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PAVEMENT REHABILITATION WITH ASPHALT REINFORCEMENT. VALIDATION OF THE BASIC PARAMETERS FOR A LONG TERM PERFORMANCE

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ABSTRACT

Asphalt reinforcement products manufactured from polyester fibers have successfully been applied in pavement rehabilitation in excess of 40 years. Its outstanding performance assists authorities to reduce maintenance intervals which does not only have economic advantages, it also lowers environmental impact through the reduced need for exhaustible resources and reduced traffic. Reflective cracking in asphalt pavement is a problem known since the first asphalt pavements were constructed. There are several reasons which causes asphalt to crack. The most popular rehabilitation process is to renew the cracked surface with a new asphalt layer. Depending on the thickness of the new asphalt layer, cracks from the bottom layer will sooner or later propagate to the surface and the pavement will require rehabilitation again. The challenge has been to develop a system which can delay or even prevent a crack to propagate to the pavement surface. By the beginning of the 1970s the first asphalt reinforcement system manufactured from polyester fibers were successfully applied. This paper will provide case histories from 4 decades of continuous research and development of an effective asphalt reinforcement system. Additionally the basic theory and most important parameters for the design will be demonstrated.

1 INTRODUCTION

Asphalt reinforcement has been used worldwide for many years to delay or prevent reflective cracks in asphalt layers. Using asphalt reinforcement can clearly extend the fatigue life and therefore the maintenance intervals of rehabilitated asphalt pavements. Currently there are a number of different products and systems of different raw materials (e.g. Polyester, Glass, Carbon, Polypropylene...) available in the market. It is not disputed that all these systems have a positive effect, however there are differences in the behavior and effectiveness of such systems.

2 BASICS REFLECTIVE CRACKING AND ASPHALT REINFORCEMENT

The type of damage considered in this paper is reflective cracking in a new asphalt overlay installed on a cracked old asphalt layer or on a cement concrete base. Traffic and temperature variations result in cyclic opening and closing of the joints and so in a high stress concentration on the edges of the openings. Without any reinforcement the overlaying asphalt suffers high stresses and overloading and cracks will be initiated. These cracks start to propagate from the existing pavement through the new overlay quite rapidly. Such cracks result primarily because of thermally induced fatigue but also because of traffic fatigue.

In order to delay the propagation of cracks into the new asphalt layers an asphalt reinforcement of high tenacity polyester can be installed. The reinforcement increases and take up a significant proportion of the horizontal tensile stresses in the asphalt layer and ensure a uniform distribution of stress over a larger area. This serves to reduce tensile stress peaks and the associated risk of overloading.

Reflective cracking is of major interest to road engineers facing the problem of road maintenance and rehabilitation to plan the most economic and durable pavement.

3 WHY POLYESTER?

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 (Table 1). 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. 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, through this it delays reflective cracking.

Material combination	Thermal expansion coefficient (1/K)	Ratio
Concrete / Steel	$1.3 \times 10^{-5} / 1.0 \times 10^{-5}$	~1 : 1
Asphalt / Polyester	$6.0 \times 10^{-4} / 1.6 \times 10^{-4}$	~1 : 4
Asphalt / Fiberglass	$6.0 \times 10^{-4} / 4.5 \times 10^{-6}$	~1 : 130

Table 1 Comparison of the thermal expansion coefficient

In 1999 de Bondt published "Anti-Reflective Cracking Design of (Reinforced) Asphaltic Overlays", which was the last phase in his Ph.D. program and a 5 year research project at the Delft University of Technology. De Bondt determined the relevance and influence of different parameters on reflective cracking in asphalt overlays, and performed comparative investigations on different commercially available products in the market.

He found that one of the most important parameters is the bonding of the reinforcement to the asphalt, defined as bond stiffness ($c_{eq,rf}$). De Bondt determined the equivalent bond stiffness in reinforcement pull-out tests on asphalt cores taken from a trial road section. Parts of the results are presented in figure 1, for full details the reader may refer to the full publication.

The equivalent bond stiffness of the polyester geogrid turned out to be the best of all the commercial products investigated. The importance of the bituminous coating for flexible grids becomes clear. De Bondt found that in flexible grids like Polyester geogrid the stresses were transmitted via direct adhesion between strands and asphalt – hence the coating plays a vital part to the ultimate performance.

