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Effect Weight Ratio of Bamboo Schizostachyum Grande fiber treated by Silane Coupling Agent

Adyla Illyana Roseli[1, a)], Nik Normunira Mat Hassan[1 b)*], Nur Faezah Yahya[1, c)], Aida Atiqah Atil[1, d)], Nofrizalidris Darlis[1, e)], Mohd Nazrul Roslan[1, f)], Tuan Noor Hasanah Tuan Ismail[1, g)], Fatimah Mohamed Yusop[1, h)], Nur Ain Arina Johan[1,i)]

[1]*Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Muar, Johor Malaysia*

[b)] corresponding author: normunira@uthm.edu.my
[a)]adylaillyana@gmail.com,
[c)]nurfaezah@uthm.edu.my,
[d)]aidatiqah.work13@gmail.com,
[e)]nofrizal@uthm.edu.my,
[f)]nazrul@uthm.edu.my,
[g)]hasanah@uthm.edu.my,
[i)]gn220024@student.uthm.edu.my

Abstract. Bamboo fiber has gained popularity in Malaysia and it is increasingly used in the production of green composites such as construction applications, roofs, flooring, and sports equipment. In this study, the Bamboo Schizostachyum Grande fiber was treated with a silane coupling agent to examine the physical characterization using TGA, SEM, and FTIR. The SEM was analyzed before (untreated) and after treatment (treated) with different weights of bamboo fiber. The results of SEM demonstrate that the bamboo fiber was treated, and the surface morphology and chemical elements reacting to silane coupling agents were improved, which shows the layer and bamboo fiber were expanded up to 7 mm than untreated. TGA results shows of the thermal degradation of untreated bamboo fiber occur at 341.08°C, which is significantly lower than the thermal degradation of 0.3 g of treated bamboo fiber at 354.84°C. It reveals that the surface compatibility and bonding strength of bamboo fiber treated with a silane coupling agent are more effective than untreated bamboo. The highest weight of bamboo fiber shows good thermal stability was 0.7 g. FTIR spectrum shows the peak from 2890 cm^{-1} to 2898 cm^{-1} indicating that treated fiber was absorbed by silane coupling agents, but the different weights of bamboo fiber exhibited significantly no effect, and the results show treated 0.3, 0.4. 0.6, 0.7 g peaks continuously from 2890 to 2898 cm^{-1} while the untreated bamboo fiber cellulose structure did not show any additional groups at this range. Hence, this silane coupling agent treatment performed better than untreated and it has the potential to be used in insulating and hydrophobic applications.

Keywords: Silane Coupling Agent, Bamboo Fiber, Treatment, Thermal degradation

1.0 INTRODUCTION

Bamboo plants are massive, fast-growing grasses with woody stems. Size, growth habits, sun tolerance, soil moisture requirements, and heat or cold temperature tolerance are some of the differences between them. It is commonly used in building, carpentry, waeving, and plaiting, among other things. Aside from bamboo composites such as household fences, strorage, floors, panels, furniture, and decoration products, it is also possible to remove bamboo fiber (BF) from bamboo trunks [1]. Bamboo is one of the crops that can be used to create polymer composites which are

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developed for ecological purposes eco-composites using bamboo fibers [2]. Fibers that account for 60 – 70 % of the total mass of the stem ensure their high mechanical strength. Bamboo is regarded as a natural resource that can be replenished in a shorter period, and no species can compete in terms of growth rate and area utilization [3]. Schizostachyum Grande (S. Grande) is an evergreen bamboo with short, woody rhizomes that grow in an open cluster of culms that range in length from 3 – 20 meters. The culms have thin walls and internodes that are from 50 – 90 cm long.

