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Creep and resilient modulus properties of asphaltic concrete containing black rice husk ash

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Abstract. Black rice husk ash (BRHA) is one of the agro-waste that could be used to improve the properties of asphalt mixture. In this investigation, the BRHA was grounded using a laboratory ball mill with porcelain balls to fine particles size less than 76 μm . Four different BRHA contents were considered in this study namely 0%, 2%, 4% and 6% by weight of binder. The performance of asphaltic concrete containing BRHA was evaluated through resilient modulus and dynamic creep test. It was found that the BRHA can be satisfactorily used as a filler material in order to increase the properties of creep and stiffness modulus asphaltic concrete. Test results also indicate that asphaltic concrete containing 2% to 4% BRHA showed excellent performance to resilient modulus and dynamic creep properties.

1. Introduction

Over the years, there has been an increase in the use of industrial, agricultural, and thermoelectric plant residues in the production of road construction. Different materials with dissimilar pozzolanic properties such as fly ash [1], palm oil fuel Ash [2], blast-furnace slag [3], rice husk ash [4], and etc., have played an important part in pavement production. Common pozzolanic agents from the industry and agricultural by-products are becoming active areas of research because their use leads to diverse product quality, reduced cost, and decreased negative environmental effects [5-8]. The current use of rice husk ash (RHA) as a modifier in bitumen has drawn considerable attention among researchers [9-10]. However, the use of BRHA as a modifier in asphalt mixture is uncommon in Malaysia. BRHA is an agro-waste that can be used on bitumen [11]. BRHA defined as RHA that contained high amount of carbon after burning process [12]. In view of all the above mentioned phenomena, it is clear that the agricultural by-products namely BRHA as modifier in binder was suitable use in road construction. Thus, this is the focus of the current research.



2. Materials and preparation

2.1 Bitumen and Aggregate

Bitumen with penetration grade 60/70 was selected as the binder for the asphalt mixture. According to Romastarika et al. (2017), the physical properties of bitumen are 69 dmm (penetration at 25°C) and 52°C (softening point (SP)) [11]. Furthermore, aggregates that were used in this study are AC14 which means that the nominal maximum aggregate size in the asphalt mixture is 14 mm (Figure 1).

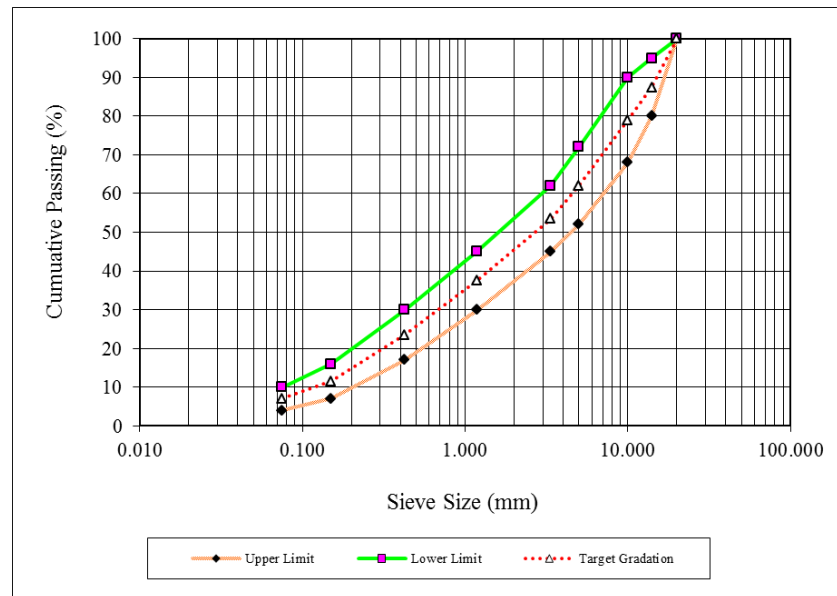


Figure 1. Aggregate gradation of asphaltic concrete AC14 [13].

2.2 Black rice husk ash

At the laboratory, BRHA was fully dried. BRHA waste was ground using a grinding ball mill for 120 min to form fine powder. Subsequently, BRHA was sieved to form a size less than 75 μm .

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 °C. 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 °C. 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 [14].

