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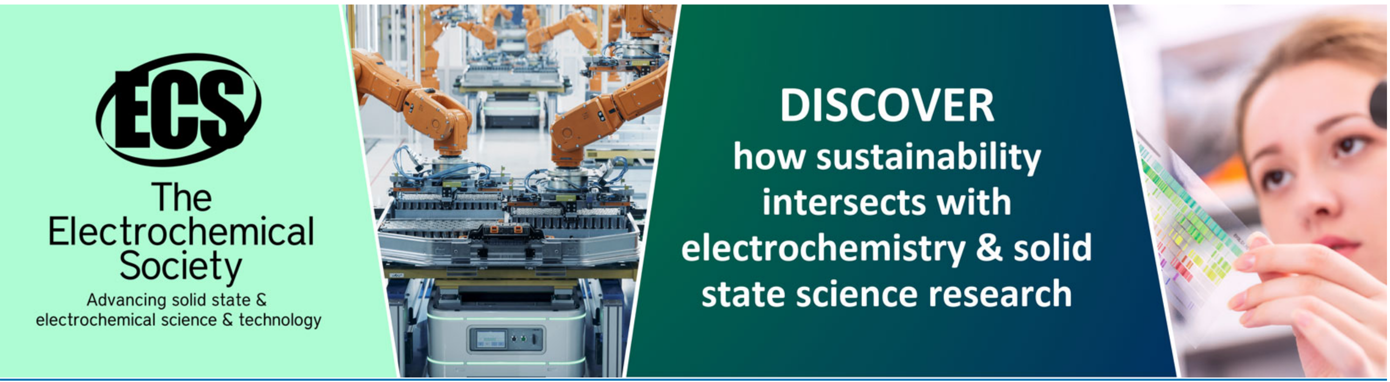

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Stability and rutting resistance of porous asphalt mixture incorporating coconut shells and fibres

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Abstract. The influence of coconut shells (CS) and coconut fibres (CF) on the stability and rutting resistance of porous asphalt mixture is examined. Four different percentage replacement of CS and three different of CF as additives were investigate. CS and CF were put through chemical treatment by soaking them in 5wt% of Sodium Hydroxide (NaOH) solution before being involved in the mixture. Marshall Stability and asphalt pavement analyzer are performed to evaluate the Stability and rutting resistance of porous asphalt mixture. It was found that there appears to be an optimum CS replacement level of 10% and 0.3% CS during which the stability and rutting resistance increase significantly.

1. Introduction

Porous asphalt is usually made with little or no fine aggregate which can create stable air pockets in the asphalt mix to allow water to flow through the pavements which produces void contents of 20% or greater when compacted [1]. Porous asphalt is a fundamental structure used to manage urban runoff quality and quantity. It promotes the infiltration of rainfall and urban runoff, either to the underlying soil or a storage reservoir [2]. Waste materials such as iron, fly ash, oil palm shells and coconut shells have been confirmed by many studies to be able to advance the pavement construction [3-6]. Also, coconut shells are among the most important lignocellulosic materials that are farmed in tropical countries like Malaysia, Sri Lanka, Indonesia and Thailand [7]. Thereby, CS has to be utilized more to downsize the abundance of this industrial waste. Dried CS contains 33 % cellulose, 36.51% lignin, 29.27% pentosans and 0.61% ash [8]. CS has low ash content but is high in volatile matter, between 65-75% [9]. The water absorption of the CS is higher than that of conventional aggregates, which is 24% compared to 0.5% [10]. CS is also more resistant against impact, crushing and abrasion compared to other conventional crushed granite aggregates [8]. It can be mixed with the asphalt mixture directly for the experiment except for the water absorption test [5,9]. Based on the available current literature, it can be seen that the use waste materials such as iron, fly ash, oil palm shells and coconut shells, etc. as partial replacement of aggregates or modified binder is an advantageous technique to improve the performance of road construction. However, very limited information is available on the porous asphalt mixture properties containing coconut shells and fibres. Hence, to explore the advantages of using coconut shells and coconut fibres in the asphalt porous mixture, this research was conducted.

2. Materials and method

2.1. Raw materials
The bitumen PG 76 from Chevron, Malaysia was used. The specific gravity of PG 76 is 1.03 with penetration at 25 °C was 55 dmm and 78°C of softening point. Besides, the crushed granite aggregates was used through this study. Previously, Ting et al. [10] reported that to produce better durability for porous asphalt mix, the aggregate used must be strong, durable, clean, cubical and possess an affinity for bitumen. Based on the laboratory testing, the properties of aggregates that were used in this research are 17% aggregate crushing value, 19% flakiness index, 23% elongation index, 50.8% polished stone value and 0.51 soundness. Furthermore, the coconut shells and coconut fibres used in this investigation was obtained from the local market. Since coconut shells were used as substitutes for the aggregates, the coconut shells were dried for a week and cleaned before being crushed and sieved to get the distribution size. The coconut shell indicated a specific gravity of 1.45 g/cm^3, as well as water absorption rate of 17.5%. On the other hand, the aggregate impact value of coconut shell used is 4.26% where the Los Angeles abrasion value approximately 14.88%.

