Transportation Geotechnics 10 (2017) 13–21

Contents lists available at ScienceDirect

Transportation Geotechnics

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

High and intermediate temperature performance evaluation of crumb rubber modified binders with RAP

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ARTICLE INFO

Article history:
Received 26 June 2016
Revised 20 September 2016
Accepted 30 October 2016
Available online 5 November 2016

Keywords:
Reclaimed asphalt pavement
Crumb rubber modified binder
MSCR
LAS
Rutting
Fatigue

ABSTRACT

The present study was undertaken to evaluate high and intermediate temperature performance of a crumb rubber modified binder (CRMB60) blended with different percentages (i.e., 0%, 15%, 25% and 40%) of binder extracted from reclaimed asphalt pavement (RAP). The Brookfield viscosity, Superpave high performance grade (PG), and complex modulus were measured for CRMB60 blended with RAP. The rutting and fatigue resistances of CRMB60 with and without RAP were evaluated using multiple stress creep and recovery (MSCR) and linear amplitude sweep (LAS) tests, respectively. The results showed that addition of RAP improves temperature susceptibility of CRMB60. The Superpave high PG of CRMB60 binder bumped by one PG interval (i.e., PG88–PG94) with addition of 15% and 25%RAP. However, further increase in RAP (40%RAP) did not alter PG, which is contrary to what have been reported in literature. The MSCR test showed that non-recoverable creep compliance (J_{nr}) of CRMB60 decreased with an addition of RAP up to 25%, indicating the improved rutting resistance of CRMB60. However, J_{nr} of CRMB60 increased with addition of higher percentage of RAP (i.e., 40%), showing poor rutting resistance compared to control CRMB60. The LAS test showed that fatigue damage resistance of CRMB60 with 15% and 25% RAP was less compared to control CRMB60. Overall the present work showed the addition of RAP increased rutting resistance, however, deteriorated fatigue performance of CRMB60. The higher percentage of RAP showed a different trend than expected, which might be due to reduced concentration of rubber particles or depolymerization of rubber particles after addition of high content of RAP.

Introduction

It is well understood fact that scrap tires poses serious environment and solid waste management problem, thus there is a thrust to utilize such materials for various pavement applications. The crumb rubber produced from scrap tires is generally used for construction of asphaltic pavements. Usually crumb rubber is used in two ways for asphaltic pavement applications (i) dry process: where crumb rubber is mixed with aggregates first and then with asphalt binder for production of mixes, and in (ii) wet process: where crumb rubber is mixed with binder first, like polymer modified binder, and then used for preparation of mixes. Utilization of crumb rubber in the wet process method is quite popular in many countries. The binder produced from wet process is called crumb rubber modified binder (CRMB).

The modification of binder with addition of crumb rubber is not chemical in nature (Zanzotto and Kennepohl, 1996; Heitzman, 1992). Crumb rubber particles adsorb

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http://dx.doi.org/10.1016/j.trgeo.2016.10.003
2214-3912/

light aromatic oil fraction, which causes swelling of rubber particles, and form gel structure (Heitzman, 1992). This phenomena result in reduction in inter-particle distance and consequently increase in viscosity of binder. The rate of reaction between rubber particles and base binder depend on mixing time, temperature, speed, production methods (ambient or cryogenic grinding), particle size, specific surface area, chemical composition (i.e., amount of natural rubber), and morphology of rubber particles (Heitzman, 1992; Putman et al., 2006; Abdelrahman and Carpenter, 1999). The swelling will continue until the rubber starts degradation/depolymerization, which may result in decrease in viscosity of binder (Billiter et al., 1997), and thus overall performance of crumb rubber modified binder.

