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Abstract. The scarcities of natural resources and increment in the waste production rates have promoted efforts to investigate the potential incorporation of various by-products in roads construction and maintenance. Various types of waste materials have been investigated, assessed and evaluated for utilization and practiced in the industry. Reusing of waste materials such as black rice husk ash (BRHA) in asphaltic concrete (AC) was considered as one of the proper management of the waste, which ensure economic and environmental benefits. This study was investigated BRHA effects on the properties and performance of asphalt mixture under different aging condition. The BRHA was added in the AC14 mixture in a proportion of 0%, 2%, 4% and 6% by weight of bitumen. The optimum bitumen content was 5% and the bitumen used was 60/70 penetration grades. The asphalt mixture 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 performance of the asphalt mixtures was evaluated by Marshall Stability and resilient modulus. The results indicate that asphalt mixtures consisting of BRHA have exhibited better performance in term of stability and resilient modulus when compared to the conventional asphalt mixtures. The short term and long term aging mixtures considerably produced higher performance than the un-aging mixtures. However, the LTA performed better than of the STA mixtures. Finally, the optimum additional percentage of BRHA was in the range of 4 – 6% since its produce excellent values in most circumstances.

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 utilization and practiced in the industry. 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) [4,5,6,7,8].

Reusing of waste materials in asphaltic concrete (AC) was considered as one of the proper management of the waste, which ensure economic and environmental benefits. Rice husk is an agriculture residue obtained from rice milling industries. Burning of rice husk becomes the favourable way to dispose it. The burning of rice husk in the air consequently leads to the formation of RHA, varying in colour from grey to black depending on inorganic impurities and unburned carbon amounts [9,10]. The use of RHA as a supplementary cementitious material in concrete production has been researched for several decades. However, the application of RHA in asphalt mixture is still at an early stage. Most of the studies have been carried out regarding replacement of RHA as filler in the asphalt mixture. The results from the previous studies showed that RHA can be incorporated instead of conventional mineral filler in the asphalt mixture [2,3]. The RHA produces mixtures that more durable in term of moisture damage and long term aging without considerable drop in its performance. But, there is relatively limited information regarding the effects of RHA on the asphalt mixture under different aging condition. Thus, this study was designed to assess the performance of different percentages black rice husk ash (BRHA) on the properties of asphalt mixture and subsequently evaluate the performance of the aging mixture.

2. Material and methods

2.1 Aggregates and bitumen

The granite aggregates were used in the study. The gradation of the aggregates was determined based on the gradation limits specified by Malaysian Public Works Department [11]. The median gradation was chosen, as shown in Figure 1. On the other hand, the bitumen of penetration grade 60/70 was used as a bituminous binder throughout the study, in accordance with specification of the Malaysian Public Work Department [11].

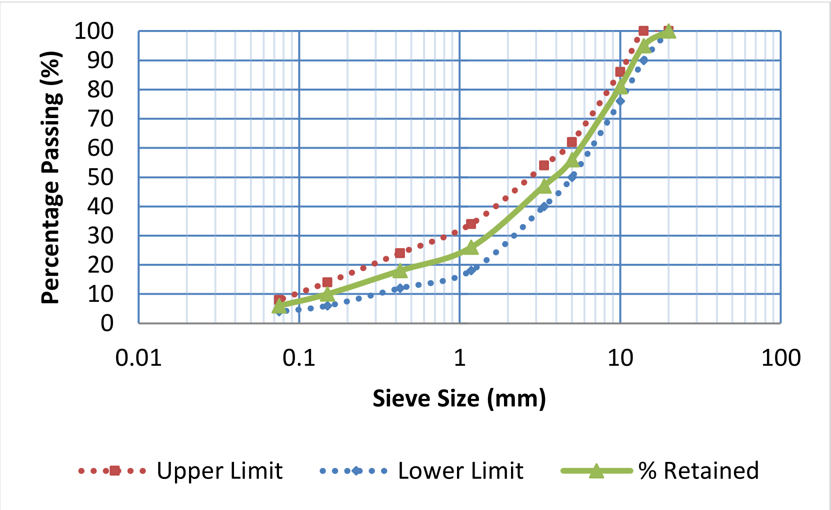

Figure 1. The aggregates gradation.

2.2 BRHA

The BRHA used in the study was ground using a grinding ball mill for 2 hours to form a fine powder. The BRHA then was sieved on the No. 200 sieve. The BRHA measured less than 75 µm later was selected to be mixed with the bitumen.

2.3 Mixture preparation

The asphalt mixtures were prepared based on the mix designated for AC14 with 5% optimum bitumen content. Four different series of mixtures were produced using 0%, 2%, 4% and 6% of BRHA. Six specimens were prepared for each series of mixtures in three different aging conditions. The bitumen was first heated until it became a melted fluid at a temperature range between 135 – 165 ºC. Then, the BRHA was added to replace 2%, 4% and 6% of the weight of 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 between 165 – 185 ºC. 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 [12].

