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Chemical and Physical Properties of Coconut Fiber in Asphalt Mixture: A Review

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Abstract: This paper is a review of the chemical and physical properties of coconut fiber in asphalt mixtures. Coconut fibers (CF) are natural fibers and also an agricultural waste, which is abundant after the extraction of juice and coconut fruit. Nowadays, CF has been studied for its potential use in the construction field to increase the strength of materials with its high tensile strength. Additionally, CF can also be one the materials in highway construction as it can improve the skid resistance of asphalt pavements. It was shown that CF treated with NaOH lowered the penetration value and increased the softening point of modified bitumen. Flow of bitumen also can be avoided at high mixing and compaction temperatures by adding 0.7% of CF.

Key words: Coconut, Fiber, Asphalt mixture, Chemical properties, Physical properties

1.0 INTRODUCTION

Coconut fiber (CF) is the tissue surrounding the seed of coconut palm which is thick, lightweight and has great abrasion resistance [1]. Coconut fiber is known as new waste materials that used in highway industry. CF has the lowest cellulose content percentage (36 - 43%) but with twice amount of lignin (41-45%) [2]. CF is a byproduct of coconut coir processing. It is extracted from the fibrous outer cover of the fruit of the coconut plant; mainly consist of lignin and cellulose. CF will acts as stabilizing additives when added into the asphalt mix around 180°C [3]. Some researchers have found that CF contains 36-43% of cellulose and 41- 45% of lignin, which is twice the amount found in jute and sisal. This can improve its resistance and hardness of asphalt mixture [4]. The physical properties, structure and chemical properties will impact the value of CF as it will influence its breaking load and tensile strength [5]. Besides that, the lignin content in CF also can helps in resisting fungal and bacterial [6]. However, the good quality of CF can get from mature coconut shell [7]. CF has outstanding moisture absorption because the irregular of crack in the cross section surface made it has unique structure [8]. The unique structure also make it has good air permeability, moisture conductivity, susceptibility, viscoelasticity and rutting resistance as well as meliorate low temperature anti-cracking properties, durability, material toughness, fatigue life and lowering reflective cracking of asphalt concrete mixtures and pavements [4,9-12].

2.0 OBJECTIVE OF THE STUDY

The objectives of the present study are the following:

a) To review the chemical and physical properties of coconut fiber in asphalt mixtures.
b) To study and review the coconut fiber modified binder characteristics.

3.0 RESEARCH FINDINGS

3.1 Chemical properties of CF

Munirah and Ahmad [13] reported that using NaOH can reduce the ability of CF to absorb water. Equation (1) shows the possible reaction mechanism during alkalized treatment base on stated by [13]. On the other hand, Figure 1 shows the tensile graph for the various treated CF composites [13]. It can be seen that CF treated with alkali (NaOH) has higher tensile strength than untreated CF and Silane treated CF.

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$$\text{Fiber} - \text{OH} + \text{NaOH} \longrightarrow \text{Fiber} - \text{O}^- - \text{Na}^+ + H_2O \quad (1)$$

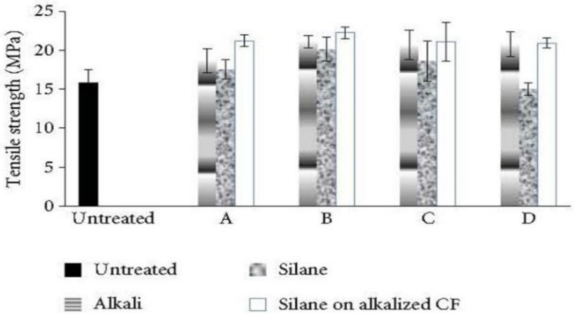

Figure 1. Tensile of various treated CF composites [13]

Figure 2 shows the water uptake graph for the various treated CF composites. The results showed that water uptake ability for CF treated with alkali is lower than untreated CF and Silane treated CF. It was concluded that CF treated with alkali can improve the tensile strength by reducing the water absorption ability [14].

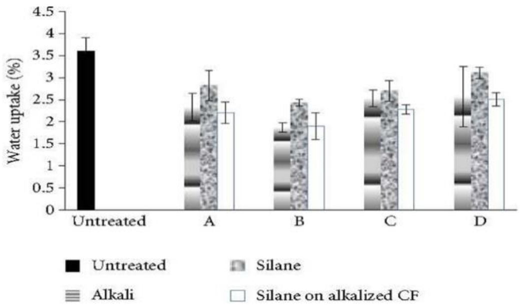

Figure 2. Water uptake graph for various treated CF composites from [13]

Figure 3 shows the scanning electron microscopy (SEM) of untreated CF and alkali treated CF. It shows that the CF has become rougher after alkali treatment and the micro-pores were more visible [15]. This is due to the alkali treatment has removed the hemicelluloses, amorphous waxy layer and also lignin from CF [16]. [16] also proved that treatment with NaOCl and NaOH affected the fiber cellulose content (Figure 4). CF provides many advantages when adding to asphalt mixture as it can reduce binder bleeds and enhance the macrotexture of coating [17]-[18]. It also behaves as stabilizing additives in asphalt mixture at around 180°C [3].

