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The Hydration Rate of EFB-Cement Mixture Based on Different Sodium Hydroxide Concentrations

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Abstract: Oil Palm Empty Bunch Fiber (EFB) is one of the major waste materials in Malaysia. EFB produce after fresh fruit bunches are process to produce palm oil. Due to the remnantsof empty fruit bunches produce too much, waste management problem will occur. Therefore, this study has been made to avoid this problem. EFB waste can be processinto fibers that contribute durable large -scale waste and make it desirable for use in cement-base products. However, the inclusion of hemicellulose, lignin, and extractives (oil, sugar, and starch) affects EFB fiber output and induces incompatibility between EFB fiber and cement. Hence, this study aims to determine the appropriate proportionof sodium hydroxide (NaOH) treatment for EFB fiber in order to improve cement compatibility. The main objectives of this research are to determine the hydration rate for EFB-cement mixture based on different NaOH concentration, and to evaluate the tensile strength of physical properties of empty fruit bunch fiber based on NaOH concentration. The main materials use in this study are EFB, cement and water. These materials mix together to obtain an experimental sample. Then, data logger and thermal copper were used to measure the temperature release by mixture cement and fiber. In this study, NaOH concentrations of 0%, 1%, 2%, 3%, 4%, and 5% are used to chemically process EFB fibers for surface morphology observation and hydration rate monitoring. Although the increasing NaOH concentration, the hydration rate on the EFB fiber-cement mixture increases dramatically and affects the physical properties of the sample. In conclusion, the hydration temperature during the pretreatment of EFB fibers is due to the concentration of NaOH, which improves the compatibility of EFB fibers with cement.

Keywords: EFB-cement mixture, NaOH, Hydration Rate, Surface Morphology, Tensile Strength

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1. Introduction

Natural fiber has recently gotten a lot of press for its potential use as a substitutematerial in a variety of industrial applications. Natural fibers are generally employed in composite materials to increase physical and mechanical qualities. Depending on the kind of fiber and its qualities, however, the right fiber should be utilized for a givenpurpose. Hemicellulose, lignin, and extractives (oil, sugar, and starch) are known to be present in EFB residues, which impair the performance of EFB fibers and induce cement incompatibility [1]. Due to the fundamental technical features offracture resistance, ductility, and energy absorption that improve infrastructure development, fiber reinforcing of cement materials remains an appealing and creativetechnique.

In addition, natural fibers cannot be utilized directly owing to a mismatch between the fiber matrix and the cement, as well as the existence of oil residues that obstruct the binding agent's penetration and influence the EFB end product's qualities.However, investigations on the handling of EFB fibers when employed as a replacement material in cement composites have been discovered. EFB fibers used with cement have been shown to increase the performance and quality of bio-composite materials in studies. EFB fibers, on the other hand, are naturally occurring composites made up of stiff and crystalline cellulose microfibrils embedded in an amorphous hemicellulose and lignin matrix [2].

The aim of this research was to determine the compatibility of Empty Fruit Bunch Cement Board (EFB-CB) in order to enhance its qualities. The chemical incompatibility of fiber and cement, which impedes cement organization and hardening because the fibers contain residual oils and sugars that impede cement arrangement and hydration, is the fundamental barrierto the fabrication of EFB fiber cement composites [3]. Natural fibre pre-treatment and cement accelerators have shown to be the most successful strategies.

2. Literature Review

2.1 Hydration Rate between Cement and Natural Fiber

Natural fibres known as lignocellulosic fibres are currently being explored as an ecologically friendly alternative to synthetic fibres that are more costly, nonrecyclable, and energy-intensive. The main issue with these lignocellulosic fibres is that they have inferior mechanical characteristics when compared to synthetic fibres. Specific chemical treatments, on the other hand, can increase the mechanical characteristics of these fibres [4]. Chemical additives also have a role in cement hydration by reducing the time it takes for the inhibitory action of the chemicals in the lignocellulosic material to take effect. Calcium chloride (CaCl2) and magnesium chloride (MgCl2) have long been employed as accelerators. Water-soluble extractives, sugars, starches, and other amorphous polymers, which play a major role in inhibiting cement hydration, are generally removed by hot water treatment. The extractive concentration of coir fibre is relatively high [5]. When extractives are present, impermeable hydrates develop around unhydrated cement grains [6].

