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Effect of Hot Water Pretreatment on the Strength of the Fibre and Heat Insulation Properties

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Abstract: Recently, the demand for palm oil from local and foreign countries are increasing. Due to the increase in demand, the production of wastes especially from empty fruit bunch has also increased. The main problem in the production of cement boards is the bonding of cement and the fibers to each other. This research aims to demonstrate the use of natural fibres (empty fruit bunch) in the production of fibre cement boards. The effects of different hot water soaking temperatures on the fibre performance according to different strand-diameter-range were determined by tensile strength and the treated fibre are used in the cement board fibre composite fabrication and tested for its thermal conductivity. Temperatures used during pretreatment were 50ºC, 60ºC, 70ºC, 80ºC and 90ºC with untreated fibre as a control sample and soaking durations was 2 hours. Cement board produced at a 3: 1 (cement: fiber) ratio, with a board size of 150 mm x 150 mm x 12 mm for thermal testing. To investigate the effects of pre-treatment to the strand durability, tensile strength testing is done using UTM Instron Machine. Results on thermal conductivity showed that higher temperature used during fibre immersion affects the speed of heat penetrates into the EFB-CB material with temperatures of 80ºC and 90ºC are found to be the optimum temperatures with good thermal resistivity. As for the tensile strength result, it was observed that diameter and pretreatment temperature greatly affect the strength of the fiber. The strongest strand is the one with diameter range between 15 mm to 20 mm treated using temperatures of 60°C achieved 869 MPa. As the strand goes thicker range, the fibre are found to be weaker to restrain higher tensile load. Of all, 60°C to 70ºC are found to be the optimum temperatures for hot water treatment that result in higher tensile strength. Hence, it is possible to conclude that hot water pretreatment has a substantial impact on the thermal conductivity of EFB cement board and the tensile strength of a single fibre strand.

Keywords: Empty Fruit Bunch (EFB), Cement Board, Hot Water, Thermal Transmission

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1. Introduction

Recently, the demand for palm oil from local and foreign countries are increasing. Due to the increase in demand, the production of wastes especially from empty fruit bunch has also increased. An increase in fresh fruit bunch to 99.85 million tons compared to 2011 of 97.38 million tons and due to high production of oil palm production of empty fruit bunch automatically increased [1]. A total of 23.8% of tons of empty fruit bunch resulted from the total amount of fresh fruit bunch. From the data obtained a sum of 23.2 million tons of empty fruit bunch were produced per years [1]. There are many ways to reduce empty fruit bunch (EFB) wastes. Utilization of EFB in cement board production could be one of the ways to reduce the growing surplus of EFB in our country. Fibers and also cement are composite materials that will usually be used to produce cement board and may contain additives. The main materials that need to be there to produce cement board are cement, water and fibers. Fiber cement board is one of the wells -known products with the method used for internal/external wall use and can also be used for roofing. Natural fibre can be as a composite material and the public can accept because of the price is cheaper and sustainable. The uses of wood can slow down carbon dioxide gas, CO2 [2]. For over a decade the uses of wood as a natural fibre [3]. There will be problems to unite or stick cement and fiber because in the fiber there is hemicellulose, sugar, tannin, lignin and hemicellulose and this will cause cement hydration [4]. Therefore, this research will focus on knowing the most suitable method for pre-treatment for EFB fibre to give the optimum performance of cement board. This research will also look for the advantages of a cement board using hot water temperature which is 50ºC, 60ºC, 70ºC, 80ºC, 90ºC of pre-treatment to improve mechanical properties.

2. Literature Review

Cement board is a mixture of cement and reinforcing fibers that is commonly utilized as a tile backing board that is molded into sheets of different thickness. Cement board is also known as building material which can be used as an interior surface and also roofing material [5]. Usually cement board not easily broken with the dampness or leakage appearance, cement board has a higher long-term stability than paper faced-gypsum core goods. Cement board can retain a lot of moisture and can dries quickly but cannot directly faced water [6]. Fiber cement board are subject to a variety of natural conditions, including humidity, significant temperature swings and temperature include via a temperature of 0oC in a 24-hour period [7]. Furthermore, fiber-cement boards are exposed to extreme loads, including high heat caused by fires and the lateral force produced by impact. For this research focuses on using hot water temperature for initial pre-treatment. The temperatures used are untreated EFB, 50oC, 60oC, 70oC, 80oC and 90oC. The fiber will be soaked for 2 hours using the set temperature to remove any dirt or liquid contained in the fiber such as cellulose, hemicellulose, lignin and others.

