Construction and Building Materials 152 (2017) 48–56

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effect of coarse aggregate morphology on the mechanical properties of stone matrix asphalt

Yufeng Liu [a], Yucheng Huang [a], Wenjuan Sun [a], Harikrishnan Nair [b], D. Stephen Lane [b], Linbing Wang [a,*]

[a] Department of Civil and Environmental Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, United States
[b] Virginia Transportation Research Council, Charlottesville, VA 22903, United States

HIGHLIGHTS

- Aggregate morphological characteristics were measured using an improved FTI system.
- APA and MMLS tests were performed to evaluate the mechanical performances of SMA.
- Rut depth increased with the increase of sphericity, angularity and texture.
- Sphericity was shown to have a negative influence on seismic modulus difference.
- Flatness ratio was shown to have a positive effect on seismic modulus difference.
- Equi-dimensional, non-flaky, angular and rough aggregates improve SMA performance.

ARTICLE INFO

Article history:
Received 2 January 2017
Received in revised form 30 May 2017
Accepted 10 June 2017

Keywords:
Coarse aggregate
Morphological characteristics
Rutting
Fatigue
SMA

ABSTRACT

The aim of this study is to examine the effects of morphological characteristics of coarse aggregates on the rutting and fatigue performance of stone matrix asphalt (SMA). A total of twenty-two coarse aggregate fractions were analyzed, and different aggregate blends were used to prepare different SMA mixtures following the job-mix formula in Virginia State. Specimens from eight types of SMA mixtures, with three replicates each, were tested for rutting resistance with an asphalt pavement analyzer (APA). Six types of the SMA mixtures were tested for fatigue resistance with a modal mobile load simulator (MMLS) in conjunction with a portable seismic pavement analyzer (PSPA). Rut depth obtained from the APA and seismic modulus difference obtained during MMLS trafficking were linked to morphological characteristics of coarse aggregates. Statistical analysis showed that flatness ratio and elongation ratio had no measurable influence on rut depth. The regression analysis demonstrated that rut depth increased with the increase of sphericity, angularity and texture, which indicates that rutting resistance of SMA can be improved by using more equi-dimensional and angular coarse aggregates with rougher texture. However, angularity and texture were found to have little influence on seismic modulus difference. Sphericity was shown to have a negative influence on seismic modulus difference, and flatness ratio was shown to have a positive effect on seismic modulus difference, which indicated that using more spherical and less flaky coarse aggregates reduces the degradation of stiffness, resulting in improved fatigue performance of SMA mixtures. The performance results suggest that flat and elongated aggregates should be used only in limited amounts.

© 2017 Published by Elsevier Ltd.

1. Introduction

Stone matrix asphalt (SMA) was developed in Germany in the 1960's and is a gap-graded hot mix asphalt (HMA). SMA has been used successfully in Europe for more than 20 years [1], and was then introduced to the United States in 1991 due to its superior performance [8,33]. To date, numerous SMA projects have been carried out using crushed coarse aggregates [7]. A proper physical particle-to-particle contact between the coarse aggregates of SMA forms into stable skeleton structure, which greatly reduces rutting [9,28]. SMA is actually aimed at creating stone-on-stone contact within the mixture to improve tire grip and rutting (deformation resistance). High quality aggregates have been found to significantly contribute to the strength and rutting resistance of SMA

* Corresponding author at: Charles E. Via, Jr. Department of Civil and Environmental Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, United States

E-mail addresses: yufeng8@vt.edu (Y. Liu), yucheng@vt.edu (Y. Huang), sunwj@vt.edu (W. Sun), Harikrishnan.Nair@VDOT.Virginia.gov (H. Nair), Stephen.Lane@VDOT.Virginia.gov (D.S. Lane), wangl@vt.edu (L. Wang).

http://dx.doi.org/10.1016/j.conbuildmat.2017.06.062
0950-0618/© 2017 Published by Elsevier Ltd.

[2,5,38]. Since SMA mixtures include a large proportion of coarse aggregate, the morphology, size and gradation of coarse aggregates become major factors to influence mechanical performance of SMA.

Previous research has found that morphological characteristics of coarse aggregates in SMA, including sphericity, flatness ratio, elongation ratio, angularity and texture, are the principal factors affecting mechanical performance of SMA [30,32,42]. It was found that spherical particles are preferable for providing proper aggregate internal friction and improving rutting performance [12]. Research shows that flat and elongated aggregates tend to break down and reduce the particle-to-particle interlock, which mostly contributes to mechanical properties of aggregate structure [10]. Because aggregate angularity is crucial for this interlocking effect, asphalt mixtures with angular aggregates exhibit stronger shear resistance than those without [20,36]. Aggregates with rougher surfaces promote interface connection between particles and asphalt binder, leading to better workability and fatigue performance of asphalt mixtures [6,14,39]. Sharp and angular coarse aggregate particles interlock and provide better surface texture, in contrast to the horizontal orientation of flat and elongated particles, which results in lower texture depths [21]. Generally, it is preferable to have more equal-dimensional, rougher and more angular aggregates than flat and elongated aggregates. Advanced image analysis technologies have been developed for capturing the aggregate morphology profiles effectively and accurately, and have been widely used for characterizing aggregate morphologies in the last decades [4,15,27,35]. Various imaging-based aggregate shape properties have been defined and linked with the performance of HMA [3,18,24,26,34]. The reliability and accuracy of using the improved FTI system to measure aggregate morphological characteristics, including sphericity, flatness ratio, elongation ratio, angularity and texture, have been validated [22,25,43].

