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RESILIENT MODULUS OF DOUBLE LAYER POROUS ASPHALT: APPLICATION OF ALKALI TREATED COCONUT SHELL AND FIBER AS AGGREGATE REPLACEMENT

Tay Lay Ting*, Ramadhansyah Putra Jaya, Norhidayah Abdul Hassan & Haryati Yaacob

Department of Geotechnics and Transportation, Faculty of Civil Engineering,
Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

*Corresponding author: *alicetae@gmail.com*

Abstract: Coconut shell and coconut fiber are the new waste that have been concerned in the highway asphalt pavement industry lately. This paper has studied about the effect of coconut shell and coconut fiber to the resilient modulus of double layer porous asphalt (DLPA). The coconut shell has been substitute to the double layer porous asphalt by 5%, 10% and 15 % of the aggregate with 5 mm size by weight while coconut fiber was added to the asphalt incorporating 0.3% and 0.5% by weight. Before mixing with others aggregate, coconut shell and coconut fiber was treated with 5%wt NaOH to reduce it water absorption ability. The samples were prepared by using Marshall Method. The result shows that DLPA with 10% has better resilient modulus under 25ºC temperature for unaged and aged samples. However, the sample with coconut fiber has lower resilient modulus as the amount of coconut fiber has increased. In general, the substitution of 10% coconut shell provided better resilient modulus among the percentages that have been chosen.

Keywords: *Resilient modulus; coconut shell; coconut fiber; double layer porous asphalt*

1.0 Introduction

Double layer porous asphalt (DLPA), was first introduced since 1990s by the European countries (Raaberg and Bendtsen 2003). Some countries have investigated the two layer porous asphalt for further phase development such as Italy, Netherlands, Germany and Denmark. This design can combine the noise reduction properties of finer porous mix at top layer and also the drainage effect of a surface course at the bottom layer(Ripke 2004) .

In Malaysia, coconut shells (CS) are one of the important and oldest plant in agro plant industries (Sivapragasam 2008). However, CS has produced about 3.18 million tonnes annually as a solid waste that contributes to the world's pollution issues (Gunasekaran *et* *al.* 2012). According to Yerramala (2012), CS can be used as coarse aggregate in concrete while Al-Mansob (2013) has used CS as additive in asphalt pavement (Yerramala and Ramachandrudu 2012; Al-Mansob *et al.* 2013). Dried CS contains 33.61% cellulose, 36.51% lignin, 29.27% pentosans and 0.61% ash (Shelke *et al.* 2014). CS has low ash content but high volatile matter which was about 65-75% (Nagarajan *et al.* 2014).CS also has resistance against impact, crushing and abrasion compared to others conventional crushed granite aggregate (Shelke *et al.* 2014).

It can be mix with asphalt mixture directly for the experiment except water absorption test (Olanipekun *et al.* 2006; Shelke *et al.* 2014). This is because CS develop from lignocelluloses which has high polarised hydroxyl group (Agunsoye *et al.* 2014). From the Agunsoye (2014), the coconut shell treated by NaOH has lower water absorption ability than untreated coconut shell (Agunsoye *et al.* 2014). Besides that, the hardness of CS also increases after treated with NaOH.

Figure 1: Coconut shell as aggregates

Coconut fiber (CF) can reduces bleeding of the binder and provide higher macro texture of the coating on surface of asphalt pavement(da Silva Dias¹ and da Silva 2014). Besides that, it has many benefit when react with asphalt mixtures as it can ameliorate the mechanical characteristics and provide higher adhesion between surface drainage and tires(Beligni *et al.* 2000).CF contains lowest cellulose content which was about 36 - 43% but with twice amount of lignin (41- 45%) compared to jute and sisal which makes it higher resistance and hardness(Esmeraldo 2006). CF will acts as stabilizing additives when added into the asphalt mix around 180°C(Vasconcelos 2004).

Do Vale *et al* and Casagrande (2006) has conducted a research on application of coconut fibers in Stone Matrix Asphalt (SMA) mixtures. The research was conducted by using two different percentage of coconut fiber which is 0.5% and 0.7%. The flow parameter has been tested in this research and the results in table 1 shows that the flow parameter with fiber is lower than without fiber and 0.7% of CF get the lowest flow parameter. The result proved that CF can reduce the flow of asphalt binder hence can decrease the clogging of air void by the binder.

