JOURNAL OF STRUCTURAL MONITORING AND BUILT ENVIRONMENT
e-ISSN: 2821-3432

Vol. 5 No. 1 (2025) 1-11
https://publisher.uthm.edu.my/ojs/index.php/jsmbe

JSMBE

Dimensional Stability of Oil Palm Empty Fruit Bunch Fibre (OPEFB) Cement Board Over The Curing Period

Ahmad Rusydi Mohd Pazai[1], Nik Mohd Zaini Nik Soh[1]*

[1] *Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Batu Pahat, Johor, MALAYSIA*

*Corresponding Author: nikzaini@uthm.edu.my
DOI: https://doi.org/10.30880/jsmbe.2025.05.01.001

Article Info

Received: 16 January 2025
Accepted: 16 June 2025
Available online: 30 June 2025

Keywords

Oil Palm empty fruit bunch (OPEFB), empty fruit bunch cement board (EFBCB), dimensional stability, physical and mechanical properties, thickness monitoring

Abstract

Oil palm fruit bunch fibre bunch (OPEFB) is a byproduct of palm oil manufacturing. Empty fruit bunch (EFB) can be recycled into compost, renewable energy, and nutrients, reducing waste and making industry more environmentally friendly and cost-effective. Asbestos and synthetic fibre exposures pose health risks, particularly mesothelioma, due to their carcinogenic effects. Natural fibres offer a sustainable alternative with comparable mechanical properties, fire resistance, and crashworthiness. They can be used in cement composite materials for biodegradability, design flexibility, and sustainability. The ratio of mixed cement- fibre is set at 3.5:1, aiming for targeted density of 1300 kg/m^3. The total number of samples is 9 samples empty fruit bunch cement board (EFBCB) with the dimensions size of 350×350×12 mm. To enhance the material's properties, hot water treatment being used at 100°C for a duration of 2 hours for treating the EFB fibre. The testing was conducted at intervals of 7, 14, and 28 days of curing process. The results demonstrated notable declines in dimensional stability and mechanical performance over the curing period. The analysis of the dimensional stability of OPEFB fibre cement board (EFBCB) during the curing period revealed significant changes in both physical and mechanical properties. The results demonstrated how the reduction in thickness, density, and other physical changes impacted the dimensional stability and mechanical performance of the boards.

1. Introduction

In Malaysia, palm oil is the main product that has had a great impact on the economy and the agricultural industry. According to [1], Malaysia is the world's top producer and exporter of palm oil, with crude output rising from 2.50 million tonnes in 1980 to 19.86 million tonnes in 2019. An increase in harvested area results in more fresh fruit bunch (FFB) harvests and waste, especially empty fruit bunches (EFB) [2]. Malaysia establishes around 23.2 million tons of EFB waste yearly[3]. Each kilogram of palm oil produced produces four kilograms of dry biomass [3]. EFB waste may be converted into sustainable energy in the form of Bio-oil, with the environmental hazards being the usage of power and the emission of chemicals [4]. EFB, a byproduct of palm oil manufacturing, may be recycled into compost, renewable energy, and nutrients, reducing waste and making for the industry more environmentally friendly and cost-effective [5]. EFB compost is a great growing medium for oil palm seedlings because it retains soil moisture, supplies essential nutrients, and promotes healthy growth, making it a long-term option that reduces the need for chemical fertilizers and promotes environmentally friendly farming practices [6]. Natural fibres are a non-polluting, safe, renewable, and legal source of fibre[7]. Natural fibre reinforcements are made from renewable resources and are affordable and biodegradable [8]. However, natural fibre must be treated before being used on cement-bonded board, therefore lowering the carbohydrate content of EFB fibre is important for improving the bonding between EFB fibre and cement. EFB fibre can replace wood fibre in cement-bonded boards due to its availability and compatibility with cement through suitable pre-treatment and cement accelerator [9].

2. Methodology

2.1 Material Preparation

The EFB fibre preparation process begins with obtaining EFB from an oil palm factory, followed by transferring it to the Timber Fabrication Laboratory at Universiti Tun Hussein Onn Malaysia (UTHM). The EFB is dried in the sun for at least a day to remove moisture, ensuring both surfaces are completely dry. A shredder machine then cuts the dried EFB into shorter fibres, which are further processed using a hammer mill to create fine fibres. The fine EFB fibres are then sieved using a 3 × 3 mm wire mesh wood mould, placed on a vibration table. The fibres are evenly distributed in the mould and sieved for 2 minutes using the vibration table. Fig. 1 shows material preparation for EFB.

(a) **(b)** **(c)**

Fig. 1 *Material preparation (a) Sun dry process; (b) Hammer mill process; (c) Sieve process*

2.2 EFB Fibre Treatment (Hot Water Treatment)

Hot water treatment is a crucial step in the production of fibre cement board because it enhances fibre properties for better application in cement board. Weight of the EFB fibre was calculated and weighed as shown in Table 1 and using equation 1 and 2. The EFB fibre was weighed and filled in the net before soaking in the water bath for 9 samples. 70% extra EFB fibre were used to compensate for the actual weight of the EFB fibre lost during the hot water treatment process.