Furthermore, fiber-cement boards are exposed to extreme loads, including high heat caused by fires and the lateral force produced by impact. Ventilated exterior cladding, overhang shields, and interior divider cladding are all made with these boards [8]. The addition of 10% agricultural waste products such as bamboo, coconut fibres, sugar-cane dregs, and rice husks to cement matrix resulted in the production of cement fibre boards that can be used as construction panel material, according to the researchers. Empty Fruit Brunch is one of the most popular and accessible fibres. The increased of palm oil production has resulted in environmental issues as well as solid waste in the form of empty fruit bunches (EFB) from the oil palm industry. Therefore, EFB has been reused in many building material products such as cement board.

Figure 1: Fibre Cement Board

3. Materials and Method

In this study material used were fibre, cement and water. For pre-treatment process, used hot water temperature using water bath machine which is room temperature, 50℃, 60℃, 70℃, 80℃, 90℃ to remove oil, sugar and other in the EFB fiber. The used of temperature range from 50°C, 60°C, 70°C, 80°C and 90°C in the case of hot water, a temperature of 90°C was exclusively applied to EFB with particle sizes ranging from 5 to 8cm, whereas EFB with particle sizes ranging from 0.149mm to 4mm were water washed at a temperature ranging from 25 to 55°C [9]. No chemicals used in this research. The ratio used was 3:1. for all sample. Because of the amount of cement and wood particles present, increasing the mixing ratio and board density affected the thickness of the board. The board with 1300 kg/m3 and a 1:3 mixing ratio had the lowest thickness swelling value, whereas the board with 1200 kg/m3 and a 1:2 mixing ratio had the highest thickness swelling value after 24 hours of cold water immersion. This could be due to differences in the density of the boards created [11]. Size of cement board was 350 mm x 350 mm x 12 mm for thermal conductivity testing as illustrated by Figure 2. The weight of cement, water and fibre were 1433. 75 g, 716.63 g and 477.75 g respectively.

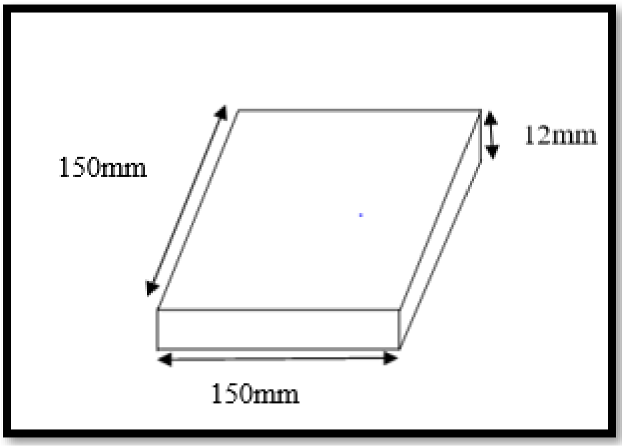

Figure 2: Size of cement board for Thermal Conductivity

3.1 Cement Board Fabrication Process

The process for making cement board is very complicated and requires high precision to produce quality panels. The weight for fibre, water, cement was 477.75 g, 716.63, and 1433.75g respectively. The ratio was 3:1 and size for a single cement board was 350 mm x 350 mm x 12mm. For this study, temperature of hot water used were 50ºC, 60ºC, 70ºC, 80ºC and 90ºC then EFB were dried under the sun for 3 days and put in the oven for 24 hours which is1 days for 100ºC.The process of mixing between empty fruit brunch fiber (EFB), cement and water using a mixer machine provided by Wood Fabrication in UTHM. When the mixing process was completed, the material put into a wooden mold with a mold size of 350 mm x 350 mm. The material that has been mixed were spreading and flattening by hand. Then placed a plate on the mold to facilitate the compact process. After forming process, it were clamped with a steel plate of 350 mm x 350 mm before starting compression. This is to prevent any movement of the test material. The steel mold placed on a compression machine until the sample reaches the desired thickness. For the process using clamps, the samples were clamped for up to 2 days which is for 24 hours before being removed from the tool in 28 days and proceeding to the curing process.

3.2 Testing of Thermal Conductivity on Cement Board and Tensile Strength

The performance of cement board and fibre was determined by conducting several tests such as Thermal Conductivity and Tensile Strength for a single fibre.

Table 1: Minimum required for specified tesing for Thermal conductivity and Tensile Strength

Properties	Test method	Requirement
Thermal conductivity	MS 934:1986	0.1 W/mK and 0.7 W/mK
Tensile strength for a single fibre	ASTM standard (ASTM D3379)	NA

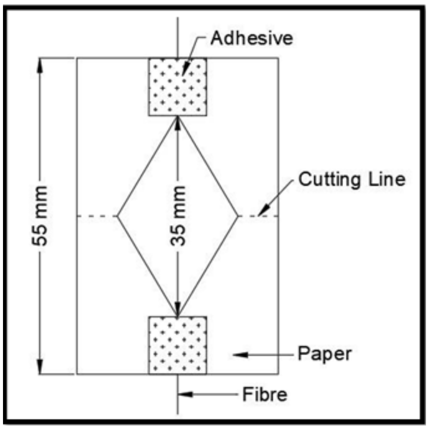

Figure 3: Schematic sketch of the experimental setup for tensile strength test

4. Results and Discussion

4.1 Results

The table below show result of thermal conductivity based on pretreatment temperature used for empty fruit bunches.