Similar to scrap tire, utilization of reclaimed asphalt pavement materials (RAP) for construction of asphalt pavement is important. Utilization of ground tire rubber modified asphalt binder with RAP can provide added benefits in terms of material saving, cost, and environmental protection. The RAP contains stiff and aged binder, thus inclusion of RAP in a mix is expected to increase rutting performance (Khosla et al., 2012; Hossain et al., 2013; Huang and Turner, 2014), however, on the other hand, addition of RAP may deteriorate fatigue and low temperature cracking potential of a mix (Kennedy et al., 1998; Lee et al., 1999; Huang et al., 2005; Bernier et al., 2012). Thus, many agencies limit use of RAP proportion for production of asphalt mixes.

However, few studies are reported to evaluate effects of RAP on rheological and chemical characteristics of CRMB binders. It is not clear how interaction of rubber particles with RAP will change overall behavior of binder. The current literature have limited studies on effects of RAP on rutting, and fatigue performance of crumb rubber binder with recently developed advanced and promising test methods such as multiple stress creep recovery (MSCR) and linear amplitude sweep (LAS). The MSCR test measures binder's rutting performance in terms of recovery (R) and non-recoverable creep compliance (J_{nr}). The MSCR test observed to have better correlation with the rutting potential of bituminous mixes (D'Angelo et al., 2007).

The LAS test uses visco-elastic continuum damage (VECD) theory in order to quantify the damage to asphalt binder due to repeated application of load. The LAS test has shown fair correlation with field fatigue cracking data (Hintz et al., 2013). Further, change in chemical properties with addition of RAP and rheological properties have not been fully explored for crumb rubber modified binders. The present study evaluates rutting, fatigue, and other rheological performance of CRMB binder blended with different percentages (i.e., 0, 15%, 25%, and 40%) of RAP. It is expected that the outcome of this study would be helpful to understand short term and long-term behavior of RAP blended binders.

Objectives

(a) Evaluate effects of RAP on viscosity, temperature susceptibility, and high temperature Superpave PG, and complex modulus at wide range of temperatures and frequencies.
(b) Evaluate rutting and fatigue cracking resistance of CRMB binder with and without different percentages of RAP using MSCR and LAS tests, respectively.
(c) Understand aging behavior of CRMB binder with addition of RAP content using FTIR.

Materials

CRMB60

The CRMB60 was prepared with 11% crumb rubber (crumb rubber 100% and 80% passing from sieve number 30 and 80, respectively). This binder is commonly used in India for construction of flexible pavements. The preliminary properties (i.e., penetration, softening point, ductility, elastic recovery, and viscosity) and other rheological properties of CRMB60 are shown in Table 1. The high temperature PG of RAP binder was measured to be 88 °C. The J_{nr} and R measured at 3.2 kPa and 64 °C were found to be 0.46 kPa^{-1} and 16.8%, respectively. The Brookfield viscosity of CRMB60 binder at 135 °C was measured to be 1127 mPa·s. The ductility and elastic recovery value of CRMB60 were found to be 15.1 cm and 30%, respectively. The softening and penetration values of CRMB6 were found to be 62 °C and 32 units, respectively. The binder satisfies criteria relevant to specific standards.

RAP binder

The RAP material used in this study was collected from the surface layer of an asphaltic pavement. The asphalt binder originally used in the surface layer was of penetration grade 50/60. The extraction of binder from RAP was done in a two stages process. In first step, the aggregates were separated from RAP with help of centrifuge extraction method using tri-chloro ethylene (TCE) as a solvent as per ASTM D2172 and thereafter the binder was sepa-

Table 1
Properties of CRMB60.

Physical properties	CRMB60	RAP	Standard code
Penetration, @ 25 °C, 100 g, 5 s	32	24	ASTM D5
Softening point (R&B), °C	62	68	ASTM D36
Ductility, @ 27 °C, cm	15.1	21.2	ASTM D113
Elastic recovery, @ 27 °C,%	30	15	ASTM D6084
Brookfield viscosity @135 °C, mPas	1127	1544	ASTM D4402
High PG grade (°C)	88	88	AASHTO T 315
MSCR at 64 °C (at 3.2 kPa)	R = 16.8, J_{nr} = 0.46 kPa^{-1}	R = 24%, J_{nr} = 0.2 kPa^{-1}	ASTM D7405