Table 1 *The calculated weight of EFB fibre for hot water treatment*

EFB fibre per sample (g)	Extra EFB fibre 70% (g)	Total EFB fibre per sample (g)	Hot water treatment temperature (^{0}C)
425	299.5	723	100

$$\begin{aligned} \text{Extra 70\% fibre} &= 70\% \times \text{weight of EFB fibre} \\ &= 70\% \times 425 \text{ g} \\ &= 298 \text{ g} \end{aligned} \quad (1)$$

$$\begin{aligned} \text{Total weight of dry EFB fibre} &= \text{Dry weight EFB fibre} + \text{extra 70\% fibre} \\ &= 425 \text{ g} + 298 \text{ g} \\ &= 723 \text{ g} \end{aligned} \quad (2)$$

First, water is added to the water bath and heated until it reaches 100°C. Once the water bath reaches the required temperature, the weighted EFB fibre is soaked for 2 hours for hot water treatment. After soaking, the EFB fibre is lightly washed to remove excess impurities. To ensure even drying and prevent clumping, the treated EFB fibre is spread over a canvas liner and exposed to the sun until fully dry. The sun-drying method removes water absorbed during the treatment process. Afterward, the EFB fibre is placed on a tray and dried in an oven at 100°C for 24 hours to remove any remaining moisture. The treated EFB fibre is then sealed and stored for use in the production of the EFB cement board. Fig.2 shows the EFB treatment before fabricating EFBCB.

(a) **(b)** **(c)**

Fig. 2 *EFB treatment (a) Filling fibre into the net; (b) Soaking process for 2 hours; (c) Sun dry process after soaking process*

2.3 Fabrication of EFB Cement Board

The fabrication of EFB cement board follows from the method of a previous study. The study requires 9 samples for hot water treatment. In the drum mixer, the weighted materials were mixed as shown in Table 2 using Equation 3 and 4 to get the weight of the materials. Pouring the EFB fibre into the drum mixer and splattering the weighed water on it was the first step in the mixing procedure. To make sure all the EFB fibre is mixed with the water, the fibre and water was mixed in the drum mixture for around two minutes. Next, the mixture was gradually mixed in with the weighed cement. Before filling the wooden mold, the mixture was mixed for 10 minutes

Table 2 *Weight of the materials*

Weight of fibre	Weight of cement	Weight of water
425 g	1487.5 g	722.5 g

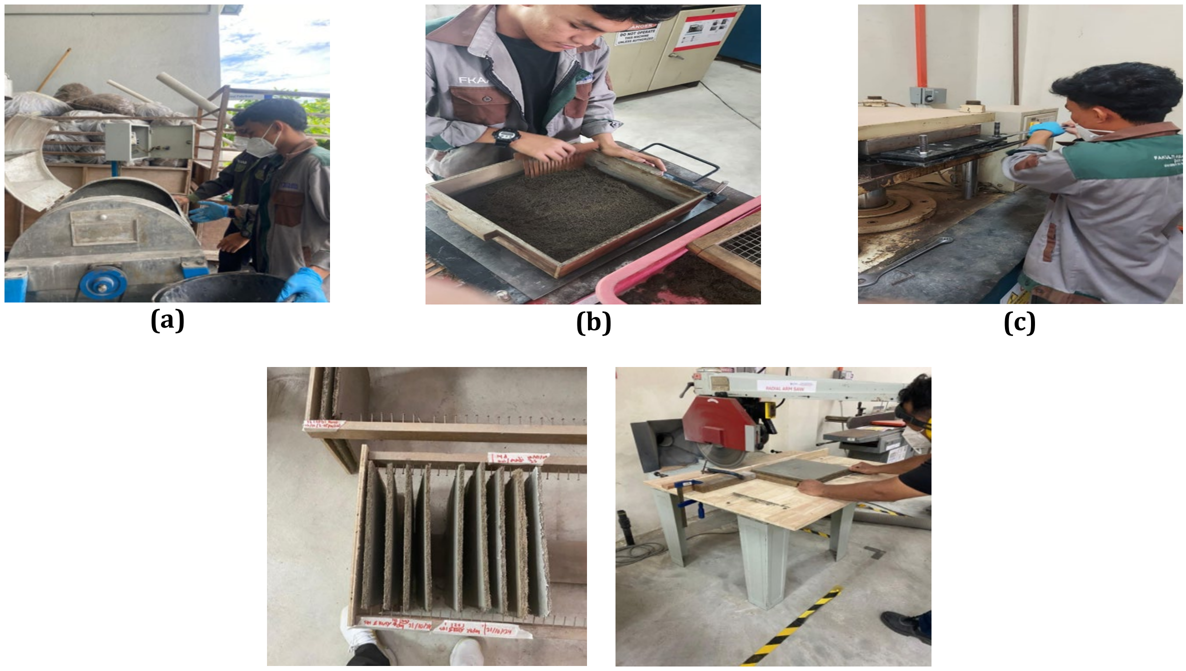
$$\begin{aligned} \text{Cement : EFB fibre} &= 3.5 : 1 \\ \text{EFB fibre} &= 425 \text{ g} \\ \text{Cement} &= 3.5 \times 425 = 1487.5 \text{ g} \end{aligned} \tag{3}$$

$$\begin{aligned} \text{Water} &= 0.4 \text{ (weight of cement)} + 0.3 \text{ (weight of fibre)} \\ &= 0.4\,(1487.5) + 0.3\,(425) \\ &= 722.5 \text{ g} \end{aligned} \tag{4}$$

