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Study on application of cement substituting mineral fillers in asphalt mixture ☆

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ABSTRACT

In order to investigate the potential of cement fillers applying in asphalt pavement instead of mineral fillers, this research did a comprehensive study, including the raw materials properties tests, mix design, and verification of mixture performance. Results show that in terms of the physical and volumetric properties, the cement fillers are similar with mineral fillers. The mix design process of asphalt mixture containing cement fillers can refer to the common asphalt mixture. The optimum asphalt/aggregate ratio was 5.0% for the materials and gradation selected in this research. The residual stability of immersion Marshall stability test was 78.9%, and the TSR of freeze–thaw splitting test was 74.4%. Both of them meet the specification requirements. The dynamic stability was 1169 time/mm, the seepage coefficient was 63.4 ml/min. These larger data than the required values demonstrated the good functional performance of asphalt mixture containing cement fillers, including the rutting resistance and the anti-permeable ability.

1. Introduction

Asphalt mixture is usually used in the surface layer of road or airport pavement. It consists of asphalt binder, coarse aggregate, fine aggregate, fillers and voids. The fillers usually mean the mineral fillers. The term mineral filler is typically referred to the mineral fine particle with physical size passing the number 200 standard mesh sieve (75 μm). Because it accounts for more than 90% of the total aggregate surface area, it forms the most interfaces between asphalt binder and aggregate. This significantly influences the service performance pf asphalt pavement. Researchers always want to find an alternative filler to improve the performance of asphalt mixture or to save investment by using the waste materials as fillers. Cement is thought as a potential alternative of traditional mineral fillers. It may improve the service performance of asphalt mixture due to its finer size and better interaction with asphalt binder.

The alternatives of mineral fillers applying in asphalt mixture have been studied by some researchers, including the cement bypass dust (CBPD), fly ash (FA), waste cement dust, alkali-activated binary blended cementitious filler, ferrite particles and brake pad waste (BPW) et al. Ramzi et al. studied the usage of CBPD as filler in asphalt concrete mixtures. They found that substitution of 5% CBPD for lime will essentially produce the same optimum asphalt binder content as the control

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mixture (4.5%, by weight of aggregate) without any negative effect on asphalt concrete properties ~stability, flow, voids in total mix, voids in mineral aggregate, and voids filled with asphalt) (Taha et al., 2002). Raja and Tapas investigated the effect of FA as alternative filler in hot mix asphalt. They found a higher stability value with lower optimum bitumen content for the mixture having 4% FA as optimum filler content in comparison with conventional mix and standard specification (Mistry and Roy, 2016). Hassan studied the influence of using waste cement dust as mineral fillers on the mechanical properties of hot mix asphalt. Test results showed an enhancement in Marshall and mechanical properties of asphalt concrete mixtures when cement dust was used. Marshall testing results have indicated an increase in the stability, unit weight and a decrease in the flow, voids ratio and voids in mineral aggregates when the percentage of cement dust content increases (Ahmed et al., 2006). Li et al. studied the effects of steel slag fillers on the rheological properties of asphalt mastic, and found that steel slag fillers can be used as potential materials to replace limestone fillers (Li et al., 2017). Dulaimi et al. concluded that incorporating an alkali activated binary blended cementitious filler with concrete for binder courses mixture significantly improves the mechanical properties and water susceptibility (Anmar et al., 2017). Sangiorgi et al. analyzed the physical characteristics of three different recycled fillers and compare them with the traditional limestone filler. They found a significant difference between these fillers, and Rigden Voids (RV) seems to have the largest potential influence on the rheology of asphalt mixtures (Cesare et al., 2017).

Dulaimi et al. developed a new fast-curing and environmentally friendly cold asphalt concrete for binder courses mixture (CACB) by using alkali-activated binary blended cementitious filler. It can be concluded from their research that incorporating an alkali activated binary blended cementitious filler (ABBCF) with CACB significantly improves the mechanical properties and water susceptibility. In addition, the high performance ABBCF mixture has a substantial lower thermal sensitivity than traditional hot asphalt concrete binder course mixtures (Anmar et al., 2017). Zhao et al. mixed ferrite particles into asphalt-based composites to upgrade the microwave absorbing efficiency and then further accelerated the self-healing rate of the composites. It was found that adding adequate amounts of ferrite fillers could notably improve temperature uniformity. The healing capability of asphalt concrete can be significantly increased by ferrite particles' superior microwave absorption properties, leading to the extension of fatigue life (Zhao et al., 2017). Hu et al. investigated the feasibility of using BPW as mineral filler in asphalt mixture. They found that the addition of BPW powder could improve the viscosity and high temperature performance of asphalt mortar. Although the low temperature property of BPW mixture was worse than the control asphalt mixture with limestone filler, BPW mixture has better anti-moisture, anti-rutting and fatigue properties. Asphalt mixture containing BPW filler showed satisfactory performance improvement (Xiaodi et al., 2017). Given all this, the alternatives of mineral fillers using in asphalt pavement can be multifarious. However, the inherent properties must be similar with mineral fillers. The interfacial interaction of alternative fillers with asphalt binder should also be considered (Anmar et al., 2017; Zhao et al., 2017; Xiaodi et al., 2017; Tan and Guo, 2013; Tan and Guo, 2014; Guo et al., 2017a,b). This may significantly influence the performance of the bulk materials, such as the asphalt mastic or the asphalt mixture (Guo et al., 2016).

The objectives of this research are to investigate the potential of cement fillers substituting mineral fillers applying in asphalt pavement.

2. Materials and methods

2.1. Raw materials

2.1.1. Asphalt binder

The asphalt binder used in this research is pure asphalt with penetration 80. Its detailed properties are shown in Table 1. The FTIR test was conducted on the asphalt binder. The result is shown in Fig. 1.

It can be seen from Table 1 that all the tested values meet the requirements according to the JTG F40-2004 (Technical Specifications for Construction of Highway Asphalt Pavements JTG F40-2004, 2004).

The FTIR result is recommended as a fingerprint of asphalt binder, to better control variability of asphalt binder at the construction stage. If the asphalt binder at the construction stage is stable, the functional groups of FTIR results should keep

Table 1
The properties of asphalt binder (Technical Specifications for Construction of Highway Asphalt Pavements JTG F40-2004, 2004).

Test item		Test result	Technical requirement
Penetration (25 °C, 100 g, 5 s)		80	80–100
Penetration index (PI)		−1.47	−1.5~+1.0
Softening point (°C)		46.5	≥44
Dynamic viscosity at 60 °C (Pa·s)		187.0	≥140
Ductility at 10 °C (cm)		36	≥30
Ductility at 15 °C (cm)		>100	≥100
Density (g/cm^3)		1.036	–
The residue after rolling thin film oven test (RTFOT)	Mass change (%)	−0.07	−0.4~+0.4
	Residual penetration ratio (%)	64	≥57
	Residual ductility at 10 °C (cm)	8	≥8

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