Fatigue, rutting and low temperature cracking are the most common distresses that occur in asphalt mixtures. For SMA mixtures, rutting occurs early in service life. Numerous laboratory tests have linked the performance of SMA mixtures to the morphological characteristics of coarse aggregates, including simple performance tests such as the static creep test, dynamic modulus test, indirect tensile test, Marshall stability test, wheel tracking tests such as asphalt pavement analyzer (APA) test, model mobile load simulator (MMLS) test, Hamburg test, and accelerated pavement tests [16,29,33,37]. Wheel-tracking devices such as APA and MMLS have shown promise as testing methods for measuring the rutting and fatigue resistance abilities of SMA mixtures. APA and MMLS are two important tools for simulating traffic and environment conditions in field. APA is one of the most common and popular loaded wheel testers for evaluating the rutting resistance of HMA mixtures [40]. MMLS also has been used widely for effective evaluation of permanent deformation or rutting and fatigue failure of scaled asphalt concrete pavement [17,41]. Rut depth obtained from APA typically is indicative of permanent deformation on the pavement surface at high temperatures. The seismic modulus or stiffness degradation obtained during MMLS trafficking using Portable Seismic Pavement Analyzer (PSPA) generally is a reliable indicator to evaluate fatigue life of SMA mixtures at intermediate and low temperatures.

The main objective of this study is to evaluate the sensitivity of mechanical performance of SMA to morphological characteristics of coarse aggregates used in the SMA. In this study, eight types of SMA mixtures used in Virginia highways were investigated. There are a total of 22 types of coarse aggregates used in the eight types of SMA mixtures. All coarse aggregates were analyzed for quantification of aggregate morphological characteristics using the improved FTI system. The rut depth was measured through APA test for SMA mixtures by the Virginia Transportation Research Council (VTRC), and the seismic moduli were measured from MMLS tests at Virginia Tech. This study consists of the following steps: (a) scanning coarse aggregates using the improved FTI system to obtain morphological characteristics, (b) testing the SMA mixtures to obtain rut depth in APA tests and seismic modulus in MMLS3 tests, and (c) evaluating the correlation between coarse aggregate morphology and rut depth of SMA mixtures from APA tests and the correlation between coarse aggregate morphology and seismic modulus difference of SMA mixtures from MMLS3 tests.

2. Material selection

Table 1 presents the mix design for all SMA mixtures, including the size, type, and origin of aggregates, and the contents of fiber and asphalt binder. These mix designs for SMA mixtures are used in Virginia highways. There are in total 22 types of coarse aggregates in the SMA mixtures. These aggregates were collected from eight quarries in Virginia State, including Staunton, Bealeton, Staunton, Stuarts Draft, Leesburg, Goose Creek, Chantilly, and Garrisonville. These aggregates mainly include the following mineralogical compositions: aplite, limestone, quartzite, arkose, diabase, and granite.

The improved FTI system was used to measure coarse aggregates, which are those that were retained on a 2.36 mm sieve after passing through a 12.5 mm sieve. All coarse aggregate samples were sieved into four size ranges, namely, 2.36–4.75 mm, and 4.75–9.5 mm, 9.5–12.5 mm, 12.5–19 mm (#8 to #4, #4 to 3/8 in., 3/8 in. to ½ in., ½ in. to ¾ in.). In this investigation, a total of 120 particles were scanned for each type of aggregate.

SMA mixtures were produced following the specification of the Virginia Department of Transportation (VDOT) SMA mix design [13]. SMA mixture specimens (SMA-9.5 and SMA-12.5) with two different nominal maximum aggregate sizes were fabricated as shown in Table 1. For each type of SMA mixture, three samples were prepared with different weight percentages of crushed coarse aggregate fractions. As shown in Table 1, SMA mixtures marked as 13-1070, 13-1081, 14-1021, 14-1047, and 15-1012 were prepared using four aggregate fractions, respectively. SMA mixtures marked as 15-1068, 15-1080, and 15-1084 included three aggregate fractions, respectively. Three different types of asphalt binder were selected: PG 70-22, PG 76-22 and PG 76-28 High Polymer (HP). The asphalt binder content for each SMA mixture varied. Table 2 summarizes the volumetric information of all SMA mixtures. These SMA mixtures exhibited diversity with regards to morphological characteristics and nominal maximum aggregate size of coarse aggregates, performance grade and content of asphalt binder.

SMA is a gap-graded hot mix asphalt (HMA) with high concentrations of coarse aggregates and high asphalt content, which greatly reduces the susceptibility to rutting and improves the durability of SMA mixtures. It is conceivable that fatigue behavior of SMA depends on physical properties of coarse aggregates and asphalt binder. Since all the mixtures prepared are all gap-graded and aggregate gradations of all SMA mixtures are similar, aggregate gradation has little influence on mechanical performance of these SMA mixtures, and consequently is not a topic of interest in this study. Since most of the SMA mixtures are SMA-9.5, the nominal maximum aggregate size is not considered as the main factor to discuss. Among the other factors, coarse aggregate morphology strongly affects mechanical performance of gap-graded SMA mixtures due to the dominant usage of coarse aggregates. This leads to the objective of this study, investigation of the influence of coarse aggregate morphology on mechanical performance of SMA mixtures in Virginia.

Download English Version:

https://daneshyari.com/en/article/4912748

Download Persian Version:

https://daneshyari.com/article/4912748

Daneshyari.com