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Warm Mix Recycled Asphalt – a sustainable solution

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ABSTRACT

The environmental issues raised over recent years, mainly the lowering of fuel consumption and the consequent emission of polluting gases, have led to a bigger concern with the environment. As a response to such concern, the asphalt road industry has developed warm mix asphalts. These are part of a set of new technologies that are being developed in order to reduce both the energy consumption and the gas emissions into the atmosphere, by lowering the mixing temperature. On the other hand, the incorporation of Reclaimed Asphalt Pavement (RAP) in these mixtures aims to improve sustainability by reducing the production of waste and the consumption of natural resources. The warm mix asphalt with RAP are environmentally friendly mixtures and have social, environmental and economic benefits in the production and application of asphalt mixtures. Thus, the main aim of this paper is to produce a comparative study of the mechanical behaviour of warm mix asphalt and of conventional hot mixtures. We also intend to study the applicability of these mixtures with and without incorporation of RAP. Initially, the optimal bitumen content for each mixture was determined and fundamental properties were calculated. The tests performed were the stiffness test by indirect tension to cylindrical specimens, water sensitivity and resistance to fatigue by four-point bending test on prismatic shaped specimens. The findings have confirmed the advantages and demonstrated good performance of warm mix asphalt compared to conventional hot mixtures. The result of the stiffness modulus to the mixture with RAP, of 4750 MPa, is very close to the hot mixture. The water sensitivity for the hot mixture and warm mixture is the same, of 97%, and the fatigue resistance of the three mixtures in analysis is very similar. However, it was also found that these mixtures require an increased care during the production and application phases, in particularly as far as the temperature control is concerned.

1. Introduction

The production of hot mix asphalt is responsible for a large consumption due to the heating of its components (aggregates and binder). This energy is spent on the burning of fossil fuels and the consequent greenhouse gas emissions (Carvalho and Barreno, 2013; Park et al., 2003; Rubio et al., 2013). The implementation of the Kyoto Protocol in 2005, which has been extended until 2020, aims to have the signatory countries undertaking measures to reduce those atmospheric emissions. Thus, new manufacturing techniques of conventional mixtures have been developed, and the decrease of the temperature of manufacture plays an important role as far as reaching these goals is concerned (Capitão et al., 2012; D'Angelo et al., 2008; EAPA, 2010; Oliveira et al., 2013). Since the late 20th century, studies with warm mix asphalt have been made and they have been evolving to the present day (Kheradmand et al., 2014; Prowell et al., 2008; Rubio et al., 2012; Zaumanis, 2010). The production of these mixtures occurs between 110 °C and 140 °C, thus allowing a reduction of approximately 40 °C when compared to the hot mix asphalt (Capitão et al., 2012; Carvalho and Barreno, 2013; EAPA, 2010), as illustrated in Fig. 1.

On the other hand, besides wanting to decrease the temperature in the production of bituminous mixtures, it is also intended that these are reusable (Reyes-Ortiz et al., 2012). The resources that make the mixtures, aggregates and binder, are natural and therefore limited. Asphalt mixtures are 100% recyclable. In Europe, every year there are about 50 million tons of RAP produced, which can be reused in the production of new bituminous mixtures. Germany, the Netherlands and Sweden are the countries that incorporate the largest percentages of RAP in Europe in the production of hot and warm mix asphalt, (EAPA, 2014). Other materials have been studied

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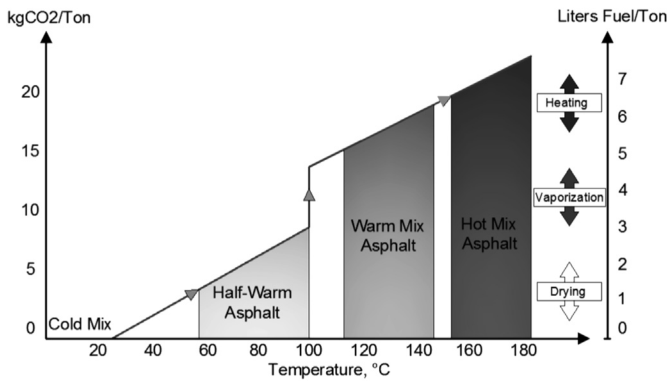

Fig. 1. Classification by temperature range, temperatures and fuel usage are approximations (Adapted from D'Angelo et al., 2008).

for reuse of bituminous mixtures components as for example the waste plastic bottles (Ahmadinia et al., 2012; Rahman and Wahab, 2013). Besides the reuse of materials in bituminous mixtures, other studies have also been carried out around the world to dispose solid waste materials by using them for partial or complete concrete aggregates replacement, particularly natural river sand, as in the case of waste tyre rubber (Thomas et al., 2014) and copper tailing (Thomas et al., 2013).

