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Mechanical damage evaluation of geosynthetics fibres used as anti-reflective cracking systems in asphalt pavements

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HIGHLIGHTS

- A new methodology to simulate damage due to installation of geosynthetics was developed.
- Mechanical and thermal effects of a Hot Mix Asphalt installation were simulated.
- Physical and mechanical damage of three different geosynthetics were analysed.
- Geosynthetics fibres presented several damages thus implying a properties variation.

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ABSTRACT

Geosynthetics are composite materials usually employed as anti-reflective cracking systems in asphalt pavements. However, materials that compose geosynthetics can be damaged due to mechanical and thermal effects produced during the installation process under Hot Mix Asphalts (HMAs). Although different studies have been carried out with the aim of evaluating the damage due to installation on geosynthetics, it is still not clear which variables have more influence on the deterioration of these materials and on the reduction of their properties. Therefore, the main objective of this paper was to evaluate the physical and mechanical damage produced on fibres of geosynthetics used as anti-reflective cracking systems in asphalt pavements. With this purpose, a new procedure to simulate in laboratory conditions the damage produced by the spread and compaction of a HMA on geosynthetics has been developed, by using dynamic compaction of aggregates at high temperatures. Thus, this procedure experimentally simulates the thermal and mechanical loads that geosynthetics undergo when they are used as anti-reflective cracking system. Thereby, different synthetic fibres such as polyester, polyvinyl-alcohol and glass fibres have been evaluated under the developed procedure. Finally, the reduction of physical and mechanical properties has been evaluated by using contrast tests, quantifying the damage produced on the fibres of geosynthetics after different deterioration procedures. Main conclusions of this research established that damage procedure using dynamic compaction of aggregates did not significantly reduce mechanical properties of the fibres strings evaluated by tensile tests on the studied geosynthetics. However, these results were different depending on the material that compose the geosynthetics.

1. Introduction

Reflective cracking is a problem that usually causes the deterioration of road asphalt pavements [1]. This phenomenon consists on the crack propagation from a deteriorated layer to the surface of a new asphalt layer that is placed as rehabilitation [2]. Therefore, with the aim of delaying crack propagation in asphalt pavements different geosynthetics are usually used as anti-reflective cracking systems, obtaining a substantial improvement in crack and fracture performance both in field and in laboratory conditions [3]. Geosynthetics are composite materials that are placed on the cracked pavements before the spread and compaction of the rehabilitation overlay layer [4]. Thus, materials that compose geosynthetics (i.e., fibres) can be damaged due to the efforts produced during the installation process under Hot Mix Asphalts (HMAs). Damage can be caused due to two reasons: first, mechanical effect produced by the extension and compaction of the

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asphalt mixture and second, thermal effect due to high temperatures of the mixture when it is placed (about 150 °C). Although some studies have been carried out with the aim of evaluating the damage due to installation on geosynthetics, it is still not clear which variables have more influence on the deterioration of these materials and on the reduction of their properties. Regarding to damage due to installation of geosynthetics, Norambuena-Contreras et al. [5] studied the effect of high temperatures on the behaviour of geosynthetics. In their work, it was proved that polypropylene, which is a very common material in geosynthetics, underwent an important damage at temperatures over 140 °C. This way, HMAs can significantly damage geosynthetics during the installation process, thus reducing their mechanical properties. Moreover, Correia and Bueno [6] studied mechanical effect produced due to the spread of an asphaltic emulsion on geosynthetics. The studied geosynthetics were impregnated with an asphaltic emulsion and then mechanically tested through a tensile test, with the aim of evaluating the variation of the secant modulus value. These authors concluded that the application of an asphalt emulsion produced an increase in the initial strength and stiffness of the studied geosynthetics, so theoretically their anti-reflective behaviour should be improved. However, this work did not consider the damage produced due to the installation process, so the obtained conclusions could be incorrect. In the same line, Delbono and Guidice [7] studied the effect of an asphaltic emulsion on the materials that compose the geosynthetics. After the study, they concluded that when a geosynthetic was impregnated with asphalt emulsion, its properties were modified reducing its melting temperature depending on the type of the emulsion used. Therefore, installation temperature of asphalt mixtures is an important aspect to consider to the correct installation of geosynthetics. In addition, Gonzalez-Torre et al. [8] experimentally proved that HMAs could damage geosynthetics during the installation process, thus reducing their tensile strength and initial stiffness. More recently, Norambuena-Contreras and Gonzalez-Torre [9] studied the deterioration of different geosynthetics from a thermal and a morphological point of view. In their study, they proved that geosynthetics fibres damaged after installation process to a greater or a lesser degree depending on the type of geosynthetic, thus concluding that materials that compose geosynthetics can be damaged due to the crushing and shear forces produced by the aggregates of asphalt mixtures during spread and compacting processes. In this context, several works concerning to the study of damage of geosynthetics subjected to a dynamic compaction of an aggregate layer on them have been developed [10–14]. As a result, these materials presented a reduction of the mechanical resistance that was different depending on the type of geosynthetics and the material that composed them. However, the effect of high temperatures of aggregates in asphalt mixtures was not considered in these studies. For all these reasons, the main objective of this work is to evaluate the damage produced on different fibres of geosynthetics used as anti-reflective cracking systems in asphalt pavements. With this purpose, a novel and simple laboratory procedure has been developed. This procedure tried to simulate the thermal and mechanical damage that a HMA produces on geosynthetics, then evaluating the variation on their physical and mechanical properties.