In this process, the EFB cement board is molded using a 350 x 350 mm wooden mould, with the top and bottom covered by a polythene sheet. The mould is placed on a 400 x 600 mm reinforced steel plate, and the mixture for the cement board is poured into the mould. The mixture is flattened using a wooden stick to form a mat. The pre-compress process follows, where a plywood plate is placed on top to compress the mixture. After removing the wooden mould, the pre-formed samples are covered with another reinforced steel plate and locked with bolts into a 400 x 600 mm steel plate. The clamped sample is then placed into a press machine and compressed to a thickness of 12±1 mm. Compression continues until the spacer and reinforced steel mold contact, ensuring the sample is secured. After compression, the sample is kept for 24 hours. Following this, the sample is cured at ambient temperature (28±1°C) and 65±5% relative humidity for 7, 14, and 28 days. The cured cement-bonded fibre boards are cut into small samples for tests including TS, WA, density, MOE, MOR, and IB as shown in Table 3 and Fig.3 shows the fabrication of EFB cement board.

Table 3 *Dimension of EFB cement board for testing*

Testing	Dimensions	British Standard
TS	50 x 50 mm	BS EN 317-1993
WA	50 x 50 mm	BS EN 319-1993
IB	50 x 50 mm	BS EN 319-1993
MOE and MOR	300 x 50 mm	BS EN 310-1993



(a) (b) (c) (d) (e)

Fig. 3 *Fabrication of EFB cement board (a) Mixing process; (b) Forming process; (c) Compression process; (d) Curing process; (e) Cutting process*

2.4 Laboratory Testing

Samples of cement boards were tested to determine their properties. The mechanical and physical properties of EFB cement board were tested including water absorption (WA), density test, thickness swelling (TS), modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding (IB). The test for dimensional stability of EFB cement board only thickness monitoring (TM).

2.4.1 Thickness Monitoring (TM)

Thickness monitoring was utilized to assess how density impacts the dimensional stability of EFB cement boards. The EFB cement board was monitored every 2 days in 28 days of curing (BS EN 324- 1:1993). A dial gauge was used and placed in the middle of EFBCB to gather readings of thickness changes during curing process. This procedure was applied on 1 sample.

2.4.2 Density Test

A density test was conducted after the curing process. The density testing procedure is based on the standard BS EN 323-1993. This sample will be in square dimensions, measuring 50 x 50 mm. The mass of the EFBCB was collected. Following that, the EFBCB length, width, and thickness were collected. The density value was calculated using formula Equation 5 below.

$$\text{Density, p} = \frac{mass}{length\ x\ width\ x\ thickness} \tag{5}$$

2.4.3 Thickness Swelling (TS)

The thickness swelling (TS) test was conducted because of the physical properties of EFB cement boards. The samples were cured for 28 days, and the thickness swelling were used to determine the water absorption of the samples using the BS EN 317-1993 standard. For 24 hours, the sample was soaked in water. The samples' thickness and physical appearance will be measured both before and after it is soaked in water for 24 hours. The following formula uses Equation 6 to determine the thickness swell values.

$$TS = \frac{t2 - t1}{t1}\ x\ 100\% \tag{6}$$

Where,

$t1$ = Thickness before immersed

$t2$ = Thickness after immersed

2.4.4 Water Absorption (WA)

This test was conducted to determine the percentage of water absorption where the mass before immersed and after immersed collected. The percentage of water absorption was calculated using Equation 7 below based on BS EN 319-1993.

$$IB = \frac{P}{wl} \tag{7}$$

Where,

P = Maximum load (N)

w = width (mm)

l = length (mm)

2.4.5 Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)

After curing, the sample were cut to 300 mm x 50 mm and evaluated for mechanical properties (MOE and MOR) using BS EN 310-1993. The width and thickness of sample was collected before the test started. The sample was placed on the supports, with its longitudinal axis at right angles to those of the supports with the center point under the load. To get MOR and MOE values, a static bending test was conducted to determine the maximum load that may be applied to the midpoint of a simply supported specimen. Equations 8 and 9 were used to compute MOE and MOR values.

$$MOE = \frac{L^2 \Delta W}{4bt^3 \Delta S} \tag{8}$$

Where,

L = distance between center of support (mm)

ΔW = increment load in Newton (N)

ΔS = increment of deflection at midpoint corresponding to ΔW

b = width of test piece (mm)

t= thickness of test piece (mm)

$$MOR = \frac{3WL}{2bt^2} \tag{9}$$

Where,

W = maximum load (N)

L = distance between center of support (mm)

b = width of test piece (mm)

t = thickness of test piece (mm)