In Malaysia, S. Grande known as *buluh semeliang* has been economically produced. It is the only commercial Malaysian bamboo species with longer internodes than any other. The culms are frequently used for sticks, toothpicks, and crafts, while the broad and long leaves are typically used to wrap delicate foods. Natural fibers are mostly composed of cellulose, hemi-cellulose, and lignin and for almost ninety percent bamboo fiber of the total weight [4]. Physical or chemical treatment of fiber are required to improve interfacial adhesion and produce outstanding qualities of the resulting data. Based on a review of previous research chemical treatment methods for natural fibers are presented such as Alkali [5], [3], Benzoylation [6], Silane [7], Acetylation [8], Peroxide [9], Isocyanate [9], Permanganate [9], and Hydrophobic [7], [10] treatment. The researcher Shah et al. [11], explained that raw bamboo materials' chemical composition and structure change following treatment where hemicellulose degradation and lignin degradation dominate changes in caramelized and bleached bamboo. The effect of silane treatment on the fiber was studied using a variety of analytical techniques [12]. According to Sepe et al. [13], the influences of alkali and silane treatment on fiber reinforced epoxy composites of fiber physical properties exhibited untreated and treated fiber composites, silane treatment of fiber gives improvement to the physical properties.

Silane (SiH_4) is a chemical compound having the formula SiH_4. Silanes act as coupling agents, allowing glass fibers to bind to a polymer matrix and stabilize the composite material. Silane coupling agents reduce the overall number of cellulose hydroxyl groups at the fiber-matrix contact. In the presence of moisture, hydroxyl alcohols create silanes. Referring to Agrawal et al. [14], the use of silanes, the hydrocarbon chains minimize fiber cramping by establishing a cross-linking infrastructure to which the fiber matrix is bonded via covalent bonds. Silane can be employed as a silane coupling agent because it possesses two functional groups with varying reactivity. The first of the two functional groups reacts with organic molecules, whereas the second reacts with inorganic elements. When utilized between organic polymers and inorganic fillers, silane coupling agents provide significant benefits and can increase resin and filler compatibility. Li et al. [15] studied the effect of various coupling agents on the characteristics and properties of natural fiber which is basalt fiber was controlled by chemical structure and it was found that the addition of 3-aminoprpyl triethoxysilane was most effective for enhancing the interfacial fatigue properties and can improve initial adhesion of fiber.

Therefore, in this paper, the bamboo Schizostachyum grande fiber were investigated the effect of silane coupling agent treatment on the physical characterization properties of bamboo fiber as an alternative filler for hydrophobic applications.

2.0 METHODOLOGY

2.1 Materials

The bamboo Schizostachyum Grande fibers were obtained from HangTerra Bamboo Sdn Bhd in Kedah, Malaysia. Bamboo fiber (BF) was extracted from the culm strip to fiber in the laboratory by using the bamboo extraction machine. Then, the fiber was cut around 10 cm before starting with the silane coupling agent treatment process.

2.2 Silane Coupling Agent treatment of Bamboo fiber

In an ethanol/water mixture with 80/20 volume ratio, a silane coupling agent solution was prepared and hydrolysed 0.1 g 3-aminopropyl (diethoxy) methylsilane. The mixture was stirred at a constant pace until the solution was completely diluted, then 10 g of bamboo Schizostachyum Grande fiber was added into the solution and soak for 3 hours. After that, the pH of 4.00 (weak acid) was adjusted into the solution using the modified method of acetic acid. Then, the bamboo fiber was dried for 24 hours and set to 80 ° C in a drying oven. Figure 1 depicts the preparation of bamboo fiber treatment by silane coupling agent and the samples were divided by the weight of 0.3, 0.4, 0.6, and 0.7 g treated, respectively.

