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Laboratory evaluation of pavement performance using modified asphalt mixture with a new composite reinforcing material

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Abstract

As a new way of modifying asphalt or asphalt mixture, composite modification has obvious effects. In order to improve the performance of asphalt pavement in a simple, fast and efficient way, a new kind of composite reinforcing material (CRM) is used in this study. The Marshall Immersion test, the freeze–thaw splitting test and low-temperature bending test were conducted to evaluate the pavement performance of the asphalt mixture with different CRM contents. Test results show that the pavement performance of modified asphalt mixtures is better than unmodified asphalt mixture. When the CRM content increases, resistance to rutting at a high temperature increases significantly, low temperature cracking resistance and moisture damage resistance first rise and then fall. In consideration of other pavement performance, such as dynamic stability (DS), indirect tensile strength ratio (TSR) and maximum tensile strain, the suggested optimal CRM dosage is 5.9‰ to 7.9‰.

Keywords: Highway engineering; Asphalt mixture; Composite reinforcing material; High temperature stability; Water stability; Low temperature cracking resistance

1. Introduction

The performance of asphalt pavements is strongly affected by the properties of asphalt mixture. With the growth of traffic, the harsh condition of high temperature and heavy axle load, there has been a higher requirement for asphalt concrete performance. In view of this situation, the modification technology to asphalt or asphalt mixture has been studied and improved. The most commonly used modification technology is to add various additives to asphalt or asphalt mixture. Single additive was used in the past but with varied improvement on pavement performance. Composite modifiers, such as composite admixtures with fiber and polymer, composite admixtures with natural asphalt and fiber, have attracted more attention. Since various components of composite modifiers are used each targeting the improvement of a certain performance, the overall road performance has been improved greatly. However, most of the studies so far focus on the single modification, and research on the composite reinforcement is still in its early stage despite of the increasing demand for its application to highway engineering.

2. Literature review of asphalt mixture additive

So far, the modification materials that are applied into asphalt and asphalt mixture are mainly of three kinds: high-molecular polymer, mineral filter and liquid modifier. Further, high-molecular polymer can be also divided into

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thermoplastic elastomer (TPE), rubber and resin. Mineral filter includes diatomite, nano materials, carbon black, fibers, etc. Those materials have different modification effects on pavement performance when added into asphalt mixtures. Many scholars and experts at home and abroad have done extensive research on all kinds of materials. The authors talk about those additives including rubber powder [1,2], polyethylene (PE) [3–5], lignin fibers, basalt fiber [6,7] have a significantly improved effect on rutting resistance of asphalt mixture at high temperatures, but not very good in anti-fatigue performance or water stability or low-temperature cracking. There are also some mineral filters have a relatively good performance when used in asphalt mixtures, but the modification effect is limited, such as rock asphalt [8], basalt fiber [9], bio-char [10]. Although additives are various, no one is very good at improving the pavement performance including rutting-resistance, deformation-resistance, anti-fatigue performance, water stability, low-temperature cracking.

Since different modification materials primarily modify a certain performance, it is hard to satisfy every aspect of pavement performance. Thus, the combined use of multiple modification materials has attracted the attention of researchers [11]. Using both the tacky property of polypropylene (PP) fiber at a temperature around its melting point and the high modulus of glass fiber is a possible way to modify asphalt concrete, such that the reinforced product got higher stability and lower flow [12]. Combining crumb rubber and Lignin fiber can improve the overall road performance of rubber asphalt mixture [13]. Double-adding technology (adding anti-rutting agent and lignin fiber simultaneously) is used in this paper to reduce rutting at high temperatures and cracking at low temperatures at the same time which can improve the pavement performance [11]. When diatomite and polyacrylate (PAE) are used together to modified asphalt mixture, the high temperature performance and the moisture damage resistance are enhanced simultaneously [14]. Research has showed that the addition of Nano-TiO_2/SiO_2 can boost the asphalt rheological characteristics and improve the asphalt mixture's rutting and fatigue resistance [15].

The modification effect of different additives on asphalt or asphalt mixtures is different. With the research of over years, it is found that lignin fibers added into asphalt mixture can absorb asphalt and make the asphalt film attached to aggregate thick, and make the connection between asphalt and aggregate more stable. Natural asphalt, of which production process is simple, is very compatible with petroleum asphalt, and is significant in improving the anti-rutting performance and water damage resistance, and as a modifier in road construction has a wide range of application advantages. Polymer modified material are various, such as natural rubber (NR), styrene butadiene rubber (SBR), styrene–butadienestyrene (SBS), polyethylene (PE), polyvinyl chloride (PVC), etc. Those materials widely used in modifying asphalt and asphalt mixture. The polymer, lignin fiber and natural asphalt have special features in modifying asphalt mixture separately. However, making the three materials into a new composite material and evaluating its effects on the performance of modified asphalt mixture is rarely studied. In this paper, the composite reinforcing material (CRM) is made from polymers, lignin fibers and natural asphalt by a special process. A series of laboratory tests about this CRM asphalt mixture are conducted to illustrate the effect on, and characteristics of, the modified asphalt mixture. This paper provides mix design method, laboratory tests and discussion on results for its application in asphalt pavement.

3. Materials and experiments

3.1. Materials

3.1.1. Asphalt binders

The Shell heavy traffic road petroleum asphalt 70# was used in this study, meeting the requirements of Chinese JTG F40-2004 [16], its main characteristics for asphalt are shown in Table 1.

3.1.2. Aggregates

The fine aggregate and coarse aggregate used in this study are all limestone, and the properties of the aggregates are shown in Table 2 (fine) and Table 3 (coarse). The mineral powder used in this study is also made from limestone, and its apparent relative density is 2.74, hydrophilic coefficient is 0.60, the plasticity index is 2.3.

3.1.3. Composite reinforcing material (CRM)

The additive used in this study is a new composite reinforcing material (CRM) that is produced by an engineering consultancy firm specialized in highway materials. It is a kind of granular material, which is made from polymers, lignin fibers, natural asphalt and other chemical additives through a special blending process. Lignin fibers in CRM can absorb some asphalt and reach a stable state after dispersion and reinforcement of asphalt. And the adhesive cementation of fibers and asphalt plays a role of filling voids in the mixture, increasing the cohesion of the asphalt mixture. Polymer materials in CRM can improve the properties of the base asphalt, and a combination of those modifications has a positive effect on the rutting resistance, moisture damage resistance and low temperature cracking resistance of asphalt mixtures. T The additive used in this study is a new composite reinforcing material (CRM) that is produced by an engineering consultancy firm specialized in highway materials. It is a kind of granular material, which is made from polymers, lignin fibers, natural asphalt and other chemical additives through a special blending process. Lignin fibers in CRM can absorb some asphalt and reach a stable state after dispersion and reinforcement of asphalt. And the adhesive cementation of fibers and asphalt plays a role of filling voids in the mixture, increasing the cohesion of the asphalt mixture. Polymer materials in CRM can improve the properties of the base asphalt,

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