Fast and easy road renovation through a steel based anti-reflective cracking interlayer for asphalt overlays

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Abstract Anti-reflective cracking interlayers for the renovation of roads have been extensively used for the last decades. Today different anti-cracking interface systems exist: SAMI's, non-woven geotextiles, geogrids (plastic, glass or carbon), combigrids and steel reinforcing nettings. The different interlayer systems all have their specific properties with advantages and disadvantages. Moreover the performance of a specific product is not only depending on the product properties and the origin of the cracks but also on the proper installation of the product.

Past research revealed that steel is an ideal reinforcement material for an anti-reflective cracking interlayer. Steel nettings as they are known today are very rigid and require a good fixing by nails or a slurry seal. Due to their dimensions, it is also advisable to use an overlayer thickness of at least 5cm in order to prevent the reflection of the crack/joint through the asphalt surface. In this paper we present a new steel based anti-reflective cracking interlayer with improved installation properties compared to traditional steel nettings, enabling a fast and easy installation.

Keywords Reflective cracking, Asphalt concrete, Interlayer, Steel

1 Introduction

Cracking of asphalt concrete roads is a widely spread phenomenon which deteriorates the road surface and which reduces the driving comfort and the life time of the total structure. Reflective cracking originates when cracks from a base layer (rigid, semi-rigid or flexible) propagate through the surface via the asphalt overlay (Sanders 2001). This is mostly due to horizontal and/or vertical movements caused by traffic combined with environmental conditions, such as seasonal and daily temperature variations (Perfetti & Sangster 1988). In order to minimize this problem, anti-reflective cracking interlayers are widely used for the rehabilitation of cracked asphalt pavements.

A wide range of anti-cracking interlayers exist, i.e. SAMI's, non-woven geotextiles, geogrids (plastic, glass or carbon), combigrids and steel reinforcing nettings. The properties of the raw materials, their possible coating as well as their appearance in the geotextile (i.e. mesh dimensions, mesh shape, etc.) are diverse which makes it very difficult to compare these products. The performance evaluation of these products has been subject to both laboratory and field testing and showed a delay of the crack propagation through the surface (Norambuena-Contreras & Gonzalez-Torre 2015, Pasquini et al. 2013, Vervaecke & Maeck 2008). The installation of these products is really dominant in achieving good anti-reflective cracking behaviour. Some products might have a high strength but due to their brittle nature or temperature sensitive properties, the high strength might not be available anymore after the installation process (Gonzalez-Torre et al 2014). Furthermore it is also important to follow the installation instructions of the producers and install these products flat and with the correct amount of tack coat in order to achieve a good performance.

Steel is widely used in construction as reinforcement in concrete, masonry and even asphalt. The current generation steel products for road reinforcement are hexagonal meshes with reinforcement bars in the transversal direction. These meshes are very rigid and in order to install them properly they need to be fixed by nails or preferentially with a slurry seal. They are known for their excellent anti-cracking properties thanks to the high Youngs modulus and good anchorage. Some disadvantages of the current generation products is their multiple step installation process and their time intensive removal process at the end of their life.

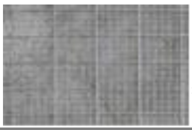
In this paper a new steel-based anti-cracking interlayer is presented. A first section describes the properties of the steel-based geotextile product. The second section describes some particularities towards installation. In a last section performance data are elaborated.

2 Product definition

The presented steel-based anti-cracking interlayer differs from existing products by the half-product as well as on the shape of the mesh. The new mesh has a rectangular shape and is made from flexible steel cord. The steel cord mesh is kept in position on a plastic carrier (i.e. a low weight plastic grid or non-woven). The steel is galvanized in order to ensure a lifetime of the product in the application of at least 15 years. The properties of the product compared to traditional hexagonal steel mesh and a classical glass-based geotextile are presented in table 1. The tensile strength is determined according to ASTM D6637 Method 1 (single rib test).

Although tensile strength is a dominant characteristic of geosynthetics, tensile strength is less important in the final application. The dominant parameters for obtaining good anti-cracking behaviour are “stiffness” EA (material cross section A * material modulus E), the secant modulus and the adhesion with the pavement layers (Gonzales-Torre et al 2014 and references). Since steel has a high Youngs modulus, the cross section of the reinforcement material can be reduced. The new mesh has an EA in the range of existing glass-based geosynthetics.

Table 1 Properties of metal and non-metal geotextiles used as anti-cracking interlayer

		Mesh properties	Mechanical properties
Existing steel mesh:		Steel wire (2.45mm) Hexagonal 118x80mm Trans. wire (3x7)mm ± 1.7kg/m²	Strength: (40x58)kN/m EA: (22600 x 32500)kN/m
Existing glass mesh:		Glass roving Square 35x35mm Plastic coating ± 330g/m²	Strength: (70x100)kN/m EA: (2800 x 4000)kN/m
New steel mesh:		Steel cord (1.05mm) Rectangular 40x30mm ± 335g/m²	Strength: (38x50)kN/m* EA: (3100 x 4400)kN/m

**the embrittled zones are considered as 0kN*

Note that the cord half-product is foreseen of embrittled zones at predetermined positions. These embrittlements are applied in order to ensure that the product can be milled together with the asphalt at the end of the pavements lifetime. Magnets enable afterwards to recover the steel from the asphalt ensuring pure waste streams and the complete re-use of both the steel and the asphalt. This is a unique property of the steel and this is not achievable with any other material.