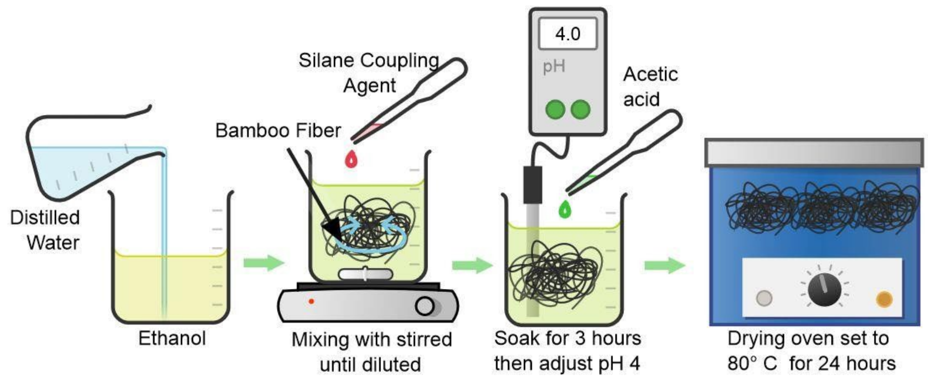

FIGURE 1: A schematic diagram of the bamboo fiber treatment work process

3.0 PHYSICAL TESTING OF BAMBOO FIBER

3.1 Scanning Electron Microscopy (SEM)

A scanning electron microscope (SEM) is a type of electron microscope COXEM EM-30AXPlus that uses a concentrated beam of electrons to scan the surface of a sample to produce images. The SEM was observed in the laboratory of University Tun Hussein Onn Malaysia, Kampus Pagoh, Johor followed by ASTM D3576. To prevent electrical charge collection, the test samples were gold coated. The front surface of the bamboo Schizostachyum Grande fiber untreated and treated silane coupling agent bamboo fiber was examined and scanned in a free-rise direction at the accelerating voltage of 20 kV followed by at 100µm 500X magnification.

3.2 Thermo-gravimetric Analysis (TGA)

Thermogravimetric analysis (TGA) is an analytical technique for determining a material's thermal stability and proportion of volatile components by monitoring the weight change that occurs as a sample is heated at a constant rate. TGA 550 TA Instrument Trios Discovery Series followed ASTM E1131 was used to determine the thermal characteristics of the bamboo Schizostachyum Grande fiber and conducted at the Process Control laboratory at University Tun Hussein Onn Malaysia Kampus Pagoh, Johor. Five samples were prepared including untreated and treated silane coupling agents of 0.3 g, 0.4 g, 0.6 g, and 0.7 g bamboo fiber samples were heated from 40 °C to 700 °C in a nitrogen environment at a rate of 10 °C/min with a flow rate of 25 ml/min.

3.3 Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

Fourier-transform infrared spectroscopy Agilent Technologies Cary 630 FTIR was used followed by ASTM D6342-12 to determine the chemical structure of bamboo Schizostachyum Grande fiber untreated and treated with silane coupling agent at various weights of fiber of 0.3, 0.4, 0.6, and 0.7 g. FTIR testing was conducted in the chemistry Analytical laboratory at University Tun Hussein Onn Malaysia, Kampus Pagoh. The measurement performed with a maximum resolution of 4 for scanning the wavelength range of about 650 to 4000 cm^{-1}.

4.0 RESULT AND DISCUSSION

4.1 Morphological structure of the untreated and treated bamboo fibers

Morphological structure was used to investigate the surface of the untreated bamboo fibers and those that had been treated with silane coupling agents. SEM images of the fiber surface at magnifications of 500x of untreated bamboo fiber and treated with silane coupling agent are shown in Fig. 2. The untreated bamboo strands were closely aligned, and the surface was clear and smooth, as seen in Fig. 2 a), as indicated by the accompanying arrow. While the treated bamboo fiber had clear structural and morphological abnormalities and bamboo fiber shows amorphous cellulose, and impurities occurred, as illustrated in Fig. 2 b). On untreated bamboo fiber, a substantial number of pectin and lignin, which contained many polar hydroxyls and phenolic hydroxyl functional groups [16] and on the surface, there are no contaminants and the length of the fiber were 20.9 mm. Furthermore, reduce of hydroxyl groups through the chemical alteration of fibers by silane coupling agents was linked with strong interfacial bonding [17].

