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Influence of Varying Fiber Length on the Mechanical and Physical Properties of Cement Bonded Fiberboard Containing Palm Empty Fruit Bunch

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Abstract: Past few years, there has been continued interest in the use of natural plant fiber in cement composites as an alternative to traditional reinforcement. The use of fibers derived from plants into the fiberboard production has increased significantly. Not only because of it strengthen the mechanical features of cement bonded fiber board (CBFB), but they are also renewable, easy to obtain and inexpensive. In this study, Oil Palm Fiber Board (OPFB) with different length of fiber are produced. The objectives of this study are to determine optimum fiber length and to evaluate the relationship of fiber length with physical and mechanical properties. Panel boards with dimensions of 350 mm x 350 mm x 12 mm were produced with a density 1300 kg/m^3. Modulus of Rupture (MOR), Modulus of Elasticity (MOE) and Internal Bonding (IB) test are conducted in order to obtain the relationship of the fiber length towards the physical and mechanical properties of the composite. A few samples of empty fruit bunch (EFB) cement board are fabricated with different Oil Palm Fiber length which is short length fiber (4.32mm), medium length fiber (14.37mm) and longest fiber (25.72mm) which to obtain the effect of the length of the fiber to its properties. In order to improve the workability of the fiber and the cement mixture, NaOH with 0.4% concentration are used as fiber treatment. The finding shows the sample that made up of medium length fiber (14.37mm) gives the higher value MOR, MOE and IB which is 4439.33 N/mm^2, 161.20 N/mm^2 and 0.4 N/mm^2 respectively. The MOE and MOR obtain are comply with the standard (BS EN 319:1993) however IB does not satisfy BS EN 319:1993 specification. The research findings indicate that the ideal fiber length that contribute to physical and mechanical properties of fiberboard is from medium length EFB which is 14.37mm.

Keywords: Fiberboard, Empty Fruit Bunch, Fiber Length, Physical Properties, Mechanical Properties

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1. Introduction

This research was conducted to identify the effect of different length of the empty fruit bunch (EFB) towards the physical and mechanical properties of the cement bounded fiberboards and to evaluate the relationship between EFB fiber length and physical properties of the cement fiberboards. Recently, there is continued interest in the use of natural plant fiber in cementitious composites as an alternative for conventional reinforcement. With the use of natural plant fiber, greatly improves engineering sustainability as it is renewable, biodegradable, energy-efficient and it is nontoxic [1]. Cement-bonded wood composite is a building component made from wood strands, particles, or fibers mixed with Portland cement and additives in the construction industry. The aggregate and reinforcing agent are wood particles or fiber, the binder is cement, the reactant is water, and the catalyst is additives [2]. Most composites used in the manufacturing of cement boards had to be strong in terms of bending, flexural strength, and internal bonding [3]. In a fiber cement composite, the length of the fibers is crucial. Short fiber reinforced composite cement fibers have higher bending strength than lengthy fibers, according to [2]. According to prior studies, the length of the fiber contained in the composite has a significant impact on mechanical performance [3]. Bending strength, compressive force, density, moisture content, and water absorption are all influenced by fiber length. Bending strength has been demonstrated to improve with longer fiber. The compressive force, on the other hand, was lowered.

The purpose of this research is to study the possible application of empty fruit bunch (EFB) fibers in cemented fiberboard. The objective of this research is to determine the optimum EFB fiber length that contribute to the highest physical and mechanical properties of cement fiberboard and to evaluate the relationship between EFB fiber length and physical and mechanical properties of cement fiberboards.

The impact of EFB fiber length on cement board manufacture is hard to come by in the literature. As a result, a thorough investigation is required to comprehend the length effect on board attributes. As a result, it's critical to investigate and specify the allowable fiber sizes that result in optimal performance.

2. Materials and Methods

Before starting any activity, the most crucial step is to prepare the materials. It's to make sure that everything is in order before moving on to the next step.

2.1 Preparation of EFB fiber.

The major raw material used in this research is the Empty Fruit Bunch (EFB) fiber. The fiber was obtained from Ban Dung P. O. IND. Sdn. Bhd located in Parit Sulong Batu Pahat. The fiber obtained was in form of bunch. Therefore, hammer mill procedure was performed in order to minimize the fibrous fiber to small pieces. Shredded EFB fiber then, undergo sieving process. This process mainly done to isolate the dust that affect the cement board consistency.

