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Test and evaluation for effects of aggregates fragmentation on performance of lightweight asphalt concrete

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HIGHLIGHTS

- The effects of aggregates fragmentation on friction of LSMA-13 are not obvious.
- 6% can be used as the aggregates fragmentation index criterion of LSMA-13.
- LSMA-13 are recommended to be applied in rainy regions engineering.

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ABSTRACT

Effects of aggregates fragmentation on performance of lightweight asphalt concrete are studied in this paper. The Marshall mixture design method was used to determine the optimum asphalt content of lightweight SMA-13 (LSMA-13). Gyratory compaction test was taken to simulate aggregates crushing. British Pendulum Tester, sand patch method, rutting test, indirect tensile strength test, freeze–thaw splitting test and soaked Marshall stability test were adopted to study the effects of aggregates fragmentation on friction, high temperature stability, low temperature crack resistance and moisture susceptibility of LSMA-13, respectively. The results show that lightweight aggregates have little effects on the fragmentation of basalt aggregates whose particle size is larger than that of lightweight aggregates, but can prevent the basalt aggregates whose particle size is smaller than that of lightweight aggregates from breaking. The number of gyrations and the replacement percentage of lightweight aggregates have negative effects on the aggregates fragmentation index (AFI) of LSMA-13. LSMA-13 have good skid resistance and the effects of aggregates fragmentation on friction of lightweight asphalt concrete are not obvious. The larger the AFI value is, the smaller the dynamic stability (DS) is. And when AFI is larger than 6%, DS of LSMA-13 is smaller than DS criteria (3000 mm^{-1}). 6% can be used as the AFI criterion of LSMA-13 for pavement engineering. Moreover, the effects of aggregates fragmentation on low temperature crack resistance of LSMA-13 are not obvious. The replacement percentage of lightweight aggregates of LSMA-13 has negative effect on its low temperature crack resistance. And the aggregates fragmentation of LSMA-13 has positive effect on its moisture susceptibility. LSMA-13 are not recommended to be applied in cold regions engineering, but are recommended to be applied in rainy regions engineering.

1. Introduction

Ceramisite, a kind of artificial lightweight aggregate (LWA), has good performance of durability, heat insulation and noise reduction. It can reduce the deadweight of asphalt concrete pavement, reduce the temperature of asphalt concrete pavement and absorb the traffic noise to replace a part of basalt aggregates of asphalt concrete pavement. So lightweight aggregate has wide application in bridge deck pavement, urban road pavement and tunnel road pavement [1]. Qian et la. [2] developed lightweight aggregate epoxy asphalt concrete (LEA) with a 70% LWA replacement percentage. The research showed that LEA had high flexural modulus, good high temperature stability and good moisture susceptibility. Moreover, LEA was applied to the bridge deck pavement of Tianjin Bascule Bridge and the mass of bridge deck pavement was reduced by 36%. Yang [3] studied the thermal properties of the asphalt mixtures containing ceramic. When the ceramic asphalt concrete was applied to upper layer of road pavement, the temperature of the bottom surface of upper pavement layer was reduced by 5.5 °C.

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The effects of ceramisite addition ratio on flexural performance, wear resistance and acoustic performance of concrete pavement was studied by Ling [4]. And the ceramisite concrete pavement was applied to Jiahuoyan Tunnel of the Shanghai-Chengdu Expressway. The traffic noise of Jiahuoyan Tunnel was reduced by 2.8 dB. Meanwhile, expanded clay aggregate (ECA) was applied to bituminous construction. And 3.5 years later, ECA asphalt concrete still performed well [5]. Moreover, ceramisite was usually applied to asphalt chip seals and surface treatments [6–8]. The asphalt chip seals and surface treatments containing ceramisite had good skid resistance [9].

