

# PREVENTION OF REFLECTIVE CRACKING - THE SUCCESSFUL USE OF POLYESTER ASPHALT REINFORCEMENT GRIDS

**Anreas Elsing\***

Civil Engineer, Huesker Synthetic GmbH, Germany

**Sven Schröer**

Civil Engineer, Huesker Synthetic GmbH, Germany

**ABSTRACT:** Reflective cracking is a well-documented and known phenomenon. Without any treatment cracks or joints in existing cracked pavement structures will propagate nearly vertical through a new asphalt overlay, creating a reflective pattern similar to the one existing before. The prevention of reflective cracking in pavements has always been an area of concern when designing for asphalt overlays. A very effective system for the delay or even complete arrest of reflective cracking has proven to be Asphalt Reinforcing Geogrids out of Polyester fibres, which have successfully been used for about 35 years now. Successful applications have been achieved in different applications as roads, highways and airports in nearly all climatic conditions. Examples of evaluations in various countries and conditions are given. The long-term interaction of the reinforcement and the asphalt layers is crucial to the proper functioning of asphalt reinforcement. The demands on a reinforcement during installation, overlaying and compaction of the asphalt and finally the dynamic loading due to traffic will be described. Various laboratory studies have been performed on reinforced asphalt systems. When a wheel passes a cracked system the system is stressed dynamically in different modes (bending and shearing) depending on the wheel position. Additionally horizontal movements may occur due to temperature variations. The results of the studies will be summarised. Attention is also given on the performance on site such as installation process, milling of reinforced asphalt and the reuse of recycled reinforced asphalt.

**KEY WORDS:** Reflective cracking, asphalt reinforcement, grids

## 1. REFLECTIVE CRACKING

Reflective cracking is a major interest for road engineers facing the problem of road maintenance and rehabilitation. Reflective cracking can be caused by traffic, temperature variations and/or uneven movements (vertical and horizontal). The literature distinguishes traffic and thermally induced reflective cracking, thereby referring to the different modes of crack propagation (Figure 1). The function of an asphalt reinforcement is to increase the resistance of the overlay to high tensile stresses and to distribute the horizontal interface shear stresses over a larger area, thereby reducing the peak shear stresses at the edges of the cracks in the existing old pavement.

The reinforcement 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. To make the benefits of the asphalt reinforcement clearer all possible load situations and failure modes should be investigated.

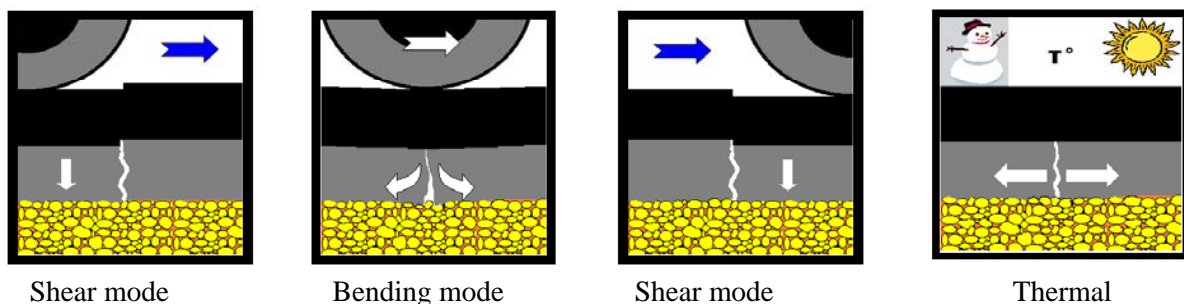


Figure 1. Reflective cracking failure modes

## 2. DYNAMIC FATIGUE TESTS

A full description and the results of a testing program performed at the Aeronautics Technological Institute in Sao Paulo, Brazil, were published [1]. In this research program which started in 1999 (and is still continuing) an asphalt wearing course was applied over an existing crack in a detailed series of tests. Both the bending mode and the shear mode were investigated under dynamic fatigue loading conditions. The results confirmed that a HaTelit<sup>®</sup> C (asphalt reinforcing grid out of high tenacity polyester) – reinforced construction considerably delayed the full penetration of cracks. Compared to the unreinforced samples, the HaTelit<sup>®</sup> C- reinforced asphalt layers were subjected to up to 6.1 times the number of dynamic load cycles before a crack reached the surface. The crack pattern clearly shows that the reinforcement takes up and distributes the tensile forces.