The recycling of pavement associated with warm mix asphalt can be seen as a sustainable option, as it brings social, environmental and economic benefits. The use of warm mix asphalt power brings advantages due to the lower consumption of energy required for their manufacture, thus implying reductions of 30–40% of carbon dioxide emissions (CO_2) and allowing a more comfortable work environment, guaranteed by a 30–50% reduction of the exposure to fumes by workers at bituminous plants and by paving teams (D'Angelo et al., 2008). The reduction of emissions allows manufacturing plants of warm mix asphalt to be located near to urban areas (Capitão et al., 2012), and they can also be used in hot asphalt plants. The use of RAP prevents the deposition of milled material in landfills, reduces the amount of new aggregates and the extraction of bitumen from the planet.

The environmental concern is an argument commonly used by several entities in order to stimulate both the use of warm mix asphalt and of warm mix asphalt with RAP incorporation, that is why studies have been conducted to verify the performance of these mixtures (Abreu et al., 2013; Dinis-Almeida et al., 2012a, 2012b; Guo et al., 2014; Miliutenko et al., 2013; Sengoz and Oylumluoglu, 2013; Silva et al., 2012; Sun et al., 2014; Tatari et al., 2012; Vidal et al., 2013). These studies have led to the conclusion that the fatigue is the cause of the cracking of bituminous pavements, because it represents the ability this material has to respond to the repeated application of loads from traffic, to certain environmental and speed conditions (Teixeira, 2000). Recently, Carvalho and Barreno (2013) have published a study in which they present some experiences with warm bitumen carried out in works in Spain, which have given origin to quite satisfactory results, and that have served as the basis and reference to the experimental work related of this paper. Carvalho and Barreno (2013) claim that reducing the manufacture temperature of bituminous mixtures, it will get economical savings due to a lower fuel consumption that can be between 25 and 35%, depending on the aggregates type and degree of humidity. On the other hand, they also claim that by reducing the fuel consumption there will be an important reduction of greenhouse emissions, observed in Table 1. The CO_2 emitted can be reduced between 25 and 40%, contributing to a better climate. The same occurs in the emissions of CO and NO_x.

This paper aims to contribute to a better knowledge of the addressed mixtures, since the success of this technology depends on their performance. Thus, the experimental study aimed to evaluate the performance of the warm mix asphalt, with or without RAP, when compared to the hot mix asphalt, at a level of resistance to fatigue by making a four-point bending test. Initially, the particle size distributions of aggregates were studied and the amount of optimum bitumen content to the three mixtures produced was determined. The study also presents the indirect tension to cylindrical specimens and water sensitivity tests. This research aims to deepen the knowledge about the warm mix asphalts, contributing to a more significant dissemination and application of such asphalts on the pavements.

2. Experimental programme

The experimental programme was developed in two phases. In the first phase presents the materials characterization tests used in bituminous mixtures. In the second phase the mechanical characterization tests carried out were the stiffness by indirect tension to cylindrical specimens, water sensitivity and resistance to fatigue by four-point bending test on shaped prismatic specimens.

2.1. Materials

2.1.1. Bitumens

In the present study both mixtures with conventional bitumen 35/50, and mixtures containing warm bitumen BT 35/50 were produced. Warm bitumen is specially formulated in order to reduce both manufacturing and application temperatures, without losing their mechanical characteristics. Depending on the type of additive used, its rheology can vary in relation to conventional bitumen. For example, the use of waxes implies changing the viscosity of bitumen, which becomes inferior to the one of the conventional bitumen, whenever temperatures are above 100 °C. The viscosity increases at below 100 °C, giving origin to bitumen with a higher softening point. There are other types of additives (surfactants), which work by reducing the surface tension at the interface aggregate/binder and that do not alter the rheology of the binder, in accordance with standard EN 12591 (Carvalho and Barreno, 2013). In this study the warm bitumen with this type of additives was used.

The characterization of bitumen was based on the penetration test (EN 1426) and on the softening point (EN 1427), which led to the results on Table 2. The warming temperatures of the components, of the mixture and of the compaction define the differences between the two types of binders. In Table 2 it is possible to see a clear reduction of approximately 40 °C in these temperatures as far as the warm bitumen is concerned.

2.1.2. RAP characteristics

The RAP used in the mixture WMA was obtained from milling pavement of a highway (A23). This material was solely obtained from the surface course thus ensuring it was homogeneous. It is composed by aggregates that maintain their original properties and bitumen which presents an advanced state of ageing due to the environmental conditions it has been subjected over the years.

The extraction of aged bitumen was performed by centrifuge extractor method, according to EN 12697-1, testing 5 samples which confirm a good homogeneity of the RAP material. Their characterization resulted in an average content of 5.0% aged bitumen, a penetration of 11×10^{-1} mm and a softening point of 82.6 °C. These results showed the bitumen of RAP quite aged with a low penetration and a high softening point.