Table 1: Results of the flow parameters.

Fiber	*Fiber content (%)*	*Flow parameter (%)*	
		T= 165°C	*T= 180°C*
Without fibers	0.0	1.06	0.70
Coconut	0.5	0.08	0.25
	0.7	0.04	0.09
Cellulose	0.3	0.01	0.03
	0.5	0.01	0.02

The main objectives of these investigations is to observe the resilient modulus of unaged and aging asphalt mixtures by replacing5mm of coarse aggregate with different percentages coconut shell (0%, 5%, 10% and 15%) and adding coconut fiber by weight with 0%, 0.3% and 0.5%. All the specimens were prepared at design binder content of PG-76 modified bitumen.

2.0 Methodology

DLPA mix is made up by two layers, top with 20 mm while base layer is 50 mm thickness. The size of aggregate for top layer is NMAS size 10 mm and NMAS 14 mm for bottom layer. The binder contents used for different mixing proportion of modified DLPA are based on their respective design binder content. The optimum binder content was tested and found for each different percentage of coconut shell. The results has showed that 4.5% of binder content was used for original specimen while 5.0% of binder content for 5%, 10% and 15% of coconut shell replacement specimen.

The amount of aggregate for top and base layers are calculated based on the Marshall density of single layer porous asphalt. Based on the preliminary test result of the density of single layer porous asphalt, the total amount of aggregate to get a 70 mm specimen is about 1000g. Based on the ratio of the thickness for a DLPA, the top layer needed 285 g while the bottom layer needed about 715 g of aggregate.

To reduce the water absorption ability of the materials, coconut shell and coconut fiber was soaked and stirring in 5%wt NaOH aqueous solution for 1 hour at room temperature. The CS and CF then filtered out and washed several times with distilled water until the CS and CF has less NaOH that is until water no longer showed any alkalinity reaction. The CS and CF then has been dried up in oven at 60°C for 24 hours(Thaker *et al.* 2013).

The compaction method will carried out in two steps at 2 x 50 blows. The base layer aggregate were mix and put in the Marshall mould and transferred into the oven to keep its temperature. The top layer were then prepared and placed on the top of the base layer mix. Each face of the mix was compacted with50 blows.

The compacted specimen then undergo the ageing test which is based on Transfund New Zealand Research Report No. 265(Herrington *et al.* 2005). The samples were put in the oven for 7 days at 60°C.Samples were wrapped with the wire mesh to avoid collapse(Mallick *et al.* 2000).The unaged and aged samples then undergo the resilient modulus test with 3 samples for different conditions and different component.

3.0 Results and Discussion

Figure 2 shows the resilient modulus of unaged modified DLPA with different replacement of coconut shell and coconut fibre. The result shows that samples with 0.3% of CF has the highest resilient modulus followed with 0.5% CF and 0% CF. This has stated that with certain amount of coconut fibers added into asphalt mixtures can helps to increase the resilient modulus while too much of coconut fibers will decrease the resilient modulus of asphalt mixtures.

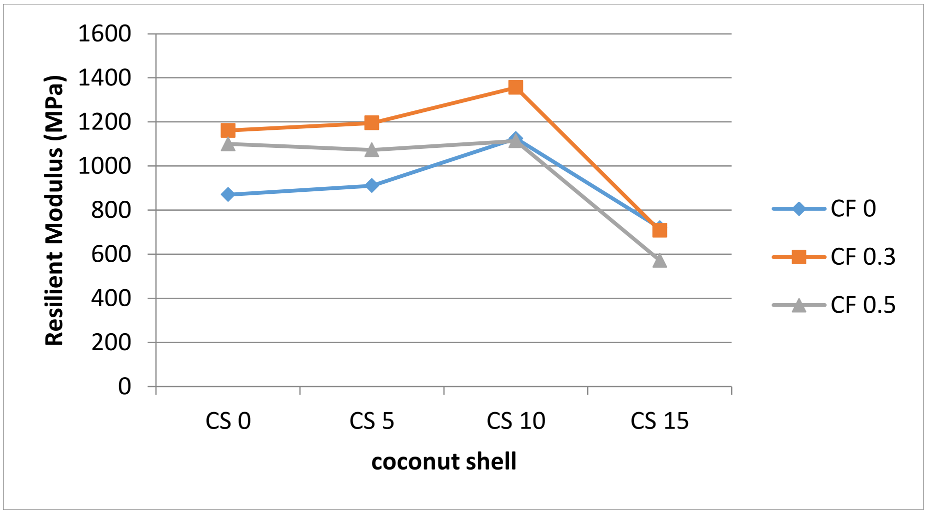

Figure 2: Resilient modulus of unaged asphalt mixtures with different replacement of coconut shell.

