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Analysis of the skid resistance and adherence between layers of asphalt concretes modified by dry way with polymeric waste

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HIGHLIGHTS

- Plastic polymeric wastes decrease the skid resistance of asphalt concrete.
- The adherence between layers depends on the type of applied load.
- Plastic polymeric wastes decrease the adherence between layers under dynamic load.
- Rubber is the polymer that less change the surface properties of asphalt concrete.

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ABSTRACT

Skid resistance is one of the most important parameters of a surface mixture due to its influence on the safety of the road. Besides, the adherence existing between the layers of a pavement makes these layers work together, which has a great impact in the useful life of the pavement. The influence on these two parameters of different polymeric waste, which have been used to modify a mixture by dry way, has been analysed.

The polymeric waste added to an asphalt concrete by dry way are: polyethylene (PE) from micronized containers, polypropylene (PP) from ground caps, polystyrene (PS) from hangers and rubber from end-of-life tyres (ELT).

The skid resistance and the adherence between layers of the reference and the modified asphalt concretes have been evaluated separately, so their performance can be compared.

The skid resistance has been calculated with the British Pendulum Tester of the TRRL (Transport Road Research Laboratory) under two conditions: on the mixture just manufactured and on polished specimens. The adherence between layers was analysed on asphalt concretes with different texture (AC22 and AC16), applying a direct shear stress at constant speed in the joint junction (LCB shear test), and undergoing three-layer specimens to a dynamic shear stress (shear fatigue test designed by the Engineering School of Santander).

The results showed that the addition of residual polymers modifies the mixtures surface properties, and the performance of the asphalt concretes changes greatly depending on the polymeric waste added.

1. Introduction

Skid resistance and adherence between layers are two basic parameters of a road. While the first has great influence on the traffic safety [1], the second is important when it comes to the pavement useful life [2,3], due to the fact that adherence between layers makes it possible that they work together. Thus, this parameter should be properly considered when the pavement is designed [4].

The most important variable that characterizes this property is texture. This is divided into macrotexture, responsible for drainage and deformation that the wheel suffers when adapting to the pavement, and microtexture, which breaks the sheet of water and conditions the punctual contact between wheel and pavement [5,6].

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Macrotexture depends on the mixture properties (voids percentage, grain size analysis, aggregates properties, etc.) while microtexture, on the other hand, depends on the surface rugosity of the coarse fraction, and is especially influenced by the aggregates polishing, which wears and becomes rounded at a microscopic scale [7].

Adherence between layers is achieved using a tack coat which keeps the joint between them. Its properties depend on the type of coat employed, the materials used in the bituminous mixtures, the traffic loads, temperature, and in the case of skid, of macrotexture [3,8–10]. A good bond between the pavement layers is required to achieve a good performance. Therefore, the higher the friction between surfaces, the interlocking of the aggregates particle and the adhesion between the asphalt binder of the two layers and the applied tack coat, the better will be the adherence between layers [11].

For years, different polymers have been used to improve the bituminous mixtures properties. The rubber began to be used in the sixties to improve skid resistance due to its elasticity and capacity to break the ice on the road [12]. Nowadays, rubber and plastic polymer are used basically to modify bitumen [13,14], but their influence on these two properties, adherence between layers and skid resistance, is not well known.

This paper studies the influence that these polymeric waste have on adherence between layers and skid resistance. For this purpose, an asphalt concrete has been modified by dry way with 4 different polymers: polyethylene coming from packaging, polypropylene coming from caps, polystyrene coming from hangers, and rubber coming from end-of-life tyres. Following, the coefficient of skid resistance has been calculated with the friction pendulum of the TRRL (Transport Road Research Laboratory), and the adherence between layers has been determined through the shear stress according to the standard NLT-382/08 and also using dynamic shear test specifically designed by the Civil Engineering School of Santander [15].

2. Methodology and materials

The reference mixture that has been used is an asphalt concrete (AC22) for surface layer, with 4.8% of penetration grade bitumen (50/70) by weight of mix. The same design process was used with all the modified mixtures: 1% of aggregates was replaced by volume by each type of polymeric waste only in the filler fraction by dry way. The rubber has a low influence on the aggregates and it was mainly mixed with the bitumen, while the plastic polymers were softened by the hot aggregates and partially coated them, having this way both types of polymers (rubber and plastic polymers) an influence on the mechanical properties of the mixture [16] while modifying also its skid resistance and adherence between layers.

Four modified bituminous concretes have been manufactured, which have been called: AC22 PE, modified with polyethylene; AC22 PP, modified with polypropylene; AC22 PS, modified with polystyrene; and AC22 ELT, modified with end-of-life tyres. Besides, an asphalt concrete AC16 was designed with the same polymers added to the mixture AC22, to study the influence of the surface texture.

The particle size distribution of the polymeric waste is shown in Fig. 1.

2.1. Study of skid resistance

Skid resistance was evaluated in two conditions: on new samples without erosion, and on polished specimens; in this way, skid resistance was analysed in the initial and use conditions.

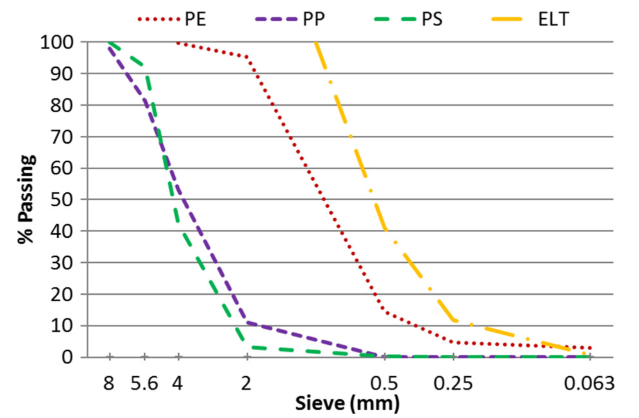

Fig. 1. Particle size distribution of waste polymers.[16]

Skid resistance was calculated with the TRRL pendulum on track specimens, as shown in Fig. 2.

Four samples of each type of asphalt concrete were employed. The wear procedure was carried out by abrading the wearing course surface. This procedure consisted in sanding 30 times the surface of the specimen in the same direction and sense, with sandpaper grit size 4 [17], trying to keep an even contact pressure, so that in all cases the procedure was performed by the same operator.

This procedure was aimed at achieving a similar polished to that of a road in real traffic conditions. The data obtained by the Public Works Ministry in the highway S-30 in Cantabria (Spain) were used to assess the abrasion produced on the samples. It was monitored by the Regional Road Administration between 2009 and 2014. SCRIM (Sideway-force coefficient Routine Investigation Machine) data were gathered along those years. In order to compare both measurements (the SCRIM data and the BPN), the correlation obtained by the New Zealand Transports Agency [18] was used:

$$SC = 0.0071 \cdot BPN + 0.033 \quad (1)$$

where SC is the SCRIM Coefficient of traverse friction and BPN is the value of the British Pendulum Number, obtained by the TRRL pendulum.

Fig. 2. Evaluation of skid resistance.