Table 1 shows the size of the mesh opening and the length of fiber obtain during the screening process. **Error! Reference source not found.** shows calculations made, in order to obtain the exact amount of fiber, NaOH and water required for pre-treatment. The fiber then, soaked with 0.4 % concentration of NaOH for 24 hours. The purpose of the treatment is, to improve the resistance to absorption and to improve the mechanical properties of the cement composite [4]. After treatment, the fiber then rinsed to wash out the excess NaOH and then place under the sun before dried in oven for 24 hours to remove the moisture content before fiberboard fabrication process.

Table 1: Fiber size based on the size of the mesh

Fiber length (mm)		
Passing 4 mesh, retain 7 mesh (R7M)	Passing 7 mesh, retain 14 mesh (R14M)	Passing 14 mesh, retain 30 mesh (R30M)
25.72 mm	14.37 mm	4.32 mm

Table 2: Amount of fiber, water and NaOH required for pre-treatment

	Longest fiber (25.72 mm)	Medium fiber (14.37 mm)	Shortest fiber (4.32 mm)
Weight of empty barrel, kg	1.50	1.50	1.06
Total weight, kg (container + water)	43.17	32.50	50.73
Total weight of water, kg	41.67	31.00	49.67
Weight of NaOH, g	0.004 × 41670 = 166.68	0.004 × 3100 = 124.00	0.004 × 49670 = 198.68
Weight of dry EFB, kg	0.06 × 41.67 = 2.50	0.06 × 31 = 1.86	0.06 × 49.67 = 2.98

2.2 Preparation of fiberboard manufacture.

This study used EFB fibers of various lengths to determine the effects of different fiber lengths on the characteristics of cement boards. The panel specimens were prepared to determine the impact of EFB fiber size on the mechanical behavior of EFB-CB with the following fiber size classifications which is long fiber (25.72 mm), medium fiber (14.37mm), and short fiber (4.32 mm). After obtaining the amount of cement, fiber and water required for fabrication process as shown in Table 3, fiber was mix into the mixer machine and water were sprinkle into the drum little by little to prevent the fiber from clumping for 2 minutes. Then wet fiber was mixed with cement little by little and let it mix for 7 minutes. The mixture then, spread into the wooden moulds on steel plate and pressed by using hand before place it under the hydraulic pressure until it touches the spacer with designed thickness which is 12 mm. The cement board then left under the pressure for 24 hours and left for curing process for 28 days after opening the moulds.

Table 3: Specimen mix design

Sample density	1300 kg/m^3
Sample size	350 mm × 350 mm × 12 mm
Volume of sample	1.47 × 10^{-3} m^3
Dry weight fiber	(1.47 × 10^{-3} m^3) (1300 kg/m^3) = 1.911g
Cement-EFB ratio (3:1)	3x + x =1911 g x= 477.75 g (EFB) 3x = 1433.25 g (Cement)
Water weight	0.4 cement weight + 0.3 EFB weight = 0.4 (1433.25) + 0.3 (477.75) = 716.63 g

2.3 Fiberboard properties test

A few tests were conducted according to BS EN 310:1993 and BS EN 319:1993 in order to obtain the properties of the cement board samples. Three tests were performed which is modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding test (IB). Once cement board reached 28 days curing period, then the sample were cut into few parts for the testing purpose which is the sample dimension for MOR and MOE is 350 × 50 × 12 mm and 50 × 50 ×12 mm for IB specimen as shown in Figure 1 . The sample size for testing was prepared according to standard specification as shown in Table 4.