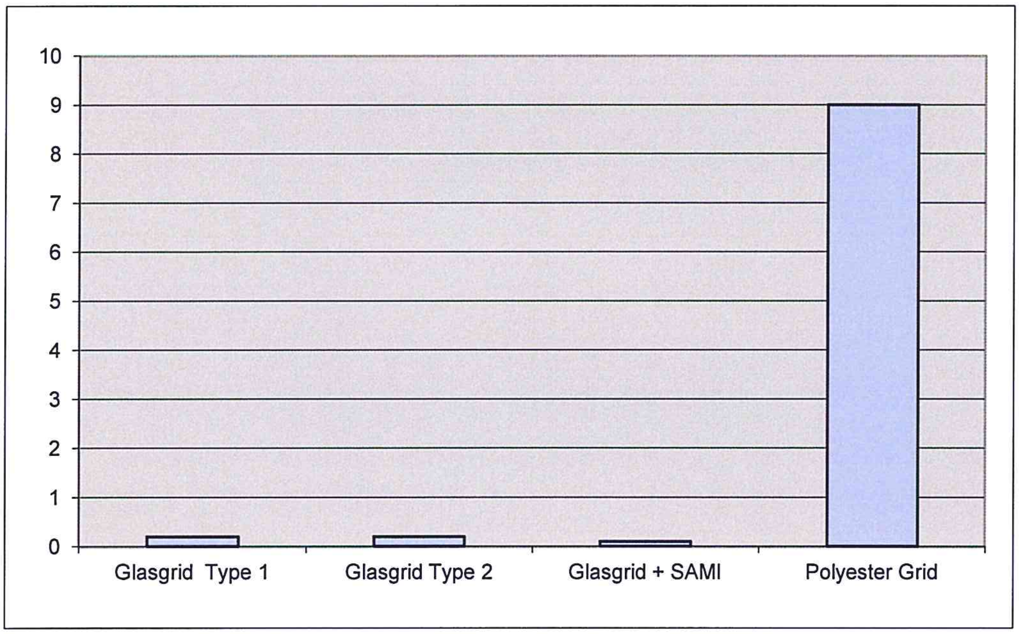


Figure 1 Equivalent bond stiffness ($c_{eq,rf}$ in N/mm/mm²) of different commercial products

By using finite element models, de Bondt calculated the improvement factors for reinforcements based on material stiffness (EA_{rf}) and pull-out stiffness ($c_{eq,rf}$). With a product stiffness of ~900 N/mm and a pull-out stiffness ($c_{eq,rf}$) of about 9, polyester geogrid achieves an improvement factor of 3.5 in de Bondt's simulation.

For a long term performance asphalt reinforcement must resist as much damage as possible from the stresses and strains applied during installation and overlaying / compaction of the asphalt. Very high forces can also be applied to the individual strands of the reinforcement by aggregate movement in the hot blacktop during compaction.

In a research at the RWTH Aachen University in Germany, called "Effectivity of asphalt reinforcement systems under consideration of installation damage" (Sakou 2011), it was found that products with a brittle raw material, like glass-fibers, can lose a significant part of their tensile strength when trafficked by asphalt delivery trucks and during the asphalt compaction. The results of the demonstrated research are also confirmed by results of tests performed according to EN ISO 10722-1 "Geosynthetics: Procedure for simulating damage during installation" (tBU 2003). In both tests Polyester as raw material exhibited a very good resistance to installation damage.

4 EXPERIENCE WITH POLEYSTER ASPHALT REINFORCEMENT SINCE 1970s

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 polyester geogrid layer was intended to pick up the tensile stresses in the asphalt like steel reinforcement in concrete and prevent cracks from forming. However, it was soon realized that the principle would not work as the developers expected, because of the completely different characteristics of asphalt and concrete. But it was found that the product proved well 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 behavior of asphalt.