The relationship between the change in surface morphology and the rate of EFB fibre-cement hydration may be determined using a compatibility test to estimate the quantity of NaOH that may be used for EFB fibre treatment. To determine the effect of natural fibers treated with NaOH, previous researchers have performed compatibility tests with different concentrations on the hydration rate of cement. However, the compatibility of cement with natural fibre is still a major challenge in the production of cement bonded fiberboards [1]. The hydration of the EFB-cement combination is inhibited by large quantities of silica bodies adhering to the fibre surface, as demonstrated on untreated fibre. As a result, processing of EFB fibre eliminates a considerable proportion of silica bodies and improves the fibre's workability [7].

3. Materials and Methods

Proper methodologies based on past studies should be employed to accomplish the study objectives. In this chapter, the methods used to test the hydration rate of the EFB-cement mixture base on different concentrations percentages of sodium hydroxide forfibre treatment are explain. The main materials use in this study are EFB, cement, water and Sodium Hydroxide (NaOH). These materials are mix together to obtain an experimental sample. The purpose of this experiment was to see how EFB fibre shapeaffects the physical properties of cement boards. A clear overview of the project is necessary because proper planning can help statistical forecasting of prospective issuesthat could affect the final results. Figure 1 shows the research methodology flowchartof this study.

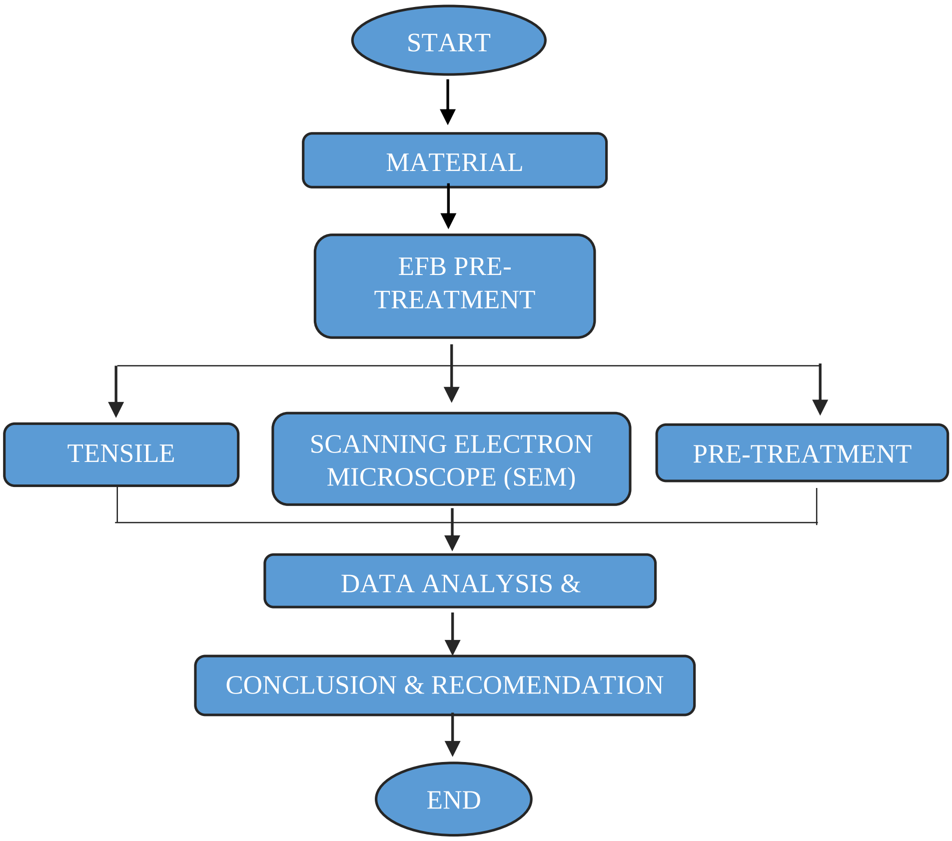


Figure 1: Methodology Flow Chart

3.2 EFB Fibre Tensile Strength

A single fibre tensile tests have been performed in previous research [8] it was conducted based on the ASTM standard (ASTM D3379). For the measurement of tensile strength, this test technique comprises the preparation, mounting, and testing of single fibres (obtained from an EFB fibre bundle). It also aims to test the workability of tensile strength of untreated EFB fibre treated with various NaOH concentrations (0%, 1%, 2%, 3%, 4%, and 5%).

According to Dullah [7] the procedures for determining single fibre tensile strength are described below;

i. For specimen mounting, a mounting tab may employ. With one end tape to the tab, centre the test specimen over the tab following the printed pattern.
ii. Tape the other end of the test specimen to the tab, being careful not to twist the fibres. It has been discovered that when torsional strain increases, the tensile strength of fibres drops dramatically.