3. Result and Discussion

3.1 Effect of Curing Duration on EFBCB Thickness Monitoring (TM)

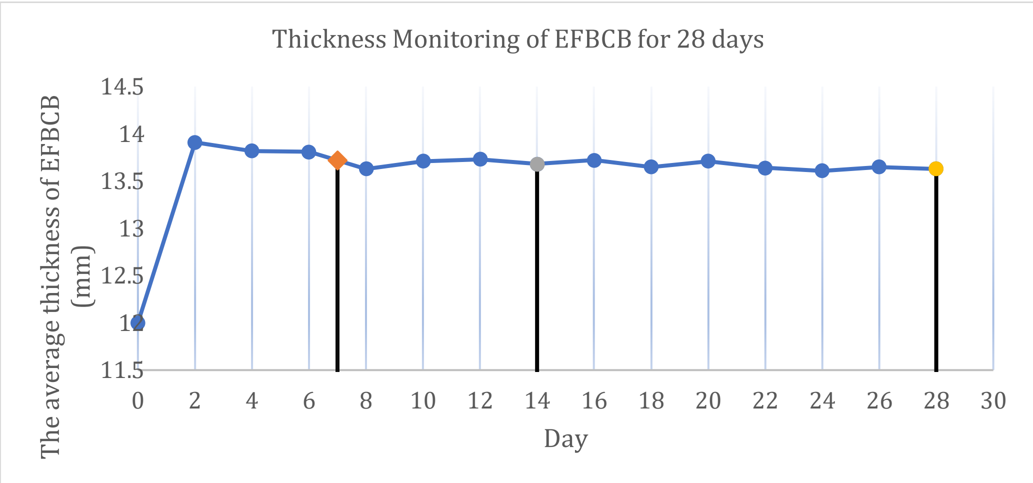


Fig. 4 *Thickness monitoring of EFBCB for 28 days*

According to Fig.4, the thickness of the sample increases and decreases during the 28-day curing process. EFBCB can absorb moisture from the environment or lose moisture during the curing process. Moisture absorption can cause swelling, while drying leads to shrinkage. Variations in environmental humidity can cause uneven changes in thickness [10]. The thickness of EFBCB increased significantly two days after it was produced, making it the optimum thickness throughout the curing process. From day 2 to day 8, the thickness of the EFBCB decreased significantly from 13.91 mm to 13.63 mm due to the drying and hardening process of the cement. During this period, the water used in the cement mix began to evaporate, causing shrinkage and a reduction in the thickness of the cement board [11].

3.2 Effect of Curing Duration on EFBCB Density

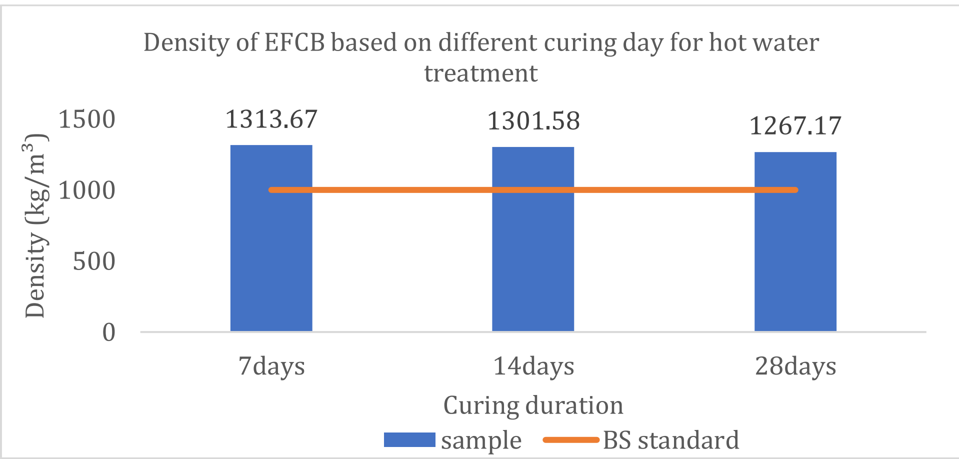


Fig. 5 *Density of EFBCB based on different curing day for hot water treatment*

Fig. 5 above shows that 7 days of curing period is the highest density with 1313.67 kg/m^3, and the lowest density is 28 days of curing period with 1267.17 kg/m^3. Over time, the cement matrix undergoes further hydration and drying, leading to moisture loss. This process can cause shrinkage and a reduction in overall mass, thereby decreasing the density of the composite material. The interaction between OPEFB fibres and the cement matrix can evolve during the curing process. Prolonged curing may lead to degradation or weakening of the fiber-matrix bond, potentially resulting in decreased composite density [11]. All sample pass the standard requirement (BS EN 323:1993) which is 1000 kg/m^3.

