road is still in an excellent condition (Figure 10). The life increasing function of the polyester grid has been proven very well. It must be emphasized at this point, that the two years estimated time has been increased up to 13 years until today.

Taking into account not only the construction costs but also the costs of traffic jams due to a road under construction, the environmental effects due to the increased quantities of bitumen used, HaTelit® has definitely proven its advantages. The above mentioned has been certified in a letter of reference by the responsible road authorities.
6.4 Salgado Filho Airport, Porto Alegre (Brazil)

In 2001 the existing access to an aircraft maintenance hangar (up to Boeing 737) had to be resurfaced after more than 40 years of use. The existing pavement was made of 6.0 × 3.5 m concrete slabs, 300 mm thick. The slabs were bedded on a layer of gravel. The design involved the installation of a new 50 mm asphalt layer on the existing pavement. In order to prevent the propagation of the expansion joints from the concrete slabs into the new asphalt layer, the asphalt reinforcement made of high modulus polyester was to be installed, in order to extend the fatigue life of the rehabilitated pavement.

It was not possible to block the access for an extended period. Therefore the rehabilitation works had to be finished in just one night. As the asphalt reinforcement must always be placed between two bituminous layers, an asphalt levelling course was installed on the existing concrete pavement first. The grid was installed on the levelling course, in 1.0 m wide strips, only over the expansion joints.

To keep to the very tight time frame it was decided, on site, just to reinforce the heavily load-ed inner part of the pavement. The outer part, where the planes normally do not taxi, was left unreinforced. The reinforcement was covered with a 50 mm asphalt layer.

What initially was thought to be a pure practical solution, developed into an ideal demonstration of the effectiveness of an asphalt reinforcement. It is now possible to compare directly, between an unreinforced, and a pavement reinforced with a polyester grid.

In October 2007, approx. 7 years after the rehabilitation, the first assessment of the pavement took place. At which time the designer, the technical manager of the airport and an employee of the manufacturer were present.

The expansion joints in the unreinforced areas had already propagated to the top of the sur-facing. The green, visible in the developed cracks, led to the conclusion that these cracks had existed for some time. In contrast to this, the PES-grid reinforced areas did not show any indications of cracking. The propagation of the expansion joints in the unreinforced areas can only be ascribed to the different temperature behaviour and the consequential horizontal stresses. As well as the temperature induced horizontal stresses the PES-grid reinforced area was also exposed to the dynamic loads from the passing planes (Figure 12).

![Figure 11: Beginning of the taxiway](image1)

![Figure 12: Joints of the concrete slabs reflect in the area where no reinforcement was used](image2)
6.4 Albany International Airport, New York

In 2000 the asphalt runway 10/28 of Albany International Airport in New York was heavily cracked, and was in need of resurfacing. To prevent the cracks from the old asphalt layers propagating through to the new surface, the airport’s consulting engineer decided to use an asphalt reinforcement out of high modulus polyester.

The project specification required milling of the existing pavement, applying the asphalt reinforcement and installing a new asphalt overlay. Because of its flexibility and exceptional resistance against shear stress it was possible to place the polyester grid directly onto the milled surface without a levelling course. This was extremely important to the contractor, as the major constraint for the project was the time the runway was accessible - 10 p.m. to 6 a.m. Nightly repairs to the runway, including line painting, had to be completed by 6 a.m., hence the contractor had to limit the area that would be milled and paved each night. Because the extra step of a levelling course was not required, the work was completed quickly and more area could be paved each night.

An inspection of the runway in 2007 showed the pavement in an excellent condition, despite the amount of traffic and the various types of aircraft that use the international airport. Airport officials were very pleased with the condition of the reinforced runway pavement seven years after its installation.
7. LIMITS IN USING A REINFORCEMENT GRID

There are limits in using an asphalt reinforcement, with no system available on the market able to prevent crack propagation resulting from vertical movements (e.g. concrete slabs which are not stable in their position, insufficient bearing capacity of a subgrade, frost heave). In the case of vertical movements from concrete slabs the voids under the slabs have to be filled, or the slabs have to be cracked and seated, in any case it must be ensured that the slabs are stable in their position.

Some reinforcements (with very brittle raw materials, e.g. glass- / carbon fibres) cannot be placed directly on milled surfaces. The peaks of the milling grooves lead to high shear load in the reinforcement and therefore cause high installation damage. When using brittle grids over milled surfaces it is always necessary to install a levelling course first.

Polyester as raw material for asphalt reinforcement grids is more flexible and it is therefore possible to use them directly on milled surfaces.

8. MILLING AND RECYCLING

Even the best asphalt reinforcement cannot guarantee an asphalt road will have an infinite life. The ease of removal of surfacing, by milling among other methods, is an increasingly frequent focus for discussion.

Huesker carried out milling trials in conjunction with the mixing plant “Schwelm” (in 2004) and RWTH Aachen University, Germany (in 2008) to demonstrate that a polyester grid (in this case HaTelit) can be milled as normal and the millings can be recycled.

In the trial at the mixing plant “Schwelm” a layer of HaTelit was installed onto an existing asphalt base and was overlaid with a 40mm thick asphalt surface course. It was removed after six weeks by a Wirtgen W 500 milling machine at a depth of 50mm (10mm below the grid). The reinforcement grid had no detrimental effect on the milling operation.

![Figure 16: Milling the asphalt surface course incorporating the PES-grid](image1)

![Figure 17: Only short residual fibres from the grid can be seen in the millings](image2)

The influence of a polyester grid (HaTelit) as asphalt reinforcement on milling characteristics was also investigated under defined conditions by the Institute of Road and Traffic Engineering at the RWTH Aachen University. The investigation aimed to analyse and evaluate the milling characteristics of the reinforced road construction in terms of process engineering and the machinery used. On its own test track the Institute installed two layers of asphalt including the polyester grid as asphalt reinforcement. A few weeks later the asphalt surface course
and the first centimetre of the asphalt binder course (including reinforcement) were removed by a milling machine in a single milling operation.

The RWTH Aachen University confirms, that during removal of the material no detrimental effect on the milling operation was observed: the millings were finely graded, and the fibres of asphalt reinforcement produced from the milling process were evenly distributed in the millings. “No negative indications were observed in the course of the asphalt testing to determine the effect of asphalt reinforcement fibres on recyclability (on the basis of Marshall Stability parameters),”

More detail may be obtained from the detailed report [7, 8].

9. CONCLUSION

Reflective cracking occurs in rehabilitated asphalt pavements. To delay the development of reflective cracks, Huesker started to produce an asphalt reinforcement made of high modulus polyester almost 40 years ago. This product was continuously improved until today. Polyester as raw material is chosen because of the high compatibility of its mechanical behaviour to the modulus of asphalt, its high resistance to installation damage and the excellent behaviour under dynamic loads.

An asphalt reinforcement made of high modulus polyester shows excellent results in delaying reflective cracking which was described by theoretical investigations, and some practical examples from the last 40 years.

It was also shown, that milling and recycling of PES-grid reinforced pavements does not show any detrimental effects, demonstrated by two investigations, one at a mixing plant and one at the Institute of Road and Traffic Engineering of the RWTH Aachen University.

All this clearly demonstrates that the use of an asphalt reinforcement made of high modulus polyester has proved to be the ideal material to delay or even prevent reflective cracking. Through this the service life of a pavement is considerably extended and the service intervals will be appreciably reduced. The associated savings lead to a considerable reduction of costs on asphalt pavement maintenance.
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