2.4 Aging
Three types of conditioning were used, namely un-aging (UA), short-term aging (STA) and long-term aging (LTA). The unaging represents mixture that was used as a control sample. The short-term and long-term aging conditions otherwise were used to simulate the aging that occurred to the asphalt mixture during the pre-compaction phase and over the service life of a pavement respectively. The aging procedures were performed according to AASHTO R 30 [13].

2.5 Marshall stability test
The Marshall Stability test was used to measure the resistance of the asphalt mixture to plastic flow under a constant loading rate. The test was conducted based on ASTM D6927 [14]. In preparation for the test, specimens were immersed in a water bath at a temperature of 60 °C for 40 minutes. The specimens then were removed from the water bath and placed into the loading apparatus. The specimens later were loaded with a constant rate of movement of 50.8 mm/min until the maximum load was reached. The peak resistance load obtained was recorded as Marshall Stability.

2.6 Resilient modulus test
The resilient modulus test was used to determine resilient modulus values using the repeated load indirect tension test. The test was conducted based on ASTM D7369 [15]. Precedents to the test, specimens were placed in a controlled-temperature cabinet for 3 hours. Two different test temperature were used i.e. 25°C and 40 °C. After being conditioned to the test temperature, the specimens were placed into the loading apparatus, and loaded with repeated load of fixed magnitude (1000 N) and cycle duration (1 sec). The resilient modulus values obtained for 5 cycles then were recorded. The procedures afterwards were repeated on the same specimens at an angle approximately 90° from the first position. Thus, two resilient modulus values were obtained for each specimen.

3. Results and discussion

3.1 Stability
The stability of the asphalt mixtures consisting of BRHA at various aging conditions are illustrated in Figure 2. Three specimens from each percentage of BRHA were tested and the average stability was reported. The results show that BRHA produces different performances in the stability of the un-aging mixtures owing to the varying percentages of addition. For instance, the stability was increased to 14.4kN when 2% BRHA was added to the mixture. The value was 5.1% higher than the value observed for 0% BRHA. Concurrently, the stability of the un-aging mixtures was increased by 5.2% and 14.5% when the percentage of the BRHA expands from 0% to 4% and 6%. The addition of BRHA has increased the stability of the mixtures as modified bitumen became more viscous and harder than unmodified bitumen which improved the performance of the mixtures [16].

3.2 Short term aging
The stability of the short-term aging mixtures was noticeably lower than the control mixtures. But, the stability of the short-term mixtures has increased substantially with the increment of the BRHA up to 4% and then decreased with further additions. This indicates that short-term aging mixtures modified with BRHA relatively have stronger performance in resistance to plastic flow when compared to the unmodified mixtures. The stability for 4% BRHA was the highest, 60.5% higher than the stability of

0% BRHA. However, there was a significant drop in the stability value when the percentage of BRHA was continuously increased from 4% to 6%.

3.3 Long term aging
The stability of the long-term aging mixtures was considerably lower than the control mixtures, but somewhat higher than the short-term aging mixtures. This probably occurs due to the oxidation reaction faced by the mixtures during the long-term aging process. The results prescribe that the stability of the long-term aging mixtures increased with the increment of the BRHA content accordingly, but decreased as the percentage of the BRHA reached 6%. Further increasing in the percentage of the BRHA adversely affects the performance of the mixtures related to stability. The optimum additional percentage of the BRHA was 4%, beyond which the stability of the mixture increased to 11.9 kN.

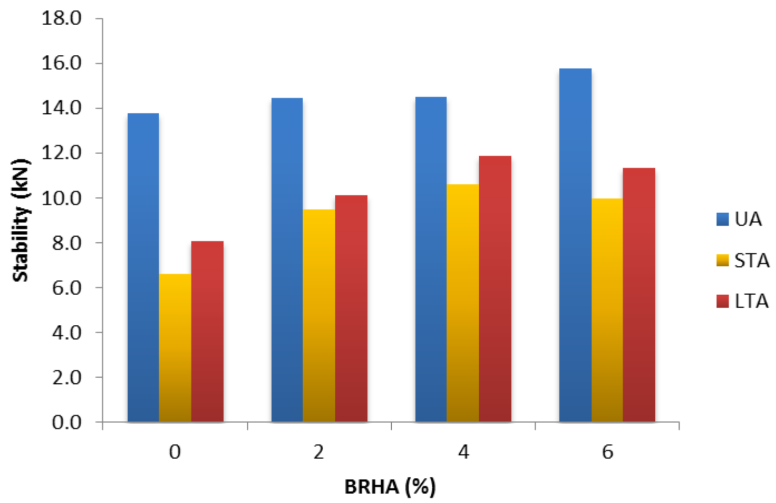

Figure 2. Stability of asphalt mixtures at different aging conditions.

