

REPORT ON VARIOUS RESEARCH PROJECTS UNDERTAKEN IN THE RECENT PAST WITH REGARD TO REFLECTIVE CRACKING OF ASPHALT PAVEMENTS

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Reflective cracking is a well documented and known phenomenon. Old cracks and/or joints will propagate through a new asphalt overlay, creating a reflective pattern similar to the one existing before. Reflective cracking can be caused by traffic, temperature variations and/or uneven soil movements (vertical and horizontal).

This paper aims to present various recent publications and research findings, in order to emphasise on the effectiveness of asphalt interlayer techniques. Furthermore there will be an example of a highly trafficked road, which was build under severe circumstances, which is still functioning in perfect condition.

1. INTRODUCTION

A very effective system for the delay and/or complete arrest of reflective cracking has proven to be Asphalt Reinforcing Geogrids since the introduction in the early 1970's. During these years various laboratory studies have been performed on this topic. This paper does not aim to be complete, it tries to summarise findings of various researchers. The theoretical basis for the description of reflective cracking and the development of a design method addressing the relevant reinforcement parameters has been part of a study at the Delft University of Technology by De Bondt (4). De Bondt managed to define the critical parameters for the well functioning of geogrids in order to delay reflective cracking. These critical parameters will be discussed and compared with the parameters valid for the asphalt reinforcing geogrid HaTelit®. Based on the work of De Bondt an attempt will be made to predict the design life of asphalt reinforced with this geogrid.

2. REFLECTIVE CRACKING

Reflective cracking can be caused by traffic, temperature variations and/or uneven soil movements (vertical and horizontal). The literature (1, 2, 3) distinguishes traffic and thermally induced reflective cracking, thereby referring to the different modes of crack propagation (*figure 2*).

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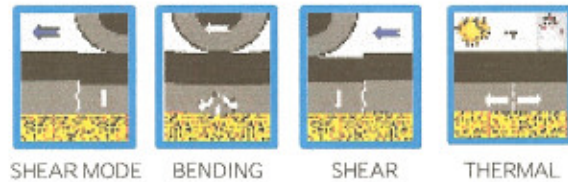


Figure 1, - Reflective cracking failure modes

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 between old and new asphalt. De Bondt (4) found that the main function of a reinforcement is to provide 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.

Either way the reinforcement provides a tensile element to the asphalt overlay which can delay or prevent the propagation of cracks to the surface, provided certain minimum parameters can be met. These critical parameters will be addressed when discussing the work of De Bondt (4).

2.1. Earlier research data

In 1990 static 3-point bending tests were performed at the Netherland Pavement Consultants. The results were reported amongst others by Kunst/Kirschner (5) and Kirschner/Kunst (6).



Figure 2 and 3 - Point static bending tests at the Netherland Pavement Consultants (Netherlands)

The testing program included comparative testing of different asphalt reinforcing systems including HaTelit®. The results indicated that the service life of the asphalt reinforced with HaTelit® could be increased by a factor of 4, while the use of a nonwoven SAMI system (Stress Absorbing Membrane Interlayer) indicated an improvement factor of 2.

Of course the test results give only an indication of performance, since the bending mode in static loading conditions was evaluated in isolation.

3. DYNAMIC BENDING AND SHEAR TESTING

Very recently the results of a testing program performed at the Aeronautics Technological Institute (ATI) in Sao Paulo, Brazil, were published (7). In this research performed in 1999 both the bending mode and the shear mode were investigated under dynamic fatigue loading conditions. Another improvement was the use of an elastic base over the full width of the sample, thus leaving the concept of 3-point bending and simulating more realistic traffic loading and road base conditions. The results indicated combined bending and shear effectiveness factors for HaTelit® varying between 2.6 and 3.6, depending on the wheel contact stresses during the test.

These recent results still correlate very well with the earlier static 3-point bending test results of NPC, despite of the fact that the recent results are much more representative. It seems that simple 3-point bending tests can give a good initial indication of performance.