2. Materials and test methods

2.1. Materials

Three geogrid type geosynthetics, an asphalt mixture and steel slag aggregates have been used in this study. All the geosynthetics were composed by a light polypropylene non-woven geotextile and resistant fibres strings covered with bitumen, see Fig. 1, and they were selected because they are commonly used as anti-reflective cracking systems in asphalt pavements. Physical characteristics of geosynthetics are presented in Table 1. In addition, a semi dense asphalt mixture type IV-A-12 according to Chilean specifications has been used [15]. Besides, the bitumen used was type conventional CA24 with density 1.039 g/cm^3. This type of asphalt mixture was selected because it is considered as the most used in asphalt pavements construction in Chile [16]. Asphalt mixture had a density of 2.357 g/cm^3 and air voids content of 5.5%. Finally, the steel slag aggregate which is 100% crushing type had a density of 3.440 g/m^3 and mass FeO content of 31.80%. This type of aggregate was selected based on the hypothesis that metallic aggregates could present a thermal behaviour similar to HMAs, but without using bitumen.

2.2. Specimens preparation

In this study, circular shaped specimens with a diameter of 10 cm were used. These specimens were cut so the fibres strings form a square grid of 40x40 mm^2 centred in the specimen. This allowed the extraction of fibres strings with a length of approximately 9.5 cm to carry out tensile tests (see Fig. 1(a)).

2.3. Morphological characterisation of fibres strings

Cross section and surface aspect of fibre strings obtained from geosynthetics were studied by using an optical microscope and a Scanning Electron Microscope (SEM). Fibre strings of geosynthetics were examined before and after the damage procedure with the aim of visually quantifying the damage produced on the materials.

2.4. Thermal behaviour of slag aggregate and asphalt mixture

With the purpose of verifying the ability of steel slag aggregates to simulate the compaction of a HMA on the geosynthetics, a study about the thermal behaviour of both materials was carried out. Therefore, their heating–cooling curves were determined. To do this, the two materials were heated inside a laboratory oven pre-conditioned at a fixed temperature of 180 °C, and both aggregate and asphalt mixture temperatures were measured each 15 min using an infrared thermometer, until they reached 165 °C, considered as an average maximum production temperature of HMAs. The fixed temperature of the oven (180 °C) was selected with the aim of keeping a temperature over 165 °C during the whole process of determining heating–cooling curves despite the oven door was opened each 15 min. When materials reached 165 °C they were removed from the oven and their temperature loss was measured each 15 min until they reached an equilibrium temperature of 20 °C.

2.5. Thermal behaviour of geosynthetics

With the aim of characterising the thermal behaviour of geosynthetics, a thermo-gravimetrical analysis (TGA) has been carried out using a TGA equipment Q50 V20.10 Build 36. Tests were performed operating at a heating rate of 20 °C/min under nitrogen atmosphere and TGA profiles were recorded in the temperature range 0–600 °C. The weight of the sample used was about 5–10 mg in all cases. These test conditions are the most commonly used to the thermal characterisation of synthetic fibres.

2.6. Damage procedure by using Proctor compaction

With the aim of studying deterioration of materials, a laboratory procedure including two phases was developed, as follows: Heating Phase (I) consisted on the heating of the geosynthetic under an asphaltic layer, and Compaction Phase (II) that simulated mechanical effect using impact compaction of steel slag aggregates at high temperature.

First, Phase I tried to simulate the thermal effect produced on geosynthetics during their installation, when the asphalt mixture layer is spread on them. To do this, circular specimens were placed between two asphaltic layers inside a laboratory oven at a temperature of 160 °C (HMAs approximate spreading temperature) during a certain period, t. In this case, geosynthetic specimens were in direct contact with the lower layer of asphalt mixture. However, with the aim of facilitating the extraction of geosynthetics after the Heating Phase (I) the upper layer of asphalt mixture was placed into a metallic bowl with a steel mesh in the base. This way, the mesh avoided the adherence between the materials but permitted heat transference by conduction (see Fig. 2(a)).

Then, after Heating Phase (I) the specimen was removed from the oven and then it was subjected to Compaction Phase (II). In this Phase, mechanical effect undergone by geosynthetics when a HMA is compacted on them was simulated. With the aim of facilitating the extraction of the specimen to a subsequent visual and mechanical analysis, steel slag aggregates were used instead an asphalt mixture. A cylindrical mould (with a diameter of 10 cm) and a Proctor Standard Hammer (with a mass of 2.5 kg and fall height of 30 cm) were used to compact the aggregate on the geosynthetics, see Fig. 2(b). The used devices were the same described in ASTM D698-12 Standard [17]. Additionally, to simulate a real installation of geosynthetics, an asphaltic Marshall specimen was placed in the bottom of the mould acting as support base. Just on it the geosynthetic was placed and then a