# ASPHALT REINFORCEMENT WITH POLYESTER GRIDS - A PROVEN TECHNOLOGY

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## ABSTRACT

Engineers considering geosynthetic interlayers, as a method of addressing the issue of reflective cracking in asphaltic pavements, possibly one of the most prevalent problems faced by pavement maintenance engineers, are able to draw on, in excess of, 25 years of worldwide experience. Geosynthetic's ability to perform in a wide variety of climatic conditions makes them ideal in addressing the issue of crack initiation and propagation, and the resulting damage caused by water ingress, and ultimate failure of the pavement structure. Bituminous bound materials are, by their very nature, unable to withstand high tensile forces and therefore benefit greatly from the inclusion of a well installed tensile reinforcement layer, where the geosynthetic and the surrounding bituminous material are able to develop an excellent bond. These forces can result from a variety of mechanisms e.g. reflective, fatigue or thermal cracking. A particular area of success has been the use of these materials to address reflective cracking, prevalent in bituminous overlays of jointed concrete pavements ('bottom up' cracking), usually subject to high traffic loading and frequently occurring in conjunction with thermal effects. The increased pavement life achieved by the use of this technology, not only prevents excessive traffic, and business disruption, but it also demonstrates a strong environmental benefit. This paper will demonstrate, by example, the success, and extended pavement life, which can be achieved, both in highway and airfield applications, from correct raw material specification, and careful final product installation of asphaltic reinforcement.

*Keywords: Asphalt reinforcement, polyester, pavement rehabilitation*

## INTRODUCTION

Asphalt reinforcement has been used worldwide 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 rehabilitated 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 not disputed that all these systems have a positive effect, however there are differences in the behaviour and effectiveness of such systems.

## 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 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 which 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 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.

Reflective cracking is of major interest to road engineers facing the problem of road maintenance and rehabilitation.

## CREATING AN ASPHALT REINFORCE-MENT OVER ALMOST 40 YEARS

The idea of a reinforcing fabric for asphalt road construction first emerged at the early 1970s (Fig. 1). First experiences had been made with Geogrids in Earthworks and Foundations, so the idea had come up to use them in asphalt pavements. The initial intention was that the embedded geotextile layer was able 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 soon 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 behaviour of asphalt. Since then many products made from different raw materials have been developed.

Fig. 1 First use of asphalt reinforcement grid (here HaTelit®) at the early 1970s.

## 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. This leads to very small internal stresses between the PET fibres 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, through this it delays reflective cracking.

As found by de Bondt (De Bondt 1999) the bonding of the material to the surrounding asphalt plays a leading role for 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.

Furthermore, 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-fibres, can lose a significant part of their tensile strength when trafficked by asphalt delivery trucks and after 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.

## DYNAMIC FATIGUE TESTS FROM AERONAUTIC TECHNOLOGICAL INSTI-TUTE, SAO PAOLO

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 formed 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 (HaTelit® C 40/17).

The type of loading was sinusoidal and the applied pressures were 330, 425 and 550 kN/m², changing the load position in relation to the crack (bend/shear).

Between the steel plate and the asphalt concrete beam, a rubber was installed in order to minimize the concentration of stresses related to the stiffness of the steel plate (Fig. 2). The termination criterion of the test was considered when the first visible crack appeared at the surface.

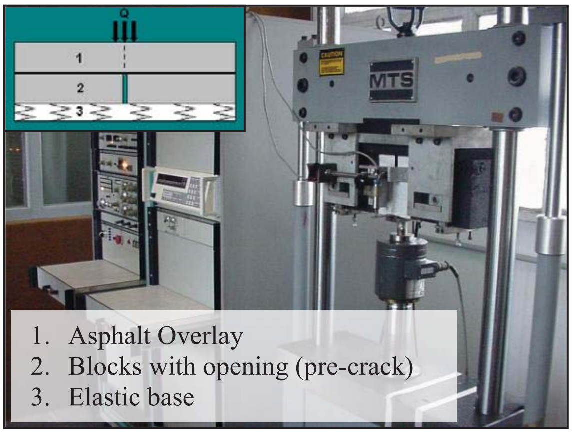


Fig. 2 Test Set-up at ATI in Sao Paolo

**Results**

In beams without a geogrid, the reflective crack came out after a few load cycles. Its growth, in bending and shearing mode, was fast and practically vertical, following the face of aggregates found on the way (Fig. 3). When the reflection crack reached the top of the asphalt beam (7.5 cm) it ruptured and marked the end of the test.