2.2. Treatment procedure
Since coconut shells and fibres have high absorption abilities, the Sodium Hydroxide (NaOH) was used to soak the coconut shells and coconut fibres. The coconut shells and fibres were soaked in 5wt% of sodium hydroxide (NaOH) for 1 hour. The samples were then washed with distilled water until there was no NaOH on the surface of samples.

2.3. Aggregates gradation
Figure 1 show the gradation of aggregates used in this investigation. The gradation follows the JKR standards for Malaysian porous asphalt mixture proportions [11]. Aggregate size of 5 mm was replaced by coconut shells at percentages of 0%, 5%, 10% and 15% by weight. Besides that, coconut fibres were added into porous asphalt mix at amounts of 0.3% and 0.5%, accordingly.

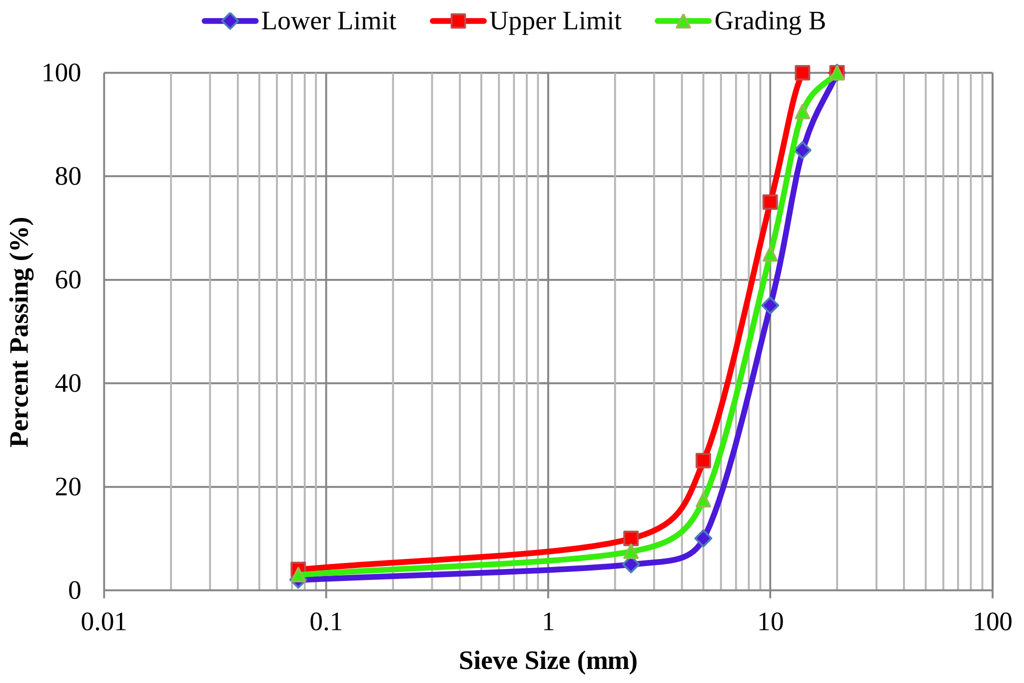

Figure 1. Gradation Limit [11]

2.4. Mix Design and sample preparations

The procedure for the Marshall Mix design was performed according to ASTM D6927 [12]. The basic procedures involve the preparation of materials including aggregate and binder, the preparation of mould, and finally, the mixing and compaction of the porous asphalt mixture. According to JKR [11] specification, an 1100 g of aggregate was weighed. Then, aggregate was heated in the oven to a desired mixing temperature prior to being used for creating the porous asphalt sample. After being heated, the mixing and compaction temperatures were established. The compaction method was carried out in 50 blows.

2.5. Marshall stability test

The Marshall Test was used to measure the stability of porous asphalt mix based on ASTM D 6927 [12]. Cylindrical compacted specimens of approximately 100 mm in diameter and 70 mm in height were used for the test. Three samples were prepared for each component and they were immersed into a water bath of 60°C for 30 to 40 minutes. The specimen was then put on the cleaned Marshall Stability testing machine and the load was applied at a constant rate of 50 mm/min until failure. The flow and stability were observed while reading and the Marshall Stability value (in kN) was recorded as the values maximized before they began to drop.

2.6. Rutting Resistance test

AASTHO TP63 [13] was used at reference to determine the rutting susceptibility of asphalt paving mixtures using the Asphalt Pavement Analyzer (APA). The sample underwent 8000 load cycles and gauge readings were taken initially and after the load cycles. The difference between two readings is the rutting depth. The samples were required to be preheated in the oven for 6 hours and then stabilized in the test chamber at the desired temperatures. The hose pressure was set at 120 psi and 534 N for the load. The samples were applied to 25 cycles to seat the samples and the gauge was set to zero to take initial rut depth readings. The APA was counted to 8000 cycles and the test was started when the test temperature stabilized. The final rut depth measurement was obtained by zeroing the gauge and the reading was taken.

