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Reuse of deconstructed tires as anti-reflective cracking mat systems in asphalt pavements

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HIGHLIGHTS

- Deconstructed tires layers have been tested to be used as anti-reflective cracking mat.
- UGR-FACT test has been applied to evaluate the effectiveness of the systems developed.
- Layer-parallel direct shear test was used to evaluate the adhesion of the systems developed.

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ABSTRACT

Fatigue cracking is one of the most common distresses that affect roads all over the world. The development of new techniques that allow minimizing the effect caused by this pathology is crucial to reduce road rehabilitation costs. For this purpose, a new product obtained from deconstructed tires has been designed and tested “anti-reflective cracking mats”. Manufactured from the resistant layers of the tyre (metallic and textile layers), it is used as a system placed between the courses of the pavement in order to reduce the effect caused by fatigue cracking processes. This article presents the characteristics of these products and resumes their mechanical performance in a pavement section tested in laboratory. The results obtained showed that the application of these anti-reflective cracking systems could be an interesting solution in order to reduce the impact caused by this pathology.

1. Introduction

Nowadays, most of the developed countries have their main road net almost constructed. Due to the economical situation and to the high quality of these infrastructures, most of these countries will reduce their investments in new highways projects. Nevertheless, these roads and highways need a maintenance or rehabilitation program in order to keep an adequate service level as well as to avoid a collapse of the structure and thus a reduction of their service life.

One of the main distresses appeared in all type of pavements and which causes the need to invest in its maintenance is fatigue cracking. This phenomenon causes the penetration of moisture and of other chemical agents that cause potholes, raveling, stripping and washing of fines. Furthermore, it reduces the bearing capacity of the superstructure and causes bad load transfers that lead to deformations and shear failure [1]. Because of these facts, it is necessary to develop pavement structures more resistant against this pathology and also new solutions towards a more effective rehabilitation, in order to reduce the number of the maintenance actions and amount of investment costs.

The research described in this paper is focused on the development of a new system to avoid the propagation of fatigue cracking in flexible pavement structures. This system is based on the reuse of used tires, as an anti-reflective cracking mat placed in the interlayer zone of the pavement. The solution proposed can be used in new roads as well as in the rehabilitation of deteriorated ones, by placing the anti-reflective cracking mat (ACM) over the damaged or intermediate layer, and finishing with an overlay in order to provide a rolling surface.

Until these days, many useful applications have been found for used tires [2]; in road engineering the reuse of this waste has achieved a big success in the manufacturing of asphalt mixtures and it is quite common its application as a modifier of the mechanical properties of these materials [3–5]. However, most of its applications implies the shredding and grinding to obtain

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crumb rubber or scraps, which on the one hand supposes a new industrial process of the waste generating additional costs, and on the other hand the loss of mechanical properties as a direct consequence of the shredding and grinding treatment applied. In addition, most of these applications only involve the tread area of the tire (mainly composed by rubber), being difficult to find an application focused in the metallic belts and textile fiber carcass which remain being a waste of no use.

In this sense, this research provides a significant step forward in the recycling of used tires because it offers an application without the need to grind up the rubber into particles or scrap. The anti-reflective cracking system developed at the University of Granada is based on a method in which the tires were deconstructed in different layers (Fig. 1), bonded and placed as mats between the existing deteriorated layer of the pavement and an overlay that provide a rolling surface (or in the interlayer zone of a new pavement). By this use, the properties of the tire remain intact and it is possible to benefit from the hi-tech qualities of this material, such as tensile strength, thermostable properties and resilience to climate impacts. Furthermore, the system is focused on the reuse of the resistant layers of the tire (carcass ply and steel belt), so it offers a new possibility for the valorization of these components in road engineering [6].

This paper presents the results obtained in the initial experimental phase of development of this new system. During these first steps, a study in a laboratory level has been carried out in order to evaluate the mechanical response of the anti-reflective cracking mat (ACM) against fatigue cracking and shear stresses. For this purpose, the UGR-FACT test [7] and the layer-parallel direct shear test [8,9] have been used. Two solutions were evaluated: an ACM made from the carcass ply (ACM-CP) and an ACM made from the steel belts (ACM-SB). Both solutions were applied in a flexible pavement structure formed by a binder and a surface course, and the results obtained were compared with those obtained from the evaluation of the same structure but using a geotextile (one of the most common anti-reflective cracking solutions [10]), and those obtained from the evaluation of the structure without any anti-reflective cracking system (in order to have a reference of the benefits of the ACM).

2. Methodology

2.1. Materials

The materials used to develop the ACM systems were carcass ply (ACM-CP) and steel belts (ACM-SB) from used tires, which have been glued using a resin and a press-temperature process in order to provide a mat (Fig. 1, right). Both parts were obtained from the deconstruction of the used tires; the carcass play is mainly composed of textile fibers and rubber, while the steel belt is made of steel fibers and rubber. As these materials were initially designed to provide resistance to the tensions suffered by the tire when the vehicle is in motion, they have a high resistance in terms of tensile efforts which can provide resistance against the stress concentration in the lips of the reflected crack. In addition, the rubber which wraps the textile and metallic fibers, provide an elastic behavior to the mat that absorbs the energy introduced by the traffic loads without generating tensions in the surface course (avoiding or retarding the appearance of cracks in the road surface). The main characteristics of these materials are presented in Table 1.

In order to evaluate the efficiency of the deconstructed layer of the tires as an ACM system, a conventional anti-reflective cracking system has been also studied during this research. For this purpose, a polypropylene filament nonwoven geotextile (Table 1) was selected to compare the mechanical response of the ACM systems developed with that offered by a traditional solution commonly used in roads.

The asphalt mixtures used during this study were an asphalt concrete AC 22 (EN 13108-1) as binder course and a stone mastic asphalt SMA 11 (EN 13108-5) as surface course. Both mixtures have been manufactured using ophite aggregates in the coarse fraction, limestone in the fine fraction, and calcium carbonate as filler. In relation to the binder, conventional bitumen B 50/70 was used for the manufacturing of the AC 22 mixture and polymer modified bitumen BM3b with addition of polyester fibers for the SMA 11. The main characteristics of these materials are presented in Table 2.

Based on these considerations, four different pavement sections were studied (Fig. 2): a reference section composed by a binder and a surface course (RS); an anti-reflective cracking conventional section composed by a binder course, a surface course and an impregnated geotextile in the interlayer zone (GS); an ACM system section composed by a binder course, a surface course and the ACM-CP placed between them (CPS); and finally, an ACM system section with the same composition but using the ACM-SB between the two layers (SBS). These sections allow evaluat-

Table 2
Properties of the asphalt mixtures used in the study.

Properties	AC 22	SMA 11
Bitumen content, %	4.2	6.8
Bulk density, kg/m^3 (EN 12697–6)	2586	2493
Voids in mix, % (EN 12697-8)	4.1	3.2
Marshall stability, kN (EN 12697-34)	12.996	10.360

Fig. 1. Description of the parts of the de tire used for the development of the ACM systems.

Table 1
Characteristics of the materials used as anti-cracking solutions.

Property	ACM-CP	ACM-SB	Geotextile
Tensile resistance (kN/m), EN ISO 10319	72.24	225.77	13.86
Elongation (%), EN ISO 10319	16.91	20.72	58.33
Thickness (mm) under 2 kPa, EN ISO 9864	2.3	3.1	1.3
Weight (g/m^2), EN ISO 9863-1	2267	4636	156
Secant tensile modulus (N/mm), ASTM D4595-86	392.5	607.5	23.5