2.4 Aging test

Three types of conditioning were used, namely un-aging (UA), short-term aging (STA) and long-term aging (LTA). The unaging represent that the mixture was used as controlled specimen. 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 [15].

2.5 Dynamic creep test

The dynamic creep test was developed to estimate the rutting potential of asphalt mixes. This test was conducted using the Asphalt Universal Testing Machine, UMATTA in accordance with the procedures outlined in BS EN 12697-25:2016 [16]. Actual dynamic creep test was conducted at 40 °C and 60 °C, 1 hour loading time and 0.1MPa applied stress.

2.6 Resilient modulus test

The resilient modulus test can be used to assess pavement mix response to traffic loading. The test was conducted by measuring the indirect tensile strength in repeated loading or pulse using Universal Material Testing Apparatus (UMATTA). Each specimen was tested at 25 °C and 40 °C after 4 hours conditioning, while the test procedures conformed to those stipulated in ASTM D7369:2011 [17]. Initially, the samples were subjected to 5 condition pulses; beyond which a 1200N peak load was applied along the vertical diameter of the sample [17]. The pulse period and pulse width applied for this test were 3000ms and 100ms respectively with 50 ms rise time.

3. Results and discussion

3.1 Dynamic creep

A comparison of the results as presented in Figure 2 shows that in general, the addition of BRHA in asphaltic concrete caused an increase in the creep modulus up to a peak level and then decreases with further additions. Increasing in creep modulus can be explained by improving of bitumen structure, using carbon from BRHA. Hence, binder can be more efficiently transferred from the bulk to the pellicle condition [18]. Fig. 2 demonstrated that the 2% BRHA in asphalt mix exhibited the highest creep modulus compared to 0%, 4%, and 6% BRHA. At 6% BRHA, the creep modulus decreases to a value lower than that of controlled specimen. Thus, 2% adding of BRHA into bitumen is considered as the optimal limit. Finally, it can be said that the use of 2% BRHA was more effective in enhancing dynamic creep of asphaltic concrete.

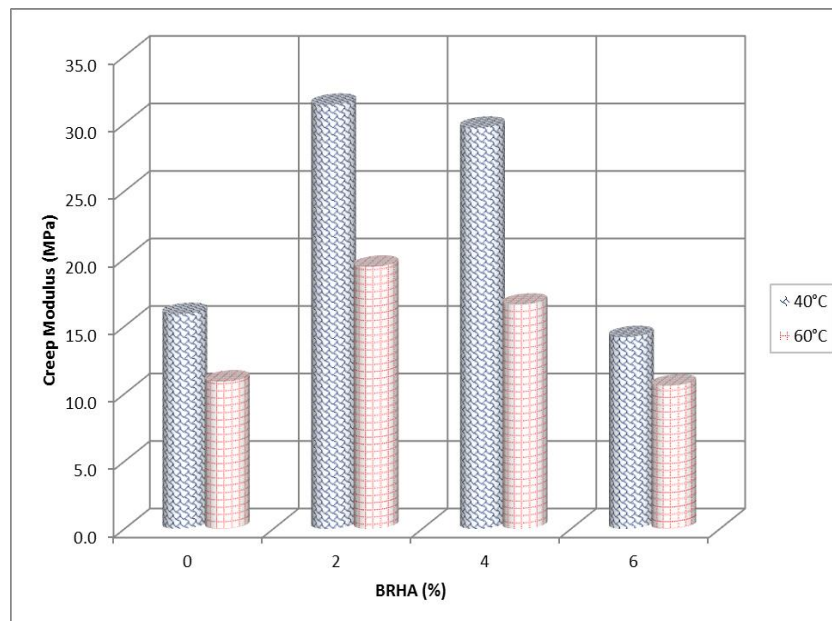


Figure 2. Creep modulus of BRHA in asphaltic concrete.

3.2 Cumulative strain and load cycle

In order to analyze the relationship between cumulative strain and load cycle, a logarithmic strain versus logarithmic load cycle measured by dynamic creep test was calculated. The results are illustrated in Figure 3. Clearly, the curves exhibited a two-stage development, namely, primary stage and secondary stage. Primary stage presents recoverable elastic strain due to densification of the mixture while secondary stage shows viscoelastic strain resulted by cumulative axial strain [19]. The tabulation of the coefficient is listed in Table 1. It is apparent that specimens prepared with 2% and 4% BRHA show a lower cumulative permanent strain compared to control specimen as seen in Table 1. However, at 6% BRHA, the cumulative strain has increased significantly. Higher accumulated axial strains values indicate that mixes have lower rutting resistance potential. On the other hand, when the temperature increases from 40°C to 60°C, the strain value rises about 0.3% to 0.8%. It implies that incorporating BRHA in bitumen provides significant impact on susceptibility of mixtures to permanent deformation.

