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To Study the Influence of Empty Fruit Bunch (EFB) on the Mechanical Properties of Cement Board in Paneling

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Abstract: More than a decade has passed since the knowledge and use of organic fibre reinforced concrete was discovered. The use of oil palm empty fruit bunch (OPEFB) fibre in organic composites has been developed in order to replace the present material predominantly wood fibre. The empty fruit bunch (EFB) was collected from Kilang Kelapa Sawit Bukit Pasir. Material use in the making of cement board are cement, fibre and water. The mixing proportion were determined by using try and error method to get the suitable mixture for EFB fibre cement board. The ratio of fibre decided to use were 0.00 %, 15.00 %, 17.00 %, 20.00 % and 23.00 %. The size of cement board used was 210 mm x 210 mm with a thickness of 12 mm for MOR, MOE, thickness swelling and water absorption. The main issue with common cement board these days is that it is not long-lasting due to its high unit weight and moisture content. As a result, Pan & Liu (2009), devised a strategy by putting fibres into the cement board composition. So, the objectives of this study were to identify the effect of using different ratio on mechanical strength properties of EFB fibre cement board and to determine the optimum ratio of EFB fibre for cement board. A test sample were performed for Thickness Swelling (TS) and Water Absorption (WA), Density, Modulus of Rupture (MOR) and Modulus of Elasticity (MOE). The results of the test indicate that among all cement boards produced using the above ratios that contains fibre, none of that satisfy the BS EN 310:1993 for MOR and MOE but only 0.00 % of fibre that satisfy both tests. For water absorption, it also not achieves the standard which is below 60.00 %. However, for thickness swelling and density obtained from the test for ratio that contains fibre achieved the standard BS EN 317:1993 and BS EN 323:1993 which is more than 1.50 % and less than 1000 kg/m^3 respectively. The study had identified that the optimum fibre ratio was 15.00 % when the result from the test achieved the standard. So, cement board produced from this study only suitable to be applied for pressure-free product such as panel and internal wall.

Keywords: Empty Fruit Bunch (EFB), Oil Palm Fibre, Cement Board

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1. Introduction

Malaysia is one of the main producers of oil palm. Besides, it is the most profitable crops, so more long-term strategies for its capacity because resource in structural and non-structural implementations are needed. The use of waste materials for construction materials has become increasingly prevalent in the building industry. Natural fibre composites are very cost-effective, low-energy consumption materials that are both environment conscious and long-lasting [1]. Furthermore, recyclable composites must be adapted not only for expense and affordability, and therefore also for the concern of resident wellbeing in the building's long-term operation [2]. This research was done to identify the effect of using (EFB) ratio on mechanical strength properties of EFB fibre cement board and also to determine the optimum ratio of EFB fibre (for cement board).

According to Dullah et al., 2017 [3], the combination between EFB fibre and cement will increase the efficiency of bio-composite materials. EFB is a type of composite that is naturally composed of cellulose. Natural fibre can be used as a binder for EFB-products since it contains no residual oil. Fibre Cement Boards (FCB) are manufactured using three main ingredients such as fibres, cement, and water in the proper proportions [4]. Due to their high strength, fibre cement composite products are widely used in several countries for both the interior and exterior purposes [5].

The biggest concern is palm oil residue abundance has been raised from one year to a year. Increased palm oil output, on the other hand, has a detrimental influence on the environment. EFB are a major waste product produced by palm oil factories [6]. EFB, which are the remnants left behind after palm oil fruit harvest and oil extraction, account for 20.00 % until 25.00 % of each tonne of Fresh Fruit Bunches (FFB) handled in the mill [7]. As a result, using OPEFB in cement board manufacture is considered as a more environmentally friendly and useful alternative. Other than that, if wood fibre still being used as construction material it will raise the demand for forest resources. In the end, using wood fibre as a bio-composites material will accelerate deforestation [3]. It also has an issue with common cement board these days is that it is not long-lasting due to its high unit weight and moisture content. Hence, Pan & Liu (2009), devised a strategy by putting fibres into the cement board composition. It is because fibre cement board having low unit weight and low moisture content other than calcium silicate and gypsum board.

