Ooms Avenhorn Holding bv
P.O. Box 1
1633 ZG Avenhorn
The Netherlands
Phone +31 229 547700
Fax +31 229 547701
Internet www.ooms.nl

Research & Development – Background Information

REQUIRED PROPERTIES OF REINFORCING PRODUCTS

dr.ir. A.H. de Bondt

September 1999

Required Properties of Reinforcing Products

dr.ir. A.H. de Bondt, Ooms Avenhorn Holding bv

Reflective cracking is the phenomenon that cracks/joints propagate from an existing pavement into and through an overlay. This implies that after a while a reprint of the old damage pattern becomes visible at the new pavement surface. This phenomenon can be caused by traffic loads, temperature variations and/or subsoil actions. Sometimes the classical reflective cracking is accompanied by so-called surface cracking; under specific conditions cracks can be initiated at the pavement surface and grow downwards. Frost heave in Nordic countries is an example of this. In case of the selection of a maintenance treatment, per location each time a number of options have to be considered, because the effectiveness of anti-reflective cracking systems highly depends on the in-situ circumstances; sometimes system A performs better than system B for pavement situation x, whereas the order is vice versa for pavement situation y.

The application of reinforcement at the bottom of an asphaltic overlay implies that even after failure of the mix at this location, “visible” via the initiation of cracks, a specific bending moment can be developed, without causing large tensile stresses in the asphalt concrete itself; in other words, for a given wheel load level, via the presence of a reinforcing product, smaller stresses in the asphalt concrete are generated, resulting in a larger overlay life. It is clear that before a reinforcing product performs as described above, it has to meet specific criteria. However, these are not (yet) written down officially in codes or guidelines, causing a lot of debate and misunderstanding; often experience from geotechnical engineering is extrapolated to the pavement field. Extensive research showed that the beneficial effect of an asphaltic reinforcement is controlled by the degree of restraint it can develop versus pullout. In case of a proper anchoring length, this so-called pullout restraint is governed by the stiffness of the reinforcing product (= elastic modulus E of the material from which the product is made, times the cross-sectional area A) and the degree of bond with the overlay on top and the old pavement surface below. A first estimate of the so-called product stiffness $(EA)_{rf}$ can be obtained by dividing the tensile strength of the product by its strain at failure. It is clear that this is only allowed if the reinforcement material shows linear behaviour. The strength value must be based on tensile tests in which single ribs/strands were used (so-called single end testing).

From the foregoing it can be concluded that, for a given bond quality, stiff reinforcing products show a higher effectiveness than soft products. Finite element analyses showed, that in case of a (wide) longitudinal crack in a Dutch rural road in a soft soil area, which is loaded by passing traffic, the degree of overlay life improvement by using reinforcement can be estimated as: $-2.18 + 1.47 \log(EA)_{rf}$. This relationship implies that for a reinforcement stiffness of 500 N/mm, compared to the plain overlay, 1.8 times the number of heavy vehicle passages are needed to let the crack grow through the reinforced overlay; for a reinforcement stiffness of 4000 N/mm this number is 3.1. In the situation of an overlay on a semi-rigid highway pavement which shows transverse cracking, it was found that the beneficial effect of applying reinforcement is: $1 + 0.001\ (EA)_{rf}$. This means that the improvement factor for a product stiffness of 500 N/mm is only 1.02; for a stiffness value equal to 4000 N/mm still only 1.06. From the magnitude of the factors given above, it can be derived that versus traffic loadings, a reinforcement is much more effective in case of a larger flexural deformation. However, it should not be forgotten that reflective cracking is not only due to traffic, but also due to environmental actions.

In case of a thin asphaltic overlay on cement concrete slabs, which are subjected to daily temperature variations, causing these to move and exert a splitting action onto the overlay, the following relationship for the effect of reinforcement on the reflective cracking life of the overlay was found recently, via parametric computational analyses: $1 + 0.031\ (EA)_{rf}$. The latter equation implies for a reinforcement product stiffness equal to 500 N/mm an improvement factor of 1.7; for a reinforcement stiffness of 4000 N/mm a factor of 3.0.