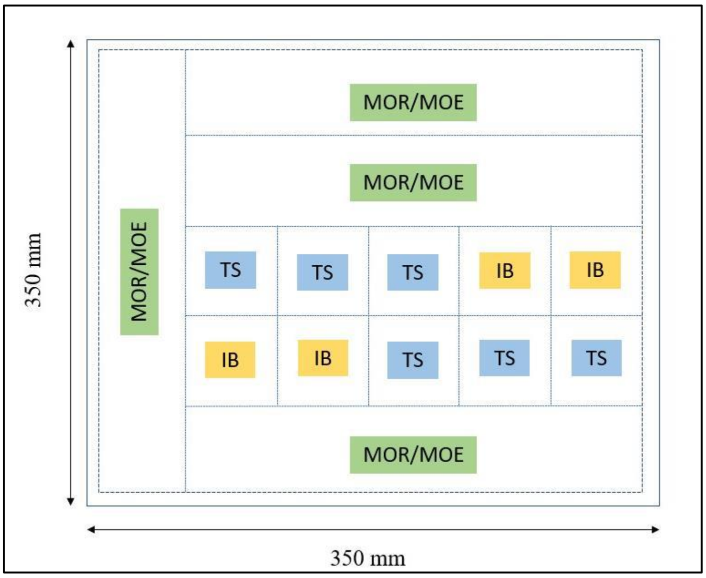

Figure 1: Fiber board cutting dimension

Table 4: Measurement of sample size accordance to specification of standard

Testing performed	Sample size, mm	Standard specification
Modulus of rupture (MOR)	350 × 350 × 12	BS EN 326-1-1994
Modulus of elasticity (MOE)	350 × 350 × 12	BS EN 326-1-1994
Internal bonding (IB)	50 × 50 × 12	BS EN 319:1993

3. Results and Discussion

Based on the researched studies, the length of the fiber significantly has effect towards fiberboard properties. According to the standard requirement based on BS EN 634:2-2007 value of MOR, MOE, and IB should comply with the fiberboard production requirement as shown in Table 5.

Table 5: Minimum requirement for OPC bonded particleboard

Properties	Minimum requirement
Modulus of rupture (MOR)	9 N/mm^2
Modulus of elasticity (MOE)	4000 N/mm^2
Internal Bonding (IB)	0.5 N/mm2
Thickness	12 to 15 mm (12±1 mm)
Density	1000 kg/m^3

3.1 Effect of fiber geometry on thickness and density of fiberboard

After thickness and density were determined, samples of different fiber lengths were prepared to evaluate the properties of fiber geometry. The EFB-CB sample's designed thickness is 12 mm, and its designed density is 1300 kg/m^3. After the curing period which is 28 days, the density of the cement board sample was recorded. Figure 2 shows the relationship between the density and the thickness of the CB. This result indicates that the length of fiber significantly influenced the physical properties of the composite. Based on Figure 5 and Figure 6, short fiber (4.32mm) has the highest value of density which is 1323 kg/m^3, 1339 kg/m^{3}and 1312 kg/m^{3}for sample 1, sample 2 and sample 3 respectively. According to Ahmad et al., (2011) short fibers are aligned and pack densely than the longer ones and shorter fiber length improved the physical performance of cement boards. However, short fiber has the smallest thickness of CB where 12.51 mm for sample 1, 12.26 mm for sample 2 and 12.39 mm for sample 3. Meanwhile, longest fiber length (25.72mm) was recorded have the lowest density which is 1288 kg/m^3 (sample 1), 1291 kg/m^3 (sample 2) and 1296 kg/m^3 (sample 3). While, the thickness recorded for sample 1, 2 and 3 for medium length fiber is 14.3 mm, 14.6 mm and 14.58 mm. Cement board specimens with longer EFB fibers tend to ball up, increasing cement board thickness [5]. This is due to the addition of long fibers to the composite mix that reduce the compaction of the sample which causing the fiber dispersion to be disrupted and resulting in large void. According to Asasutjarit et al., (2007) [6] it was discovered that incorporating long fibers into cement boards reduced their workability and increased the void space. The result in Figure 2 indicates that the thickness and density of samples are inversely proportional, in other words, the increasing of EFB thickness causes the sample density decreasing. It can be said that more void space apparently produces a composite with low density.