iii. Apply a little quantity of appropriate adhesive (epoxy) to the markings on the mounting tab that specify the gauge length and carefully adhere the fibre to it .
iv. As shown in figure 2, the mounting tabs are grasped or linked to the load train, allowing the test specimen to be positioned axially along the test machine's line of action.

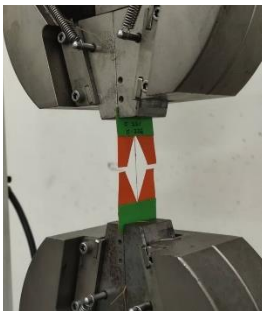


Figure 2: Position of the EFB fibre sample for the tensile test

3.3 Surface Morphology Examination

The surface morphology of EFB fibre was investigated using a scanning electron microscope (SEM) in this research. Untreated and treated EFB fibre, as well as EFB-CB samples, had different surface morphologies. The EFB fibre utilised in this physical experiment is made up of untreated EFB and EFB that has been treated with NaOH at concentrations ranging from 1% to 5%. The SEM examinations was carried out at magnifications ranging from 200 to 500 to get a clearer picture of the surface characteristics and to have a deeper knowledge of the distinct effects at various NaOH concentrations. Ibrahim [9] discovered that using a SEM picture of 200 to 500 magnification to reach a judgement based on changes in EFB fibre surface morphology owing to variation treatment effect is suitable.

3.4 Hydration Test

This test is important because it can indicate the quantity of NaOH that use to treat EFB fibres, as well as the relationship between surface morphology and the rate of EFB fibre-cement hydration. The main material for these studies is empty fruit bunches (EFB), sodium hydroxide and cement. These materials mixed together to obtain an experimental sample. Guided by [5], this is the procedure of hydration rate test.

i. The EFB screened to obtained fine particles that are passing 30 mesh and retained to 80-mesh screener.
ii. Twenty grams (20 g) of EFB particle (retained on 80 mesh) are thoroughly mix with 250 g OPC in the sealable polyethylene bag. Then mixed with 114 mL of water and the mixture evenly stirrer for 2 minutes.
iii. Immediately after well blending the mixture, temperature thermocouple (type T) was tape on the outside of the sample bag.
iv. To ensure the temperature release by mixture completely detect by thermocouple, the bag containing mixture was folding neatly around it. The bag then place inside polystyrene cup and properly seal inside a thermos flask.

v. 9 thermocouples have been connected to the data logger (Midi Logger Graphtec GL220) to record the temperature for each sample cases throughout the process.

vi. The experiments are conduct in ambient temperature (27 ±2°C) and the data measured for 24 hours.

