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# Effect of bituminous impregnation on nonwoven geotextiles tensile and permeability properties

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ABSTRACT

Geosynthetics interlayer systems are effective techniques to control reflective cracking in damaged pavements. It comprises the inclusion of nonwoven geotextiles between the damaged layer and the new overlay of the pavement to reduce the propagation of cracks and to extend pavement life. However, the success of this technique depends directly on the understanding of the geotextile's behavior when impregnated with asphalt. This paper evaluates different nonwoven geotextiles frequently used in anti-reflective cracking systems, focusing on initial stiffness gain and permeability reduction after asphalt impregnation. Fresh and impregnated samples of polyester and polypropylene nonwoven geotextiles were tested. Cationic rapid setting emulsified asphalt was used as asphalt binder. Wide-width tensile tests were carried out based on the specification of ABNT – NBR 12824 (1993). Water vapor transmission tests were conducted according to ASTM E 96M (2005). Results of tensile tests on impregnated geotextiles showed a significant increase on tensile strength values, probably due to the inter contact of the fibers. Results also showed high increase in strength values at strain levels less than 0.05% and decrease on stiffness gains with increase of strains. Water vapor transmission tests demonstrated that cationic asphalt emulsion applied on nonwoven geotextiles allows a drastic reduction in permeability values to turn nonwoven geotextiles into a low permeability barrier.



## 1. Introduction

Asphalt overlay is the most common way to recover damaged pavements and is extensively used to improve flexible pavements. When an overlay is placed on an existing pavement, physical tearing of the overlay occurs due to movements at the joints and cracks in the underlying pavement layer. Hence, the reflection of cracks is the main cause of deterioration of pavements in both short and long term.

Paving fabrics interlayer system has appeared as an alternative that comprises the incorporation of a tensile strength reinforcing element to prolong pavement life. The mechanism that leads to the enhanced performance of reinforced overlays demonstrate that the stiffness added by the reinforcement allows cracks energy to be intercepted and reoriented horizontally. Moreover, the selected paving geosynthetic must have the ability to absorb and retain the asphalt tack coat to effectively form a low permeability barrier. However, the mechanisms that govern the behavior of paving fabrics to reduce reflective cracking had not been clearly understood. It is important to evaluate initial tensile stiffness and permeability reduction imposed by geosynthetic impregnation to provide designing parameter for all candidate materials and improve the understanding of the mechanisms that govern the success of the technique.

## 2. Objective

This paper presents results of tensile strength tests conducted with nine nonwoven geotextiles impregnated with different rates of cationic emulsified asphalt, highlighting the initial tensile stiffness at strain levels compatible with field demands. In addition, water vapor transmission tests were conducted on impregnated nonwoven geotextiles to evaluate permeability reduction of these materials.

## 3. Literature review

The reflective cracking phenomenon consists in the propagation of joints and cracks through the asphalt overlay until they appear on the road surface. Cracks allow water penetration into the structure, increase irregularities and accelerate the pavement deterioration process. They occur in all types of pavement structures (flexible and semi-rigid) and impose high strain levels. The

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reflective crack has two main driving forces: the applied external wheel load – which contributes to high stress and strain levels in the overlay above the existing crack – and another driving force that involves daily temperature cycles, traffic load repetition or both combinations (Lytton, 1989; Kim and Butllar, 2002; Virgili et al., 2009; Baek et al., 2010). Also, the discontinuity in the existing pavement reduces the bending stiffness of the rehabilitated pavement section and creates a stress concentration. When it exceeds the fracture resistance of the overlay, a reflective crack can be initiated or propagated.

Researchers have proposed solutions to retard reflection of cracks on road surfaces based on laboratory and field studies, as well as numerical investigations. Due to the number of variables involved in the nature of reflective cracking, no solution for the complete prevention was suggested yet. Only delaying the process is the best strategic solution adopted so far (Jayawickrama and Lytton, 1987; Khodaii et al., 2009; Zamora-Barraza et al., 2010). Since 1990s, reinforcement by means of paving fabrics has been an accepted method to reduce reflective cracking in asphaltic pavements and had become an important alternative for pavement rehabilitation. The technique uses an incorporation of a tensile strength reinforcing element between the damaged pavement and the new asphalt overlay.