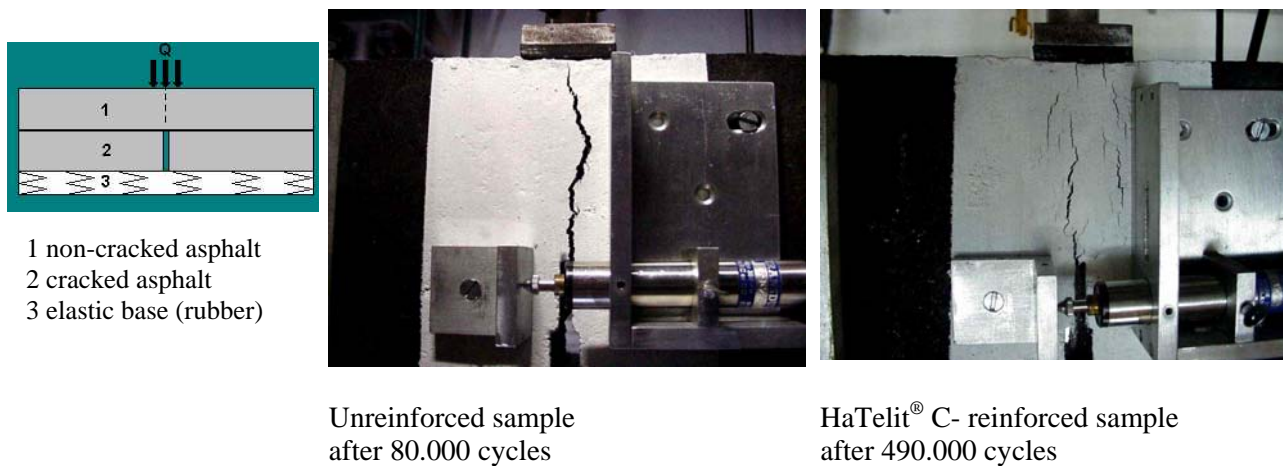


Figure 2. Dynamic fatigue testing at ATI (Brazil)

In a later stage of this research program, the most effective interlayer system should be found. Therefore various asphalt reinforcing products made of different raw materials had been tested under the same conditions. It turned out that the shear mode is the most critical in respect to the lifetime of the system, which means the improvement factors are lower than for the bending mode. Table 1 shows a comparison of the results from the shear mode tests.

Table 1. Results of the dynamic fatigue tests (shear mode) on different asphalt reinforcements

type of reinforcement	number of cyclic loadings until a crack reaches the surface	multiplier (improvement factor)
unreinforced reference sample	145715	1
uncoated glass fibre reinforcement 1	396119	2,7
on a thick PP-nonwoven 2	393582	2,7
coated glass grid	421429	2,9
HaTelit C 40/17	584375	4
HaTelit XP 50	748572	5,1

## 3. THERMAL CRACKING TESTS

The Belgium Road Research Centre (OCW) has developed a test device to assess the effectiveness of anti-cracking interlayers, more particularly when used on concrete slabs subject to thermal expansion and shrinkage [2]. In the thermal cracking test, schematically represented in Figure 3, specimens comprising a cracked concrete base, an interface system and a bituminous overlay are subjected to opening and closing cycles until the crack in the base becomes apparent at the surface of the overlay.