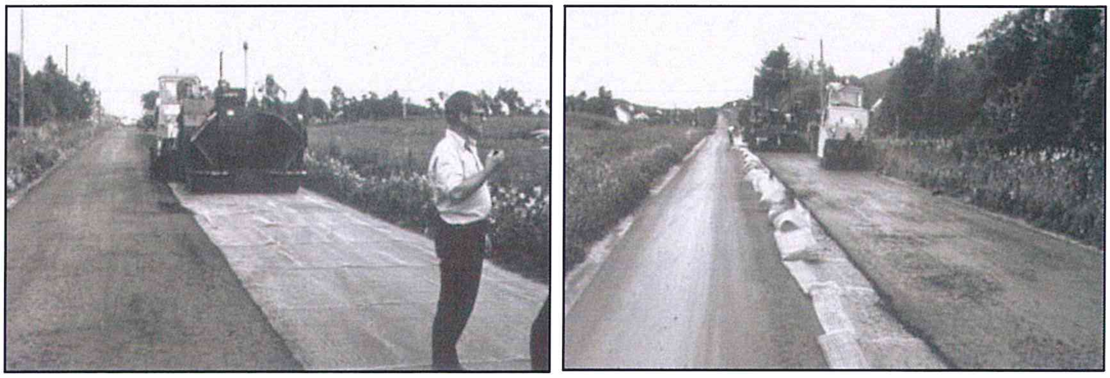


Figure 2 First use of asphalt reinforcement by the end of the 1960s

4.1 REHABILITATION OF BRUSSELS AIRPORT BY THE END OF THE 1970s

The existing concrete runway was showing such a serious damage that a complete refurbishment was considered essential. In order to delay the propagation of cracks from the expansion joints of the concrete slabs through to the surface, this would be the first time that asphalt reinforcement had been used at the airport. First the cracked runway surface was milled off and any loose concrete slabs were under filled. A bituminous regulating course was applied on top of the concrete and polyester geogrid was installed.

As the highest loading from landing aircraft occurs in the center 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 runway surface was then overlaid with a 5 cm binder course and a 5 cm surface course. The refurbishment works should just 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 the asphalt surface. In the reinforced zone no individual cracks could be seen. The last assessment took place in 1990 (10 years later). The runway was still in excellent condition.

Figure 3 Brussels Airport rehabilitation by the end of the1970s

4.2 Rehabilitation of Schumacherring, Ahaus – Germany in 2007

In context of a master-thesis more than 40 projects, in which a Polyester asphalt reinforcement has been used, have been evaluated. The age of the pavements was in a range of 8 to 17 years.

In 2007 the road Schumacherring had to be rehabilitated because a lot of transversal and alligator cracks in the old asphalt pavement. Additionally the road have been upgraded from a communal road to a state road. Not only the reflective cracking have been a challenge, also the technical requirements have increased due the higher traffic volume. So the local road authorities “Strassen NRW” had to decide for rehabilitation method. The normal rehabilitation method would have been to replace the cracked wearing course by a new one. But the rehabilitation wouldn´t have been sustainable, because the cracks would have been still there and propagate to the surface again in a short period of time. Another approach would have been to rebuild the road completely by installing a new base course and a complete new asphalt pavement.

Both solutions have not been satisfying to the local road authorities. By the end of the day they have decided to use a polyester asphalt reinforcement, as a cost effective alternative to rehabilitate a pavement with reflective cracking. The polyester asphalt reinforcement is delaying significantly the propagation of reflective cracks and increases therefore the maintenance intervals of a pavement.

The polyester asphalt reinforcement has been installed directly on the cracked base course. Afterwards a 4cm asphalt binder course and 4cm stone mastic asphalt as wearing course has been installed.

The pavement has been investigated in March 2013, 6 year after the installation. The condition of the road has been still in a good condition. Only one crack has been spotted on the length of 1355m. Here it is still questionable if this is a reflective crack or a local failure. In the end it can be stated that using a polyester asphalt reinforcement have shown an outstanding performance in relation to the durability of the pavement.