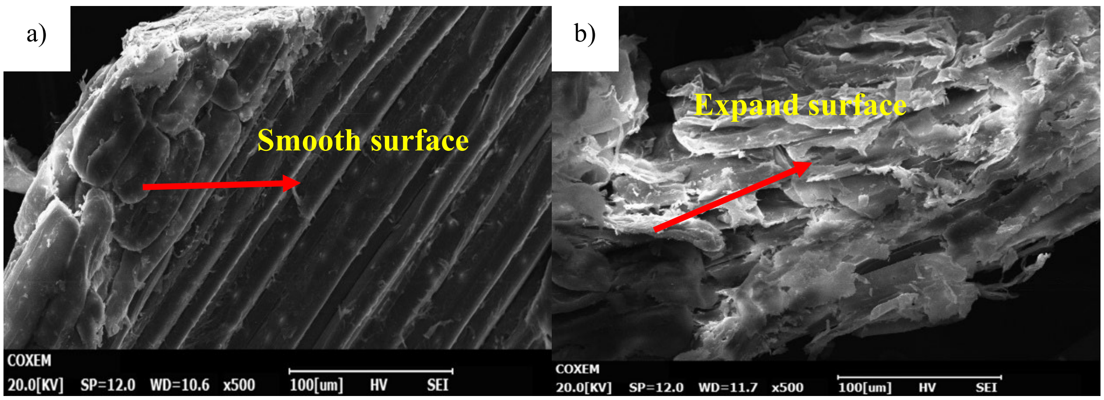

FIGURE 2: a) untreated and b) treated bamboo with silane coupling agent

After the silane coupling agent treatment, part of the lignin, pectin, and other impurities was dissolved and untreated bamboo fiber surfaced was changed as shown in Fig. 2 b). Because of the absorbent silane coupling agent treatment, the treated bamboo fiber length of 27.8 mm expands. In this case, the surface of treated bamboo fiber presented a form shape and a wrinkled surface might enhance the effective contact area and give additional bonding sites by increasing the specific area [18] and also the bonding got stronger compared to the untreated shape of samples. Likewise, after silane treatment, the treated bamboo fiber exhibits a surface of contaminants which is similar to other researchers [19].

4.2 Thermo-gravimetric (TGA) Analysis

The thermal degradation of untreated and treated silane coupling agents with various weights of bamboo fiber was investigated. The weight loss and derivative weight percentage was shown in Fig. 3 and 4. Thermal degradation of untreated bamboo fiber occurs at 341.08 °C showed completely obvious which was lower than that of the 0.3 g treated bamboo fiber occuring at 354.84 °C in Fig. 3. It is possible that the thermal degradation was affected by the outcome of the degradation that occurred throughout the treatment processing by counter-rotating mixer, as well as the addition of bamboo fiber. Also, below 100 °C temperature is volatile material due to the water content of samples. From Fig. 3, the thermal degradation temperature of 0.7 g was higher than the other untreated and treated silane coupling agent 0.3, 0.4, and 0.6 g bamboo fibers. This may had happened as a result of a decrease in the amount of hydroxyl groups that reacted with silane coupling agent as a side effect [20]. As bamboo fiber decompose thermally at temperatures between 200 to 300 °C, the first stage is when weight is lost. The second stage shown in Fig. 4 is 300 to 400 °C related to heat degradation of treatment of bamboo fibers in derivative weight.