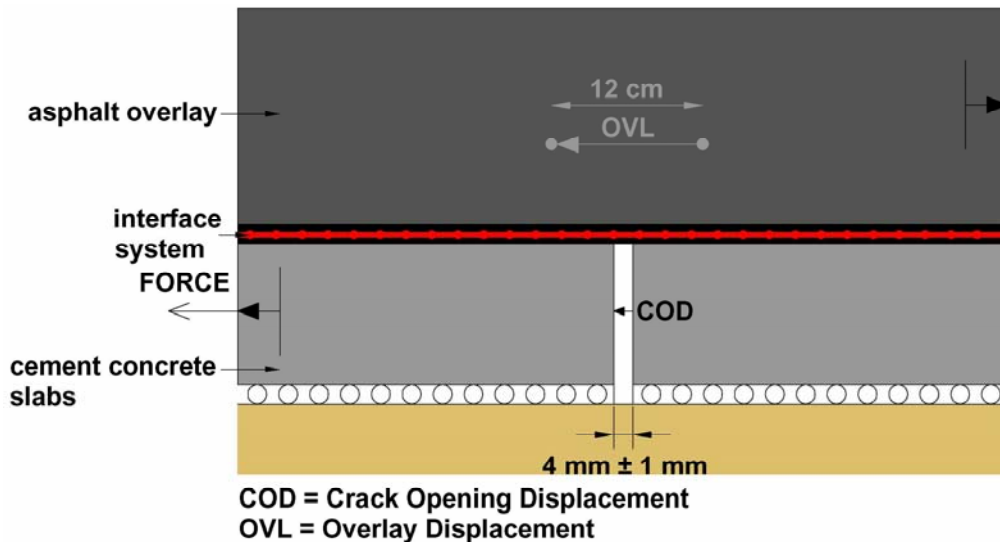


Figure 3. Schematic view of the thermal cracking test

The test sample is placed in an environmental chamber on a bed of steel balls to permit free horizontal movement. The right side of the cement concrete base is fixed and a cyclic force is applied to the left side. The force is driven by the width of the discontinuity: in one cycle the discontinuity in the cement concrete base is increased by 1 mm and decreased to its initial width. The rate of displacement is very slow, typically a few tenth of a millimetre per hour. This simulates the effect of subsequent shrinkage and expansion of the cement concrete slabs as a result of thermal variations. Figure 4 represents the development of crack length observed in a bituminous overlay during tests performed with various interface systems.

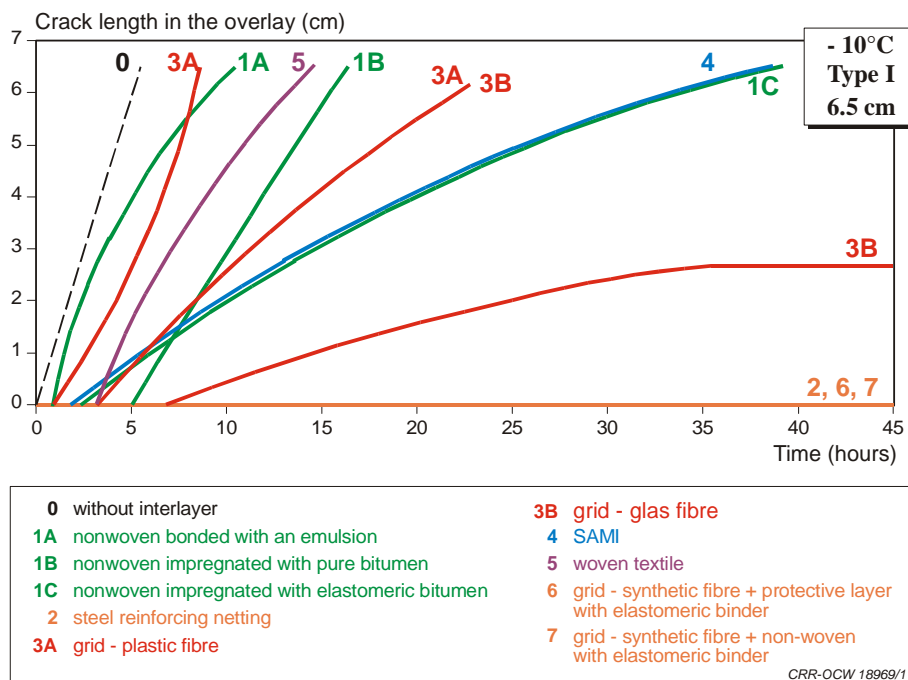


Figure 4. Vertical crack growth in the overlay for different types of interface systems