Table 2: Thermal Conductivity of EFBCB based on pretreatment temperatures

Temperature, ◦C	Thermal conductivity, W/ mK
Untreated Efb	0.0097 W/mK
50◦C	0.0053 W/mK
60◦C	0.0030 W/mK
70◦C	0.0016 W/mK
80◦C	0.0002 W/mK
90◦C	0.00016 W/mK

Based on the results obtained, pretreatment will affect the thermal conductivity of a cement board. According to the standard MS 934:1986, the set range for thermal conductivity is between 0.1 W/mK and 0.7 W/mK for densities values of 600-1600 kg/m^3 and it will reduce by decreasing densities. Furthermore, the moisture percentage in concrete is another factor that has a considerable impact on thermal conductivity.

The table below show the result for tensile strength with different diameter range based on the temperature treatment used.

Table 3: Tensile strength for strand with different diameter range

Temperature (°C)	15 to 20 (mm) Tensile Strength (MPa)	25 to 30 (mm) Tensile Strength (MPa)	30 to 35 (mm) Tensile Strength (MPa)
untreated	NA	63	27.5
50	103.3	103.3	78.5
60	859	212	65.1
70	480.7	144.3	96.6
80	281.8	106.5	46.5
90	NA	96.1	38

Tensile strength is a test to determine the strength of a fiber. 5 strands of fiber were selected for each temperature selected to determine the strength of the fiber. Because celululose is the major element of EFB, the tensile strength of the fibres is primarily determined by the fibrillary structure, microfibrillar angle, and celululose content.

4.2 Thermal conductivity

Based on the Figure 4 above shows the results for thermal conductivity obtained for each temperature. It can be concluded that for untreated EFB has high thermal conductivity which is 0.0097 W/mK compared to other temperatures and at 90°C the lowest thermal conductivity value is 0.00016 W/mK While it can be concluded that the higher the temperature the lower the thermal conductivity of a cement board. At a temperature of 80°C which is a thermal value of 0.0002 W/ mK can see the thermal conductivity decreases compared to a temperature of 50°C which is 0.0053 W/mK. So it can be concluded that the treatment with hot water is very good to produce quality fiber because it produces low thermal conductivity while giving the cement board a good insulation for use as a wall. This is because the moisture content in the fiber makes the thermal conductivity flow faster. For untreated EFB there is oil or impurities that are not treated as well as produce water accumulation in the fiber causing increased thermal conductivity. The higher the temperature used to treat the fiber, the less oil or dirt in the fiber which causes the heat flow to slow down. Thermal conductivity is also increased when the air in the pores has been partially replaced by water or moisture, because water has a conductivity around 25 times that of air [11].

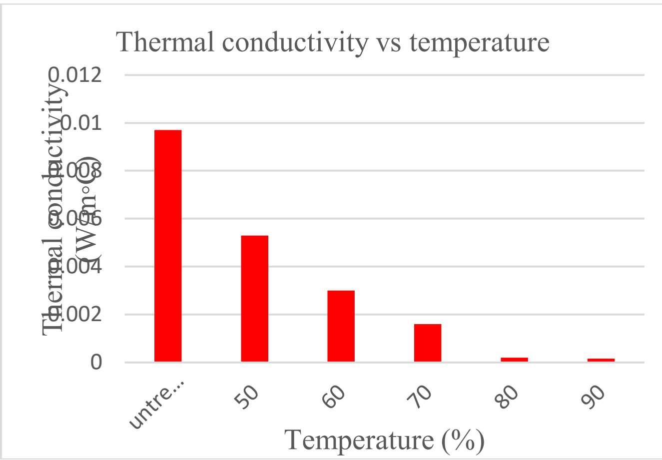

Figure 4: The result of thermal conductivity

4.3 Tensile Strength

The Figure 5 shows the diameter for each sample which is 15 mm-20 mm, 25 mm-30 mm and 30-35 mm. Based on the data obtained after tensile strength testing found that diameter affects the strength for the fiber. The data shows that the smaller the fiber diameter, the stronger the tensile strength. . The tensile strength of a fibre is proportional to its diameter, with the strength increasing as the diameter decreases [12]. For diameters of 15 mm-20 mm the tensile strength is higher than for diameters of 25 mm-30 mm and 30 mm-35 mm. In short, a large diameter will produce a small strength compared to a small diameter. In addition, pretreatment using different water temperatures also plays an important role for fiber strength. Data show that for temperatures of 50°C and 60°C increase the strength which can see the value of tensile strength at this temperature are higher than other concentrations. For temperatures of 80°C and 90°C will cause the fiber strength to decrease. It can be concluded that the best temperature for pretreatment is 50°C, 60°C, 70°C. While the temperature of 80°C and 90°C°C is not suitable for use because it can reduce the strength of the fiber. So, the pretreatment at temperature of 50°C, 60°C, 70°C, is suitable to increase the tensile strength of fibers.