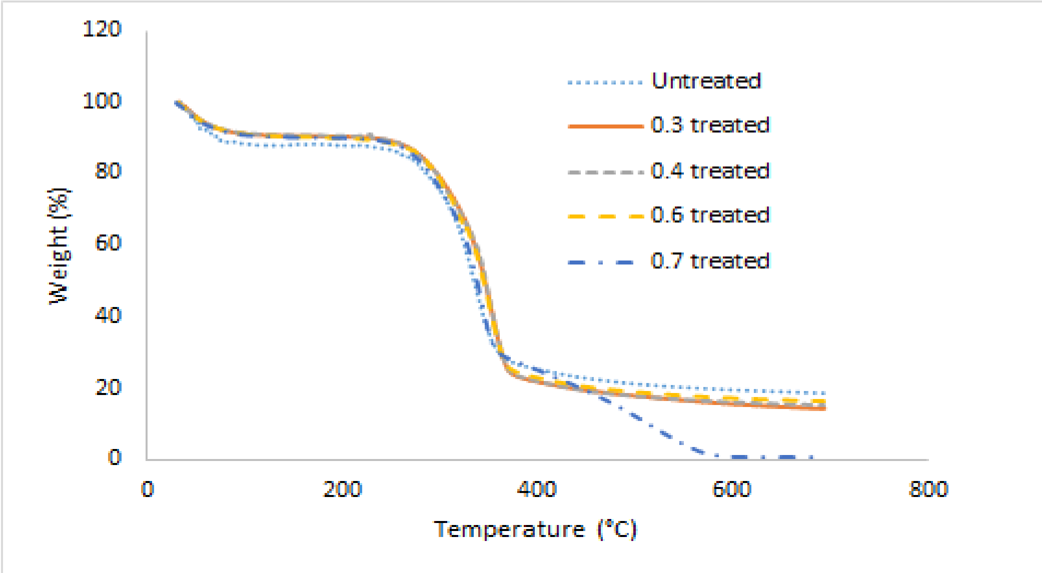

FIGURE 3: Thermo-gravimetric curve of thermal degradation weight

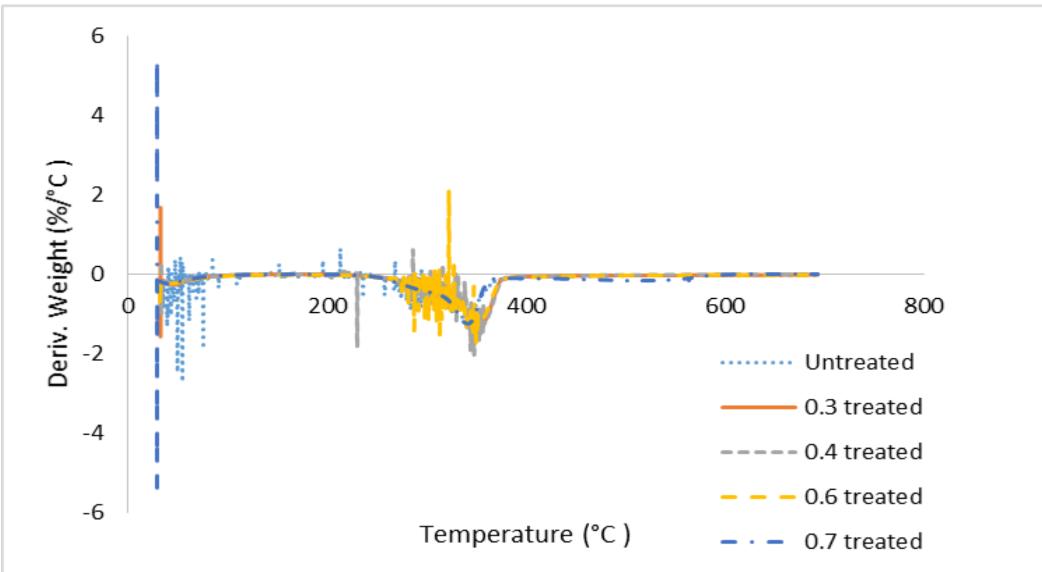

FIGURE 4: Curve of derivative of bamboo fiber untreated and treated with silane coupling agent

Because of the reaction, which could enhance the thermal degradation temperature, the result indicates that the treatment silane coupling agent had improved interfacial adhesion with bamboo fiber [16]. The increased in thermal degradation of bamboo fiber because the treatment absorbs substantial amounts of heat. In comparison between untreated and 0.7 g, the weight percentage loss is 56% to 76 between ranges of temperature 341 to 417°C. In addition, the treated silane coupling agent of bamboo fiber further improves in thermal compared to the untreated bamboo fiber because the strengthened fiber significantly restricts the heat of molecular chain [19].

4.3 Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

FTIR spectrum of untreated and treated bamboo fiber with various weights 0.3, 0.4, 0.6, and 0.7 g are shown in Fig. 5. The presence of a signal between untreated and treated bamboo fiber ranging from 1023 to 1026 cm^{-1} could be due to hydrogen bonds at the broad peak. This broad peak shows that the natural fiber contains hydroxyl groups of cellulose [17]. The second peak from 2890 to 2898 $cm^{-}1$ indicates that treated fiber by silane coupling agents was absorbs, but the difference of weight bamboo fiber does not affect, and the result shows treated 0.3, 0.4, 0.6 and 0.7 g peaks constantly from 2890 to 2898 cm^{-1}. The range of 1150 to 1060 cm^{-1} mode of the antisymmetric stretching bond of C-O-C ethers. All samples including the untreated show a broad peak occurring between 3250 and 3335 cm^{-1} in Fig. 5.