3.5 Summary

This chapter describes the experimental method. The experiment for the hydration rate of EFB-cement mixture based on different sodium hydroxide concentrations was conducted is Hydration rate, tensile strength and surface morphology. A clearoverview of the project is necessary because proper planning can help statistical forecasting of prospective issues that could affect the final results. The purpose of thisexperiment was to see how EFB fibre shape affects the physical properties of cement boards.

4. Results and Discussion

This chapter will discuss the results of this study. In essence, one of the objectives of the study is to determine the hydration rate for EFB-cement mixture based on different NaOH concentration. Then the second objective is to evaluate the tensile strength of physical properties of empty fruit bunch fibre based on NaOH concentration.. The effects of Sodium Hydroxide (NaOH) pre-treatment on hydration rate, surface morphological examination, tensile properties, and chemical composition of Empty Fruit Bunch (EFB) fibre were explored. The concentrations of NaOH used were based on high concentrations which is 1%, 2%, 3%, 4%, 5%.

4.1 Hydration rate of cement mixed EFB fibre pre-treated with NaOH

In cement-bonded fibreboard manufacture, natural fibre to cement compatibility is still a serious issue. The hydration temperature of cement composites is dramatically reduced when a particular proportion of natural fibre is added. To examine the temperature change of the combined material, the hydration rates of plain cement and cement-EFB fibre were observed for 24 hours.

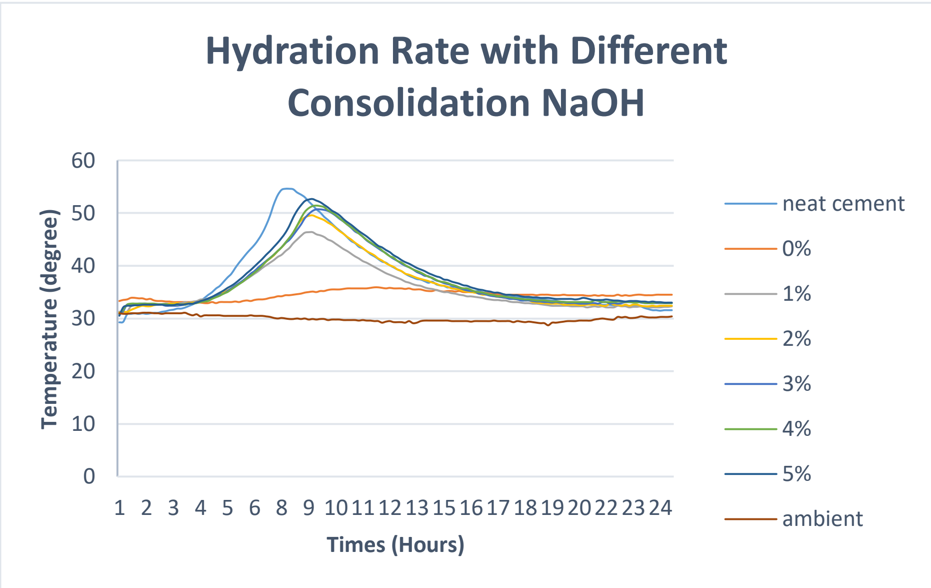


Figure 3(a): Hydration rate of cement mixed EFB fibre with different consolidation NaOH

After 8.5 hours, the temperature of plain cement reached its maximum hydration temperature of 54.6°C, as shown in Figure 3(a). The temperature of untreated fibre combined with cement, on the other hand increased for the first 3 hours to 31.1°C, then steadily decreased for the remaining time to 28.7°C. Due to the presence of natural extractives in EFB fibre, it is clear that it cannot be utilised simply as the primary material for cement-bonded fiberboard.