Previous research mainly focused on the road performance of lightweight cement concrete and lightweight asphalt concrete. Zhuang et al. [10] studied the effect of lightweight aggregate type on early-age autogenous shrinkage of concrete. Lightweight aggregate concrete (LWAC) with crushed shale ceramisite showed smaller early-age autogenous shrinkage than LWAC with spherical shale ceramisite when the lightweight aggregate had not been pre-wetted. And LWAC with crushed shale ceramisite showed larger early-age autogenous shrinkage than the LWAC with spherical shale ceramisite when the lightweight aggregate had been pre-wetted. Mallick et al. [11] replaced a part of basalt aggregates of asphalt concrete by synthetic lightweight aggregates made from waste fly ash and plastics. And according to laboratory tests, 15% by weight of aggregate appeared to be an optimum replacement amount of lightweight aggregates for lightweight asphalt concrete and synthetic lightweight aggregates enhanced stiffness and resistance against rutting and moisture-induced damage of asphalt concrete. Khan [12] and Dawson [13] studied the thermal properties of asphalt concrete containing lightweight aggregates. The research showed that lightweight asphalt concrete had lower thermal conductivity and thermal diffusivity. And lightweight aggregates could mitigate frost damage in asphalt concrete pavements. Shen et al. [14] used granulated synthetic lightweight aggregate (GSLA) to replace a part of basalt aggregates of porous asphalt concrete so that to improve the permeability of it. The study showed that porous asphalt concrete with GSLA had good permeability and the optimum replacement percentage of GSLA was 15%.

For aggregates fragmentation of asphalt concrete, previous researchers mainly studied aggregates fragmentation in the fracture process of asphalt concrete. However, only a few studies focused on aggregates fragmentation in the compaction process of asphalt concrete. Moreover, basalt aggregates fragmentation had been studies in many papers, while lightweight aggregates fragmentation had seldom been focused on. Chen et al. [15] and Qian et al. [16] studied the fracture process of coarse aggregates and asphalt mortar under meso-scale by numerical simulation. Furthermore, Wang et al. [17] studied the rules and mechanism of aggregates fragmentation by gyratory compaction test. The research showed that the aggregates of framework structure broke into the lower-size aggregates firstly, and when there were enough force bearing points, the aggregates would stop breaking.

For the reason that the compressive strength of lightweight aggregate is much smaller than that of basalt aggregate [18], lightweight aggregates fragmentation is more obvious than basalt aggregates fragmentation. Meanwhile, a part of coarse aggregates of LSMA-13 break and the aggregate skeleton is damaged in the compaction process. So the effects of aggregates fragmentation on performance of lightweight asphalt concrete need to be studied. In this paper, the Marshall mixture design method is used to determine the optimum asphalt content (OAC) of lightweight SMA-13 (LSMA-13). Gyratory compaction test is taken to simulate aggregates crushing. British Pendulum Tester, sand patch method, rutting test, indirect tensile strength test, freeze-thaw splitting test and soaked Marshall stability test are adopted to study the effects of aggregates fragmentation on friction, high temperature stability, low temperature crack resistance and moisture susceptibility of LSMA-13, respectively.

2. Mix design

2.1. Materials

The specimens of this paper are composed of SBS modified asphalt binder, lignin fiber, limestone filler, basalt aggregate and spherical shale ceramisite as lightweight aggregate (Fig. 1). The aggregate gradation of SMA-13 is adopted, as is shown in Fig. 2. The densities of basalt aggregate, limestone filler and lightweight aggregate are presented in Table 1. According to the aggregate gradation of SMA-13 and the densities of raw materials, the aggregate volume ratio of each sieve size range of SMA-13 is calculated, as is shown in Fig. 3.

2.2. Replacement percentage of lightweight aggregates

The particle size of lightweight aggregate is smaller than 13.2 mm and larger than 9.5 mm. Meanwhile, according to Fig. 3, the volume ratio of basalt aggregates whose particle size ranges from 9.5 mm to 13.2 mm is 32.2%. So specimens were manufactured with different replacement percentages of lightweight aggregates (0%, 10%, 20% and 30% by volume) blended with basalt aggregate.

2.3. Optimum asphalt contents

The Marshall mixture design method based on SHC F40-01-2002 [20] was used to design and prepare specimens for testing. The lignin fiber mixing amount of each LSMA-13 Marshall specimen was 4.8 g. The Marshall test results of LSMA-13 are shown in Table 2.

According to Table 2, the larger the replacement percentage of lightweight aggregates is, the larger the OAC of LSMA-13 is, which indicates that the asphalt absorption of lightweight aggregate is larger than that of basalt aggregate. Moreover, the density and stability of LSMA-13 decreases with the increase of replacement percentage of lightweight aggregates.

Fig. 1. Spherical shale ceramisite.