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Effect of Black Rice Husk Ash on Asphaltic Concrete Properties under Aging Condition

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Abstract. The scarcities of natural resources and increment in waste production rates have promoted efforts to investigate the potential incorporation of various by-products in roads construction. Reusing of waste materials such as black rice husk ash (BRHA) in asphaltic concrete was considered as one of the proper management of the waste, which ensures economic and environmental benefits. Hence, this study investigates the effect of black rice husk ash on asphalt mixtures properties under different aging condition. BRHA was added in the asphalt mix in a proportion of 0%, 2%, 4% and 6% by weight of bitumen. 5% optimum bitumen content with 60/70 penetration grade binder was selected for this study. The asphalt mixtures for each fraction was prepared in three different aging conditions i.e. un-aging (UA), short term aging (STA) and long term aging (LTA). The properties of asphalt mixtures were evaluated by voids, stiffness and dynamic creep tests. The results indicate that asphalt mixtures consisting of BRHA have exhibited better performance in term of voids, stiffness and creep modulus when compared to the conventional asphalt mixtures. The STA and LTA mixtures modified with BRHA produced higher performance than the unmodified mixtures. It can be concluded that the optimum additional percentage of BRHA was in the range of 4% to 6%.

1. Introduction

There was a growing trend towards the development and use of waste materials in construction industry as supplementary materials [1,2,3]. Various types of waste materials have been investigated, assessed and evaluated for utilizations and practiced in the industry [5,6]. The most prevalence materials are steel slag, scrap tires, plastic wastes, foundry sands, bottom and fly ash, rice husk ash (RHA), oil sands, marble dusts, recycled concrete aggregates and reclaimed asphalt pavement (RAP) [7,8,9]. The inclusion of these waste materials in road construction industry preserves natural precious resources while reducing the amount of waste requiring disposal [10,11]. Nowadays, due to the environmental and economic concerns, the reusing of waste materials in road pavements has considerably extended. The idea of using waste material as additives has been developed by numerous researchers, in which different additives have been used for different purposes. Their studies showed that additives created from waste materials improve the performance of asphalt concrete mixture. Common pozzolanic agents from agriculture by-products and industry such as RHA, ground granulated blast furnace slag and fly ash are becoming active areas of research since it leads to diverse product quality and reduction in cost and environmental effects [12,13]. Reusing of waste materials in asphaltic concrete was considered as one of the proper management of the waste which ensures economic and environmental benefits. The reuse of waste materials transforms the residue to useful raw materials, thus benefit the environment related to the disposal of waste materials.

2. Materials and Specimen Preparation

2.1. Binder, Aggregate and Black Rice Husk Ash

This study used a 60/70 binder supplied by Chevron Malaysia. Standard laboratory test results for binder are 68 dmm (penetration at 25°C), 52°C (softening point), and 1.03 (specific gravity). The physical properties of binder used was met all the requirements by JKR standard [14]. Granite aggregates used in this investigation is nearly always massive, and hard. The gradation test (figure 1) was conducted following the procedure outlined in JKR specifications for AC14 asphalt mixture. Furthermore, black rice husk ash (BRHA) was collected from the uncontrolled burning of rice husk.

The mean particle size and specific gravity of the BRHA was 10.93µm and 1.94 g/cm^3, respectively. Silicon dioxide or SiO_2 was identified as the main component of the BRHA (91%). The other elements in BRHA are alumina, iron oxide, magnesium oxide, sodium oxide, potassium oxide and sulphur trioxide, which contained 0.07%, 0.07%, 0.45%, 0.28%, 0.01%, 2.64% and 0.05%, respectively. In addition, SiO_2, Al_2O_3, and Fe_2O_3 comprised 90.48% of the material, in accordance with C618-17 [15] of the American Society for Testing and Materials (ASTM), which requires that these three main oxides should comprise no less than 70%.

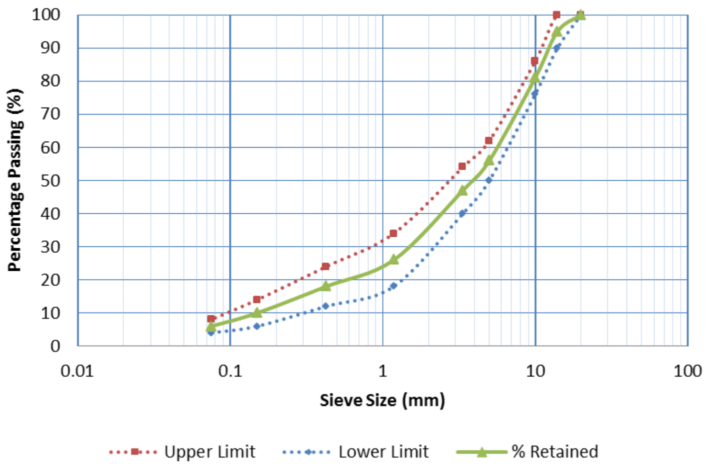

Figure 1. The aggregates gradation used in this study [14]