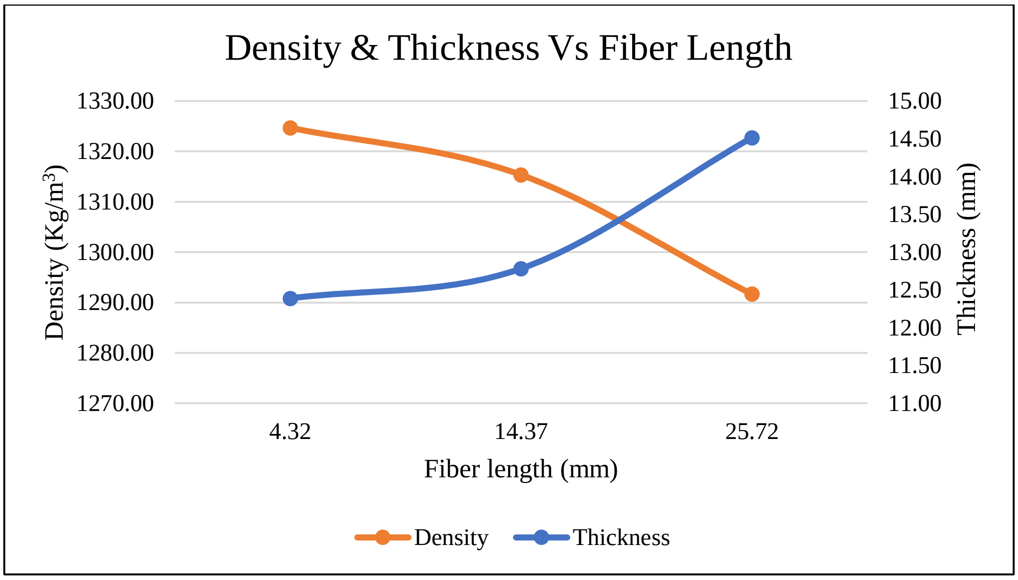

Figure 2: Density & Thickness Vs Fiber Length

3.2 Effect of fiber geometry on mechanical properties

Cement fiberboard were tasted after left for curing in 28 days. The results showed that the length of fiber in the composite had a substantial impact on the mechanical performance of the cement fiberboard. The longest fiber (25.72mm) shows the lower value of MOE (3856 N/mm^2, 3921 N/mm^2, 4211 N/mm^2), MOR (131.4 N/mm^2, 133.8 N/mm^2, 130.8 N/mm^2) and IB (0.329 N/mm^2, 0.328 N/mm^2, 0.326 N/mm^2) as shown in Figure 7,Figure 8 and Figure 9. Based on Figure 2. Longest fiber has the lowest density (1291.7 kg/m^3) and the highest thickness (14.51 mm). This is due to the addition of long fibers to the composite mix, which reduces sample compaction, causing fiber distribution to be disrupted and resulting in large voids. As there is large void space, it resulting to low in flexural (MOR), tensile (MOE) and internal bonding (IB) strength.

The shortest fiber (4.32mm) also shows low value of MOE (4121 N/mm^2, 3765 N/mm^2 and 3362 N/mm^2), MOR (141.6 N/mm^2,136.8 N/mm^2,129.6 N/mm^2) and IB (0.333 N/mm^2,0.326 N/mm^2,0.346 N/mm^2). Due to shorter fiber has bigger surface area than longer fiber, therefore a higher adhesive amount is required to optimize cement setting. According to [5] the rate of hydration for short fiber is high due to the large exposure area, leading the sample to be brittle. The MOE, MOR and IB for both longest (25.72 mm) fiber and shortest (4.32 mm) fiber was compared to medium length fiber which is (14.37 mm) which the value of MOE obtained is 4521 N/mm^2,4332 N/mm^2, and 4465 N/mm^2. Meanwhile, the value for MOR and IB are 160.8 N/mm^2, 169.2 N/mm^2, 153.6 N/mm^2 and 0.395 N/mm^2, 0.402 N/mm^2, 0.408 N/mm^2 respectively. the overall average of the mechanical and physical properties of the fiberboard, sample that produce from medium fiber (14.37 mm) shows the highest flexural, tensile and internal bonding strength value as shown in Figure 3 and Figure 4. Due to it medium length, the hydration rate of the sample is at the optimum level. The thickness and the density result are ideal as the void space of the sample are optimal. It can be concluded that medium length fiber are suitable for future research.