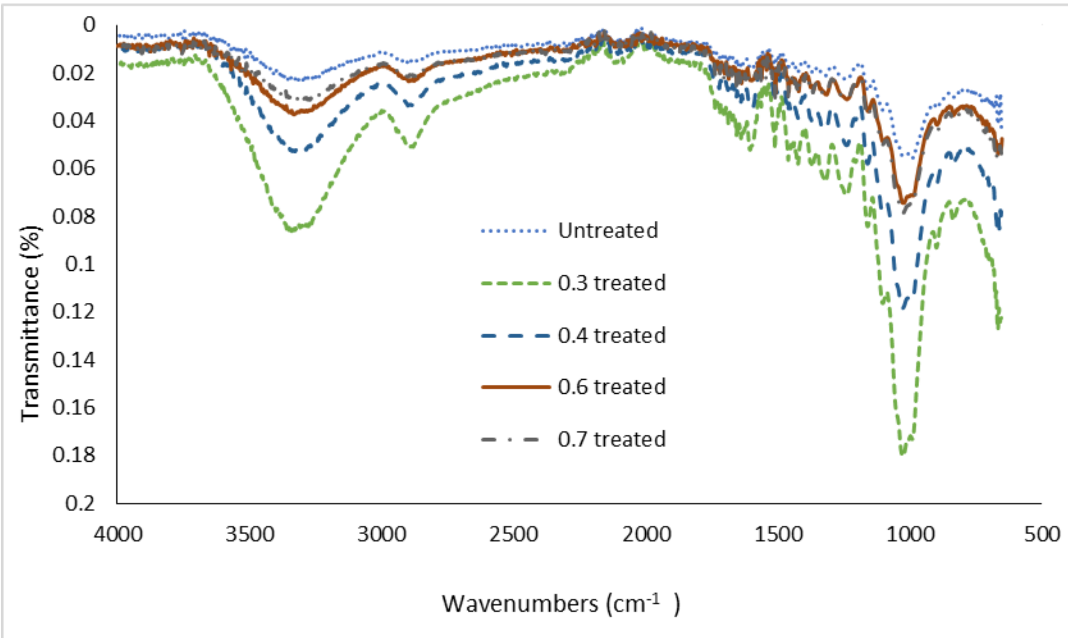

FIGURE 5: FTIR spectra of the bamboo fibers untreated and various weight treated with silane coupling agent

At 1650 to 1590 cm^{-1} the carbonyl (C=O) stretching of acetyl groups of hemicellulose from the natural fiber are shown. The peak of intensity at 1140 to 1080 cm^{-1} represents either the Si-O-Si stretching vibration or the C-O-C stretching variation of cellulose fiber. For silane bamboo fiber, peaks at 3250 to 3326 cm^{-1} which are linked to Si-O-Si and Si-O-C stretching vibrations, are stronger after silane coupling agent treatment, indicating that new chemical bonds have been created between bamboo fibers and the silane coupling agent. Also, the range between 3000 to 3400 cm^{-1} clearly shows the transmittance reduction from 0.09 to 0.01 due to the absorbance of the silane coupling agent to the samples. Overall, the cellulose structure of the untreated bamboo fiber remained the function from groups. Hence, the treated of bamboo fiber between 0.3, 0.4, 0.6 and 0.7 g shows the additional peak OH peak range of 3400 to 3000 cm^{-1}, and the best bonding bamboo fiber with silane coupling agents was bamboo fiber treated at 0.3 g. This evidence confirms that chemical bonds are formed during the treatment and bamboo fiber can absorb the fiber structure.

5.0 CONCLUSION

In this study, the physical characterization of untreated and treated bamboo fibers with different weights was investigated. The treatment of bamboo Schizostachyum Grande fiber with a silane coupling agent was employed in this paper. Because of the interfacial adhesion of silane coupling agents with treated bamboo fiber, the morphologies of the surface of bamboo fiber also confirmed that surface treatment improved interfacial adhesion which is untreated smooth compared to treated silane coupling agent showing more layers and the bamboo fiber were expand. The thermal properties revealed an obvious improvement in thermal stability as shown in TGA. The thermal degradation temperature of 0.7 g was higher than the other untreated and treated silane coupling agents 0.3, 0.4, and 0.6 g bamboo fibers. In comparison between untreated and 0.7 g, the weight percentage loss is 56% to 76 between ranges of temperature 341 to 417 °C. Moreover, bamboo fiber reacts to the silane coupling agent, forming chemical bonds, according to FTIR spectra. When compared to untreated bamboo fiber, the treated bamboo fiber performs well, although the best weight of the bamboo fiber treated was 0.3 g. The peak from 2890 to 2898 cm^{-1} implies that treated fiber by silane coupling agents was absorbed and bonding of treatment is stronger. Hence, the treated silane coupling agent was better than the untreated and has more potential to use in roof insulation applications.

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