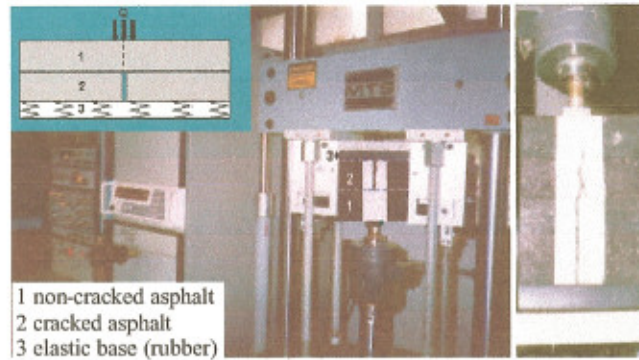


Figure 3. - Dynamic fatigue testing at ATI (Brazil)

In 1996 a simple design method was suggested by Molenaar/Nods (8) taking into account the results of the 3-point bending test. The method was well received by the market, and was included in the latest editions of Koerner's standard design manual for geosynthetics (9). The recent results of ATI (7) provide valuable input for the design method for initial feasibility studies.

4. THERMAL CRACKING TESTS

In 1997 a test program was implemented by the Belgium Road Research Centre (OCW), investigating the HaTelit[®] performance in the thermal cracking mode. The results were published at (10). Both, HaTelit[®] C made of high tenacity polyester (PET) combined with a thin polypropylene nonwoven for ease of installation, and an alternative HaTelit[®] M made of polyvinyl alcohol (PVA) were investigated in a thermal cracking test, placed over the joint of a concrete slab. The test method and set up are described in (11). In the non-reinforced case the joint reflects to the surface after just one load cycle. In the case of HaTelit[®] C and HaTelit[®] C-M the joint still does not reflect after 37 load cycles. The force required to open the joint is largest in the case of the M-type. The effectiveness of the reinforcements is apparent. Further results of this study are to be published at a later stage.

5. SHEAR TESTS

In the period 1996 up to 2000 on various international projects asphalt bore cores (diameter 150 mm) with and without HaTelit[®] have been investigated in the laboratory in interface shear tests as developed by Leutner (DIN 1996 T7). The results of cores with HaTelit[®] as compared to cores without reinforcement typically indicate that HaTelit[®] does not reduce the bond strength between old asphalt and new overlay. In Germany the minimum required shear strength in the Leutner test in accordance with ZTV Str 91/Erg.96 is 15 kN between binder and wearing courses and 12 kN between other asphalt layers. The actual results in table 1 of cores taken from a project in Germany in 1996 indicate very good shear and bond strengths, also in the overlap area

Table 1. - Leutner shear test results of asphalt cores (diameter 15 cm) with HaTelit[®] C

Core No.	Shear force	Required shear force acc. to ZTV Str 91/Erg.96	Remarks
1	27,36 kN	15,0 kN	single layer reinforcement
2	23,64 kN		overlap of reinforcement
3	28,44 kN		single layer reinforcement
4	26,33 kN		overlap of reinforcement

The conclusion is that as long as the installation guidelines are followed, HaTelit[®] asphalt reinforcement will not create any bonding problems.

6. DE BONDT RESEARCH (UNIVERSITY OF TECHNOLOGY IN DELFT)

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, partly funded by the Dutch Technology Foundation (4).

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 a reinforcing product with a high axial stiffness which is adequately anchored in the surrounding asphalt can perform well.

Included in the research, among various other products, was the original HaTelit® 30/13 as manufactured and supplied in 1994.

The importance of the reinforcement stiffness as being one of the critical parameters has been proven by De Bondt. The initial modulus (reinforcement stiffness EA_{rp}) at 1% strain of C 40/17 is 800 N/mm and of the modulus of C40/17 M is 1700 N/mm.

Another critical parameter turned out to be the bonding of the reinforcement to the asphalt, defined as bond stiffness (c_{bqr}). 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 9*, for full details the reader may be referred to the full publication.

The equivalent bond stiffness of HaTelit® turned out to be the best of all commercial products investigated. The importance of the bituminous coating for flexible grids becomes clear. De Bondt found that in flexible geogrids like HaTelit® the stresses were transmitted via direct adhesion between strands and asphalt.

A further critical parameters found by De Bondt is the bond between overlay and old pavement, defined as interface shear stiffness.

In flexible pavements a large interface bond stiffness is giving an improved performance, while in the case of asphalt over concrete or cement stabilised bases (high shear stresses governed by relative horizontal deflections, the temperature mode) a reduced interface shear stiffness near and over the concrete joint may bring improved performance. This explains the successes of the use of SAMI's in these cases, creating a controlled de-bonding or sliding effect.

