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Investigation of the properties of asphalt mixtures incorporating reclaimed SBS modified asphalt pavement

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HIGHLIGHTS

- Recycling asphalt mixtures containing RAP, RA and control asphalt mixture were prepared.
- RAP increase the stiffness and decrease the anti crack performance of asphalt mixture.
- RA can restore and soften the binder in RAP and improve the fatigue of asphalt mixture.
- RA can improve the anti crack performance of asphalt mixture containing RAP.

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ABSTRACT

With the increasing environmental considerations and rising costs of construction materials, reclaimed asphalt pavement (RAP) has been frequently added into asphalt paving mixtures during pavement construction. Many studies have been conducted with regard to the study of reclaimed unmodified asphalt pavement, but the reclaimed SBS modified asphalt pavement is still unknown. In this study, the effects of RAP and rejuvenating agent on the performance were studied. The moisture susceptibility, rutting resistance, dynamic modulus, low temperature anti cracking performance and fatigue was tested. Furthermore, in order to better understand the effects of RAP and rejuvenating agent, the control asphalt mixture was measured using the same methods. The results indicated that the asphalt mixture incorporating reclaimed SBS modified asphalt pavement with better moisture susceptibility, rutting resistance, dynamic modulus, low temperature anti cracking performance and fatigue resistance was obtained by blending new SBS modified asphalt binder and rejuvenating agent. Thus, the rejuvenating agent will benefit the effort of preparing more sustainable asphalt pavement containing RAP.

1. Introduction

Reclaimed asphalt pavement (RAP) has been used in most country because of the environmental benefits and costs reduction. According to the Federal Highway Administration 80% of the RAP removed each year during resurface projects, approximately 73 million tons, is reused in the United States [1,2]. Various percentages of RAP content are permitted by current specifications depending on the traffic level. Nevertheless, there are several references in literature that addressed the asphalt behavior containing RAP materials [3–5].

The use of Polymer Modified Asphalt (PMA) to obtain better asphalt pavement performance has been investigated for a long time. Styrene-butadiene-styrene (SBS) copolymer modified asphalt were developed mainly for the reason that can improve the permanent deformation, low-temperature cracking, fatigue, stripping, wear resistance and anti aging [6,7]. There is a need for research into recycling issues involved with SBS modified asphalt mixtures. The reclaimed SBS modified asphalt mixtures are different from reclaimed asphalt binders due to the presence of SBS [8–10]. However, there is very little literature concerning about whether recycling of aged SBS modified asphalt mixture can follow the same recycling process as those for unmodified asphalt mixture. The mix design process for hot mix asphalt (HMA) with RAP is similar to mix design for virgin HMA when the RAP percentage is lower than 25% [11–14]. Despite the similarity in mix design, some challenges remain for maximizing RAP used and routinely using high RAP content. Thus, there is also a need for research into the

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mix design for reclaimed SBS modified asphalt mixture and the application of RAP is still far from desired in some countries.

Generally, the rejuvenating agent is utilized to recover and soften the properties of aged binders by reconstituting the chemical compositions of the binders [15–17]. In most case, the RAP in asphalt mixture can increase the modulus of the asphalt mixture, which is beneficial for the resistance to permanent deformation at high service temperatures [18]. But it also makes the asphalt mixture to show an increase in stiffness and brittleness at low temperature, which results in reduced resistance to fatigue and low temperature cracking [19,20]. The rejuvenating agent has the potential to restore the rheology and chemical components of aged RAP binder and decrease the modulus of asphalt mixture with RAP [21]. In addition, rejuvenating agent would allow a significant increase in the amount of RAP used in asphalt mixture. From economic and environmental benefits points of view, it is good thing to increase the RAP contents. However, some researcher or research groups are reluctant to allow the use of rejuvenating agent due to potential rutting damage or ineffective blending of the rejuvenating agent with the RAP [22,23]. Excellent diffusion can decrease the potential rutting damage. Thus, the rejuvenating agent should have better diffusing into the RAP binder and long term stability besides restore and soften. In a previous work showed that the regenerated SBS modified asphalt binder with appropriate physical properties and pavement performances can be obtained by blending recovered SBS modified asphalt with fresh SBS modified asphalt and rejuvenating agent [24]. The result of RTFOT indicated that the regenerated SBS modified asphalt binder have good aging resistance, especially rejuvenating agent II was used to reclaimed SBS modified asphalt binder.

2. Objective

The objectives of the research are as follows:

(a) Assess the impact of the contents of RAP on asphalt mixture with/without rejuvenating agent and compare the performance with control asphalt mixture.
(b) Evaluate and compare the use and no use of rejuvenating agent for restoring the properties of asphalt binder with RAP.

