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Case Study

Investigation of dynamic behavior of hot mix asphalt containing waste materials; case study: Glass cullet

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ABSTRACT

This paper aims to study the performance of asphalt concrete in which some of the fractional fine aggregate is substituted with crushed glass material. This asphalt containing glass cullet as an aggregate is called "glasphalt" and has been used as a means of disposing surplus waste glass since the 1960s. In this study, some important dynamic properties of glasphalt, including fatigue life, stiffness modulus and creep compliance, are investigated. The data show that the dynamic properties of glass–asphalt concrete are improved in comparison with ordinary asphalt concrete. The research has demonstrated that it is feasible to use and recycle waste glass in asphalt concrete.
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1. Introduction

Numerous waste materials result from manufacturing operations, service industries, sewage treatment plants, households and mining. Performance of building materials is one of the most important aspects that engineers must consider. Glass is a non-metallic and inorganic material made by sintering selected raw materials, so it can be neither incinerated nor decomposed. Glass recycling can save energy and decrease environmental waste. A focus on glass recycling technology will widen the application domain of waste glass and promote further development of glass techniques. Nearly ten million tons of waste glass is generated in metropolises every year, about 3–5 wt% of the domestic waste (Wu et al., 2004). In glassphalt, fine aggregate is substituted with crushed glass material. Glass materials are brittle and rich in silicon, so the key technical indexes of glass–asphalt concrete are strength and resistance to water damage (Wu et al., 2004). Asphalt pavements containing 10–15% crushed glass in surface course mixtures have been observed to perform satisfactorily. The maximum size of crushed glass commonly accepted (considering a range of engineering properties, including safety issues) for that application is 4.75 mm. Glass in asphalt of higher content and larger size is reported to have resulted in a number of problems such as insufficient friction and bonding strength, and is thus considered more suitable for use in lower courses. An anti-strip agent, typically 2% hydrated lime, is added to retain the stripping resistance. In practice, the same manufacturing equipment and paving method used for conventional asphalt can be used for asphalt containing recycled glass (Huang et al., 2007). The initial applications of glasphalt took place in constructed test roads with glasphalt to testify the water stability of pavements. From 1990 to 1995, the total amount of glasphalt in New York reached about 250 thousand tons. Until now, there

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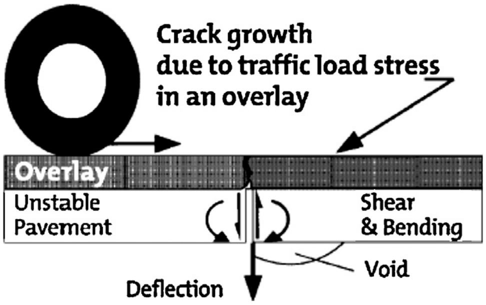

Fig. 1. Crack growth due to traffic load stress.

has been little investigation, not to mention field applications, into the application of waste glass in the field of pavement in China (Wu et al., 2004).

A study on the dynamic characteristics of asphalt mixtures containing waste glass aggregates and conventional asphalt concrete mixtures showed an increase in the stiffness modulus of glass–asphalt pavements in comparison with conventional asphalt-mix. Four percent of hydrated lime was used as an anti-stripping agent additive, and the results were compared with those of a specimen without anti-stripping. The stiffness modulus of the glass–asphalt mixtures with hydrated lime showed considerable increase in comparison with other specimens (Arabani and Mirabdolazimi, 2009; Arabani, 2011).

Flexible pavements are the most common pavement structure. Scientists and engineers are constantly trying to improve the performance of asphalt pavements (Maherz et al., 2005). As bitumen is a viscoelastic binding material, viscoelastic properties can also be found in the bituminous mixtures. One explanation for the phenomenon of rutting in pavement surfaces is the viscoelastic properties of the pavement structures. Creep analysis can be used to describe the viscoelastic properties in bituminous mixtures. Creep involves time-dependent deformation under constant compressive stress and temperature level. A bituminous mixture is loaded with a constant load, and the response of vertical deformation is measured (Tjan and Adrian, 2003). In a flexible pavement structure, there is a creep phenomenon. The phenomenon is accelerated by increases in stress and temperature. The creep property of a bituminous mixture (i.e., creep compliance) is very important when predicting rut depth in flexible pavement structures due to traffic loading. The standard creep test is the application of constant stress (or load) to bituminous mixture; deformation is then recorded as a function of the amount of time the load is applied. For pavement structures, it is more realistic if the strain formulation is expressed for various stress and temperature levels (Tjan and Adrian, 2003). Stiffness modulus is the ratio of stress under uniaxial loading conditions and is analogous to young modulus of elasticity. Since asphalt mixtures are sensitive to temperature and loading time, this alternative terminology is used since stiffness modulus is also a function of these parameters and is therefore not a constant for a particular material (Arabani et al., 2006a,b). Reflective cracks destroy surface continuity, decrease structural strength, and allow water to enter sub-layers. Thus, the problems that weakened the old pavement extend into the new overlay. The cracking in the new overlay surface is due to the inability of the overlay to withstand shear and tensile stresses created by the movements of the underlying pavement. This movement may be caused by either traffic loading (tire pressure) or thermal loading (expansion and contraction). Fatigue-associated cracking occurs when shear and bending forces due to heavy traffic loading create stresses that exceed the fracture strength of the asphalt overlay (Fig. 1); this is a structural stability problem. Instability in asphalt cement concrete pavement is typically characterized by a series of closely spaced, multidirectional fatigue cracks (Glasgrid Technical Manual, 2002).

The deformation potential of a material under load is evaluated by stiffness modulus, which is the relationship between stress and strain, and is directly affected by some qualities of the material and the conditions under which the experiment is conducted, such as load-spreading ability of the material used as reinforcement, and the temperature and speed with which load is applied (Arabani & Kheiry, 2006a).

In this study, some important properties of glassphalt, including fatigue life, stiffness modulus and creep compliance under dynamic loading conditions, are evaluated. Sensitivity to temperature and the relationship between fatigue life and stiffness modulus are also investigated for glass asphalt specimens.

2. Experimental

2.1. Materials

The aggregate gradation in this experimental work (Arabani et al., 2007) is shown in Table 1.

In this experimental investigation, a neat bitumen 60/70-penetration grade from Isfahan mineral oil refinery was used. Bitumen properties are shown in Table 2.

The glass cullet gradation used in this experimental work is shown in Table 3.

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