For the cement combined with EFB fibre that was treated with various concentrations of Sodium Hydroxide (NaOH), an increase in hydration temperature was obtained. As demonstrated in Figure 3(a), a rise in temperature is proportional to the quantity of NaOH. The hydration temperature increased with the rise in NaOH concentrations during the fibre pre-treatment procedure according to the experimental results. After 9 hours, the highest temperature (Tmax) of EFB fibre treated with 1% NaOH was 46.4°C. Between 8 and 9 hours, 2% NaOH produced a maximum temperature of 49.6°C. After 9 hours, the 3 percent maximum temperaturereaches 50.7°C. The highest temperature after 9 hours for 4 percent NaOH is 51.4°C.Finally, after 9 hours of treatment with 5% NaOH, EFB fibre reached 52.7°C. The temperature of hydration of the EFB-cement mixture rises as the concentration of NaOH increases. According to [9] pointed out, eliminating lignin and hemicellulose increased the fibre matrix interaction, resulting in greater fibre integration.

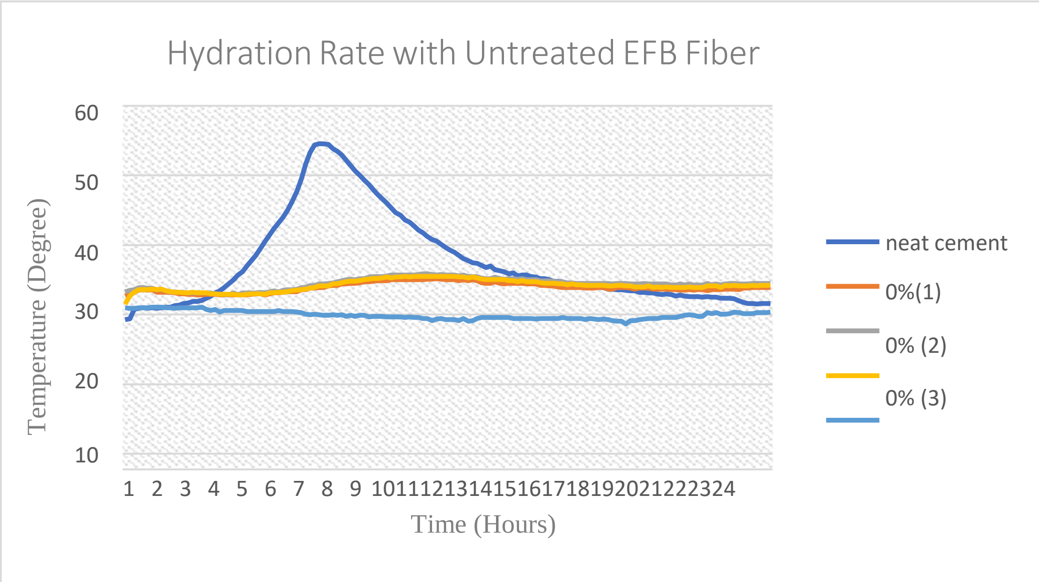
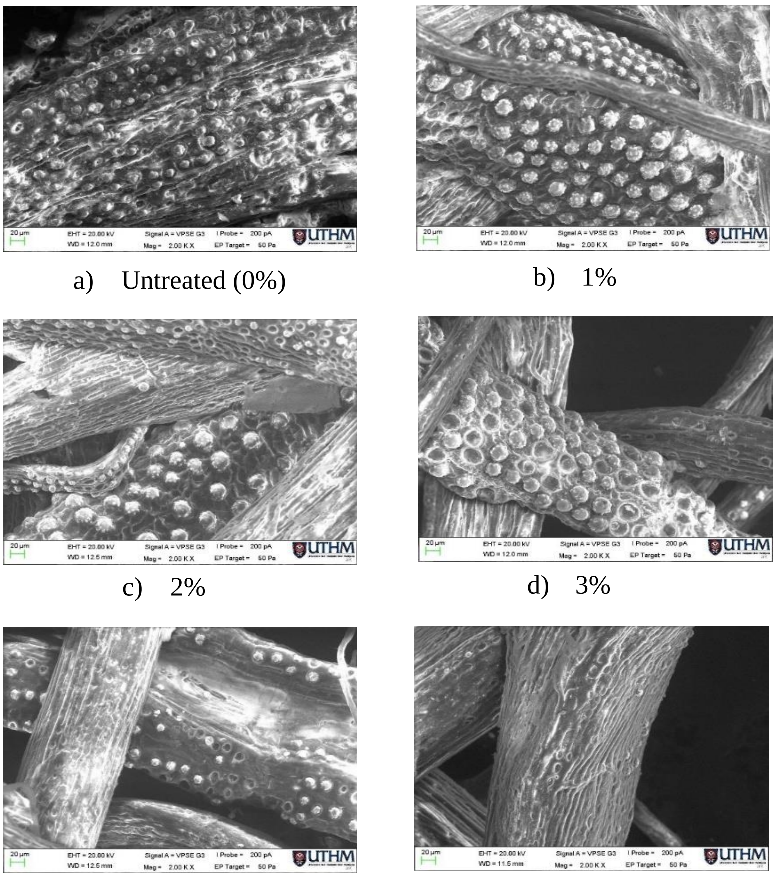