1.2 Fibre Cement Board

Fibre cement board not physically break down in the appearance of moisture or leakage, cement board has a higher long-term stability than paper-faced gypsum core goods. Waterproofing is not possible for cement board. It retains a lot of moisture but still dries quickly [4]. Fibres are thread like materials that can be used for a wide range of purposes. During their lifespan, fibre cement boards are subject to a variety of environmental conditions, including humidity, significant temperature swings and temperature including via a temperature of 0 ℃ in a 24-hour period [5]. Extreme temperatures induced by fires and the lateral force created by impact are two common stresses that fibre-cement boards are subjected to. This is because ventilated facade cladding, balcony shields, and interior wall cladding are all constructed with such boards [8].

Researcher made a comparative study caused by the addition of 10% agricultural waste products such as bamboo, coconut fibres, sugar-cane dregs, and rice husks to cement matrix for the development of cement fibre boards that can be used as a construction panel material [9]. In Taiwanese construction, the use of cement board, calcium silicate board, and gypsum board are widely applied. The moisture content of calcium silicate and gypsum boards can reach up to 80% and 75%, respectively, due to Taiwan's humid atmosphere [9]. As a result, applying fibres to the partition board is one strategy for eliminating humidity-induced deformation in building partitions.

2. Materials and Methods

Material preparation is one of the essential processes for the successful running of the new project. Empty fruit brunch (EFB), cement, and water are ingredients that have to be supplied to make sure all the process going smoothly. This is intended to manufacture cement fibre board. The mixing proportion were determined by using try and error method to get the suitable mixture for EFB fibre cement board. The ratio of fibre decided to use were 0.00 %, 15.00 %, 17.00 %, 20.00 % and 23.00 %. The initial water cement ratio 0.50 were used in this study. The cement and water content were fixed and the mixture without fibre was using as control sample. The target density of 1000 kg/m3 and total of board are 10.

2.1 Materials

In this study, the materials that were used include:

1. EFB fibre – treated with Sodium Hydroxide
2. Cement – Ordinary Portland Cement (500 kg)
3. Water -250 ml
4. Mould – 210 mm x 210 mm x 12 mm

Table 1: Ratio to be tested

Ratio (%)	Cement (kg)	EFB (g)	Water (ml)
0	500	0	250
15	500	75	250
17	500	85	250
20	500	100	250
23	500	115	250

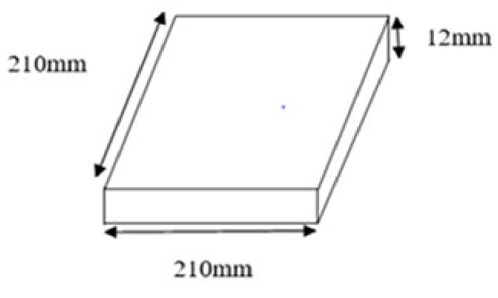

Figure 1: Size of cement board sample for MOR, MOE and thickness swelling and water absorption

2.2 Cement Board Fabrication Process

The EFB were cut manually using scissors into the required size of length for the mixes, which is 0.50 cm to 1.00 cm to be used as the fiber reinforced in producing oil palm EFB fiber cement board. After the required size of fibres was achieved, the fibres were immersed in water and sodium bicarbonate to make sure that they are cleaned enough to be used. The function of sodium bicarbonate is to remove oil in EFB and also to firm the fibre, thus enhance the strength of fibre. The fibres were then hand-washed and oven dried to reduce the moisture content. The EFB fibre, cement which is Ordinary Portland cement (OPC) and water are were mixed together before being poured into the mould. The mixed material was then placed into the 210 mm x 210 mm wooden mould after it was completed. To make proper demoulding smoother, grease was added to the surface of the mould. To avoid the specimen from having an irregular surface and to make demoulding smoother, plate of plywood for precompact processing are put on top of a mixed substance. After pouring the mixture into the mould, it was squeezed until it reached the desired thickness. The sample was then dried at room temperature for about 28 days.

2.3 Board Dimension

To carry out the test, the board will be cut into several pieces according to Figure 2.

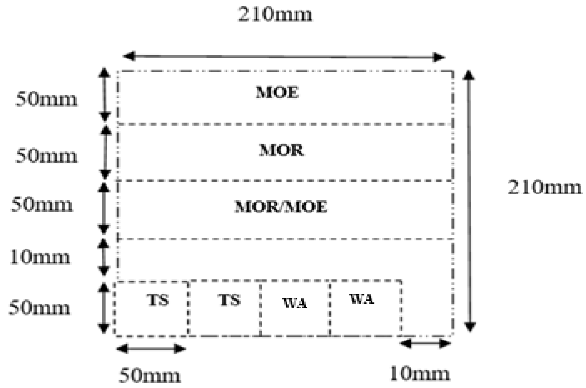

Figure 2: Cutting dimension of EFB cement samples

2.4 Testing of Cement Board

The performance of cement board was determined by conducting several tests such as Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Thickness Swelling (TS), Water Absorption (WA) and Density. Table shows the minimum required for specified OPC bonded particle boards [10].