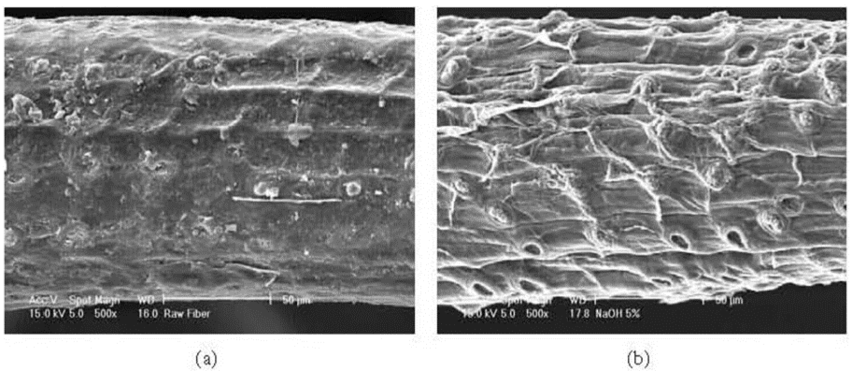

Figure 3. SEM of (a) untreated CF and (b) treated CF [15]

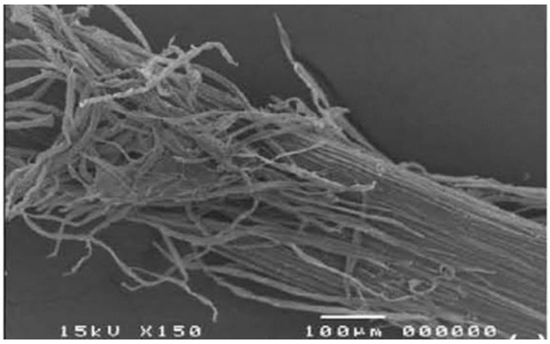

Figure 4. SEM of CF treated with NaOCI/NaOH [16]

3.2 Physical properties of CF

CF has many advantages when adding to asphalt mixture as it can reduce binder bleeds and enhance the macro texture of coating [17]. It also behaves as a stabilizing additive in asphalt mixture at around 180°C [3]. [19] reported that the mechanical characteristics of pavement with tires also can be improved by the incorporation of CF. The discontinuous grain size in CF also helps in increase binder content as the aggregates are coated with a thicker film and hence prevent oxidation of asphalt mixtures and separation [20].

Meng, Guo and Han [8] reported that the irregular cracks in the cross section surface of CF improve the moisture absorption and air permeability. Also its unique structure amends the anti-cracking properties of asphalt mixture at low temperatures and also reduces the reflective cracking of asphalt pavement.

On the other hand, by adding CF into bitumen its brittleness can be reduced at low temperatures [21]. CF, also, enhances the range of temperatures that asphalt pavement could withstand without forfeiting its efficiency and without degradation [22]. CF also can reduce the flow of asphalt at high mixing temperatures and hence prevent bleeding and reduce air void clog of asphalt binders [23].

[7] reported two methods to mix fiber into bitumen for modification. Firstly, the wet process, which blends the fibers with asphalt binder prior to incorporating the binder into the mixture. Secondly, the dry process is when mixing the fiber with aggregate before adding asphalt. [24] concluded that there was no difference in the Marshall properties between the dry process and wet process. However, the dry process is easier to carry out and permits the distribution of fiber in the mixture. Besides that, there is no advantage carrying out the wet process since fibers would not melt in the asphalt and the field work normally uses the dry process.

[23] conducted a study on the application of coconut fibers in Stone Matrix Asphalt (SMA) mixtures. The research was conducted by using two different percentages of coconut fiber, which were 0.5% and 0.7%. Table 1 shows the characteristics of CF used in this research. The flow parameter has been tested in this research and the results are shown in Table 2. This table shows that the flow parameter with fiber is lower than without fiber and 0.7% of CF has a lower flow parameter than 0.5% of CF. The results proved that CF can reduce the flow of asphalt binder and hence can decrease the clogging of air voids in the binder. Based on Table 1, it can be seen that the CF can increase the tensile strength by using Super pave compaction when compared to Marshall Mix design.

Table 1 Characteristics and properties of the coconut fiber [23]

Characteristics of granulated	Results
Average length of the granulated one	10-20mm
Average thickness	0.1mm
Amount (percentile in weight)	0.5-0.7%
Ph	5.4
Electric Conductivity	1.8dS/m
Capacity of cationic exchange	92
Relation C/N	132
Specific mass	70g/L
Water retention	538ml/L
Capacity of aeration	45.5%
Porosity	95.6%

Table 2. Result of flow parameter from [23]

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

Table 3. Result of static tensile strength and resilient modulus from [23]

Mixture	Tensile strength (MPa)		Module of Resilience(MPa)		Relation Resilient Modulus and Tensile Strength	
	Marshall	Superpave	Marshall	Superpave	Marshall	Superpave
SMA CAP 50/70 without fiber	0.78	0.91	2165	3121	2776	3429
SMA CAP 50/70 Coconut fiber	0.74	0.98	2784	3377	3745	3854

4.0 CONCLUSIONS

CF has been studied for its potential use in the construction field to increase the properties of materials. In addition, CF can also be one the materials in highway construction as it can improve the skid resistance of asphalt pavements. It has been shown that when treated CF into NaOH, the penetration value and softening point of modified bitumen was increased. On the other hand, different chemical treatments has been found that the most effective chemical that could reduce the water absorption yet does not change its properties. Finally, CF also should be used in various type of asphalt mixture as it can influence the flow parameter and also the skid resistance of the pavement.

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