#### 4. SHEAR TESTS

The long-term interaction of the reinforcement with the asphalt layers is crucial to the proper function of the asphalt reinforcement. Without bonding tensile forces in the reinforcement cannot be mobilized. Bitumen coated grids out of polyester fibres show an excellent and durable bonding behaviour. The choice of polyester for reinforcement grids is based on its mechanical properties, which are well compatible with the

elasticity and stress-strain behaviour of asphalt. Since 1994 asphalt bore cores (diameter 150 mm), from various international projects with and without reinforcing grids have been investigated in interface shear tests as developed by Leutner (DIN 1996 T7). The results of cores with HaTelit<sup>®</sup> compared to cores without reinforcement confirmed that HaTelit<sup>®</sup> does not reduce the bond strength between old asphalt and new overlay. Table 2 shows the test results for 150mm diameter cores from the re-surfacing at an airport in Germany (Airport Jagel). The milled surface was coated with 0.5 kg/m<sup>2</sup> bitumen emulsion U 70 K and overlaid with HaTelit<sup>®</sup> C 40/17 and finally covered with 4.0 – 6.0 cm wearing course. This rehabilitation work was carried out 1998 and until today the surface is still satisfactory in every respect. The first four cores were taken four weeks after construction. One of the cores was an un-reinforced reference sample.

Table 2. Leutner shear test results of asphalt cores

Core No.	Description	Shear force kN
1	HaTelit <sup>®</sup> C 40/17	36.42
2	Unreinforced reference sample	30.17
3	HaTelit <sup>®</sup> C 40/17	37.48
4	HaTelit <sup>®</sup> C 40/17	36.72

The shear strength measured in the tests was very high on all the cores and in this instance even higher in the reinforced samples than in the un-reinforced. However, it cannot be concluded from this that HaTelit<sup>®</sup> C 40/17 improves the bond, but it clearly shows that the bond is not reduced. Reinforced product without a bituminous coating as well as composite products (reinforcement with a non-impregnated nonwoven) all showed a considerable reduction in bond strength between the layers. In many instances these samples separated during drilling. Similar results showing the reductions in the bond between layers for various reinforcement types are described in [3].

In such composite products the non-woven has to be saturated during installation, in order to have a SAMI (Stress Absorbing Membrane Interlayer) effect. At the same time the grid should provide a reinforcing function. If, however, the non-woven reduces the bond between layers, the reinforcement cannot mobilise the tensile force. A reinforcing effect can only occur if there is sufficient bond between the layers to transfer the forces. The two effects cannot simply be added together. Using a thick non-woven, the required amount of bitumen to saturate the non-woven must be known exactly and applied correctly, because of the danger of bleeding, resulting from too much spray being applied, or the danger of a poor bond resulting from too little spray being applied.

## 5. PROJECT EXAMPLE UNDER SEVERE CIRCUMSTANCES

The following is an example of the successful use of asphalt reinforcement. The project is located in the Northwest German town of Rosendahl. The road is highly trafficked. The majority of vehicles are trucks because the road is the main connection to the nearby border to the Netherlands. The observation revealed severe alligator cracking and longitudinal as well as cross cracking in large scale. The original concept (and budget) called for milling the surface (approx. 5 cm) and installation of a new wearing course of 5cm. The expected lifetime of the new surface was just 2 years.

A more durable (but very expensive) solution was to take up the cracked binder and base course. The alternative, as a more durable solution to that, included a layer of HaTelit<sup>®</sup> over the cracked binder. The thickness of the new wearing course remained 5 cm. Hence, the economical advantage had to be proven by a longer lifetime. This 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 life time of the surface over the old cracked area. After the milling process the finding was a very thin layer of bituminous bound gravel. (Figure 5). In local sports the bonding was almost not present, but still the result was very satisfactory. On top of this layer HaTelit<sup>®</sup> was installed. Under such circumstances a very controlled and carefully organised installation is important.



Figure 5. Surface after milling



Figure 6. Difficult spots during installation

The project was finished in summer 1996. Regular inspections, with the last taking place late in 2004 showed that the road is still in perfect condition and that HaTelit<sup>®</sup> has proven its life increasing function very well. It is important to note that the two years estimated time has been increased to eight years. 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<sup>®</sup> has proven its advantages.

## 6. DEMANDS OF ASPHALT REINFORCEMENT

The interaction of the bonding between layers and the axial stiffness of the reinforcement are of particular importance. To ensure these are maintained in the long-term, the reinforcement has to be able to resist the demands during installation due to trafficking with asphalt lorries and finishers; and the overlaying and compaction of the asphalt. This results in dynamic load bearing capacity requirements. Even during installation the reinforcement may be subjected to high loading, when trafficked by tracked pavers or blacktop lorries. Very high forces can be applied to the individual strands of the reinforcement by aggregate movement in the hot blacktop during compaction.