3.4 Resilient modulus
The resilient modulus of the un-aging, short-term and long-term aging asphalt mixtures at 25 ºC and 40 ºC are presented in Figure 3 and Figure 4 respectively. The values represent the average reading of three samples. The results specify that the resilient modulus of the un-aging mixtures increased when the BRHA content was increased. The finding suggested that BRHA modified mixtures were more durable than unmodified mixtures in accordance to stiffness. The resilient modulus at 25 ºC was increased from 2648 MPa to 3856 MPa as the BRHA content increases from 0% to 2%. However, the resilient modulus decreased to 3511 MPa when tested at 4% BRHA. On the other hand, at 6% BRHA, the resilient modulus increases to 4017 MPa. The results also show increasing the test temperature from 25 ºC to 40 ºC inevitably decrease the resilient modulus of the un-aging mixtures up to 82.4%.

3.5 Short term aging
The resilient modulus for short-term aging mixtures was relatively higher if compared to the control mixtures. The results disclose that increment of BRHA content at 2% interval cause general increase in the resilient modulus. A resilient modulus of 3532 – 4558 MPa was achieved when the BRHA content was increased from 0% to 6%. Meanwhile, the same inclination was identified for mixtures tested at 40 ºC. A value of 848 – 1028 MPa was recorded as the BRHA content expands from 0% to 6%. The values obtained at 6% BRHA were the highest resilient modulus for both test temperatures.

3.6 Long term aging
The resilient modulus for long-term aging mixtures was obviously higher than those control and short-term aging mixtures. The mixtures with higher resilient modulus indicate less flexibility under loading [17]. The resilient modulus was dramatically increased to 6420 MPa when the percentage of the BRHA increases up to 2%. However, when the BRHA content was increased from 2% to 4%, a significant drop was observed in the resilient modulus value. The resilient modulus of the mixtures decreased by approximately 68.8% to 82.0%, when the test temperature increasing from 25 ºC to 40 ºC.

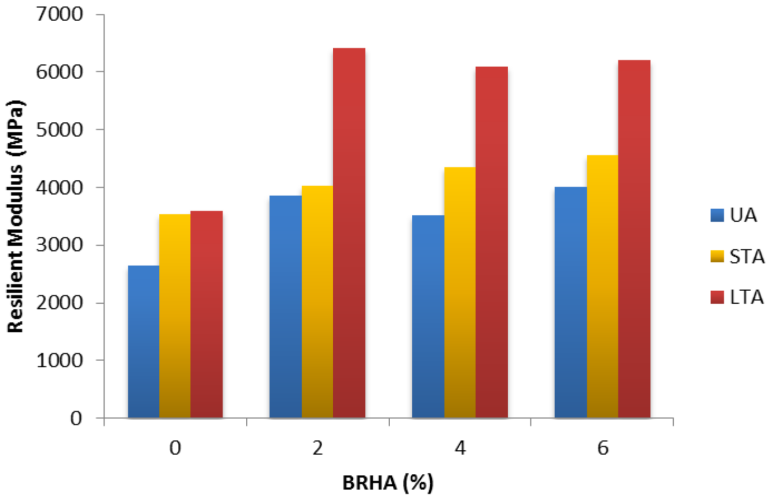

Figure 3. Resilient modulus of asphalt mixtures at 25 ºC.

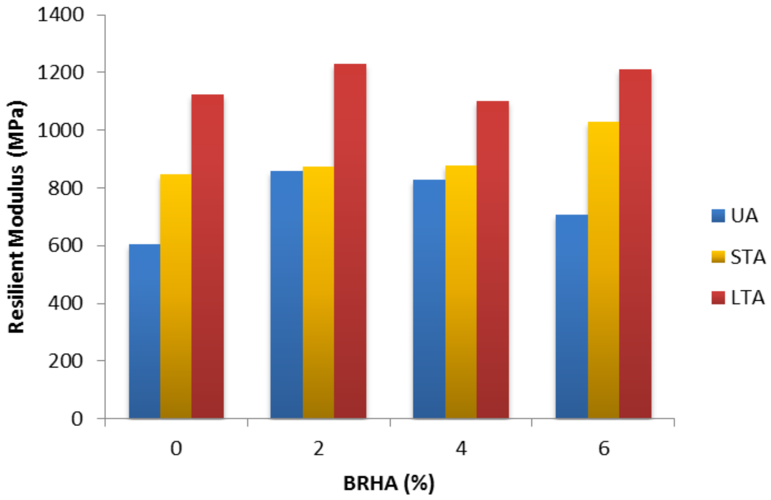

Figure 4. Resilient modulus of asphalt mixtures at 40 ºC.

4. Conclusions
The results indicate that asphalt mixtures consisting of BRHA have exhibited better performance in term of stability and resilient modulus if compared to the conventional asphalt mixtures. The BRHA remarkably influence the asphalt mixtures properties and performance under different aging conditions. The short-term and long-term aging mixtures considerably produced higher resilient

modulus than the un-aging mixtures. However, the long-term aging mixtures predominantly gained better performance instead of the short-term aging mixtures. It can be concluded that the optimum additional percentage of BRHA was in the range of 4 – 6% since its produce higher values in most circumstances.

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