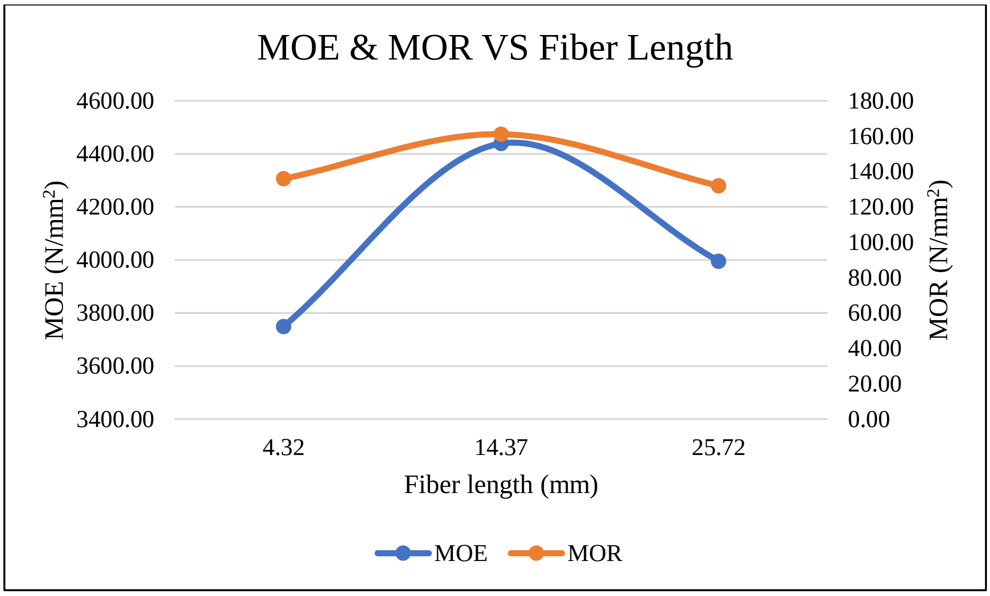

Figure 3: MOE & MOR against fiber length.

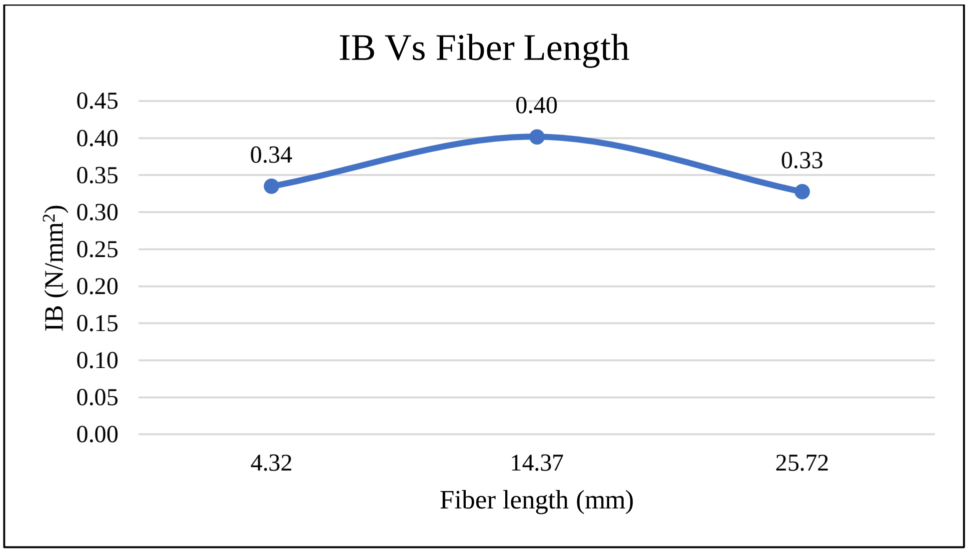

Figure 4: Internal bonding against fiber length graph

4. Conclusion

Based on the data observed, it can be concluded that;

i. The optimum fiber length obtained is from medium length fiber (14.37 mm)

ii. The thickness of the fiberboard affected the density of the cement board. As the thickness of the board decreasing the density are increasing

iii. The sample made up of longer fiber (25.72mm) had the lowest density, which was 1291.7 kg/m^3. Both the density and thickness of the board (14.37mm) meet the minimum requirements.

iv. The highest performance in term of mechanical properties was obtained by medium length fiber (14.37mm) with MOE, MOR and IB value 4439 N/mm^2, 161.2 N/mm^2 and 0.402 N/mm^2 respectively. However, the internal bonding of medium length fiber and the others sample does not comply with BS minimum requirement which it should be ≥ 0.5 N/mm2. This is due to certain reasons.