Figure 3(b): Hydration Rate with Untreated EFB Fiber

While, figure 3(b) shows that the temperature did not rise throughout the cement setting process since all of the untreated EFB fibre was present. The degree of temperature suppression may be used to quantify the retarding impact of EFB fibre on the cement setting process. The hydration temperature for untreated natural fibre claim that increased hemicellulose and lignin content on untreated natural fibre might slow down the pace of EFB-cement hydration temperature.

4.2 The Effect of EFB on Physical Properties (SEM)

The scanning electron microscope (SEM) is a kind of electron microscope that creates pictures of material by scanning it with a focused stream of electrons. It's a great way to look at the surface morphology of fibre composites. The morphological alterations that occurred following the fibre treatment were investigated in this research. The change in the surface morphology of EFB fibre before and after pre-treatment was observed using scanning electron microscopy (SEM) imaging at different magnifications ranging from 200x to 500x.



a) Untreated (0%)

b) 1%

c) 2%

d) 3%

e) 4%

f) 5%

Figure 4: Scanning Electron Microscope (SEM) image for EFB fibre untreated (0%) and treated NaOH 1% to 5% at 200x Magnification

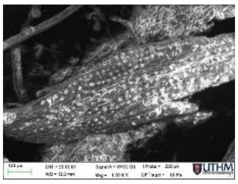
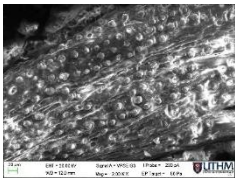
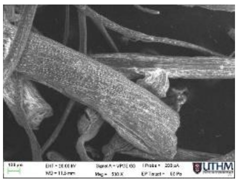
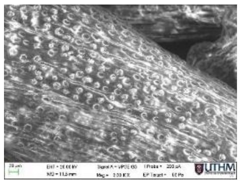
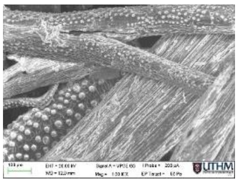
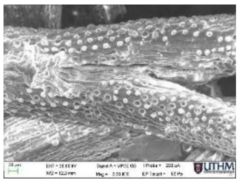
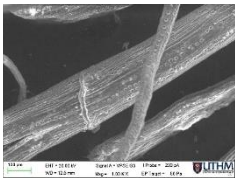
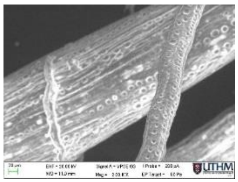
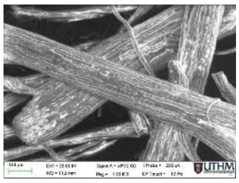
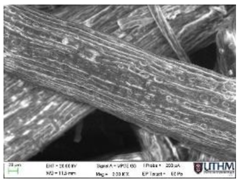
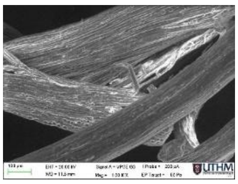
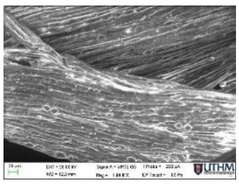
Figure 4(a) shows that the untreated fibre strand has silica bodies embedded in it. They attached to circular craters on the EFB fibre surface and dispersed uniformly, with a 10-14 µm rounded, spiky size. [10] identified a large number of silica bodies on EFB fibre strands, while [11] detected silica bodies with a rounded, spiky size distribution of 10-15 µm on EFB fibre strands. Figure 4(b) shows that in the OPEFB treated with NaOH, the presence of silica bodies was decreased. The number of silica bodies on EFB fibre strandsreduced as the concentration of NaOH employed increased, according to [1]. Figures 4(b) to 4(f) show a scanning electron microscopy (SEM) image of an Oil Palm Empty Fruit Bunch (OPEFB) treated with Sodium Hydroxide (NaOH) concentrationsranging from 1% to 5%.