Figure 2 shows that the resilient modulus has increased with the higher amount of CS. However, the resilient modulus reduced when 15% of CS replaced in the samples meanwhile samples with 10% of substitution of CS has the highest resilient modulus compared to others samples.

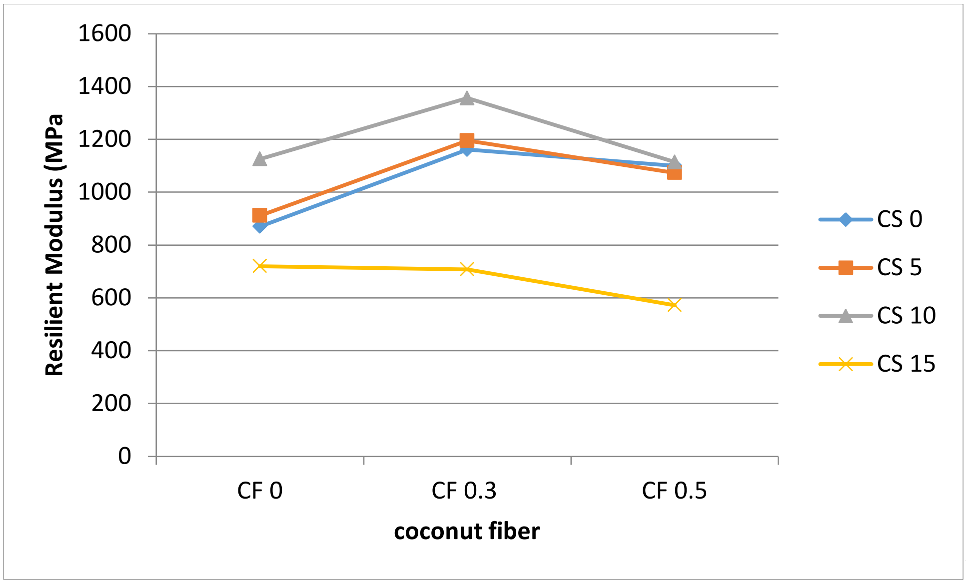

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Figure 3: Resilient modulus of asphalt mixtures with different additives of coconut fiber.

Besides that, from the Figure 2 and Figure 3, the asphalt mixture with replacement of 10% of CS and 0.3% of CF has the highest resilient modulus. However, with the comparison between the replacement of CS and the additives of CF, the replacement of CS has more effect on the resilient modulus of asphalt mixtures than additives of CF since the modified asphalt mixtures with 15% of CS has much lower resilient modulus than others even with additives of CF.

Figure 4 shows the result of the resilient modulus of long-term aging asphalt mixtures with different replacement of coconut shell. The result shows that the 10% replacement of CS has the highest resilient modulus followed with 5%, 0% and 15% of CS replacement.

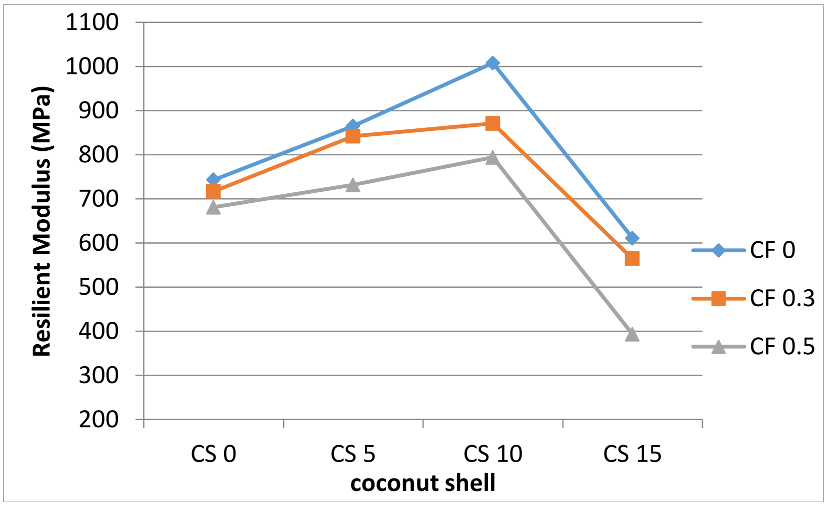

Figure 4: Resilient modulus of long-term aging asphalt mixtures with different replacement of coconut shell.