2.2. Mix Design

Firstly, BRHA was fully dried, then ground using a grinding ball mill for certain minute to form fineness size. Next, BRHA was sieved to form a size less than 75 µm. Four different series of mixtures were produced using 0%, 2%, 4% and 6% of BRHA and 5% optimum bitumen content was selected for this study. At the laboratory, the bitumen was first heated until it became a melted fluid at a temperature range between 135 ºC to 165ºC. Then, the BRHA was added to virgin bitumen. The mixture was blended using mixer for 60 minutes to ensure the BRHA was uniformly dispersed in the bitumen. The bitumen later was mixed with the aggregates at a temperature range of 165 ºC to 185ºC. The mixture afterwards was placed in mould and compacted using the standard 75 blows Marshall Hammer compactor. The asphalt mixtures were prepared in accordance with ASTM D6926 [16].

2.3. Dynamic Creep Test

The dynamic creep test was developed to estimate the rutting potential of asphalt mixes in accordance with the procedures outlined in BS EN 12697-25 [17]. This test applies 0.3 MPa repeated pulses of uniaxial stress parallel to the specimen with 3600 recovery cycles and measures the deformation in the same direction using Linear Variable Differential Transducers (LVDT). Actual dynamic creep test was conducted at 40°C, 1 hour loading time and 0.1 MPa applied stress.

2.4. Aging Procedure
The asphaltic mixture procedure for aging was adopted based on the strategic highway research program described in the AASHTO R30-02 [18]. At the laboratory, separate specimens were prepared at the time of mixing to represent the un-aged condition. As soon as mixing was completed, the specimens were compacted using a Marshall compactor. Short-term aging was carried out on loose mix. The method consisted of curing mix samples in a forced-draft oven at 135°C for 4 hours. After curing, the samples were brought to the compaction temperature and compacted via impact mode. The long term aging was carried out on compacted specimens after subjected to short term aging. Specimens were placed in a forced-draft oven at 85°C for five days. After the aging period, the oven was turned off and allowed to cool to room temperature. The specimens were then extruded and tested for dynamic creep.

3. Results and Discussion

3.1. Voids in Total Mix (VTM)
Figure 2 represents the VTM of asphalt mix with BRHA at different aging condition. The results show that the VTM decreased when the BRHA content was increased. The VTM was decreased from 4.3% to 3.7% as the BRHA content increases from 0% to 2%. However, the VTM then was increased up to 4.1% when tested at 4% BRHA. On the other hand, at 6% BRHA, the VTM was decreased approximately 3.2%. Based on short-term aging condition, the results indicated that increment of BRHA content at 2% interval cause significant decrease in the VTM values. Voids in total mix of 9.8-7.7% were obtained when the BRHA content was increased from 0% to 6%. The lowest VTM was recorded at 2% BRHA with a rate of 7.3%, a reduction of 25.5% than the unmodified mixture. According to Abdullah et al. [8] reported that lower air void contents minimize the aging of the asphalt cement films within the aggregate mass and also minimize the possibility of moisture penetrating the thin asphalt cement film and strip the asphalt cement off aggregates. In this study, the VTM of asphalt mixtures containing BRHA after long term aging was consistently lower than the unmodified mixture. It can be seen that the VTM was decreased to 8.5% when the percentage of the BRHA increases up to 2%. The values have continually decreased to 8.2% and 7.5% when the percentages of BRHA increase to 4% and 6%.

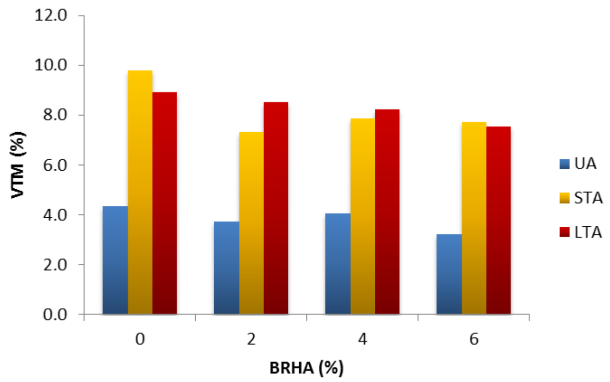

Figure 2. Voids in total mix of asphaltic concrete with BRHA under aging

3.2. Voids Filled with Bitumen (VFB)
Figure 3 shows the VFB of asphalt mix with BRHA at varying aging condition. The results reveal that modified mixtures have higher values of VFB when compared to unmodified mixture. For instance, when 2% BRHA was added to the mixture, the VFB was increased by 4.1%. The VFB values were continually increased by 1.8% and 7.7% when 4% and 6% BRHA was added to the mixture. From short-term aging circumstance, the VFB significantly increased with the increasing of BRHA content. The VFB was increased by 14.2% when the BRHA content increases from 0% to 2%. The value then was

increased by 10.8% as the BRHA increases up to 4%. Otherwise, the VFB was increased by 11.5% when the BRHA increases to 6%. On the other hand, when specimens exposed to long-term aging, the VFB has increased as percentage of the BRHA was increased accordingly. The VFB values increased to 56.5% and 57.3%, when 2% BRHA and 4% BRHA was added to the mixture respectively. The highest VFB was obtained when the percentage of the BRHA was increased from 4% to 6%. An increment in the percentage of the BRHA has increased the VFB, lead to production of denser mixtures [19,20].