It must be realized that the examples described above, are only indicative. More detailed analyses per specific project are of course always recommended to be carried out. Furthermore, it is not allowed to conclude from the foregoing that a stiffer reinforcement is in all cases more effective than a softer one; if an asphaltic reinforcement is anchored inadequately, no useful contribution can be expected to occur. Anchoring of reinforcement is possible in two different ways: a) via bearing of mineral aggregates which are locked in its spacings or b) via adhesion along the ribs/strands. Which one of the anchoring mechanisms is predominant, mainly depends on the characteristics of the connection between the longitudinal and the transverse ribs/strands of a reinforcing product.

In case of a rigid junction, bearing is of main importance. This then implies that a proper stone skeleton has to be build-up in the apertures of the product and also that the ribs/strands of the product must have a certain thickness to avoid a “knife” effect. It is thus clear that with respect to spacing, a lower end criterion exists. However, on the other hand the apertures must not be too wide, because then the in-plane flexural stiffness of the ribs dramatically drops and furthermore, in the middle of the spacing hardly any “reinforcing” effect is available anymore.

In case of a disconnected junction between longitudinal and transverse ribs/strands, adhesion along the ribs/strands is of key importance. This then implies that the product must interact well with the surrounding media (overlay and existing pavement). This can be achieved via reinforcing products with a large surface (contour) area, or by means of using high-quality (stiff and durable) tack coats. In contrary to what is often believed, the size of the spacing between the ribs/strands of these products is of no importance for the magnitude of the pullout resistance which can be generated, since in this disconnected situation, this mechanism is not influenced by the composition of the stone skeleton in the apertures; in case of the application of the proper type and amount of tack coat it is even possible to use reinforcements which cover the whole existing pavement surface.

It must be realized that in reality, purely disconnected junctions do not exist; longitudinal and transverse ribs/strands are always linked to each other in one way or another. Especially in case of the passage of a heavy wheel load, because then confining pressure is available. This fact implies, that depending on the geometrical properties, the transverse rib/strand contributes via the mechanism of bearing and/or adhesion to the pullout resistance of the product. This phenomenon becomes apparent from pullout testing in a laboratory. An important aspect is, that connections between longitudinal and transverse ribs/strands can be of a mechanical or a chemical nature; mechanically via special knotting techniques or chemically via the use of coatings or glue. It is reminded that these connections must not be influenced by the heat produced by the hot overlay mix during the laying process; for "chemical" connections this can sometimes perhaps be a problem.

With respect to the preparation of the construction phase of a pavement repair project, it must be realized that the beneficial effect of a reinforcement is lost if it is damaged during the laying of the asphaltic mix. This aspect can sometimes found to be critical in case of products which are composed of glass-fibres, because these tend to break during the process of overlaying, due to the shearing and torsional actions which are imposed by the delivery trucks and the paver. Some manufacturers have solved this potential problem by coating the individual fibres in order to get a rib/strand which has a considerable flexural strength. This can be checked by a user by carrying out a three-point bending test on the reinforcing product itself; a very easy way of doing this, is literally by hand, by using two fingers (the two supports) and a thumb (the point load). This aspect of construction induced rib/strand breaking is of key importance, since it is clear that a damaged product is much less effective in delaying or resisting reflective cracking, because then part of the product stiffness $(EA)_{rf}$ is lost. Field experience has shown, that quite a big difference in coating quality exists between the glass-fibre products which are currently available on the market. Unfortunately, at this moment regulations on this topic are not yet written down officially. All in all, it can be concluded that in case of glass-fibre reinforcements, it might be possible that products which are initially cheaper, because of their lower coating quality, are in the end much more expensive compared to their level of effectiveness, because their anti-reflective cracking performance in the field is less than expected.

Furthermore, for its long term performance, it is required that reinforcements remain flat during the overlay construction process. Therefore, reinforcing products should be manufactured in such a way that they are easy to handle on site, without causing much disturbance for the contractor; only via this it is possible to get a reliable anti-reflective cracking system, without extreme demands on craftmanship and experience for the contractor.

Another important aspect is that proper adhesion between the overlay and the old pavement surface is necessary to prevent layer slippage and early overlay failure, due to alligator cracking, which has unfortunately often been observed in the past at several reinforcement projects.

References:

- "***Prevention of Reflective Cracking in Pavements***".
  RILEM Report 18, 1997. http://www.efnspon.com
- de Bondt, A.H.
  "***Anti-Reflective Cracking Design of (Reinforced) Asphaltic Overlays***".
  Ph.D-Thesis, Delft University of Technology, 1999.
  http://www.ooms.nl/adebondt/adbproef.html