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Influence of geosynthetic type on retarding cracking in asphalt pavements

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HIGHLIGHTS

- Eight different geosynthetics were studied via a reflective cracking test.
- Morphological, mechanical and thermal properties of geosynthetics were analysed.
- Damage on geosynthetics due to installation and dynamic loads was evaluated.
- Contribution of geosynthetics to retard reflective cracking was quantified.
- Good mechanical behaviour of geosynthetics does not necessarily imply a contribution.

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ABSTRACT

Geosynthetics are one of the most popular anti-reflective cracking systems used in asphalt pavements, although it is not clear how this reinforcement works and what are the optimum materials and installation process needed in order not to have a negative impact on the materials and consequent reinforced pavement. For these reasons, an experimental evaluation of the influence of geosynthetic type on retarding reflective cracking in asphalt pavements has been developed in this paper. With this purpose, eight different geosynthetics commonly used as anti-reflective cracking systems have been studied using a dynamic test in order to evaluate their contribution to the cracking resistance. Additionally, their mechanical and thermophysical properties and deterioration effect due to the installation and compaction conditions, have also been measured with the aim of evaluating the real behaviour of the geosynthetics under experimental conditions. Results show that a geosynthetic that presents a good tensile behaviour does not necessarily present a high contribution on retarding the crack propagation in asphalt pavements. Finally, it has been found that the resistance to deterioration is a decisive factor on the behaviour of geosynthetics.

1. Introduction

One of the main problems that affect road pavements is damage due to reflective cracking. Reflective cracking consists on the propagation of cracks from a deteriorated layer to the surface of an overlay layer that is placed as rehabilitation [1]. This is mostly due to horizontal and vertical movements caused by traffic loads combined with environmental conditions, manifested as temperature variations. Localized bending and shear stresses appear on the existing crack and cause the origin and further development of cracks [2]. Hence, in order to minimize this problem, there are several techniques to rehabilitate cracked pavements such as stress absorption interlayers and steel meshes. However, geosynthetics are one of the most popular anti-reflective cracking systems. These materials are composed of polymeric materials (e.g., polypropylene, polyester, polyvinyl alcohol, etc.), and they are placed on the cracked surfaces before the spread of the overlay layer with the aim of acting as reinforcement or stress absorbing layer and thus, delay the propagation of cracks [3]. As summary, it can be stated that there are eight types of geosynthetics, three of whom are designed to reinforce pavements: geotextiles, geogrids and geocomposites [4]. However, to quantify the retarding of reflective cracking on pavement structure is not a simple issue, because of

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the different mechanical and environmental variables involved. In this way, with the aim of quantifying the improvement of the cracking resistance of pavements when a geosynthetic is placed between layers, several laboratory tests have been developed during the last decades. These tests have tried to simulate the solicitations that a pavement undergoes during its lifetime by using bilayer asphalt mixture specimens. For example, some authors have employed mechanical tests based on the Wheel Tracking Test [5,6]. Additionally, there are also numerous tests based on fatigue tests that use vertical cyclic loads to simulate the traffic dynamic effect [7–10]. The most recent studies have developed tests that take into account the effects of dynamic traffic loads and temperature variations. Amongst these, Moreno-Navarro et al. in 2013 [11,12] have developed the UGR-FACT test that study via a new laboratory device the effect of tensile and shear stress caused by traffic loads and of tensile strains that simulate thermal contractions. Additionally, Gonzalez-Torre et al. in 2015 [13] have presented a new test that considers simultaneously traffic and thermal effects by applying a combined cyclic load that overlaps two loads with different frequencies and wave amplitudes. Thereby, to evaluate the contribution of the geosynthetics, all these tests quantify the number of cycles that the specimens resist until failure, considering it as the propagation of a crack through the upper layer of the specimen. However, these tests only take into account the mechanical behaviour of the geosynthetics but no other aspects like the deterioration of these materials during their lifetime, such as the installation of the material on site. In this context, Norambuena-Contreras et al. [14] studied the effect of high temperature on the geosynthetics' behaviour showing that polypropylene geosynthetics suffered important deterioration with a temperature up to 140 °C. More recently, Gonzalez-Torre et al. [15] have demonstrated that asphalt mixtures can damage the geosynthetics during the installation, so an initial variation of their mechanical properties can be expected. However, despite the fact that mechanical behaviour of geosynthetics is an important topic in road engineering, there is still a limited literature on the real determination of influence of geosynthetic type on retarding reflective cracking in asphalt pavements and about the contribution of these materials into pavement structure compared with not having them. For all these reasons, the main objective of this paper is to evaluate the influence of the geosynthetic type on retarding reflective cracking in asphalt pavements. With this purpose, eight different geosynthetics commonly used as anti-reflective cracking systems have been studied in order to evaluate their contribution on the cracking resistance through a dynamic reflective cracking test. Additionally, their mechanical and thermal properties and deterioration effect due to the installation and compaction processes have also been studied, with the aim of understanding the real behaviour of the geosynthetics under experimental conditions.