3.3 Effect of Curing Duration on EFBCB Thickness Swelling (TS)

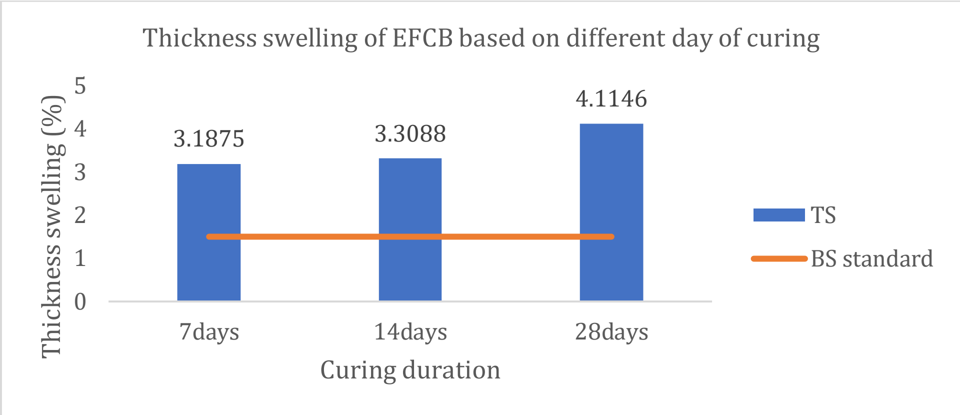


Fig. 6 *Thickness swelling of EFBCB based on different day of curing*

Fig. 6 above shows that the thickness swelling for 28 days of curing period is the highest percentage with 4.11% meanwhile for 7 days of curing period is the lowest percentage thickness swelling with 3.19%. The graph shows that percentage of thickness swelling increased through the curing period. The expected result of thickness swelling should be decreased through curing period. However, the result above shows that the thickness swelling increased through curing period due to variations in environmental humidity and temperature during curing can influence moisture content and swelling behavior [12]. All samples should not exceed the standard requirement (BS EN 323-1993) which is 1.5%.

3.4 Effect of Curing Duration on EFBCB Water Absorbtion (WA)

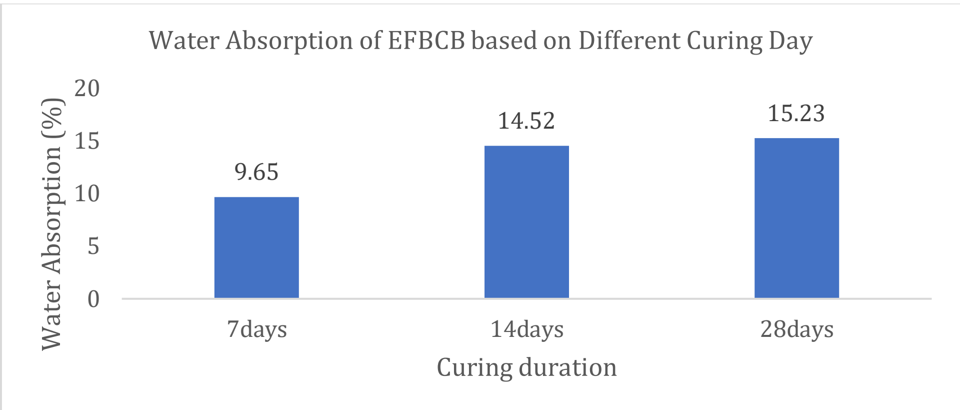


Fig. 7 *Water Absorption of EFBCB based on different curing period*

Water absorption for 28 days is the highest percentage with 15.23% and the lowest percentage of water absorption is for 7 days with 9.65% as shown in Fig.7 above. The percentage of water absorption increased through the curing period. During the initial curing period, the cement matrix undergoes hydration, leading to the formation of a hardened structure with reduced porosity. However, as curing continues, additional hydration and drying processes can create microcracks and voids, increasing the material's porosity and, consequently, its capacity to absorb water [13].

3.5 Effect of Curing Duration on EFBCB Internal Bonding (IB)

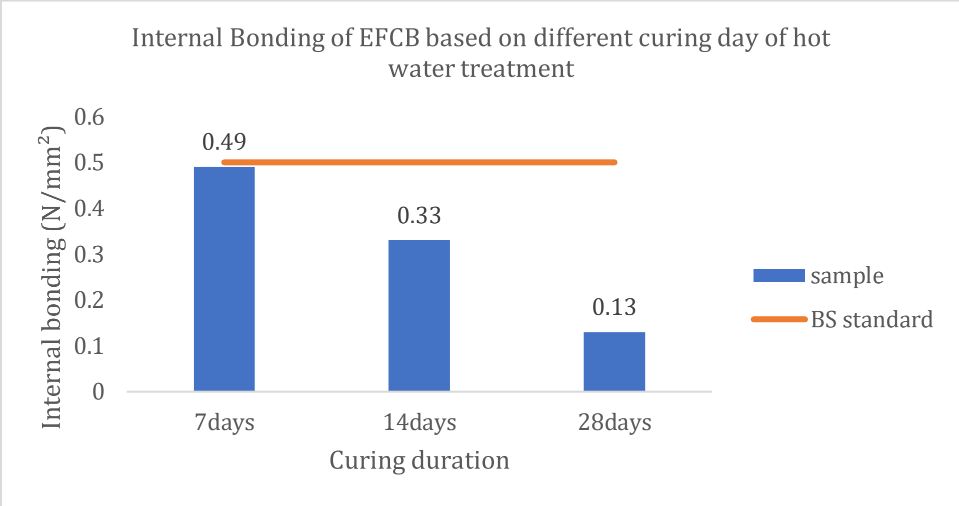


Fig. 8 *Internal Bonding of EFCB based on different curing period*

According to Fig.8 above, average IB for 7 days curing period is the highest value with 0.49 N/mm^2 and the lowest value is 28 days with 0.13 N/mm^2. The result shows that the IB value decreased through the curing period. Extended curing periods can result in changes in the moisture content of the material. If the material loses too much moisture, it can become brittle and less cohesive, reducing the IB strength [14]. As shown in graph, all sample does not exceed than standard requirements (BS EN 319-1993), which is 0.5 N/mm^2.