3. Results and discussion

3.1. Effect of coconut shells on stability

Figure 2 show that the Marshall stability of all samples has passed the minimum requirement. Previously, Hamzah et al. [14] and Norhafizah et al. [15] reported that the minimum requirement of stability in porous asphalt is 5 kN. Based on Figure 2, the Marshall stability increased as the percentage of coconut shell replacements increased. However, the 15% of coconut shell replacement sample shows reduced stability at about 2.4% when compared to 10% of coconut shell replacement samples. On the other hand, the Marshall stability is lower when comparing untreated coconut shell samples with treated coconut shell samples. This shows that coconut shells can strengthen the samples after being treated with Sodium Hydroxide (NaOH). Besides that, the results show that a certain amount of coconut shells can improve the interlocking between aggregate particles and hence obtain better Marshall Stability. But, the excessive amount of coconut shells (15%) reduces the interlocking between aggregates and coconut shells. This is due to the shape of coconut shells which reduces the Marshall stability.

3.2. Effect of coconut fibres on stability

Figure 2 demonstrates that coconut fibres can help in improving Marshall Stability but excess coconut fibre (0.5%) will lower the Marshall Stability. A sample with 0.5% of coconut fibre added has gained a higher Marshall Stability than samples without coconut fibres added. The highest Marshall Stability obtained in this study is the sample with 10% of coconut shell replacement and 0.3% of coconut fibre additives. A certain amount of coconut fibre can prevent bleeding and reduce clogging in the mixtures. However, excessive coconut fibre (0.5%) has reduced the flow of asphalt. This may lead to aggregates being incompletely coated by asphalt, resulting in reduced interlocking between aggregates.

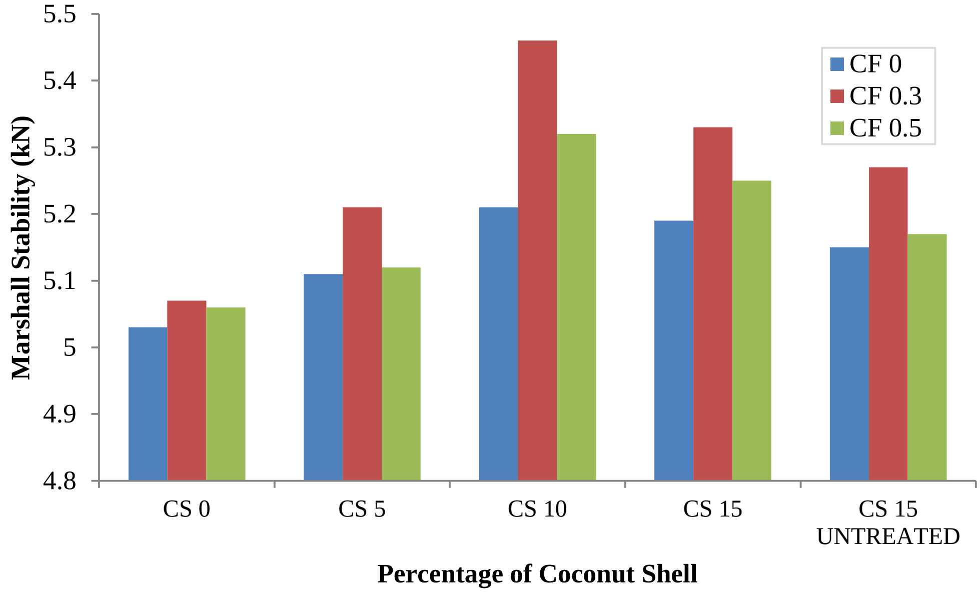

Figure 2. Stability of porous asphalt mixture containing CS and CF

3.3. Rutting resistance

Rutting is referred to as the permanent deformation of the asphalt surface that forms by repeated traffic loading cycles. The roadway surface needs to be supported to resist the load from traffic while the design of asphalt mix has to resist deformation. Three types of samples underwent the APA test and three samples were prepared for each proportion. Table 1 shown that the sample with 10% of CS replacement and 0.3% of CF added has the best result for rutting resistance since the rut depth of this sample is lowest when compared to others. However, replacements containing 15% of CS and 0.5% of CF added has the lowest rut depth as increased CS in the samples have reduced the interconnection between aggregates hence the rutting resistance decreased. Besides that, the result has shown that CF as additive has improve the rutting resistance of sample as the result show that sample with CF has lower rut depth. In addition, excessive amount of CF will lower the rutting resistance ability since it can reduce the interconnection between aggregates. From the result, it can conclude that rutting sensitively along pavement depth depended on pavement structure and mixture content used in asphalt mixture.

Table 1. Rut resistance of porous asphalt mix

Description	Rut Depth at 8000 cycles (mm)
Control	4.07
10% of CS replacement and no CF added	4.53
10% of CS replacement and 0.3% of CF added	3.57
15% of CS replacement and 0.5% of CF added	4.02

4. Conclusions

a) The use of 10% coconut shells in porous asphalt mixture resulted in good stability development in comparison with the other CSs replacement content.
b) Addition of 0.3% coconut fibres in porous asphalt mixed has high potential to develop superior stability.
c) There appears to be an optimum coconut shells and coconut fibres of approximately 10% and 0.3%, for which stability and rutting resistance increased significantly.

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