Recent Trends in Civil Engineering and Built Environment Vol. 4 No. 3 (2023) 153-162

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Effects of Hot Water and NaOH Pretreatment on Fiber Diameter and Acoustic Properties of EFB Cement Board

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DOI: https://doi.org/10.30880/rtcebe.2023.04.03.017
Received 06 January 2022; Accepted 15 May 2023; Available online 31 December 2023

Abstract: Residue and residual oil on oil palm empty fruit bunch (EFB) fibers must be removed using appropriate pre-treatment before they can be utilized in the fabrication of EFB cement board. Pre-treatment resulting in variations in diameter and affects the acoustical performance of fiber composites. The purpose of this research is to define the effects of different treatment methods on the fibers diameter and to determine and compare the sound absorption performance of EFB Cement Board based on different treatment methods. The diameter of the fibers was measured by average using 5 strands of each treatment. Meanwhile, the cement board's sound absorption is measured using an impedance tube. Pretreatment of fibers are accomplished by the use of two distinct methods which are Sodium Hydroxide (NaOH) at concentrations of 0%, 2%, 4%, and 6%, and hot water treatment at temperatures ranging from 50°C to 60°C and 70°C. In both pretreatments, 3 hours of soaking time will be maintained. The diameter of strand is measured using digital microscope which is Scanning Electron Microscope (SEM), and the sound absorption of the EFB were determined in accordance with ISO10534-2:2001. Results shows that the untreated average data was 472.93 μm, whereas the hot water pretreatment obtained the thinnest strand diameter at 417.46 μm at 50°C, and the 2 % NaOH obtained the thinnest at 384.31m. The maximum value sound absorption for NaOH pretreatment was obtained with 6 % NaOH treated 0.586 and for hot water pretreatment 0.584 with temperature 70°C, both at 1600Hz, compared to the highest value sound absorption for untreated 0.486 at 1400 Hz. The average diameter of the untreated was 472.93μm, whereas the thinner diameter of the NaOH pretreatment was 417.46 μm at 50°C, while the 2 % NaOH was 384.31μm. Based on the comparison results, it is possible to conclude that NaOH pretreatment was superior to hot water pretreatment in terms of reducing fiber diameter. As a result, the NaOH pretreatment is suggested when treating EFB fiber to remove the outer layer of the strand.

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Keywords: Empty Fruit Bunch, Sodium Hydroxide Pretreatment, Hot Water Pretreatment, Fiber Diameter Measurement, Sound Absorption

1. Introduction

The use of wood fiber as a natural composite in cement-based items like cement bonded board has grown rapidly. However, the usage of wood fiber will result in an increase in demand for forest resources. The use of wood fiber as a bio-composites material will ultimately increase deforestation rates. The rising use of palm oil production has resulted in environmental issues as well as solid waste in the form of an abundance of empty fruit bunches (EFB) from oil palm mills Dullah *et al.*, [1]. The challenging issue with natural fiber cement board production was the incompatibility of cement and fiber. According to Khalili, Kim & Kong [2], one of the key disadvantages of natural fibers is the chemical incompatibility of hydrophobic polymeric molecules with the hydrophilic nature of natural fiber molecules. This property greatly hinders load transfer from matrix to natural fiber due to poor fiber interfacial adhesion.

Treatment on EFB using Sodium Hydroxide (NaOH) by varieties concentrations such as 0%, 2% 4%.and 6% and hot water temperature treatment on EFB by 50°C, 60°C and 70°C by soaking the EFB in the hot water in fixed time within 3 hours. The EFB fiber untreated and treated will be testing on physical properties of fiber diameter using digital microscope Scanning Electron Microscope (SEM). Sound absorption performance of EFB fiber will be obtain by using impedance tube system according to ISO10534-2:2001. On the whole the outcoming data of the study there will be the effects of the fiber diameter and acoustical performance of EFB cement board that have been determine through the concentration of NaOH and hot water involved. The present study research conducts a pre-treatment of NaOH and hot water will affect the fiber diameter and acoustical performance of EFB cement board.

