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Permeability coefficient of porous asphalt mixture containing coconut shells and fibres

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Abstract. The abundance of coconut shells (CS) have been involved in environmental issues. Yet new sources of aggregates should be found from environmental waste. CS and coconut fibres (CF) have been chosen from environmental waste to use in this study. Generally, this research concerns the partial replacement of coconut shells in coarse aggregates and coconut fibres as additives in porous asphalt mixture. CS and CF were put through chemical treatment by soaking in 5wt% of Sodium Hydroxide (NaOH) solution before being involved in the mixture. CS has been used to substitute 5mm of coarse aggregate with 0%, 5%, 10% and 15% while CF were added into porous asphalt mixtures with 0%, 0.3% and 0.5%. Permeability and air voids test were carried out to analyse the durability characteristics of porous asphalt mix. The results show that coconut shells and fibres can reduce the drainage time since coconut fibres in the samples could reduce clogging by binders. On the other hand, 15% of treated CS has a lower air void than untreated CS.

1. Introduction

Porous asphalt, also known as open graded courses, was introduced in Malaysia in 1991 [1]. It drains water easier than conventional asphalt, reduces hydroplaning potential and has better skid resistance properties under high speed usage [2]. It is also known as “Drain asphalt” in France, Popcorn Mix in the United States of America and whispering asphalt in Germany [3]. Porous asphalt can help in improving traffic safety, especially during rainy days as it has a drainage system that reduces hydroplaning potential and enhances skid resistance properties under high speeds [4]. Besides that, porous asphalt can help in resisting permanent deformation [5]. With the increasing exploitation of natural aggregates, the restrictions of natural sources are concerning and environmental wastes have been introduced to replace natural sources in order to reduce the landfill cost and protect the environment from the possible effects of pollution. Waste materials such as scrap tires [6], clinkers and coconut shells [7] can be used to replace coarse or fine aggregates in the asphalt pavement. Besides that, the cost of disposing the waste material is prohibitive and the wastes usually take up 10 to 30% of landfill sites around the world for demolition [8]. Waste materials that are used as aggregate replacements in roadways can reduce the usage of landfill sites for demolition. Not only will using waste materials reduce the landfill cost, it can also help to improve the properties of asphalt pavement

[9]. Some of this waste can be used wisely in the construction field as aggregate replacements in asphalt concrete such as oil palm shells, coconut shells and crumb rubber [10]. However, coconut shells are fresh waste materials that have not yet been applied in the highway construction field. Therefore, coconut shells were selected to be studied in this research since researchers have proven before that it can help to improve the properties of asphalt mixtures.

2. Materials and method

2.1. Bitumen properties

The bitumen PG 76 from Chevron, Malaysia was used. Table 1 shows its physical properties.

Table 1. Physical properties of PG 76

Specific gravity	1.03
Penetration at 25 °C (dmm)	55
Softening point (°C)	78

2.2. Aggregates properties

The crushed granite aggregates was used in this research. According to Ting et al. [11] the aggregate used must be strong, durable, clean, cubical and possess an affinity for bitumen to produce better durability for porous asphalt. The Table 2 shows the properties of aggregates that were used in this investigation.

Table 2. Properties of crushed aggregates

Aggregate crushing value (%)	Flakiness index (%)	Elongation index (%)	Soundness	Polished stone value (%)
17	19	23	0.51	50.8

2.3. Coconut Shells and fibers properties

The coconut shells and coconut fibres used in this study was obtained from the local market. Before mixing it with other materials, the coconut shells were dried for a week and cleaned before being crushed and sieved to get the distribution size. Since coconut shells were used as substitutes for the aggregates, it possesses significant characteristics as an aggregate. The physical properties of coconut shells are listed in Table 3.

Table 3. Physical properties of coconut shell

Aggregate impact value (%)	4.26
Los Angeles abrasion value (%)	14.88
Specific gravity	1.45
Water absorption (%)	17.3

2.4. Treatment process

Since coconut shells and fibres have high absorption abilities, the Sodium Hydroxide (NaOH) was used to soak the coconut shells and coconut fibres. In this study, 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.

2.5. Aggregates gradation

Table 4 show the gradation of aggregates used in this investigation. The gradation follows the JKR standards for Malaysian porous asphalt mixture proportions [12]. The 5 mm of aggregate was replaced by coconut shells at percentages of 0%, 5%, 10% and 15% by weight. Besides that, coconut fibres were added into samples at amounts of 0.3% and 0.5%, accordingly.

Table 4. Aggregate gradation of porous asphalt

Sieve size (mm)	% passing	Average %	Mass passing (g)	Mass retained (g)	Cumulative (g)
10.0	55-75	65.0	185.25	99.75	99.8
5.0	10-25	17.5	49.88	135.38	235.1
2.36	5-10	7.5	21.38	28.50	263.6
0.075	2-4	3.0	8.55	12.83	276.5
pan	2-4	3.0	8.55	8.55	285.0
					285.0

2.6. Porous asphalt mix design

Porous asphalt mix was prepared using the Marshall Method according to ASTM D6927 [13]. At laboratory, 1100 g of aggregate was weighed in according to JKR/SPJ/2008 specification [12]. The 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, respectively. The compaction method was carried out in 50 blows.