The appearance of the silica body was not significantly different in OPEFB treated with 1% NaOH, as shown in figure 4(b). However, at the 2% NaOH concentration in figure 4(c), a portion of the silica body was removed from theEFB strand, resulting in crater-shaped holes. Figure 4(d) show the silica body was eliminated from the EFB fibre strand at a concentration of 3 percent NaOH, but itwas not completely dissolved, leaving residues on the strand. When NaOH concentrations reach 4%, the presence of silica body is eliminated and disintegrated (Figure 4(e)). The roughness and irregularity of the surface of EFB fibre strands. The roughness and irregularity of the surface of EFB fibre strands seems to be growing. The crater-shaped hole in the EFB fibre strand started to degrade and distort at a 5% NaOH concentration, as seen in Figure 4(f)

4.3 The Effect of Hydration Rate with Cement-EFB Mixture

The effects of various NaOH concentrations on hydration and surface morphology are listed in Table 1. To understand the influence on EFB-CB, several percentages of NaOH pre-treatment were chosen: 1%, 2%, 3%, 4%, and 5%. According to the similarity of the surface morphological inspection and the maximum temperature (Tmax) of hydration, the kinds of pre-treatment were separated into two categories which is untreated (UT) and treated with NaOH concentration (Tmax).

Table 1: The effects of different NaOH concentrations on hydration and surface morphology are tabulated

NaOH	T_{max}	t_{max}	Surface Morphology (SEM)	
			500x Mag	200x Mag
Untreated (0%)	35.9℃	12h		
1%	46.4℃	9 hours		
2%	49.6℃	9 hours		
3%	50.7℃	9 hours		
4%	51.4℃	9 hours		
5%	52.7℃	9 hours		

A higher NaOH concentration reduces the number of silica bodies on the EFB fibre surface. The EFB fibre treated with NaOH at 1%, 2%, 3%, 4%, and 5% obtained maximum temperatures (Tmax) of 46.4°C, 49.6°C, 50.7°C, 51.4°C, and 52.7°C, respectively, ata time taken (tmax) of 9 hours. The time taken (tmax) was recorded is to know the duration maximum temperature of hydration can be reached. As a result, as illustrated on untreated fibre, huge volumes of silica bodies adhered to the fibre surface hinder the hydration of the EFB-cement combination. As a result, pretreatment of EFB fibreeliminates a large proportion of silica bodies and improves the fibre's workability.