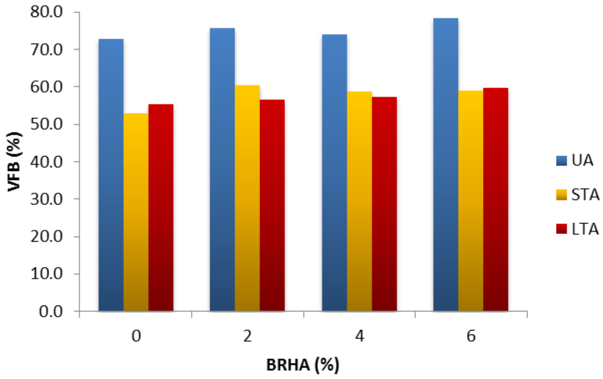

Figure 3. Voids filled bitumen of asphaltic concrete with BRHA under aging

3.3. Stiffness

Figure 4 illustrated the stiffness of asphalt mix with BRHA and subjected to different aging condition. The results reveal that modified mixtures have lower values of stiffness than the unmodified mixture. The stiffness is influenced by the stability and flow of the mixture; therefore higher flow values have affected the stiffness of the modified mixtures. For instance, when 2% BRHA was added to the mixture, the stiffness value was decreased by 8.8%. The values were continuously decreased by 11.8% and 7.5% when 4% and 6% BRHA was added to the mixture. After short-term aging condition, the stiffness increased simultaneously with the increasing of BRHA content. This indicates that BRHA potentially leads to the high strength of the pavement. The stiffness was increased by 60.3% when the BRHA content increases from 0% to 2%. The value then was increased by 40.2% as the BRHA increases up to 4%. Otherwise, the stiffness was increased only by 13.6% when the BRHA increases to 6%. Furthermore, the stiffness of specimens after long-term aging has increased as percentage of BRHA was increased accordingly. The stiffness values increased to 2.5 kN/mm and 3.5 kN/mm, when 2% and 4% BRHA was added to the mixture respectively. However, when the percentage of the BRHA was increased from 4% to 6%, a significant drop in the stiffness value was observed. This gives indication that the optimum additional percentage of BRHA was in the range of 4-6%.

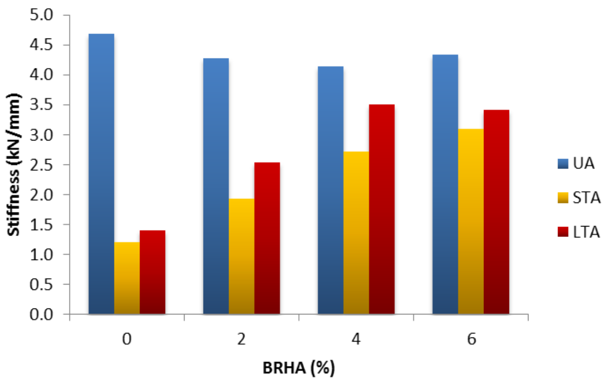

Figure 4. Stiffness of asphaltic concrete with BRHA under aging

3.4. Dynamic Creep

Figure 5. demonstrated the creep modulus of asphalt mix with BRHA after different aging condition. The results signify that BRHA have a positive effect on mixtures, resulted in higher values of creep modulus. This revealed that modified mixtures have an improved performance against permanent deformation. For example, when 2% BRHA was added to the mixture, the creep modulus value was increased to 15.1 MPa. The values were continuously increased up to 22.3 MPa and 27.2 MPa when 4% and 6% BRHA was added to the mixture. The creep modulus value for 6% BRHA was the highest, 13.9 MPa higher than the value for 0% BRHA. The creep modulus increased simultaneously with the increasing of BRHA content after aging condition. This demonstrated the ability of the modified mixtures to reduce rutting and permanent deformation potential [21]. Based on aging conditions (Fig. 5), the creep modulus has increased as percentage of BRHA was increased accordingly. The creep modulus values increased to 19.48 MPa and 34.42 MPa, when 2% and 4% BRHA was added to the mixture respectively. However, when the percentage of the BRHA was increased from 4% to 6%, a significant drop in the creep modulus value was observed. This gives evidence that the optimum additional percentage of BRHA was in the range of 4% to 6%.

4. Conclusions

The properties of the asphalt mixtures are remarkably influenced by the percentage of the BRHA as its producing mixtures that relatively denser than the unmodified mixtures. The result also found that asphaltic concrete containing BRHA have exhibited better performance when compared to the conventional specimen. In addition, long term aging mixtures predominantly gained better performance instead of the short term aging mixtures, occurs due to the oxidation reaction faced by the mixtures during the aging process. Finally, the optimum additional percentage of BRHA in asphalt mixture was in the range of 4% to 6%.

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