Based on the discussion in this study, there are a few suggestions for improving the mechanical and physical properties of EFB fiber to improve the production of cement bonded fiberboards.

i. In this study, only NaOH with 0.4% concentration were used to treat the fiber. Therefore, the treatment of the fiber should be diversified for an example use different concentration percentage in order to gain better understanding on the effect of the treatment towards the fiberboard qualities.

ii. The manipulation combinations of different fiber length in the fabrication of fiberboard cement composites should be carried out to examine their impact on board properties and qualities. For an example mixing different fiber length as a mixture composite.

iii. The impacts of different fiber to cement ratios on EFB-CB characteristics should also be investigated.

iv. The effect of additive towards the fiberboard production such as magnesium chloride ($MgCL_2$), calcium chloride ($CaCl_2$) and more should be studied on it effect towards the physical and mechanical properties of the board as it acts as cement setting accelerators to counteract the inhibiting effects of sugar in fiber.

v. Other alternative forming method should be studied to make sure that the fiber mixture is evenly spread to obtain high quality of fiberboard.

vi. To gain a better knowledge of the qualities of manufactured EFB-CB, more thorough experimental study on the usage of various types of curing techniques in board manufacturing is required.

Acknowledgement

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Appendix A

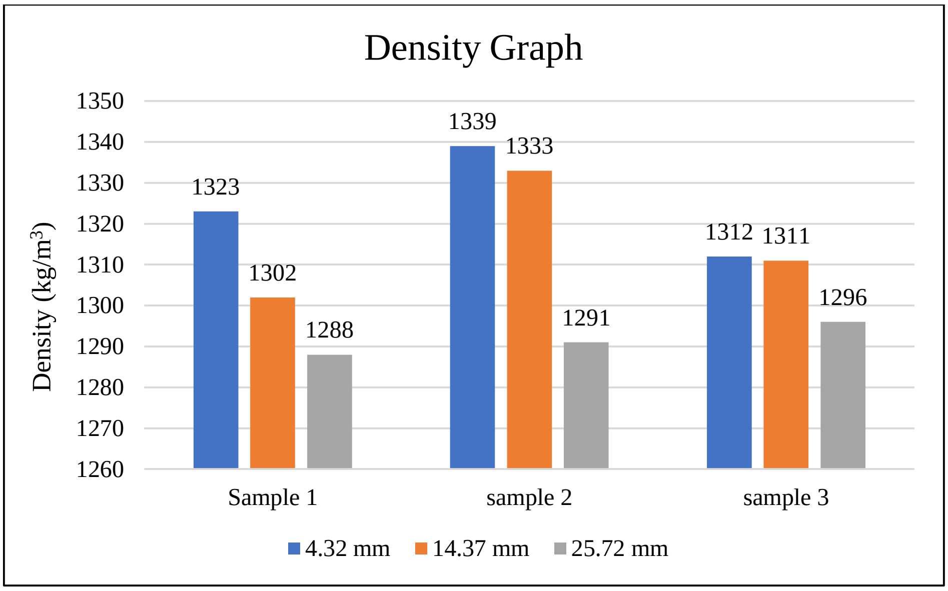

Figure 5: Graph of density

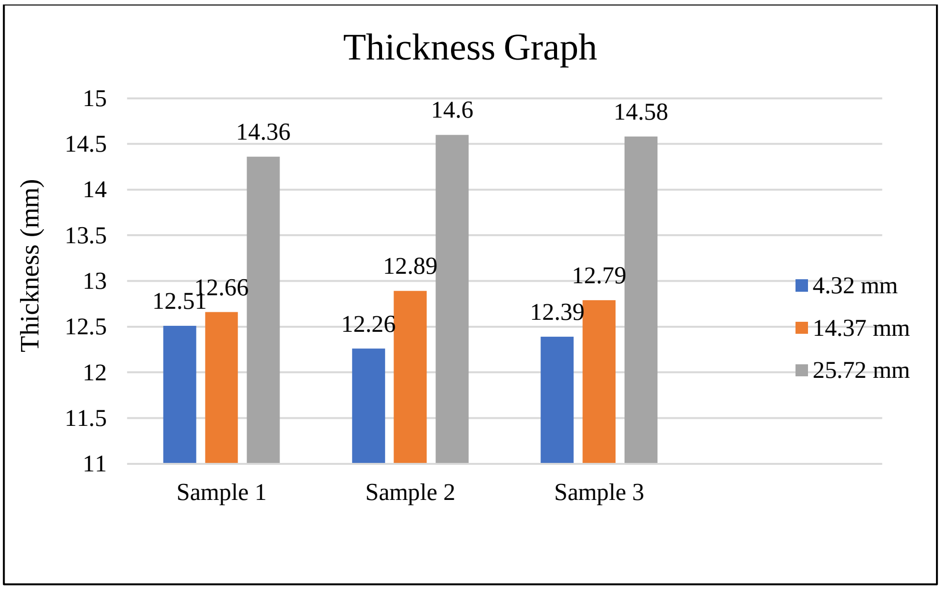

Figure 6: Graph of thickness

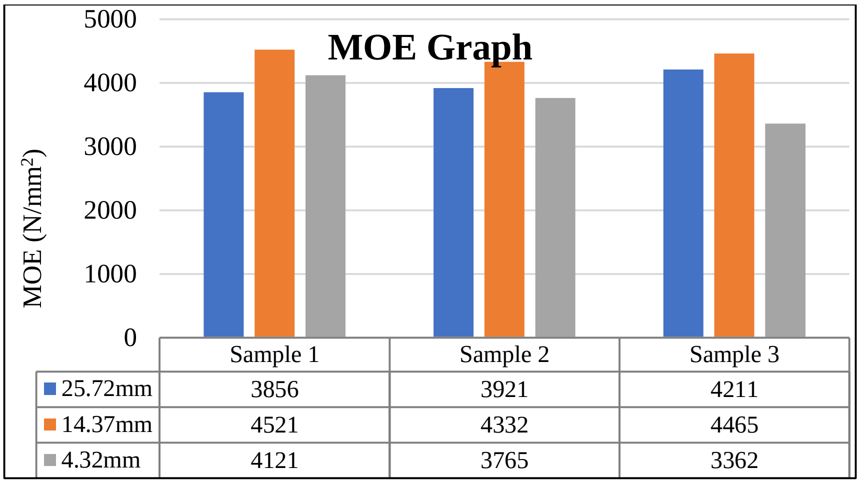

Figure 7: MOE Graph of fiberboard

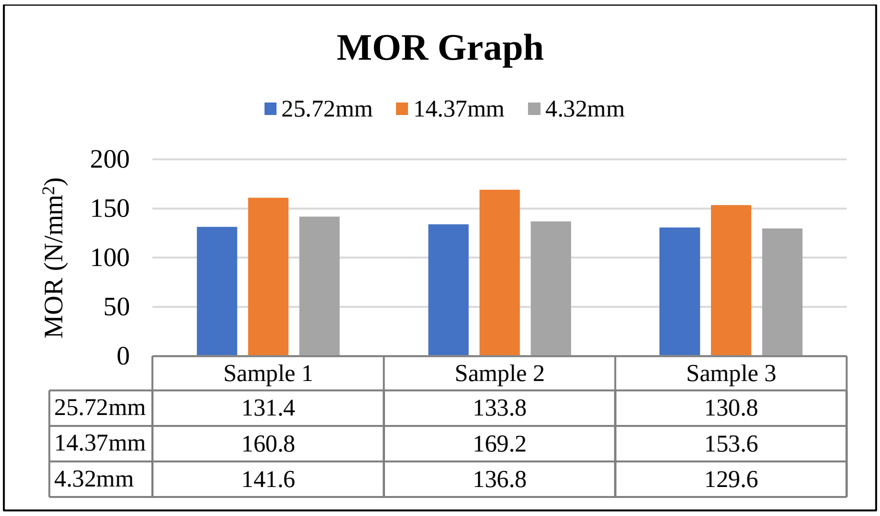

Figure 8: MOR Graph of fiberboard sample

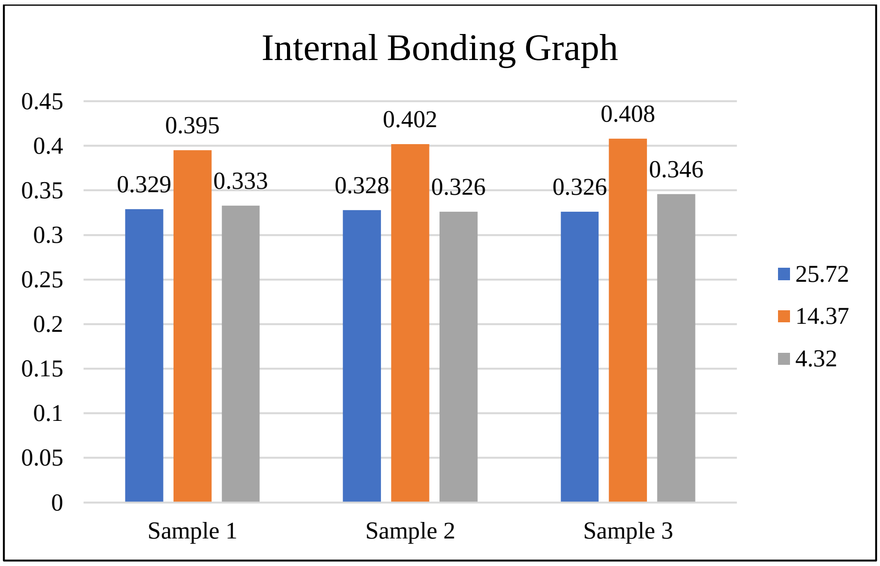

Figure 9: internal bonding graph

References

[1] K. Zhao, S. Xue, P. Zhang, Y. Tian, and P. Li, "Application of natural plant fibers in cement-based composites and the influence on mechanical properties and mass transport," *Materials (Basel).*, vol. 12, no. 21, 2019, doi: 10.3390/ma12213498.

[2] Z. Ahmad, S. Iis, Z. Halim, and N. Sarifuddin, "Effect of Fiber Length Variations on Properties of Coir Fiber Reinforced Cement-Albumen Composite (Cfrcc)," *IIUM Eng. J.*, vol. 12, no. 1, pp. 63–76, 2011, doi: 10.31436/iiumej.v12i1.116.