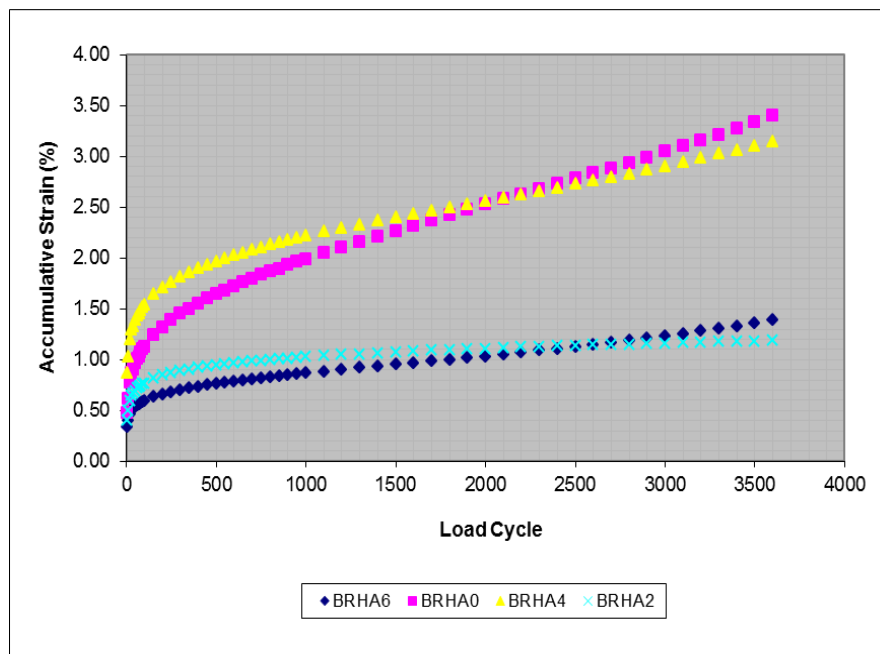


Figure 3. Relationship between cumulative strain and load cycle.

Table 1. Cumulative permanent strain versus load cycle tested at 40 °C and 60 °C.

BRHA (%)	40°C		60°C	
	Creep Modulus (MPa)	Cumulative Strain (%)	Creep Modulus (MPa)	Cumulative Strain (%)
0	15.9	1.625	10.9	1.943
2	31.4	1.123	19.4	1.870
4	29.7	1.456	16.6	1.745
6	14.2	2.109	10.6	2.122

3.3 Loss of weight

The weight loss of the specimens was calculated using Equation (1) as follows:

$$\text{Weight loss (WL) (\%)} = \frac{WL_{dw} - WL_{ch}}{WL_{dw}} \times 100\% \quad (1)$$

Where WL_{dw} is the average initial weight of three specimens before test and WL_{ch} is the average weight of three specimens after test.

The weight loss of BRHA asphalt mixture initially decreased due to an increase in BRHA content as presented in Figure 4. The weight loss of specimens at 0% BRHA is about 0.55%. However, increasing BRHA content, the value of weight loss for BRHA2, BRHA4, and RHA6 asphalt mixture was about 0.15%, 0.33%, and 0.3%, respectively.