2. Literature review

Chemical composition levels of lignin, hemicellulose, and cellulose are about 13-43.51 %, 17-47.7 %, and 22.90-57.8 %, respectively, on EFB fibers natural fiber's application as a cement-based material is limited due to its cell structure and the weathering conditions Peter, Nik Soh, Akasah, and Mannan [3]. Reviewed by Khorami, Ganjian & Srivastav [4] a wide range of natural and synthetic fibers, including Bagasse, Wheat, Kraft pulp, Sisal, jute, Steel, Glass, Acrylic, and Polyvinyl Alcohol fibers, have been employed as asbestos substitutes in the fabrication of fiber-cement boards, depending on their qualities, effectiveness, and cost. According to Khalili, Kim & Kong [2] there was no fiber fibrillation found in untreated fibers, only a compact and smooth surface. However, alkali treatment resulted in progressively regular, rough, and clean surfaces which is the fiber treatment reduces the diameter due to the removal of a large amount of natural oils, waxy compounds, lignin, and hemicellulose.

Experimented by Khalili, Kim & Kong [2] a 5 wt% concentration of sodium hydroxide (NaOH) solution was created. The needed amount of EFB fibers were soaked in alkaline aqueous solution at ambient temperature for 1 hour, 13 hours, and 24 hours before being carefully rinsed with distilled water until all traces of NaOH were removed. After that, the fibers were dried in a 70 °C oven for 24 hours. According to Taban *et al.*, [5] there are several ways for determining the absorption coefficient of sound absorbers. In this investigation, the sound absorption coefficient was measured using an impedance tube and the transfer function method in accordance with ISO 10534-2:2001.

3. Materials and Methods

The Empty Fruit Bunch (EFB) was gathered from an oil palm factory in Ayer Hitam, Johor about 5 tons of lorry and sent to Timber Fabrication Laboratory at Faculty of Civil Engineering and Built

Environment. Following that, the EFB fiber was sieve and was treated with different pretreatment. The physical and acoustic properties were tested with different method testing.

3.1. Materials

The EFB fiber was sun dried for 2-3 days before being shredded with a crusher machine. The collected raw (EFB) was treated using Sodium Hydroxide (NaOH) and hot water. To bind together diverse materials Ordinary Portland Cement (OPC) cement was the main materials chemical reactions are frequently involved, which are assisted by the presence of water. Pretreatment material as Sodium Hydroxide (NaOH) was used for physical properties modification method. NaOH was a caustic base and alkali that decomposes proteins and can cause significant chemical burns. The EFB fiber has the ability to change the surface of EFB fiber and disrupt the crystalline area in cellulose, causing total de-crystallization and weakening of the cellulose energy bonding.

3.2. Methods

There are 2 types of pretreatments involved which is Sodium Hydroxide (NaOH) and hot water treatment for physical and acoustic properties testing.

3.2.1.Sodium hydroxide (NaOH) pretreatment

The raw EFB fiber were immersed in the dissolved of NaOH with different concentration which are 0%, 2%, 4% and 6% Nasidi, Ismail & Samsudin [8]. Then, the EFB fiber was soaked for 3 hours in a container. The NaOH and EFB fiber were weighed and will be mixed together. After 3 hours soaked, the EFB fiber will be washed clean and then sun dry for a while then for fully the fiber need to be put in the oven. The NaOH pretreatment process was to eliminated the outer layer of the EFB fiber that has caused the modification of the EFB fiber.

3.2.2.Hot water pretreatment

Hot water pretreatment also a physical modification method that was similar to the NaOH method pretreatment which is before dried the EFB fibers was soaked into the hot water within different temperature such as 0° C, 50°C, 60°C and 70°C Santos *et al.*, [8]. The EFB fiber also was soaking for 3 hours. The water bath equipment was prepared and the temperature was set up according to required temperature. When the temperature had achieved as temperature required**Error! Reference source not found.** the fiber was soaked in for 3 hours. The fiber was washed and dried same as NaOH pretreatment. This study was to obtain the result of the reaction of the fibers with the different of temperature that was affect to the physical properties of EFB fibers.