[3] Z. A. Akasah, N. M. Z. N. Soh, H. Dullah, A. A. Aziz, and E. Aminudin, "The influence of Oil Palm Empty Fruit Bunch Fibre Geometry on mechanical performance of cement bonded fibre boards," *Int. J. Mech. Eng. Robot. Res.*, vol. 8, no. 4, pp. 547–552, 2019, doi: 10.18178/ijmerr.8.4.547-552.

[4] T. E. Omoniyi, "Potential of Oil Palm (Elaeisguineensis) Empty Fruit Bunch Fibres Cement Composites for Building Applications," *AgriEngineering*, vol. 1, no. 2, pp. 153–163, 2019, doi: 10.3390/agriengineering1020012.

[5] H. Dullah, "Compatibility Assessment for Physical and Mechanical Properties of Empty Fruit Bunch Cement-Bonded Fibreboard Compatibility Assessment for Physical and Mechanical Properties of Empty Fruit Bunch Cement-Bonded Fibreboard A thesis submitted in fulfillment o," no. August 2018, 2019, doi: 10.13140/RG.2.2.32026.08645.

[6] C. Asasutjarit, J. Hirunlabh, J. Khedari, S. Charoenvai, B. Zeghmati, and U. C. Shin, "Development of coconut coir-based lightweight cement board," *Constr. Build. Mater.*, vol. 21, no. 2, pp. 277–288, 2007, doi: 10.1016/j.conbuildmat.2005.08.028.