Figure 7. HaTelit® C 40/17 trafficked by a tracked paver



Figure 8. HaTelit® C 40/17 trafficked by a blacktop lorry

The very high resistance to mechanical damage allows HaTelit® C 40/17 to be placed directly onto milled surfaces. Manufacturers of grids made of very high modulus brittle materials like glass fibres 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 products shall 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.

## 7. MILLING OF REINFORCED ASPHALT

At the end of the pavements life a polyester grid can easily be milled together with the asphalt pavement [4]. Large powerful milling machines will reach about 90 % of their usual milling speed of unreinforced asphalt. In 2004 a HaTelit® C 40/17 reinforced section has been milled off for investigation purpose (Figure 9). A section of 60 m length and 4.0 m width has been milled with a small milling machine Wirtgen W 500 (Figure

10). The width of the milling roller is 50 cm. Even with this milling machine, which does not have a very powerful engine, continued milling of the reinforced section was possible, at a reduced but acceptable speed.



Figure 9. Milling of reinforced asphalt



Figure 10. Milling machine

It can be concluded that the better the bond between the asphalt layers with the interlaying reinforcement, the easier is the milling process. If the bonding is significantly reduced milling problems can occur. Milling of asphalt with interlaying non-wovens or composite products showed the problems that due to the high elongation of the non-wovens the fibres are not being cut-up during the milling process, but were found around the milling cutter.

## 8. RECYCLING

The reinforced milled material can be reused in the mixture for asphalt base courses with a percentage of 30% of milled polyester grid reinforced asphalt without any decrease in quality. The mixtures examined fulfil the requirements of the German guidelines for bituminous base course material not only with regard to composition but also with regard to mix material characteristics [5]. Tables 3 and 4 show the properties of

the recycled asphalt produced after the milling process. The new mixtures exhibit a good quality asphalt for use in bituminous bases courses.

Table 3. Test sieve details

Size mm	Content Vol. -%	Accumulated Mass - %
>31,5	0,0	100,0
22,4-31,5	1,6	100,0
16-22,4	17,1	98,4
11,2-16	18,0	81,3
8-11,2	14,1	63,3
5-8	9,4	49,2
2-5	9,4	39,8
0,71-2	7,6	30,4
0,25-0,71	11,5	22,8
0,09-0,25	5,2	11,3
<0,09	6,1	6,1

Table 4. Relevant properties of the new mixture

Solvent Binder Content	3,75	M.-%
Insoluble Binder Content	0,18	M.-%
Total binder content	3,9	M.-%
Mineral Content	96,1	M.-%
Specific Density at 25°C	2,538	g/cm <sup>3</sup>
Specific Volume of MPK	2,399	g/cm <sup>3</sup>
Void content	5,5	V.-%
Marshall stability	10	kN
Flow Index	2,9	mm
Softening Point	52,1	°C
Needle penetration	57	1/10mm
Filler content	24,0	M.-%

## 9. CONCLUSIONS

Numerous laboratory investigations and over 35 years experience in practice have shown that asphalt reinforcement using polyester fibres is often a cost-saving and economically viable alternative to conventional construction solutions.

*REFERENCES:*

- [1] Montestruque G.E., Rodrigues R.M., Montez F.T., Elsing A., Experimental Evaluation of a Geogrid as an Anti-Reflective Cracking Interlayer on Overlays, *Proceedings of the Second European Geosynthetics Conference EuroGeo 2000*, Bologna, Italy, 2000.
- [2] Vanelstraete A., Francken L., Laboratory testing and numerical modelling of overlay systems on cement concrete slabs, *Proceedings of the Third International RILEM Conference*, Maastricht, Netherlands, 1996.
- [3] De Bondt, A.H., Anti-Reflective Cracking Design of (Reinforced) Asphaltic Overlays, *Ph.D.-thesis*, Delft, Netherlands, 1999
- [4] Schniering, A., Thureau, W., (in German) Untersuchungen an einer armierten Asphaltbefestigung hinsichtlich der Ausbaumöglichkeiten durch Fräsen sowie der Wiederverwendbarkeit des Fräsgutes, 1992
- [5] Damisch A., Kirschner R., *Recycling of Grid Reinforced Asphalt Pavements*, Proceedings of the Fifth International Conference on Geotextiles, Geomembranes and Related Products, Singapore, 1994