4.4 Tensile Strength Of EFB Fiber With Pre-treatment

Figure 5 shows the mean tensile strength of untreated and treated EFB fibres. The fibre treatment appears to increase the tensile strength of the fibres substantially when compared to the untreated fibres. The results also show that increasing the concentration of NaOH enhanced the tensile strength of EFB fibres significantly. According to [9], treating fibre to an alkaline treatment such as 4% NaOH concentration increased its tensile strength. When the fibre is exposed to greater concentrations of NaOH which is 5% and above, the tensile strength falls owing to lignocellulose breakdown and fibre surface rupture. The elimination of lignin and hemicellulose increased the tensile strength of EFB fibres substantially when they were treated with alkaline.

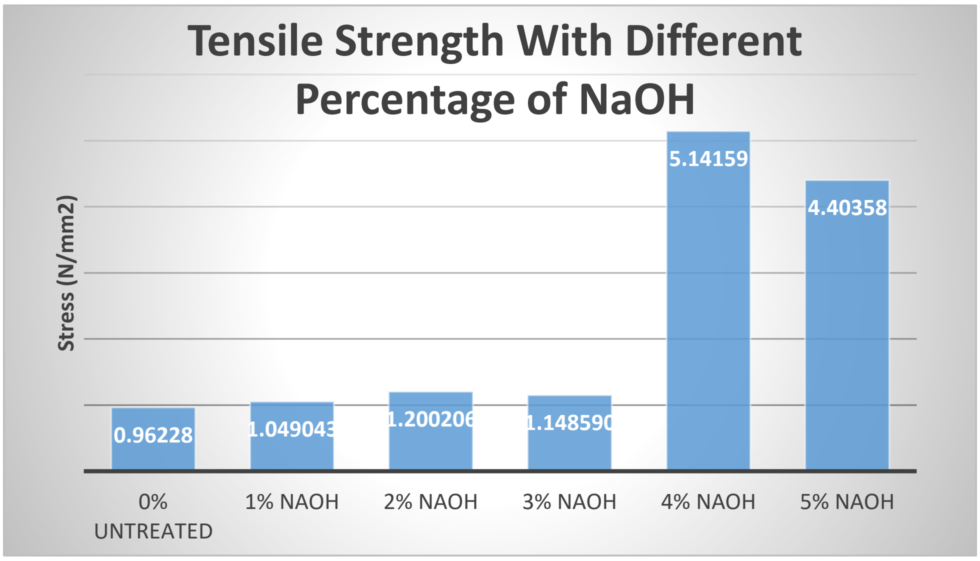


Figure 4: Tensile Strength of 0% (Untreated) and Treated 1%, 2%,3%, 4% and 5% NaOH

4.5 Summary

Due to the presence of natural extractives in EFB fibre, it is clear that it cannot be utilised simply as the primary material for cement-bonded fiber-board. A higher NaOH concentration reduces the number of silica bodies on the EFB fibre surface. as illustrated on untreated fibre, huge volumes of silica bodies adhered to the fibre surface hinder the hydration of the EFB-cement combination. As a result, pre-treatment of EFB fibre eliminates a large proportion of silica bodies and improves the fibre's workability. Pre-treatment of EFB fibre eliminates a large proportion of silica bodies and improves the fibre's workability. While, the elimination of lignin and hemicellulose increased the tensile strength of EFB fibres substantially when they were treated.

5. Conclusion

From the research it can be concluded that the increasing in NaOH concentration during pretreatment, the effect of the hydration rate on the EFB fiber-cement mixture increased significantly. After pre-treating EFB fibres with 4 % of NaOH, similar results were achieved in terms of surface morphology, which captured full elimination of silica bodies. After being treated with 4% of NaOH concentration improved EBF tensile strength. However, it's the tensile strength of the strand decreased when treated with 5% of NaOH. Tensile tests on EFB fibres revealed that alkali-treated fibres had better mechanical characteristics than untreated fibres. Immersion in NaOH eliminates surface contaminants from the fibres, modifies their surface, and increases their thermal stability. These results were further verified by the SEM analysis of each strand according to NaOH concentrations.

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