3.2.3.Cement board fabrication

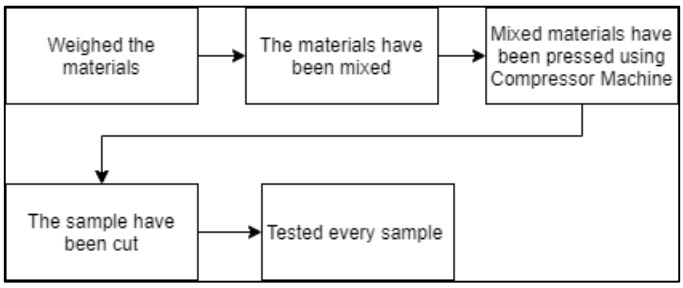


Figure 1: Cement board fabrication process

The fabrication of fiber cement board process as in **Figure 1** was made in Timber Fabrication Laboratory at Faculty of Civil Engineering and Environmental Built, UTHM. The EFB fiber that has been treated earlier which is treated by NaOH and hot water pretreatment was used in the fabrication process. The untreated and treated EFB fiber, cement and water have been weighed and prepared before mix together. The fiber cement board fabrication mixture according to ratio 3:1. At the beginning process, the EFB fiber and water were put inside the mixer machine and mixed for 2 minutes. The mixture was mixed well and then the cement was mixed together with the previous mixture. Leave it mixed for 8 minutes so that the mixture of cement, fiber and water mixed well. A steel plate has been prepared at the first place as the base and then put a 350 mm x 350 mm x 13 mm of square mold on the steel plate. Pour mixture into the mold and spreading on the net mold so that the fiber mixture can be spread equally in the mold. The mixture was flattened by using wooden comb after the first layer was laid. The process repeated until third layer has been flattened and this process repeated so that the mixture fully impact in the mold.

Consequently, the mixture was compressed and compacted using wood plate. The pre-compact works was formed pre-compressed fiber cement board. To make it fully compacted the fiber cement board was compressed using compressor machine with spacer 13mm was put at every edge of the pre-compressed before it was compressed so that the fiber cement board compressed by followed the spacer. Thus, the compacted EFB fiber cement board was clamped and unclamped after 48 hours. After 28 days curing process, the EFB fiber cement board was cut into 100 mm diameter of circular shape and proceed for the further testing Chand & Fahim [6].

3.2.4. Fiber diameter measurement

The physical properties of EFB fiber were investigated using a Scanning Electron Microscope (SEM) at various NaOH concentrations. The diameter of the fibers was measured to determine the effect of treatment. There are 35 samples untreated and treated EFB fiber which were contained NaOH pretreatment and hot water pretreatment have been placed on the plate with double sided tape which is the EFB fiber was put on the tape according to 7 different types of concentration and temperature of treatment which were untreated, 2%, 4% and 6 % of NaOH pretreatment also 50°C, 60°C and 70°C degree of hot water pretreatment. The EFB fibers were insert in the SEM equipment for the diameter measurement observed. Every tape consists 5 strands of EFB fiber and there was 10 points randomly were measured. Within 10 points diameter data were concluded into an average diameter of EFB fiber.

3.2.5. Impedance tube testing

The sound absorption coefficient of the samples was determined using an impedance tube testing method according to ISO 10534-2:2001. To generate sound, the loudspeaker was put at one end of the impedance tube, while the sample was positioned at the other end of the same tube. A circular tube with diameters of 100 mm and operating frequencies ranging from 0 Hz to 1600 Hz for lower frequency. The absorption testing needed 3 samples of EFB fiber cement board for every different concentration of NaOH pretreatment and temperature of hot water treatment. The sound absorption testing was obtained by AFD1001 software that has been connected from the impedance tube to computer.