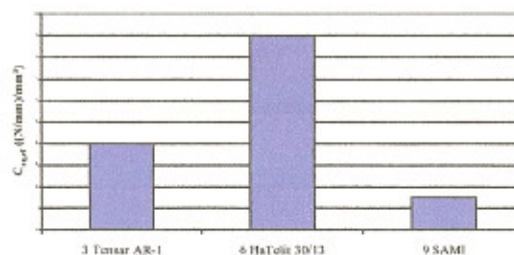


Figure 4. - Equivalent bond stiffness of different commercial products to asphalt

The importance of the parameters described above becomes apparent in the following case of a flexible pavement of a rural road in an area with poor soil support, as described and analysed with finite element methods by De Bondt (Slachterlaan simulation). Only the *combination* of high reinforcement stiffness and high bond stiffness can create an improvement of the overlay life, for a certain interface shear stiffness.

When applying the parameters valid for HaTelit® one can assess that for this specific case the overlay life improvement factor is approximately 3 for the polyester type and approximately 3.5 for the C40/17 M.

In another case of a semi-rigid pavement (A50) De Bondt found that when applying asphalt overlays over concrete bases (thermal mode), controlled de-bonding (e.g. the use of a SAMI) near the concrete joints becomes important, while reinforcements contribute by providing additional tensile strength to the asphalt overlay provided they are having sufficient axial reinforcement stiffness (over 250 N/mm).

7. PROJECT EXAMPLE UNDER SEVERE CIRCUMSTANCES

The project reference to be presented herein shall give an example of successful use of asphalt reinforcement. The project is located in the Northwest German town of Rosendahl. The road is a highly trafficked road. The majority of vehicles are trucks, because the road is the main connection to the nearby boarder 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 at the surface (approx. 5 cm) and installation of a new wearing course of 5 cm. The expected lifetime of the new surface was 2 years.

The alternative solution proposed included a layer of Hatelit 30/13. The thickness of the new wearing course remained 5 cm. Hence, the economical advantage had to be realised due to 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.

After the milling process the finding was a very thin layer of bituminous bound gravel. (Compare *Figure 6*).



Figure 6. - Surface after milling



Figure 7. - Difficult spots during installation

On top of this layer HaTelit was installed. Obviously very important in under such circumstances is a very controlled and carefully organised installation.

In local spots the bonding was almost not present (*Figure 7*), but still the result was very satisfactory.

The project was finished in summer 1996. Regular inspections, with a last one taking place late 2002 showed, that the road is still in perfect condition, and that HaTelit has proven its life time increasing function very well. Important to note is, that the two years estimated time have been increased up today to seven 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 has proven its advantages.

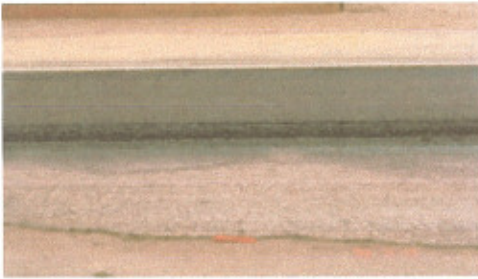


Figure 8. - Layer after installation

CONCLUSIONS

The following can be concluded:

- Earlier simplified research data is giving good indications of performance of asphalt reinforcement in the case of vertical deflections. The typical life improvement factor for the bending and shear mode is approximately 3, as confirmed by recent research data.
- On semi-rigid pavements with predominantly horizontal displacements (thermal mode) the asphalt overlay can effectively be reinforced with HaTelit[®] asphalt reinforcement combined with a SAMI over the joints and/or cracks.
- The critical parameters for the performance of an asphalt reinforcement are the reinforcement stiffness, the bond stiffness of reinforcement to asphalt, and the interface bond stiffness between old pavement and overlay. The combination of mentioned parameters defines the performance. A large database of parameters valid for HaTelit[®] is available.
- It is possible to provide the responsible Site Engineer with sufficient proof in advance that a specific asphalt reinforcement is meeting the specifications, without the need to verify the specifications after supply of the material.
- The increased life time of the road with the same layer configuration is an important aspect in the design of a new or in the rehabilitation of an existing road.

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