For the beams reinforced with a geogrid, this vertical growth occurred up to 2cm and 3cm, 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 appeared 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 (Fig. 4). 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.

On 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. With these results a factor of effectiveness was calculated. For the reinforced specimen with a 3mm pre-crack it was calculated to 6.14.

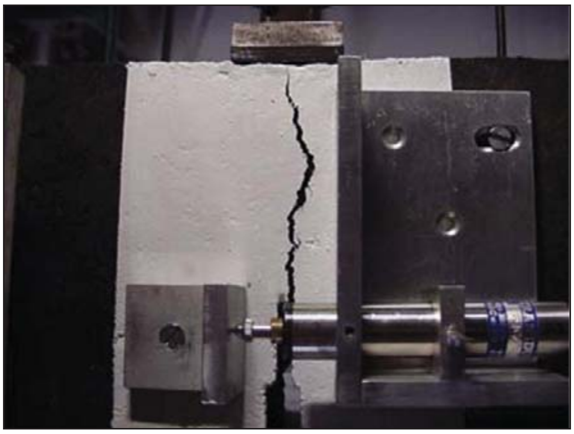

Fig. 3 Unreinforced beam

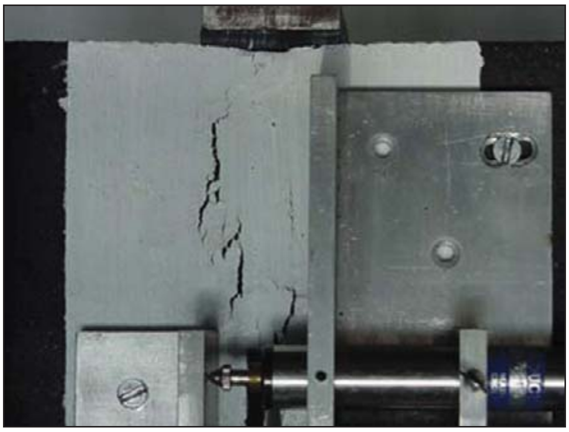

Fig. 4 Reinforced beam

For further details the reader is referred to the full version (Montestruque et al. 2004).

## PRACTICAL EXPERIENCE: 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 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. A bituminous coated PET Geogrid was then installed as asphalt reinforcement 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 PET-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 by the project engineer Francis Knappenberg (Knappenberg F., 1983) the refurbishment of the runway using a reinforcement grid had been successful!

Fig. 5 Installation of the PET asphalt reinforcement 1979

## PRACTICAL EXPERIENCE: MUNICIPAL ROAD "ROSENSTRASSE" IN GERMANY

This project reference shall also give an example of the successful use of asphalt reinforcement in roads. The project is located in the Northwest German town of "Ochtrup". 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 rehabilitation the road revealed severe alligator cracking, longitudinal and transverse cracking in large scale. The original design, and budget, called for milling the surface, approx. 50 mm, and installation of a new 50 mm asphalt surface course. Due to the problematic condition of the existing base the expected lifetime of the 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 a high modulus polyester grid as asphalt reinforcement over the cracked binder course, in which the thickness of the new wearing course should remain 50 mm. 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 milling off the 50mm surface course a PET grid as asphalt reinforcement was installed, and covered again with a 50mm 0/11 AC asphalt layer. The whole project was finished in summer 1996.

Fig. 6 Surface after milling

**Project Update: June 2002**

Six years after the repairs were carried out, the Steinfurt District's Chief Executive was asked for a condition report on the "Rosenstrasse". In his answer, the responsible clerk commented as follows: "(..) I'm happy to inform you that the repairs at the time to Kreisstrasse 57, Rosenstrasse, using HaTelit® 30/13 have fully stood the test of time. The use of the asphalt-reinforcement system under the 0/11 asphalt layer has meant that, to this day, no cracks have appeared in the asphalt-concrete surface. This method was chosen at the time to avoid the necessity of the additional work required for the binder and base course (...)"

**Project Update: September 2009; Assessment by TUV Rheinland LGB Bautechnik GmbH,**

With the permission of Ochtrup municipality, the TÜV Rheinland LGA Bautechnik GmbH was commissioned to record the cracking and assess the condition of "Rosenstrasse" along the length repaired in 1996.

The appraisal also compared the current

condition with the condition that existed before repairs were carried out in 1996. This comparison permitted conclusions to be drawn about whether the use of the asphalt-reinforcement system was able to delay the occurrence of cracks propagated from the lower courses.