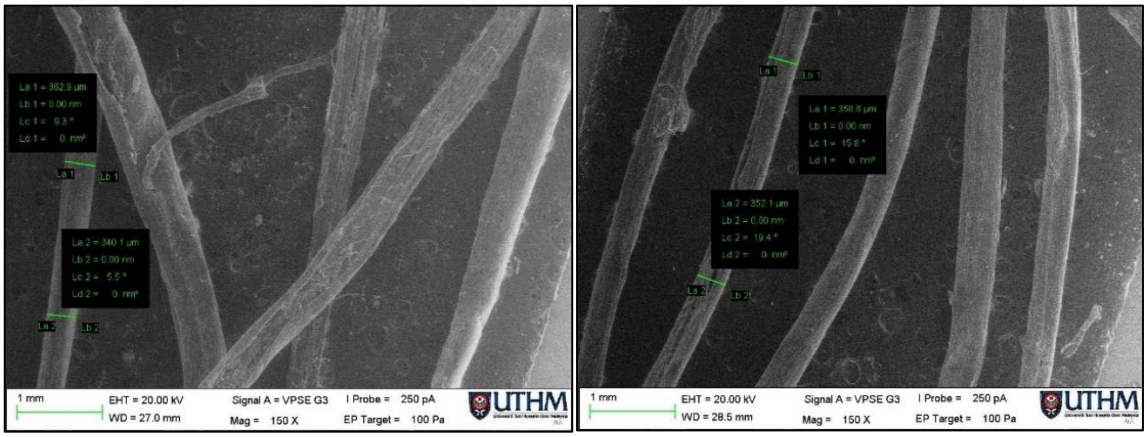
4. Results and Discussion

The pretreatment of sodium hydroxide and hot water had affected the physical diameter and acoustical properties of Empty Fruit Bunch Cement (EFB) cement board. Pretreatment may well be utilized to evacuate the oil and contaminants from EFB fiber. The testing was held at Faculty of Civil Engineering and Built Environment.

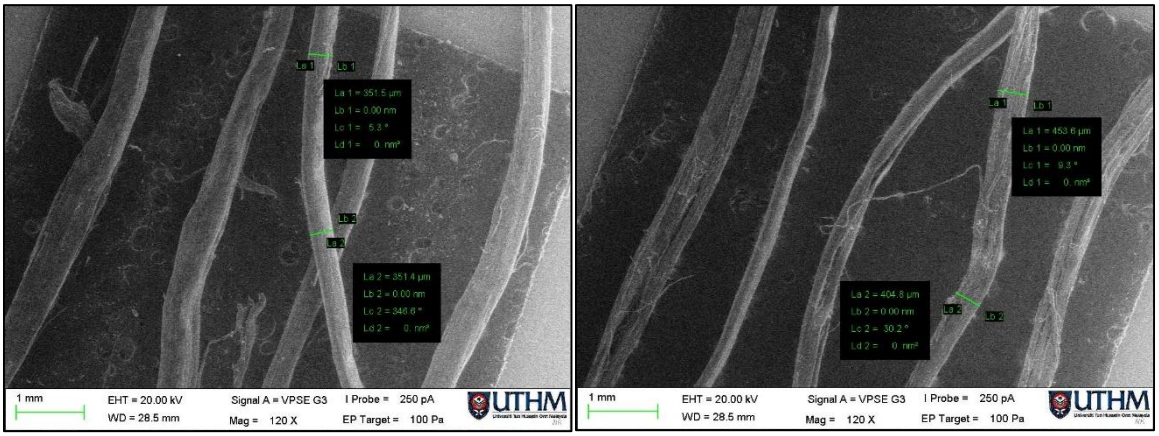
4.1 Physical properties diameter measurement

The EFB fiber image analysis was done with a Scanning Electron Microscope (SEM) which the EFB physical properties of EFB fiber diameter was measured. In accordance with ISO 10534-2:2001, experimental work for sound absorption measurement was carried out using an impedance tube to evaluate the acoustic properties sound absorption of EFB fiber cement board.

As shown in Figure 2 the fiber was the untreated (a) while in (b), (c) and (d) were immersed in NaOH for duration 3 hours. There are 5 strands of fiber for each concentration with 4 different concentrations of NaOH which are 0%, 2%, 4% and 6%.