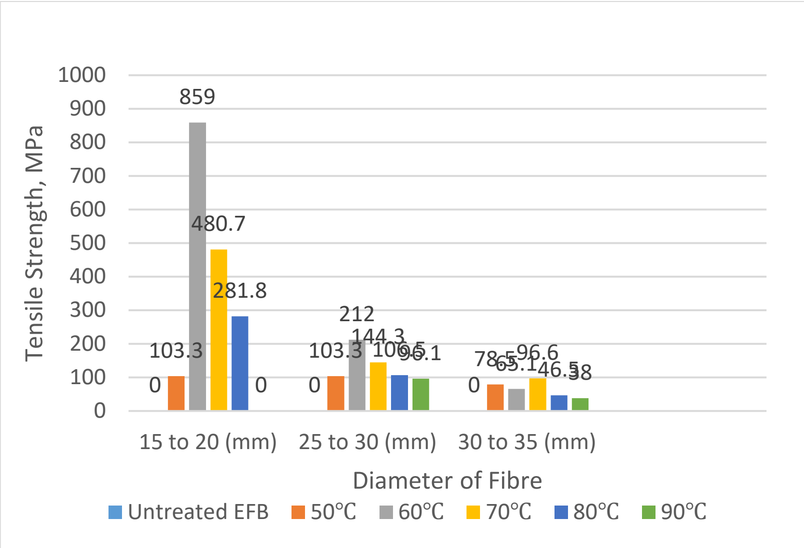

Figure 5: Comparison of tensile strength

5. Conclusion

The first objective is to examine the effect of different Hot Water Soaking temperatures based on different strand diameter range on the tensile strength of EFB fibre. and on the tensile strength of EFB fiber. As stated in that immersion in hot water will affect the strength of the fiber. Based on the graphs in figure 4 the diameter of 15 to 20 mm, 25 to 30 mm and 30 to 35 mm shows that small diameter will produce strong strength compared to large diameter. Temperature also plays an important role in adding strength based on the graph shown above. So, for the first objective is achieved. For second objective which is to determine and compare the thermal conductivity of EFB cement board based on different Hot Water soaking temperature. Based on the graph shown in Figure 5 shows that high temperature greatly affects the thermal conductivity. The data stated that for untreated EFB has high thermal conductivity which is 0.0097 W/mK compared to other temperatures and at 90°C the lowest thermal conductivity value is 0.00016 W/mK. It can be concluded that the treatment with hot water is very good to produce quality fiber because it produces low thermal conductivity while giving the cement board a good insulation for use as a wall. For this experiment does not reach the standard MS 934: 1986 that is the set range for thermal conductivity is between 0.1 W/mK and 0.7 W/mK for dry densities values of 600-1600 kg/m³ but the value obtained is between 0.00016W /mK to 0.0097 W/mK. However, the conductivity values are logical based on the data obtained. One of the factors is because of the size of the cement board for the thermal conductivity test. The size used during testing is 150 mm x 150 mm and the size that should be used is 300 mm x 300 mm according to the prescribed procedure [13]. This is due to the lack of time and also the equipment in the laboratory for the production of limited cement board. The cement was cut into 4 parts to a smaller size. The second objective is achieved. Hopefully in the future, the study will be continued and expanded in the long term, considering one of most suitable techniques, as well as the most recent technology, to produce cement boards of the best quality, expense, and standard compliance.

This research is only a small part of the extensive research that must be carried out in order to achieve the goal of improving oil palm EFB fibre cement board to the point where it will be a widely known request for cement board one day. So, after the end of the report and analysis, a few suggestions for further research and experiment on the effect of cement-fibre ratio on mechanical properties are made. The first point to mention is doing one of the available empty fruit bunch fibre modification procedures, like soaking the fibre in hot water. The EFB fibre must be soaked approximately 2 hours in hot water at a temperature of 50°C, 60°C, or 70°C. The goal of the heat treatments is to minimize the incompatibilities of cement and natural fibre while increasing overall the fiber's strength. Because there is no need to invest in NaOH, the cost can also be reduced.

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