3 Installation

The new steel-based anti-cracking interlayer can be installed in a very easy and simple way. The existing road surface should be prepared by milling the toplayer, the treatment of the cracks, the cleaning by high pressure rinsing and brushing. Subsequently, the appropriate type of tack coat is applied in a minimum amount of 300g/m² (residual weight). The new steel mesh is then applied in the fresh tack coat in order to assure an immediate interaction between tack coat and carrier. The system is then covered with at least 3cm of asphalt concrete. The flexible and low weight steel cord makes that this product can easily be unrolled manually as well as automatically from a truck. Moreover, the weight of the steel compared to the weight of the carrier, ensures a flat installation on the surface and the carrier on the other hand ensures a good contact with the tack coat. Some impressions of the installation process are shown in Figure 1.

Fig. 1 Installation process of the new flexible steel-based anti-cracking interlayer

Traditional geosynthetics made from plastic, glass or carbon are sensitive to damage during the installation process. Gonzalez-Torre et al 2014 investigated several mechanisms to assess the damage during the installation process, i.e. mechanical damage (ISO 10722:2007), real installation and installation in laboratory. Depending on the material, damages of 10 to 90% are reported in tensile strength and secant modulus. Steel was however not investigated in that research.

Steel half product, i.e. rectangular and round wire from the traditional steel product was tested on damage during installation. The material was placed on an asphalt layer, subsequently fresh asphalt was installed by a paver and the fresh layer was compacted. Before the complete cooling of the fresh asphalt the steel wires were removed from the asphalt (Figure 2).

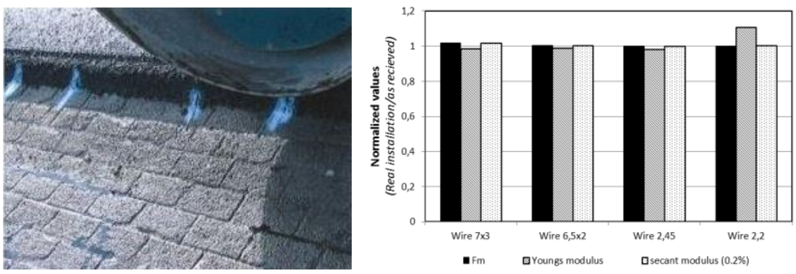


Fig. 2 Left: white paint indicates steel pieces installed under 4cm of asphalt; Right: normalized values for Fm, Youngs modulus and secant modulus at 0.2% from different steel half product

Virgin as well as material which underwent the installation process were tensile tested according to EN ISO 6892-1:2010. The normalized values of tensile strength, Youngs modulus and secant stiffness at 0.2% are presented in Figure 2. There is no decrease visible in the mechanical properties of the steel during the asphalt installation. Steel is not sensitive to mechanical damage by stone aggregates and is thermally stable at temperatures up to 700°C. As such steel can be assessed as ideal material for asphalt reinforcement. Moreover due to its stability during asphalting, it can be applied on both a smooth or rough/milled surface.

4 Performance

There is no standard test available for the evaluation of the performance of anti-cracking interlayers in the asphalt application. Several research groups have developed their own system to simulate a certain fracture mechanism. Note that since reflective cracking is a fatigue mechanism, cyclic testing is very important. Apart of this the dimensions of several products can be very different and they have to be taken into consideration during the interpretation of the test results. In the early 90'ies, BRRC developed a horizontal plate test to simulate the crack formation by thermal movement (De Visschere & Vanelstraete 2010). This test was found to be relevant and shows a good differentiation between different products and how they are installed.

The horizontal plate test is performed on samples of (600x175x140)mm³. The samples consist of a 70mm thick concrete base layer with a rough surface finishing (brushed) and an artificial notch (7mm) in the middle. The anti-cracking interlayer is installed according to the producers recommendations and covered by 40mm of asphalt. The samples are conditioned for 12h at -10°C, the bolts are tensioned and the test is started. During the test the notch is opened and closed by 1mm at a very slow rate by the thermal expansion of steel bars holding the sample. The maximum force is recorded and the crack propagation is followed as a function of the number of cycles and the total testing time.

Table 2 Properties of metal and non-metal geotextiles used as anti-cracking interlayer

	F_{max} (kN)	Crack initiation		End of test		Remarks
		cycles	time (h)	cycles	time (h)	
Reference	8	1	2	5	10	crack
New steel grid	9	Na	Na	Na	130	no cracks
	8,7	35	126	35	126	delamination
	9,5	15	42	24	90	crack
Glass mesh	9,6	8	32	11	48	delamination + crack
	9,3	28	108	28	108	delamination

In this test series 2 different anti-cracking interlayers (glass and new steel product from table 1) are tested together with a reference sample without any reinforcement. The samples were all prepared the same way with the same amount of tack coat 300g/m² residual. The results of the horizontal plate test are presented in table 2. One can conclude that an anti-cracking interlayer increases the maximum force take-up by the asphalt samples and delays the occurance of the first crack in the asphalt. Both the crack initiation and the crack propagation are better for the steel product compared to the glass product. This is a striking result since both products have a similar EA and the steel product has only half the strength of the glass grid. The reason for the performance difference can be found in the better anchorage of the steel in the asphalt. The round cords are nicely anchored in the asphalt and work as such as a real reinforcement while the flat glass is only adhering to the asphalt via the coating. This hypothesis is also demonstrated by the failure mechanism of the glass product which is preferential delamination.

Conclusions

A new steel grid made from steel cords has been presented in this article with some specific advantages compared to traditional geosynthetics and existing hexagonal steel mesh. First of all, the flexible steel cords enable a fast and easy installation of the anti-cracking interlayer. The steel is stable during the installation process and its properties are not reduced to mechanical or thermal interaction with the asphalt. And finally, the anti-cracking properties clearly outperform other glass based anti-cracking interlayers with a similar EA and a higher tensile strength.

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