(a) 0% & 0°C of NaOH fiber diameter (b) 2% of NaOH fiber diameter



(c) 4% of NaOH fiber diameter (d) 6% of NaOH fiber diameter

Figure 2: SEM image of NaOH diameter measurement analysis

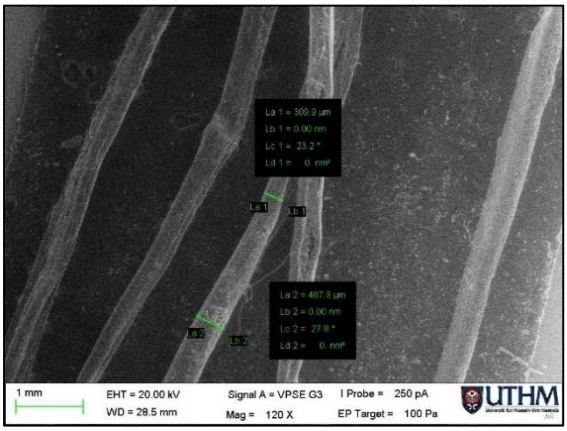
The result in **Table 1** shown that there are 10 data evaluated on 5 random strands of fiber which is to determine the average data of fiber diameter. The average data stated that the untreated diameter of fiber 472.93 μm was thicker than the fiber that have been treated with NaOH 384.31 μm, 407.39 μm and 444.77 μm.

Table 1: Diameter fiber of NaOH pretreatment

NaOH % (SOAKING 3 HOURS)	DIAMETER FIBER (µm)										
	DATA 1	DATA 2	DATA 3	DATA 4	DATA 5	DATA 6	DATA 7	DATA 8	DATA 9	DATA 10	AVERAGE DATA
0%	362.9	340.1	640.9	535.7	503.4	393.3	457.9	504.1	558.1	432.9	472.93
2%	382.1	341.8	358.6	352.1	360.2	396.7	436.7	464.5	372.5	377.9	384.31
4%	437.5	592.5	468.7	529.0	351.5	351.4	337.6	383.9	475.5	520.1	444.77
6%	571.6	586.1	258.6	233.1	350.1	349.6	453.6	404.8	462.3	404.1	407.39

Chand & Fahim [6] stated that Sodium hydroxide (NaOH) is the most often used chemical for bleaching or cleaning the surface of plant fibers, it also alters the fine structure of native cellulose I to cellulose III, resulting in depolymerization and the formation of short length crystallites. It was adequate to clarify that the NaOH pretreatment had effect on the EFB fiber surface and the EFB fiber thinner cause of the erosion on the EFB fiber surface. NaOH promoted both a reduction in fiber diameter and an increase in fiber surface area the most effectively. The EFB fibers were not only pretreatment using NaOH also the analysis of EFB fibers were treatment by soaking in the hot water treatment as in Figure 3 with different temperature such as 50 °C, 60°C and 70 °C degree Celsius as in (a), (b) and (c).

(a) 50°C of water bath fiber diameter (b) 60°C of water bath fiber diameter



(c)70°C of water bath fiber diameter

Figure 3: SEM image of hot water diameter measurement analysis

Table 2 shows the results of 10 data points examined on 5 random strands of fiber to calculate the average data of fiber diameter. According to the average results, the untreated diameter of fiber 472.93 μm was thicker than the fiber treated with hot water 417.46 μm, 420.39 μm, and 428.70 μm. The fiber diameter seems reduce from the untreated fiber which it was caused of defibrillation.

Table 2: Diameter fiber of hot water pretreatment

HOT WATER ◦C (SOAKING 3 HOURS)	DIAMETER FIBER (μm)										
	DATA 1	DATA 2	DATA 3	DATA 4	DATA 5	DATA 6	DATA 7	DATA 8	DATA 9	DATA 10	AVERAGE DATA
0°C	362.9	340.1	640.9	535.7	503.4	393.3	457.9	504.1	558.1	432.9	472.93
50°C	428.2	332.1	436.8	465.9	461.9	467.9	338.5	357.0	422.3	464.0	417.46
60°C	596.8	669.6	277.8	381.2	169.4	205.9	575.1	618.2	374.5	418.5	428.70
70°C	404.1	467.0	450.6	357.4	309.9	487.8	358.2	402.8	520	446.1	420.39

Based on experimented by Santos *et al.*, [7] Nasidi, Ismail & Samsudin [8] fiber defibrillation was produced by treatment with hot water and NaOH. Defibrillation occurred in the treated fiber with hot water as well, albeit the top of the fiber appears to be smoother and less rough than the surface part of the NaOH treated fiber. It is possible to see the effect of hot water treatment; this outcome could be attributed to the elimination of surface elements of the treated fiber, resulting in an exceedingly clean surface with this EFB fiber. Removing surface components may aid in the interfacial interaction between fiber and polymer.