On August 24th 2009, a visual inspection was undertaken in accordance with Working Paper No. 9 by the "Forschungsgesellschaft für Strassen und Verkehrswesen" (FGSV: Research Association for Road and Transport in Germany).

The LGA used the image documentation of the construction measures prepared in May 1996 as the basis for its assessment. The District's Chief Executive employed by the Steinfurt District at the time also provided additional necessary information.

**Results**

After 13 years of use, the cracking condition value (ZWRIS) for the section of the road repaired with the PET asphalt reinforcement in 1996 was determined as being excellent. According to the LGA, the visual inspection of the road surface revealed almost no damage to the substance. Two repair sites were recorded over the entire section; these, however, were due to work carried out on the drainage system. A few lateral cracks were discovered at one point on the outer edge of the built-up road. Small cracks along the road surface were also found at a few other points on the outer edges (Fig. 7).

The photos documenting the condition of the site in 1996 (Fig. 8) show that the distance between the reinforcement system and the road edge was always around 150 - 300 mm. TÜV Rheinland LGA also confirmed: "The entire remaining road area is free of cracks."


Fig. 7 Lateral crack at the edge

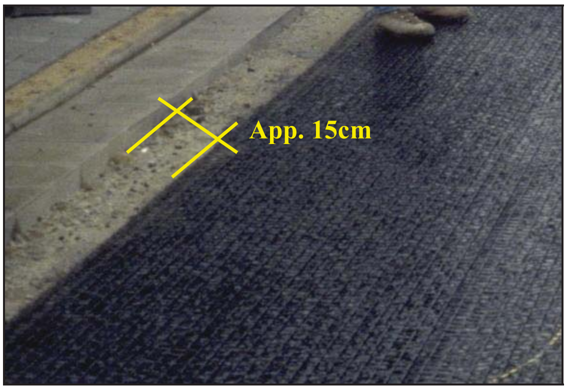


Fig. 8 Fitted reinforcement (detail)

**Conclusions**

The condition assessment by TÜV Rheinland LGA revealed that the "Rosenstrasse" in Ochtrup has in spite of constant heavy traffic, remained in a good condition to this day. The deployment of the asphalt reinforcement system to effect repairs has completely stood the test of time.

This measure has shown that a PET asphalt reinforcement can keep the condition of repaired roads may be maintained at high levels over extended periods of time.

**PRACTICAL EXPERIENCE: SALGADO FILHO AIRPORT, PORTO ALEGRE (BRAZIL)**

In 2001 the existing access to an aircraft maintenance hangar (up to 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 bedded on a layer of gravel.

The rehabilitation design involved first the installation of an asphalt leveling layer. In order to prevent the propagation of the expansion joints from the concrete slabs into the new surface course, an asphalt reinforcement made of high modulus polyester was to be installed. Onto the reinforcement a new 50 mm asphalt surface course was installed.
It was not possible to block the access for an extended period. Therefore the rehabilitation works had to be finished in just one night.

To keep to the very tight time frame it was decided, on site, just to reinforce the heavily loaded inner part of the pavement. The outer part, where the planes normally do not taxi, were left unreinforced.

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 reinforced.

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 surfacing. The green, visible in the developed cracks, led to the conclusion that these cracks had existed for some time. In contrast to this, the PET-grid reinforced areas did not show any indications of cracking (Figs. 9 and 10). 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 PET-grid reinforced area was also exposed to the dynamic loads from the passing planes.

For further details the reader is referred to a paper prepared by Monser and Montestruque (Monser et al. 2010).

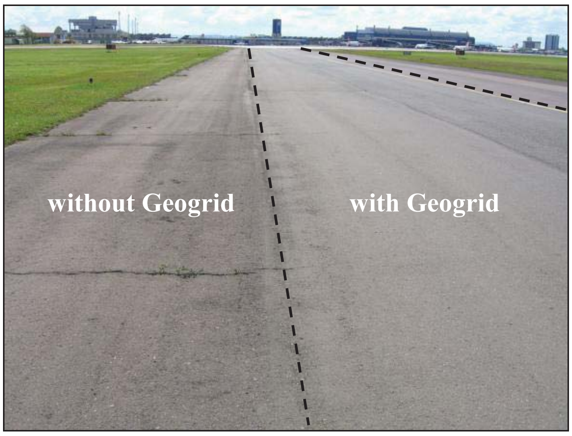


Fig. 9 Overview of the studied section: view from the dockyards to the terminal.