The resilient modulus of long-term aging asphalt mixtures with different additives of coconut fiber is shown in Figure 5. Based on the result, the additives of CF have no contribution for resilient modulus after long term aging. The resilient modulus has decreased as the amount CF increased.

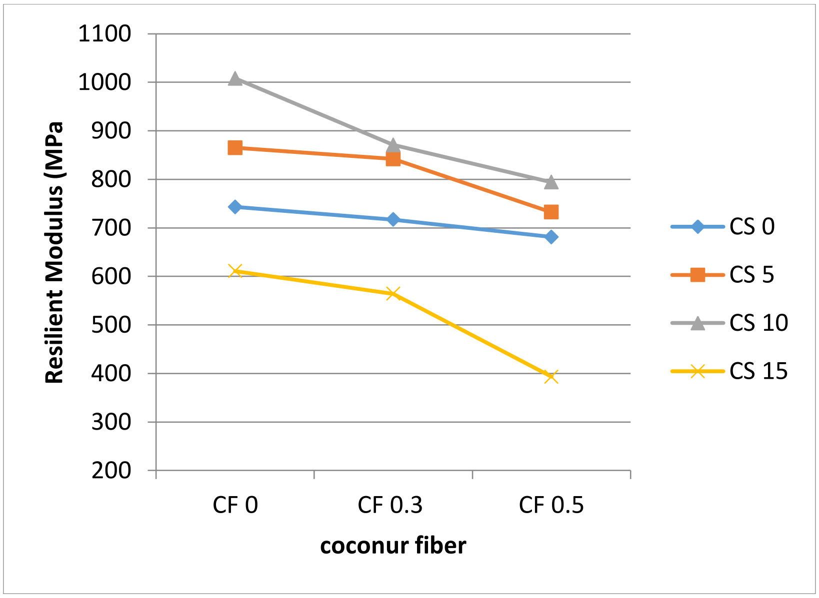

Figure 5: Resilient modulus of long-term aging asphalt mixtures with different additives of coconut fiber.

Table 2 shows the comparison of resilient modulus for unaged and long-term aging asphalt mixtures with different replacement of coconut shell and coconut fibre. The result shows that long-term aging asphalt mixture has lower resilient modulus than unaged asphalt mixtures. However, 10% replacement of coconut shell still has highest resilient modulus for both aged and unaged sample. Apart from that, Table 1 also shows 0%, 5% and 10% CS replacement in unaged samples shows that 0.3% CF added on unaged samples has the highest resilient modulus and followed by 0.5% CF and 0% CF. However, the result also shows that unaged samples with 0.5% CF has lower resilient modulus when compared to 0.3% CF.

Table 2: Comparison of resilient modulus for unaged and long-term aging asphalt mixtures

Resilient modulus							
Unaged				*Long-term aging*			
	CF 0	CF 0.3	CF 0.5		CF 0	CF 0.3	CF 0.5
CS 0	870	1161	1100	CS 0	743	717	681
CS 5	911	1195	1073	CS 5	865	842	732
CS 10	1125	1356	1114	CS 10	1008	871	794
CS 15	720	708	572	CS 15	611	564	393

4.0 Conclusion

The asphalt mixtures with 10% of CS replacement have highest resilient modulus for unaged and long-term aging result. CS replacement can helps in increasing the resilient modulus. However, if it is more than 15% CS replacement, it will reduced the resilient modulus.

0.3% of CF has helps to increase the resilient modulus for unaged asphalt mixtures. However, the CF additive does not improve resilient modulus for the long term aging asphalt mixtures. Asphalt mixture with 10% of CS replacement and 0.3% additives of CF has highest resilient modulus compare to others modified unaged DLPA while for long-term aging DLPA, the asphalt mixtures with 10% of CS replacement and 0% additives of CF has the highest resilient modulus.

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