4.2 Sound absorption testing

The impedance tube was made out of a set of test tubes that included a measurement chamber and sample container, two microphone units, a transducer, and an electronic sound generator. For the low frequencies, samples were evaluated with frequency ranges ranging from 0 Hz to 1600 Hz and tube diameters of 100mm. However, for sound absorption coefficient values ranging from 0 to 1, where 0 represents total reflection and 1 represents pure sound absorption.

The analysis data low frequency of sound absorption can be observed as in **Figure 4** the maximum absorption was achieved by 6% of NaOH of pretreatment with 0.586 at the highest frequency 1600Hz. At the earlier range 200Hz to 300Hz the absorption seems to decrease until the negative value but it started to rise from range 300Hz until 1600Hz. The optimum absorption for every concentration such as untreated 0.486 at 1400Hz, for 2%,4% and 6% achieved at highest 1600Hz which are 0.592, 0.528 and 0.586.

As a result, the treatment with the highest concentration of NaOH % attained the highest absorption value. At 1400Hz to 1600Hz, every varied % of NaOH pretreatment had obtained the best absorption. This is because the sound absorption value is affected by the physical properties of the treated EFB fiber. As previously noted, the NaOH pretreatment led the EFB diameter measurement to become thinner as the percentage of NaOH concentration increased.

The higher the concentration of NaOH pretreatment the higher the sound absorption value of EFB fiber cement board. It also can be defined the thinner the diameter of EFB fiber the higher the EFB cement board can absorb sound. [8] stated that the sodium concentration rises, the lignin layers are eliminated, resulting in rougher surfaces on the fiber strands. The sodium concentration increases, significant changes in the strand surfaces occur, changing the morphology of the fiber. It was discovered that a certain quantity of silica bodies was eliminated, resulting in open pores on the surface of the strands.

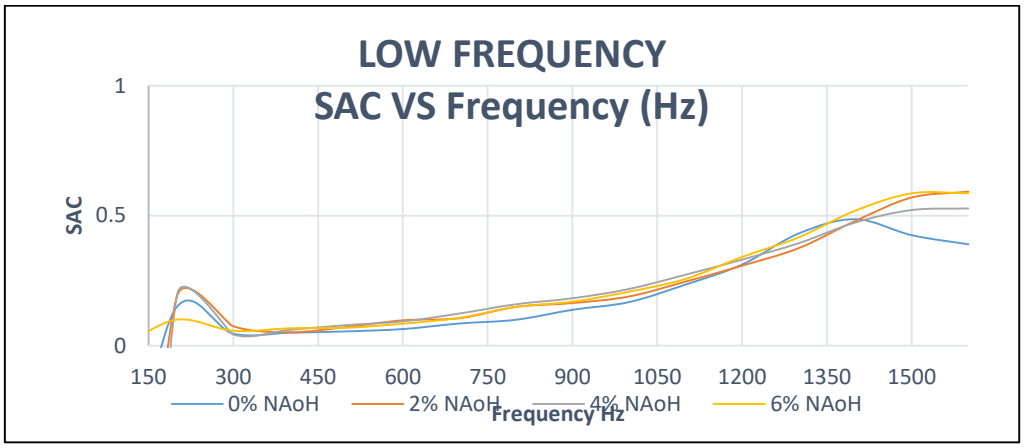


Figure 4: SAC Graph for NaOH pretreatment

According to the graph analysis in **Figure 5**, the optimum sound absorption value was 0.584 at 1600Hz, indicating that the EFB cement board had been treated with hot water treatment at 70°C. The sound absorption decreased from 200Hz to 300Hz, but then began to climb until the greatest frequency, 1600Hz. The optimum value of sound absorption testing was attained with each alternative hot water temperature pretreatment. At 1400 Hz, the untreated fiber cement board reached the best value of 0.486, while the other temperatures of 50°C, 60°C, and 70°C achieved 0.203, 0.239, and 0.584 at the highest frequency of 1600Hz.