3.6 Effect of Curing Duration on EFBCB Modulus of Rupture (MOR)

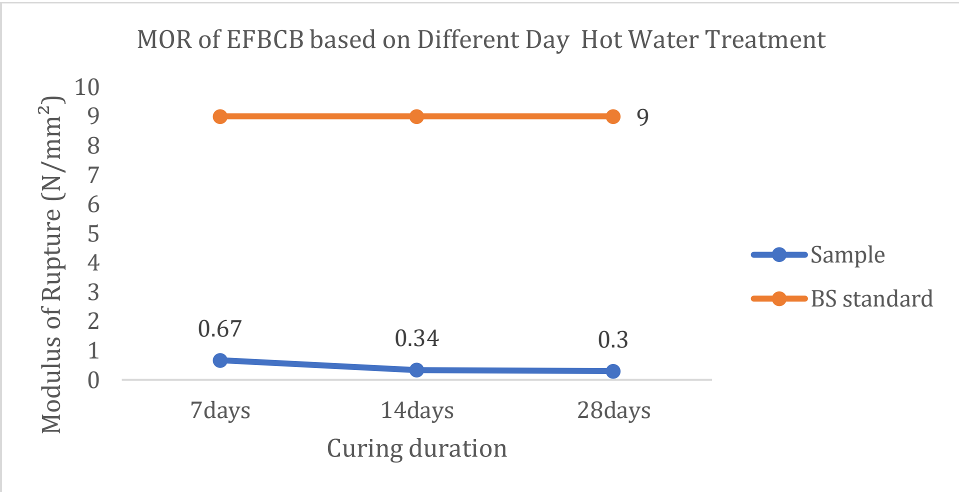


Fig. 9 *MOR of EFBCB based on different curing period*

According to Fig.9 above, the highest value for MOR is 7 days of curing period with 8.05 N/mm^2 meanwhile the lowest value of MOR is 28 days with 3.65 N/mm^2. The graph above shows that the MOR value decreased through the curing period. Natural fibres, such as oil palm empty fruit bunch fibres, can degrade within the cementitious matrix, especially under prolonged exposure to moisture and varying temperatures. This degradation weakens the fibre-matrix bond, leading to reduced mechanical properties, including MOR [15]. MOR is strongly related to MOE. MOR is strongly related to MOE. Graph above shows that all sample does not exceed standard requirement (BS EN 310-1993), which is 9 N/mm^2.

3.7 Effect of Curing Duration on EFBCB Modulus of Elasticity (MOE)

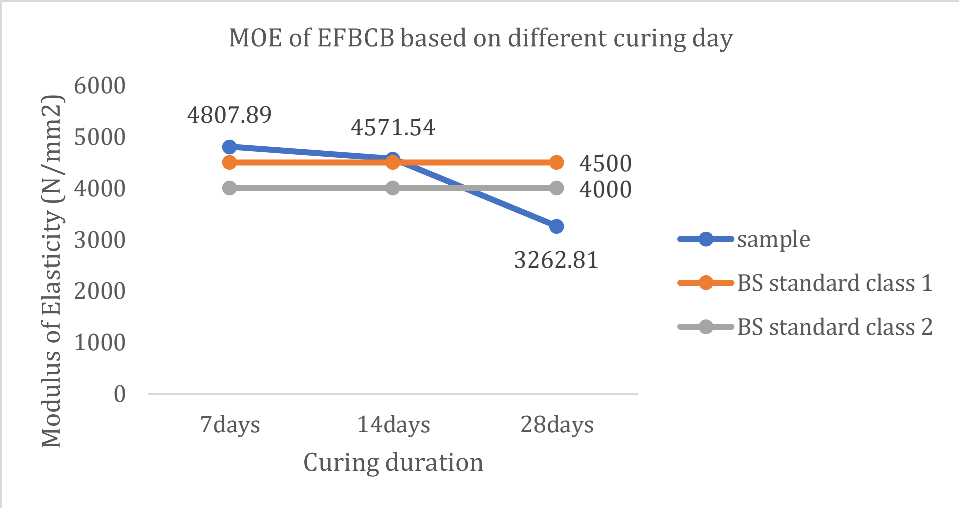


Fig. 10 *MOE of EFBCB based on different curing day*

According to Fig.10 above, the highest value for MOE is 7 days of curing period with 4807.89 N/mm^2 meanwhile the lowest value of MOE is 28 days with 3262.81 N/mm^2. The graph above shows that the MOE value decreased through the curing period. The MOE of Empty Fruit Bunch Cement Board (EFBCB) generally decreases over time due to factors like those affecting the Modulus of Rupture (MOR). MOE measures the stiffness of the material and reflects its ability to resist deformation under stress. The inclusion of oil palm empty fruit bunch fibers in cement boards can promote internal stress development, known as the spring-back effect. This internal stress can compromise the structural integrity of the board over time, contributing to a decrease in MOE [16]. Graph above shows that only sample 28 days does not exceed both standard requirements (BS EN 310-1993) which is 4500 N/mm^2 for BS standard class 1 and 4000 N/mm^2 for BS standard class 2.