### 3.1. *Geosynthetics as an anti-reflective cracking system*

The diversity of geosynthetic materials used as reinforced elements allows the execution of practically all the existing layers on a pavement structure. Geosynthetics, in general, are used as reinforcement or separation in subgrades, base and subgrade reinforcement and asphalt overlays. In this last one, they act as a blocking layer to attenuate and retard reflective cracking through the new asphalt overlay, as well as providing a waterproofing barrier to control water flow through layers below. This technique is not common in South America, due to frequent problems with incorrect materials selection and the strong tradition of conventional overlay systems. Nevertheless, the literature shows positive results for reflective cracking, regarding asphalt-impregnated geosynthetics (Lytton, 1989; Cleveland et al., 2002; Prieto et al., 2007; Penman and Hook, 2008). On the other hand, some of the applications showed little or even negative performance (multiple and transverse cracks) on retarding reflective cracking due to a lack of understanding of the interlayer system mechanism and/or as a result of inappropriate installation of the interlayer (Al-Qadi et al., 2009; Chowdhury et al., 2009).

Nonwoven geotextiles are the most outstanding materials to rehabilitate damaged pavement structures due to their good absorption of asphalt. The materials of smaller thickness are preferred, since they facilitate workability. Studies using polyester nonwoven geotextiles indicated that the application of paving treatment in the rehabilitation of pavements, using emulsified asphalt as tack coat, resulted in significant reduction of reflective cracking (Marienfeld and Baker, 1999; Alvarez, 2008). Field experiences with asphalt binders have demonstrated that cationic emulsions are easier to apply due to the electrostatic attraction of positively charged asphalt droplets and negatively charged aggregate surfaces. Cationic bituminous emulsions deposit more rapidly than anionic emulsions, which results in stronger bonds between layers.

### 3.2. *Mechanisms of asphalt reinforced with geosynthetics*

Nonwoven geotextiles can be used to extend pavement life by means of two entirely different reasons: *reinforcement* and *waterproof barrier*, as reported in literature (Lytton, 1989; Koerner, 2005; Al-Qadi et al., 2009). Koerner (2005) stated that in the dilemma of reflection of cracks, geotextiles have multiple-functions, which are difficult to analyze, since a clear-cut primary function cannot be easily defined. Therefore, two completely different designs can be developed, also depending on the existing overlay and the environmental conditions. Considering these extremes, a combination of these phenomena may possibly work together.

#### 3.2.1. *Reinforcement*

The reinforcement mechanism contributes to the fatigue life of the overlay since it retains its stiffness due to repeated traffic load (Austin and Gilchrist, 1996). The interlayer must have high tensile stiffness and consequently, little elongation. In order to stop opening of cracks, the interlayer also needs to control horizontal movement of the asphalt pavement. A stiff interface between the interlayer and the pavement is necessary for its occurrence and also it retards the development of cracks by absorbing the stresses rising from the damaged pavement.

Studies have shown that high-stiffness grids and fabrics can possibly turn reflective cracks into a horizontal plane beneath the interlayer and can delay reflective cracking for an indefinite period; however, studies are needed to provide a reliable estimate of material stiffness. According to Sprague et al. (1998), stiffness has been proposed as a first classification of the potential contribution of the interlayer to the strength of the overlay system. Nonetheless, little has been reported about the influence of initial stiffness contribution of impregnated nonwoven geotextiles, since deformation levels of the pavement system are relatively low under work conditions. In fact, it is necessary to understand and emphasize the initial stiffness increase after impregnation. High-strength and high-stiffness grids and fabrics are intended explicitly to provide reinforcement for the overlay, and sufficient stiffness has been identified as the single most critical property. However, it should be noted that manufacturers commonly publish quality control of their products, although they do not always describe specific characteristics applicable to design. Therefore, it is necessary to be acquainted with force-elongation characteristics of each candidate material, regarding high-stiffness under low strain levels.

#### 3.2.2. *Waterproof barrier*

The waterproof barrier function provided to the pavement structure helps to minimize the infiltration of water and maintains the layers below at lower moisture contents (Marienfeld and Baker, 1999). Keeping the material at lower moisture contents may result in higher levels of tensile strength. The interlayer also waterproofs the pavement, and when cracking does occur, water cannot worsen the situation. Furthermore, there are evidences that the nonwoven fabric impregnated with asphalt will resist the infiltration of water even after the appearance of cracks on the surface (Button and Lytton, 2007; Baek et al., 2008).

The pavement structure will work as a drainage system to dissipate water flow through road sideways, rather than allowing infiltration of water through base and subgrade layers. The membrane formed from this practice provides at least temporary waterproofing

**Table 1**
Technical characteristics of cationic rapid setting emulsion (CRS).

| Properties | Specification | CRS |
|---|---|---|
| Tests on emulsions | | |
| Viscosity Saybolt-Furol at 50 °C [Pa s] | ASTM D 7496, 2009 | 21.0 |
| Sieve test [%] | ASTM D 6933, 2008 | 0.1 |
| Identifying cationic emulsified asphalts | ASTM D 7402, 2009 | Positive |
| Residue by distillation [%] | ASTM D 6997, 2004 | 63.0 |
| Demulsibility [%] | ASTM D 6936, 2009 | 64.1 |