3. Experimental

3.1. Materials

The RAP used in the manufacture of mixtures was from a road rehabilitation work of a pavement, corresponding to a wearing course (4 cm), which is the surface layer in direct contact with traffic loads. This recycled project, which has been built using the SBS modified asphalt binder with 5.0 wt% SBS and used for 8 years, was selected in this study. The asphalt content of RAP was determined by centrifuging extractor method (according to ASTM D2172 standard). The results are showed in Table 1. After extraction of binder in RAP with the centrifuge extractor method, its characterization followed. The results obtained are displayed in Table 2. The gradation of RAP was established after the extraction of the asphalt. The aggregate grading used in this study was the aggregate grading for dense graded asphalt mix as showed in Fig. 1.

A PG76-22 SBS modified asphalt binder was adopted for the new asphalt binder. The results regarding the characterization of additional new asphalt binder were also described in Table 2.

The low-viscosity rejuvenating agents (RA) were selected for blending with recycled asphalt mixture. Table 3 lists the basic properties of the rejuvenating agents prepared in laboratory. The rejuvenating agents can reduce the viscosity of recycled asphalt mixture to meet the target viscosity and restore the old binder [24].

Table 1
The results of asphalt contents of RAP by centrifuge extractor method.

Samples	A1	A2	A3	A4	A5	Average	Standard deviation
Asphalt contents (wt%)	4.75	4.18	3.92	4.17	4.53	4.31	0.328

Table 2
Characterization of recovered asphalt and new asphalt binder.

Properties	Recovery asphalt	New asphalt binder
Softening point (°C)	61.7	67.5
Penetration at 25 °C (0.1 mm)	34	30
Ductility at 5 °C (cm)	0.5	26.5
Viscosity at 135 °C (Pa s)	2.67	2.26
SBS contents (%)	5.0 (Before using)	5.1

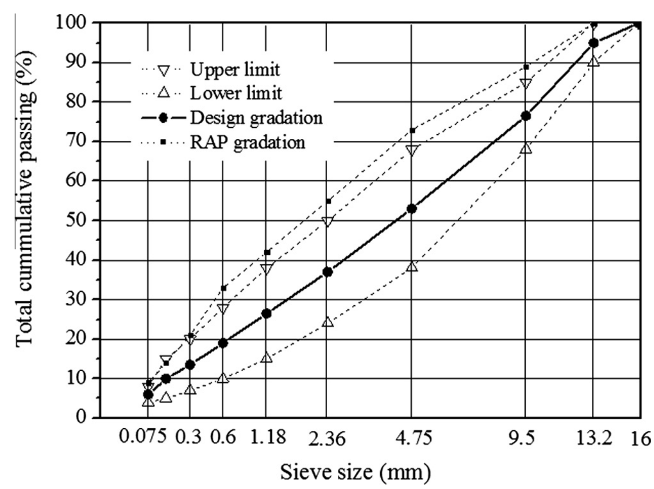

Fig. 1. Gradation curve of design dense grade.

Table 3
Chemical components and physical properties of rejuvenating agents.

Properties	Rejuvenating agent
Asphaltenes (%)	3.4
Resins (%)	28.2
Aromatics (%)	52.8
Saturates (%)	15.6
Viscosity at 60 °C (Pa s)	1.72
Flash point (COC) (°C)	230
RTF-C, Viscosity ratio (%)	1.23

3.2. Testing methods

The Marshall mix design procedure was employed to design the mixtures according to ASTM D1559. Mix designs included a control mixture of 0% RAP and three asphalt mixtures with 15% RAP, 25% RAP, and 30% RAP. After the control (0% RAP) mixture with virgin aggregates was designed, different percentages of RAP were added, and the percentage of virgin aggregate was altered such that the new combined blend, which contained RAP, had approximately the same percent passing the primary control sieve as that of the control mixture. The optimum asphalt content for each mixture was 4.8%, that is, asphalt obtained from RAP together with new asphalt binder and rejuvenating agent was 4.8% by the weight of the mix. The rejuvenating agents were added to the mixture at a dosage of 5% and 10%, which was calculated on the basis of the RAP binder. The mixture design for the 10 mixtures investigated and the voids in mineral aggregates (VMA), voids filled with asphalt (VFA) and air voids (Va) as Table 4 showed.

To investigate the moisture susceptibility of asphalt mixture, the loss in Marshall stability and the loss in indirect tensile strength was measured according to AASHTO T283 test procedure. Specimens prepared with 75 blows were tested for Marshall stability after immersion in water at 60 °C for 35 min and 24 h to determine the loss in Marshall stability. Marshall specimens with 7% air void content were subjected to indirect tensile strength (ITS) on un-conditioned (after 2 h soaking in water at 25 °C) and conditioned specimens (15 min immersion in vacuum container with 98.5 kPa plus 16 h frozen at a temperature of −18 °C, then 2 h soaking in water at 25 °C) to determine the loss in indirect tensile strength.

The wheel-tracking test was employed to measure rutting resistance of asphalt mixture. The experiment condition were as follows, the square slab specimens with 300 mm in length, 300 mm in width and 50 mm in thickness are immersed in dry atmosphere at 60 ± 0.5 °C for 6 h and then a wheel pressure of 0.7 MPa, the wheel