Fig. 10 Joints of the concrete slabs reflect in the area where no reinforcement was used

## MILLING AND RECYCLING

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

For this reason the influence of high-modulus polyester asphalt reinforcement on milling characteristics was investigated under defined conditions by the Institute of Road and Traffic Engineering at the RWTH Aachen University (RWTH 2008).

On the University's own 26m long, 1m wide test bed, the Institute can lay, and remove, lengths of road construction using ordinary methods typically employed on site.

The road materials were laid by a rail-mounted paver machine with a high performance compacting screed. The surface was given its final compaction by a tandem vibratory roller.

A small milling machine with a milling drum width of 500mm was used for the milling tests.

The aim of the investigation was to analyse and evaluate the milling characteristics of the reinforced road construction in terms of process engineering and the machinery used. In addition to investigating particle size distribution and the type and size of reinforcement fibres in milled asphalt, the possibility of recycling the removed asphalt containing reinforcement fibres in the form of asphalt granulate in bitumen-bound layers was examined.

### Test Procedure

A 60mm asphalt binder course (AB 0/16S) and an asphalt base were laid over a frost protection layer on the test bed. After a resting time of about one week, the PET asphalt reinforcement was installed in accordance with the manufacturer's installation instructions. This was then overlaid with a 40mm asphalt surface course (AB 0/11S).

### Removal - Milling Tests

A milling depth of about 50mm was selected to ensure that the asphalt surface course and the first 10mm of the asphalt binder course (including reinforcement) were removed by the milling machine in a single milling operation (Fig. 11). This procedure was recommended by the manufacturer for the removal of reinforced roads.

Result: During removal of the material no detrimental effect on the milling operation was observed. Over the full test length, the millings were finely graded. The fibres of asphalt reinforcement produced from the milling process were evenly distributed in the millings. The fibres had an average length of about 100mm.

Fig. 11 Milling the asphalt including the reinforcement

Fig. 12 Virtually no fibres on the milling drum

After completion of the milling operations, the milling drum was checked for adhering fibres. It was clear that over the whole test bed almost no (only 2) fibres had been trapped in the milling drum (Fig. 12). During this test, no detrimental effects on the milling process were observed.

**Recyclability: Effect of the Reinforcement Fibres on Marshall Stability**

As part of tests on the asphalt, the effect of asphalt reinforcement fibres in the asphalt material on its recyclability was investigated. Marshall test specimen were made from the asphalt binder layer material with and without asphalt reinforcement fibres and their Marshall stability and flow value was determined. The reference sample was equivalent to the asphalt binder course laid on the test bed. The asphalt reinforcement fibre content was the major difference between the two variants and the purpose of the test was to determine the effect of these fibres.

Result: There were only relatively small differences with respect to bulk density and void content between the Marshall test specimen used for the tests. The values for Marshall Stability and flow were virtually identical.

The results for the Marshall test parameters are shown in the following table.

Table 1 Results of recyclability test

| | Reference sample | With reinforcement fibres |
|---|---|---|
| Marshall Stability | 8.4 kN | 8.5 kN |
| Marshall Flow | 3.6 mm | 4.3 mm |

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 and -Flow parameters).

## LIMITS IN USING AN ASPHALT REINFORCEMENT GRID

There are limits in using asphalt reinforcement, with no system available on the market able to increase the bearing capacity. When having an insufficient bearing capacity it is necessary to carry out other measures, e.g. base reinforcement or increasing the asphalt 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).

One has to consider, that reinforcement grids made of brittle raw materials (e.g. Glass- / Carbon-fibres) cannot resist shear forces. For this reason they tend to quickly deteriorate especially when having vertical movements (e.g. of concrete slabs, even when they are low).

Manufacturers of grids made of brittle materials often point out that, because of its fragility and brittleness (i.e. the low shear strength of glass fibre and the resulting high risk of damage) glass fibre grids should not to be placed directly onto milled surfaces. How glass fibre reinforcements behave when placed directly over the sharp edges of cracks, especially during compaction, has not been clarified up to now and requires further investigation.

## CONCLUSIONS

Reflective cracking occurs in rehabilitated asphalt pavements. High tenacity Polyester is often chosen as a raw material because of the high compatibility of its mechanical behaviour to the modulus of asphalt, and its good performance under dynamic loads. A bituminous coated PET-grid as asphalt reinforcement 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 PET-grid reinforced pavements does not show any detrimental effects, demonstrated by an investigation at the Institute of Road and Traffic Engineering of the RWTH Aachen University.

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