2.7. Permeability test

The ability of porous asphalt to drain away water from the surface of asphalt pavement is paramount. Hence, a permeability test was conducted to find out the relative permeability of porous mixtures. The test was carried out at a room temperature of 25 ºC. The samples were sealed at the sides of the specimen to achieve a satisfactory seal between the membrane and the sample. The permeability coefficient was calculating using equation (1).

$$k= [al/At] \ln [h_1/h_2] \qquad (1)$$

Where k is Coefficient of water permeability (cm/s); a is inside cross-sectional area of inlet standpipe (cm^2); l is thickness of test specimen (cm); A is cross-sectional area of test specimen (cm^2); t is average elapsed time of water flow between timing marks (s); h_1 is hydraulic head on specimen at time t_1 (cm) and h_2 is hydraulic head on specimen at time t_2 (cm).

3. Results and discussion

3.1. Effect of coconut shells on permeability

Figure 1 shows that drainage time increases yet decreases at 10% of coconut shell replacement. The drainage time of 5% of coconut shell replacement is highest and decreases at 10% and 15% of coconut shell replacement. This shows that the samples have a higher void, thus have a higher drainage time. However, samples with untreated coconut shells have the lowest drainage time with a 47.3% difference when compared to control samples and 50% when compared to 5% of coconut shell replacement samples. Besides that, the difference between 15% of coconut shell replacement treated and 15% untreated coconut shell replacement is 53.5%. This shows that the void in untreated samples is larger. Yet, the results obtained from all samples only have a slight difference.

3.2. Effect of coconut fibres on permeability

The results in Figure 1 show that an increment in coconut fibre has decreased the drainage time. This may be due to the coconut fibre reducing the flow of asphalt at high mixing temperatures and therefore, there is less clogging of the air voids by asphalt binders. However, the largest difference between CF 0 and CF 0.5 happens on untreated coconut shell samples which are at about 42%. Meanwhile, the difference between 0.3% of coconut fibre and 0.5% of coconut fibre is huge at 29.3%. This may be because having 0.5% of coconut fibre in the mixture is excessive and reduces the interconnection between the aggregates. Hence, the increased void leads to lower drainage times.

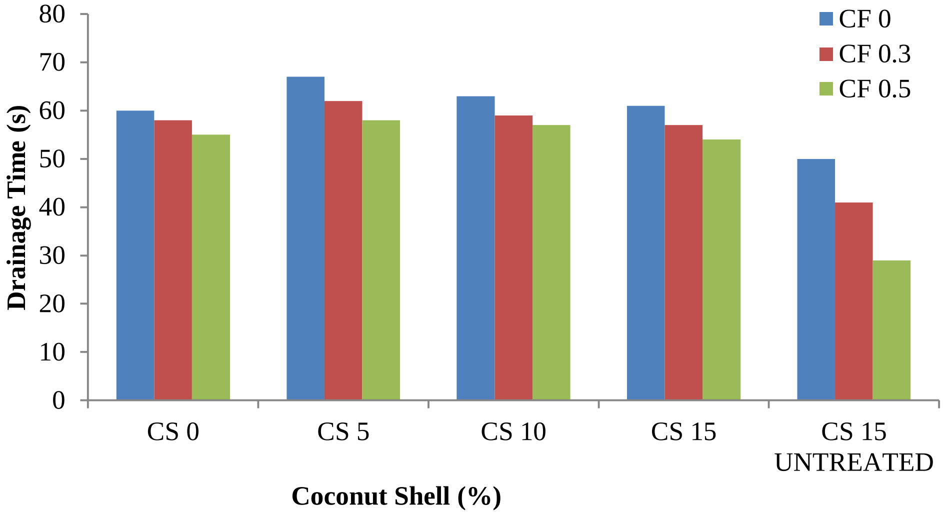

Figure 1. Water Permeability of porous asphalt mix containing CS and CF

3.3. Air Voids

An air void is the main component that determines the properties of porous asphalt. Based on the JKR specification [12], the air voids of porous asphalt should be in the range of 18 to 25 percent. The air voids of porous asphalt mix at different percentages of coconut shell are presented in Table 5. The results show that air voids of all samples variant as the coconut shell content increased. However, porous asphalt mix with 15% of untreated coconut shells had the highest air void when compared to the treated coconut shell samples and the control samples under all contents. This is because the untreated coconut shells have high absorption abilities as it absorbs bitumen content and the samples leak bitumen to fill up the void. On the other hand, the sample with 15% of treated coconut shells has a lower air void than untreated coconut shell samples. This shows that the water absorption ability of coconut shells have been reduced by sodium hydroxide. Conversely, the water absorption of coconut shells is still high when compared with the control samples since the air void content of the control sample is lower than that of the samples with 15% of treated coconut shells.

Table 5. Air void results of porous asphalt

Coconut shell (%)	Description	Voids (%)
0	Control	20.1
5	treated	22.6
10	treated	24.1
15	treated	24.6
15	untreated	30.1

4. Conclusions

In this study, permeability and air voids of porous asphalt containing CF and CS has been measured. It can be seen that porous asphalt mix without CF additives and 5% of treated CS replacements have better water permeability results. Furthermore, the air void properties investigated have successfully described that the air voids formation within the mixtures which reflects the result of permeability. This shows that air voids distribution within the sample plays an important role in determining the effectiveness of water transmission. Finally, it can be said that the air voids content influences the performance of porous asphalt mixtures.

5. References

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