2. Experimental method

2.1. Materials

Eight different geosynthetics, one asphalt mixture and one bituminous emulsion have been used in this study. The used geosynthetics were: a polypropylene non-woven geotextile (G1), a polypropylene non-woven geotextile reinforced with glass fibre filaments (G2), a polyester geogrid bonded to a polypropylene non-woven light geotextile (G3), a polyvinyl alcohol geogrid bonded to a polypropylene non-woven light geotextile (G4), a polypropylene stiff monolithic geogrid bonded to a polypropylene/polyester fabric (G5), two glass fibre geogrids covered with an epoxy resin bonded to a polyester non-woven light geotextile (G6, G7) and a glass-carbon fibre geogrid covered with a bitumen (G8). Additionally, Table 1 presents their main physical and thermal properties. From this Table, it is important to consider the maximum working temperature analysed later in this paper. Moreover, Fig. 1 shows a scheme of their morphological composition. As it can be seen, geotextiles (see Fig. 1a) have a continuous structure composed by fibres randomly placed, while geocomposite and geogrids (see Fig. 1b) have a resistant grid structure with oriented fibres usually bonded to a low-density geotextile. Further, an AC16 Surf 50/70 dense asphalt mixture with bitumen content 4.8%, specific density 2.523 g/cm^3 and air void content 5.5%, has been used to manufacture the asphalt pavement specimens. Finally, a C69 B3 emulsion with a residual bitumen content of 69% has been used as tack coat.

Table 1
Physical and thermal properties of geosynthetics.

Geosynthetic	Unit weight (kg/m^2)	Grid size (mm × mm)	Thickness (mm)	Maximum working temperature (°C)
G1	140	n/a	1.2	165
G2	430	40 × 40	1.8	400
G3	270	40 × 40	1.9	190
G4	160	40 × 40	1.5	190
G5	220	65 × 65	4.1	165
G6	205	40 × 40	1.1	400
G7	400	40 × 40	1.4	400
G8	460	20 × 20	1.0	400

n/a: not applicable.

2.2. Test specimens preparation

A total of 36 asphalt mixture slab specimens were manufactured following the procedure described in Ref. [13]. These specimens consisted of two slabs of asphalt mixture of 260 × 410 mm^2, where the lower one simulates an existing asphalt layer that is cracked, and the upper one represents the overlay layer placed as rehabilitation, see scheme in Fig. 2. All the specimens were manufactured at a temperature of 150 °C according to the following methodology. First, an asphalt layer with a thickness of 50 mm was compacted by using a roller compactor. Second, a bituminous emulsion was manually spread over the layer as tack coat and after the breaking of the emulsion, the geosynthetics were placed. After that, a second asphalt layer was spread and compacted on the geosynthetic with a thickness of 50 mm. Table 2 shows the amount of residual bitumen that each geosynthetic needs for its correct installation, according to the recommendations of the manufacturers. In addition, in order to simulate a road crack in the specimen, a crack with 45 mm high and a thickness of 4 mm was induced in their lower layer by using a cutting machine (see Fig. 2). Therefore, this ensured that the crack propagation started locally in the centre of the specimen. Finally, before testing the specimens a thin plaster layer was spread above the crack so that the evolution of cracks can be visually perceived during the reflective cracking test.

2.3. Reflective cracking test

Reflective cracking test (RCT) recently developed by Gonzalez-Torre et al. [13] has been used in this study. RCT procedure consists on a dynamic test at low frequency that considers the effects produced in a pavement due to the traffic loads and temperature variations. For that purpose, this test considers the superposition of two function loads (see Fig. 3). First, a sinusoidal function load with a frequency of 10 Hz and amplitude of 5 kN, and second, a triangular function load with a frequency of 0.005 Hz ranged from 3.5 to 11 kN. According to the test methodology, test specimens were placed on a steel base which has two rolling supports on both sides. Between the base and the specimen a rubber plate with a thickness of 25 mm was placed, see Fig. 2. This layer was placed with the aim of reaching a good support of the specimens and helping the recovery of the initial position after applying the load. Moreover, this plate was divided into two parts facilitating the initiation and subsequent propagation of the cracks. In addition, a rigid steel prism with a width of 100 mm was used to apply the loads over the central zone on the surface of the specimen, see scheme in Fig. 2. Additionally, during the test the crack opening was real-time recorded using two Linear Variable Differential Transducers (LVDT) placed on both the front and back sides of the specimen and at a distance of 10 mm above the interface between the layers. Finally, all the tests were carried out in a controlled room at a temperature of 20 °C. Furthermore, after the test, the geosynthetics were recovered from the specimens by heating them at a temperature of 110 °C during two hours, with the aim of evaluating the damage produced due to installation procedure and dynamic loads.

2.4. Tensile characterization of geosynthetics

With the objective of measuring the reduction of mechanical properties of geosynthetics after the dynamic test, a tensile test has been carried out according to EN ISO 10319:2008 [16]. Tensile strength, maximum elongation and secant modulus have been obtained before and after the dynamic test. Secant modulus (J_{sec}) has been obtained in this study because this value indicates the initial geosynthetics' stiffness. J_{sec} value is calculated as the slope of the stress–strain curves under a specific deformation value (ε), see Fig. 4. This value is commonly calculated at deformations of 2%, 5% and 10% but in this case it has been calculated at a deformation of 1%