3.8 Dimension Stability of EFBCB Through Curing Duration Based on Physical and Mechanical Properties

Table 4 *Dimension stability of EFBCB through curing duration*

Curing duration	TM (mm)	Physical Properties			Mechanical Properties		
		TS (%)	WA (%)	Density (kg/m^2	IB (N/mm^2)	MOR (N/mm^2)	MOE (N/mm^2)
7 days	13.72	3.19	9.65	1313.67	0.49	8.05	4807.89
14 days	13.68	3.31	14.52	1301.58	0.33	4.65	4571.54
28 days	13.63	4.11	15.23	1267.17	0.13	3.65	3262.81

Table 4 shows that the thickness of EFBCB decreases from 13.72 mm at 7 days to 13.63 mm at 28 days. This indicates that the thickness of EFBCB shrinks over time. Thinner boards tend to swell more when exposed to moisture, as indicated by the increase in TS from 3.19% at 7 days to 4.11% at 28 days. WA also increases with the reduction in thickness, from 9.65% at 7 days to 15.23% at 28 days, indicating that thinner boards absorb water more easily, which can affect dimensional stability [11].

The density of EFBCB decreases from 1313.67 kg/m^2 at 7 days to 1267.17 kg/m^2 at 28 days. Lower density is usually associated with lower mechanical strength. IB decreases from 0.49 N/mm^2 at 7 days to 0.13 N/mm^2 at 28 days, indicating that thinner boards have weaker internal bonding. MOR also decreases from 8.05 N/mm^2 at 7 days to 3.65 N/mm^2 at 28 days, indicating that thinner boards are less capable of withstanding loads before breaking. MOE decreases from 4807.89 N/mm^2 at 7 days to 3262.81 N/mm^2 at 28 days, indicating that thinner boards are less elastic and more prone to bending [11].

Thinner boards have more pore space that allows water and moisture to penetrate more easily, causing an increase in TS and WA. Lower density means there is less material per unit volume, which reduces mechanical strength such as IB, MOR, and MOE. Thinner boards may have weaker internal bonding because there is less material to support the board's structure [17].

4. Conclusion and Recommendations

4.1 Conclusion

The study successfully monitored the physical (TM, TS, WA, density) and mechanical properties (MOR, MOE, IB) of OPEFB fibre cement board over 7, 14, and 28 days of curing. TS increased from 3.19% to 4.11%, and WA increased from 9.65% to 15.23%, indicating water absorption and reduced dimensional stability. IB decreased from 0.49 N/mm^2 to 0.13 N/mm^2, MOR from 8.05 N/mm^2 to 3.65 N/mm^2, and MOE from 4807.89 N/mm^2 to 3262.81 N/mm^2, showing weakened bonding, reduced strength, and rigidity. The study achieved its objective and highlighted the need for improvements to enhance stability and performance. The analysis of the dimensional stability of OPEFB fibre cement board during curing revealed significant changes in physical and mechanical properties. Thickness decreased from 13.72 mm at 7 days to 13.63 mm at 28 days, leading to increased susceptibility to moisture, as shown by the rise in TS from 3.19% to 4.11% and WA from 9.65% to 15.23%. Density dropped from 1313.67 kg/m^3 to 1267.17 kg/m^3, resulting in weaker mechanical properties. IB declined from 0.49 N/mm^2 to 0.13 N/mm^2, MOR from 8.05 N/mm^2 to 3.65 N/mm^2, and MOE from 4807.89 N/mm^2 to 3262.81 N/mm^2. Thinner boards with lower density were more prone to moisture penetration and mechanical degradation. The study successfully achieved its objective and highlighted the impact of thickness and density reduction on dimensional stability and mechanical performance, emphasizing the need for further improvements.

4.2 Recommendations

There are a few recommendations that can be used to improve the production of EFBCB for further studies.

- Use fiber pre-treatment methods (e.g., alkaline or silane treatment) to improve fiber-matrix bonding and minimize swelling or shrinking.
- Leverage the findings to promote EFBCB as an eco-friendly alternative to asbestos and other harmful materials in construction.
- Optimize curing conditions to reduce moisture-induced dimensional instability, such as using controlled humidity chambers.

Acknowledgement

The authors would like to express their sincere gratitude to Faculty of Civil Engineering and Bulit Environment, Universiti Tun Hussein Onn Malaysia for providing the resources and support required to carry out this work.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

References

[1] N. W. Ismail, S. N. M. Kamal, M. Firdaus, and N. M. Hariri, “Export Demand of Palm Oil in Malaysia: Analysis Using Ardl Approach,” *Asian J. Agric. Rural Dev.*, vol. 12, no. 3, pp. 157–163, 2022, doi: 10.55493/5005.v12i3.4531.