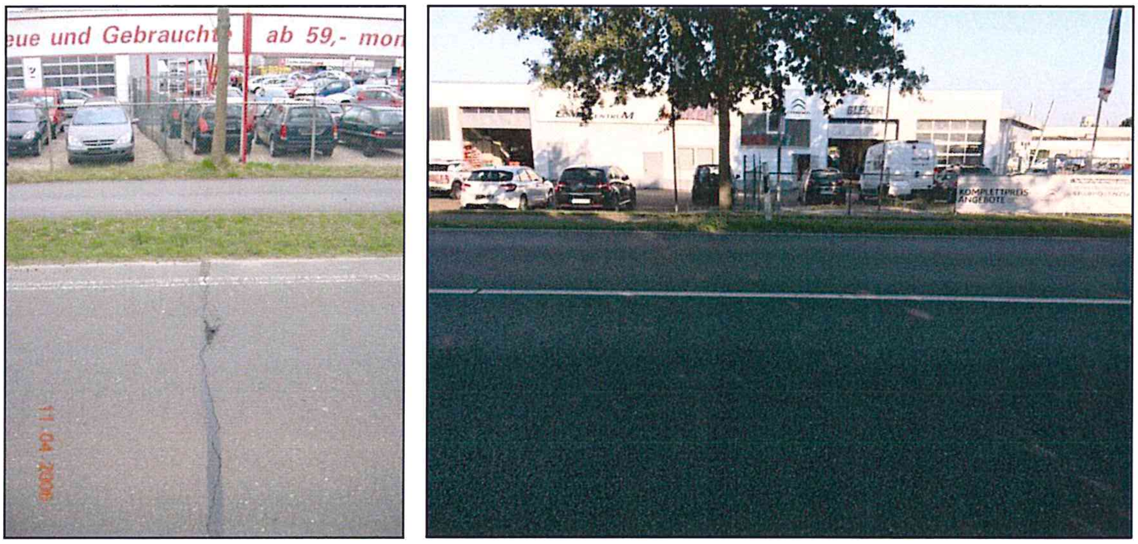


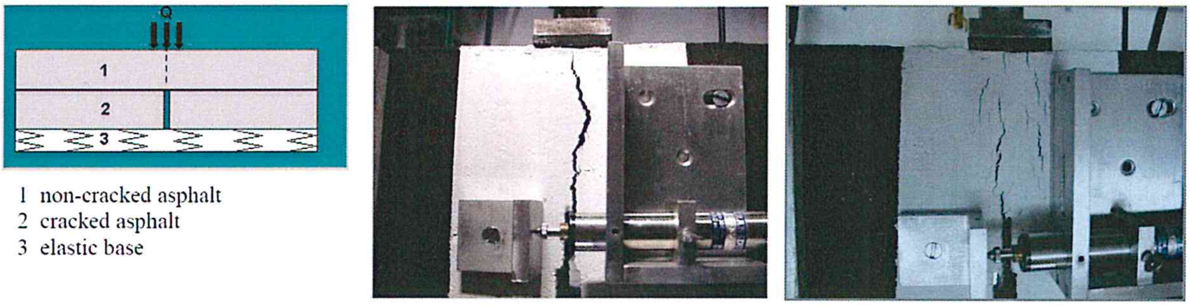
Figure 4 Pavement condition in April 2006 in comparison after 9 years in August 2015, no transversal crack visible.

5 PROOF OF EFFECTIVNESS BY RESEARCH

The effectiveness of PET asphalt reinforcement is the key to sustainable rehabilitation of pavements. Parallel to the practical experience of the last 40 years with PET asphalt reinforcements, various laboratory tests and design methods exists, proving, that the lifetime extension factor is 3 – 4 times when using polyester geogrid. The most significant research is presented hereafter:

5.1 Dynamic fatigue Tests (Bending and Shearing)

A full description and the results of a testing program performed at the Aeronautics Technological Institute in Sao Paulo, Brazil, were published by Montestruque in 2004. In this research program which stated in 1999, an asphalt wearing course was applied over an existing crack in a detailed series of tests (Figure 5). Both the bending and the shear mode were investigated under dynamic fatigue loading conditions. The results confirmed that the polyester geogrid considerably delays the propagation of cracks. Compared to the unreinforced samples, the polyester geogrid reinforced asphalt layers were subjected to up over 5 times the number of dynamic load cycles before a crack reached the surface. The crack pattern clearly shows that the reinforcement absorbs the high tensile forces and distributes over a larger area.



Unreinforced sample after 80,000 cycles

HaTelit® reinforced sample after 490,000 cycles

Figure 5 Dynamic Testing at ATI (Brazil) - Bending Mode

6 CONCLUSION

This paper has shown that the use of an asphalt reinforcement made of high modulus polyester is an ideal method to delay or even prevent reflective cracking. The high resistance of polyester against installation damage and dynamic loading combined with an effective interlayer bonding and easy installation are key factors for the success of asphalt reinforcement. The project experience and research presented proves that the pavement life can be increased by a factor of 3 - 4 by using polyester geogrid asphalt reinforcement.

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