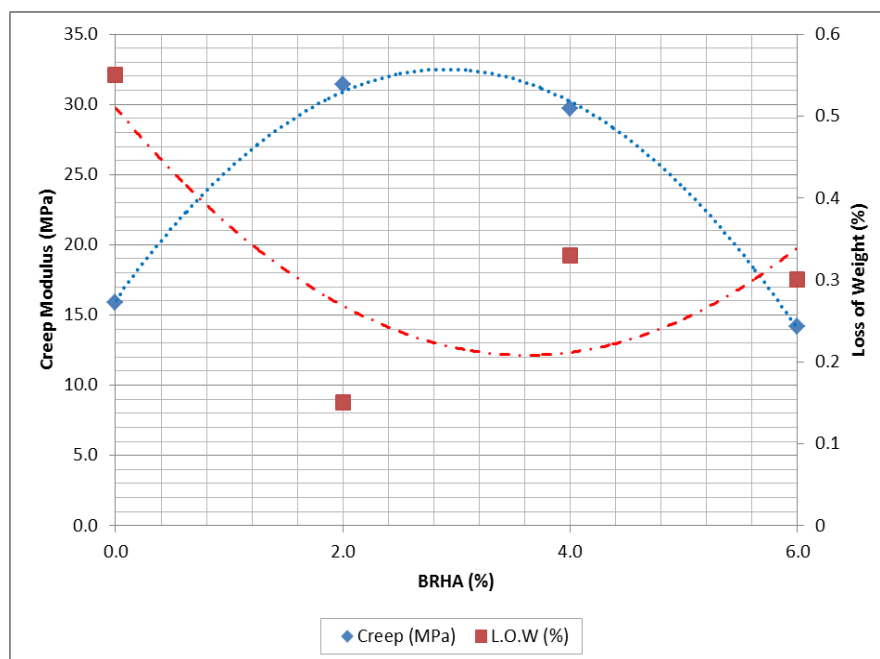


Figure 4. Weight loss of BRHA.

3.4 Resilient modulus

The results of the resilient modulus test at 25 °C and 40 °C are presented in Figure 5. The resilient modulus at 25 °C resulted in better performance than with that at 40 °C. The high resilient modulus indicated stiff mixes are owing to the strong chemical bonding [20]. The 2% BRHA mixture achieved a high resilient modulus value, whereas the 0% BRHA mixture recorded the lowest resilient modulus at both temperatures. For example, the resilient modulus for 4% BRHA at 25 °C was 6612 MPa. However, the modulus of resilient was decreased about 1412 MPa when test temperature increase from 25 °C and 40 °C. This result shows that asphaltic concrete is sensitive towards temperature change in term of resilient modulus. In this study, the higher resilient modulus of asphaltic concrete containing 2% BRHA at 25 °C indicates that these mixes exhibit a higher probability of cracking at 25 °C than at 40 °C. Previously, Ramadhansyah et al. (2016) reported that higher resilient modulus indicates less flexibility under loading [5].

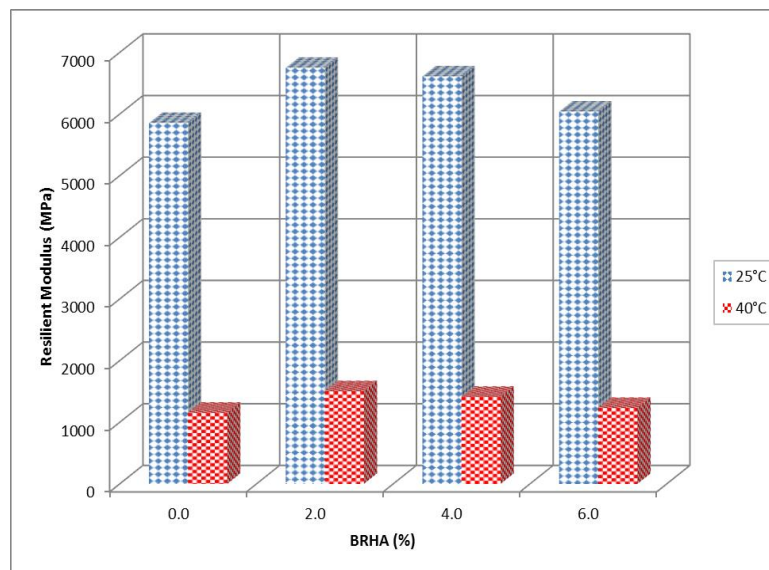


Figure 5. Resilient modulus of BRHA in asphaltic concrete.

4. Conclusion

It was found that the BRHA can be satisfactorily used as a filler material in order to increase the properties of creep and stiffness modulus asphaltic concrete. Test results also indicate that asphaltic concrete containing 2% to 4% BRHA showed excellent performance to resilient modulus and dynamic creep properties with the loss of weight was found to be 0.15% to 0.55%.

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