[2] & W. H. Rahayu, D. E., Brjodirdjo, W., “Availability of Empty Fruit Bunch as Biomass Feedstock,” no. June 2012, 2019.

[3] A. Saleem *et al.*, “Effect of Palm oil and Their Main Compounds in the Management of Cardiovascular Disease Risk Factors,” *Sch. Bull.*, vol. 8, no. 2, pp. 59–65, 2022, doi: 10.36348/sb.2022.v08i02.002.

[4] D. Wulandari, R. Rusdianasari, and M. Yerizam, “Life Cycle Assessment of Production Bio-oil from Thermal Cracking Empty Fruit Bunch (EFB),” *AJARCDE (Asian J. Appl. Res. Community Dev. Empower.*, vol. 6, no. 3, pp. 34–39, 2022, doi: 10.29165/ajarcde.v6i3.118.

[5] M. F. Omar, N. A. A. Hamid, N. H. Othman, S. S. Ayop, and N. Sulaiman, "A Review of Strength Performance of Empty Fruit Bunch as Replacement Material in Building Structures," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1022, no. 1, 2022, doi: 10.1088/1755-1315/1022/1/012048.

[6] N. A. Zakri and S. Adam, "A review on the potential of empty fruit bunch (EFB) compost as growing medium for oil palm seedling production," *Food Res.*, vol. 5, pp. 15–20, 2021, doi: 10.26656/fr.2017.5(S4).003.

[7] R. A. Kurien, M. Maria Anil, S. L. Sharan Mohan, and J. Anna Thomas, "Natural fiber composites as sustainable resources for emerging applications- a review," *Mater. Today Proc.*, no. xxxx, 2023, doi: 10.1016/j.matpr.2023.04.363.

[8] A. Kandemir, T. R. Pozegic, I. Hamerton, S. J. Eichhorn, and M. L. Longana, "Characterisation of natural fibres for sustainable discontinuous fibre composite materials," *Materials (Basel).*, vol. 13, no. 9, 2020, doi: 10.3390/ma13092129.

[9] H. Dullah, Z. A. Akasah, N. M. Z. Nik Soh, and S. A. Mangi, "Compatibility improvement method of empty fruit bunch fibre as a replacement material in cement bonded boards: A review," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 271, no. 1, pp. 0–7, 2017, doi: 10.1088/1757-899X/271/1/012076.

[10] N. Ersoy and M. Tugutlu, "Cure Kinetics Modelling and Cure Shrinkage," *ICCM 17 Int. Conf. Compos. Mater.*, pp. 6–11, 2009.

[11] M. N. Ridzuan, H. A. Bakar, E. M. Samsudin, N. M. Z. N. Soh, and L. H. Ismail, "Effects of Density Variation on the Physical and Mechanical Properties of Empty Fruit Bunch Cement Board (EFBCB)," *Pertanika J. Sci. Technol.*, vol. 31, no. 3, pp. 1157–1172, 2023, doi: 10.47836/pjst.31.3.02.

[12] I. Budiman *et al.*, "The properties of cement boards reinforced with coconut coir fiber (Cocos nucifera) as building materials," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 762, no. 1, pp. 4–12, 2021, doi: 10.1088/1755-1315/762/1/012074.

[13] C. E. M. Gomes and H. Savastano, "Study of hygral behavior of NON-asbestos fiber cement made by similar hatschek process," *Mater. Res.*, vol. 17, no. 1, pp. 121–129, 2014, doi: 10.1590/S1516-14392013005000180.

[14] R. S. Maail, K. Umemura, H. Aizawa, and S. Kawai, "Curing and degradation processes of cement-bonded particleboard by supercritical CO2 treatment," *J. Wood Sci.*, vol. 57, no. 4, pp. 302–307, 2011, doi: 10.1007/s10086-011-1179-9.

[15] P. Peter, N. M. Z. Nik Soh, Z. A. Akasah, and M. A. Mannan, "Durability Evaluation of Cement Board produced from Untreated and Pre-treated Empty Fruit Bunch Fibre through Accelerating Ageing," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 713, no. 1, 2020, doi: 10.1088/1757-899X/713/1/012019.

[16] Z. A. Akasah, H. Dullah, N. M. Z. N. Soh, and N. A. A. Guntor, "Physical and Mechanical Properties of Empty Fruit Bunch Fibre-Cement Bonded Fibreboard for Sustainable Retrofit Building," *Int. J. Mater. Sci. Eng.*, vol. 7, no. 1, pp. 1–9, 2019, doi: 10.17706/ijmse.2019.7.1.1-9.

[17] R. Wahab, S. M. M. Dom, M. T. Mustafa, H. W. Samsi, S. M. Rasat, and I. Khalid, "Properties of empty fruit bunch oil palm (Elaeis guineesis) composite boards at different densities and resin contents," *J. Plant Sci.*, vol. 10, no. 5, pp. 179–190, 2015, doi: 10.3923/jps.2015.179.190.