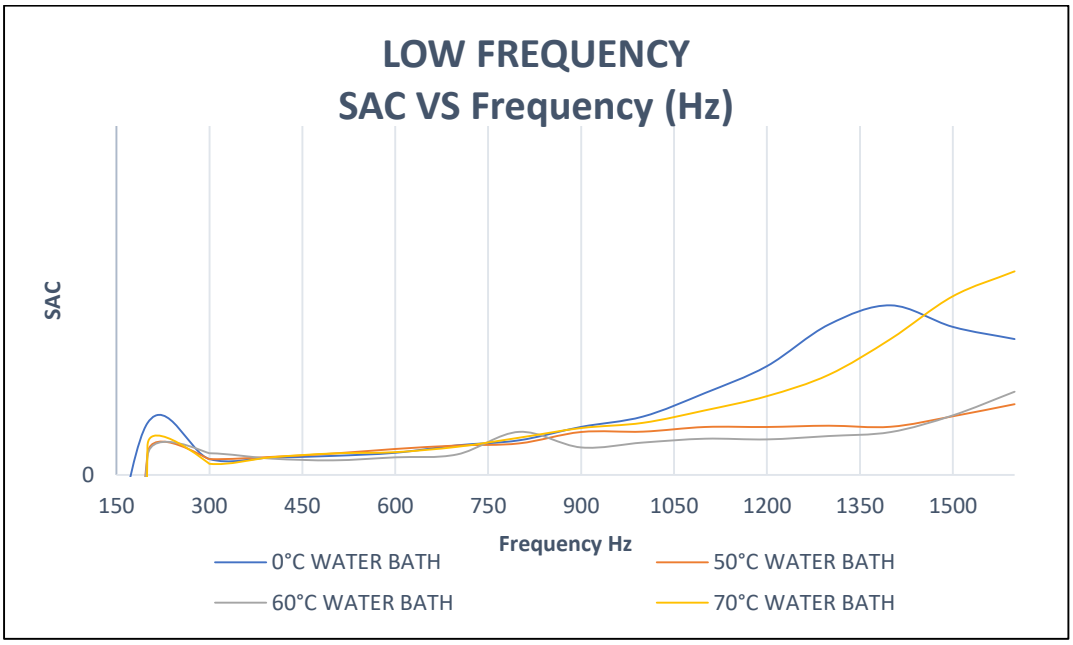


Figure 5: SAC Graph for hot water pretreatment

As a result, the EFB fiber cement board's sound absorption rating was affected by the hot water treatment. 70°C had reached the maximum sound absorption value. Earlier diameter measurements using a scanning electron microscope revealed that the diameter of the EFB fiber shrank as it was treated in hot water. This could be because the EFB fiber cement board's sound absorption was affected by the hot water pretreatment. Experimented by [8] pre-treatment is essential for eliminating impurities, cleaning the fiber surface, and removing a layer of lignin, wax, and excess oils. This process has several

other benefits for the physical properties of a fiber, such as improving bonding, lowering moisture absorption, and modifying the surface of the fiber.

5. Conclusion

Both pretreatments had an effect on the EFB fiber diameter alterations between untreated EFB fiber and pretreated EFB fiber with varied concentrations of NaOH and hot water. The average data of untreated was 472.93μm compared to NaOH pretreatment the thinner diameter was observed 417.46 μm at 50°C while the 2% NaOH was 384.31μm. This compared result can be conclude that NaOH pretreatment was better than hot water pretreatment in reducing fiber diameter. Therefore, the NaOH pretreatment is recommended in treating EFB fiber in order to eliminate the outer layer of the strand. The acoustic testing achieved the highest value sound absorption for NaOH pretreatment was obtained with a 6 % NaOH treated 0.586 at 1600Hz, while another highest value sound absorption for hot water pretreatment was obtained with a 0.584 with a temperature of 70°C at 1600Hz, compared to the highest value sound absorption for untreated 0.486 at 1400 Hz. The higher the concentration NaOH pretreatment had the best sound absorption value obtained. Soaking in 80°C and 90°C for 1 to 3 hours is recommended for future research on the comparison of EFB and Kenaf fibers. Also, the EFB cement board should be replaced with Kenaf fiber cement board.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Timber Fabrication Laboratory and Acoustic Laboratory, Universiti Tun Hussein Onn Malaysia for its support.

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