Table 2: Minimum required for specified OPC bonded particle boards

Properties	Test method	Requirement
Modulus of Elasticity (MOE)	BS EN 310:1993	>4000 N/mm2
Modulus of Rupture (MOR)	BS EN 310:1993	>9 N/mm2
Water Absorption (WA)	BS EN 319:1993	<60 % ** (based on industrial requirement)
Thickness swelling in 24 hours (TS)	BS EN 317:1993	>1.5% (From initial thickness)
Density	BS EN 323:1993	<1000 kg/m^3

3. Results and Discussion

3.1 Results

Table 3 below shows the results of testing that had been conducted on cement board fibre.

Table 3: Average test value of cement board produced by using oil palm EFB fibre

Ratio	Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)	TS (%)	WA (%)
0%	1924.99	10.05	4176.07	0.24	3.07
15%	892.51	2.93	1901.24	1.79	74.63
17%	791.86	1.13	1379.89	2.21	94.46
20%	636.25	0.82	1624.56	2.45	132.68
23%	625.55	0.67	739.88	2.62	148.36

3.2 Thickness swelling

Based on the Figure 3 below, it shows that the thickness swelling of fibre ratio 23.00 % with 2.62 % was the higher thickness swelling than another sample. The second higher was the ratio 20.00 % with 2.45 % of thickness swelling. The sample with 0.00 % of fibre was the lower thickness swelling which is 0.24 %. Lower thickness swelling value indicates a more stable board. It can be observed that, the ratio 23.00 % contain high fibre content than the other ratio. The cement board with a high fibre content in the sample was not entirely crushed, and there was a gap that allowed water to enter the cement board readily. The existence of larger void space in cement boards increased water absorption, which altered the percentage of thickness swelling values [11]. The standard of thickness swelling for cement boards used according to BS EN 317:1993 is 1.50 % of the initial thickness. The thickness swelling for each type of fibre ratio tested, as shown in the graph analysis above, meets the criteria.

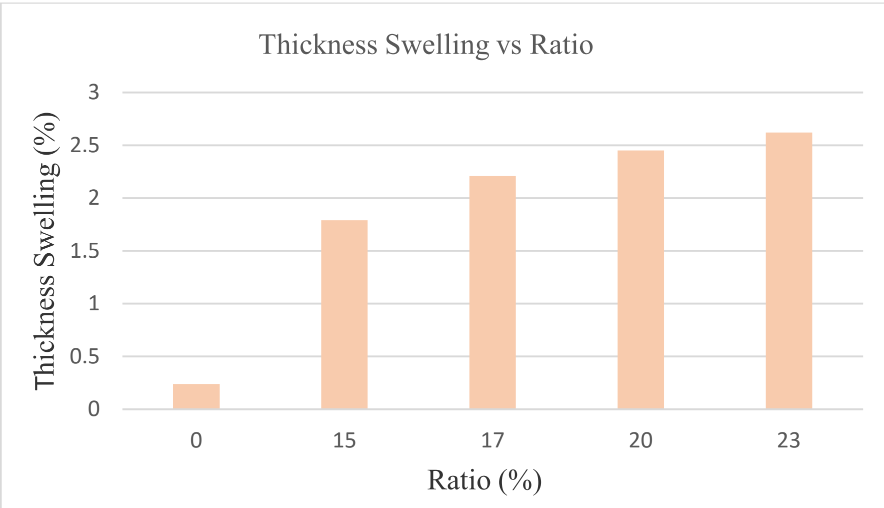

Figure 3: Thickness swelling of cement boards based on fibre ratio

3.3 Water Absorption

The entire ability of the cement board to absorb moisture is measured by water absorption. Figure 4 illustrates the effect of EFB fibre ratio content on water absorption after the samples had been submerged in water for 24 hours. The optimum value of water absorption is 148.36 % which occurred at 23.00 % ratio of fibre. For 20.00 % and 17.00 % of fibre ratio, the water absorption values were 132.68 % and 94.46 % respectively. The water absorption of EFB fibres cement board increased when the fibre content was increased. This is due to the presence of dry fibres and voids inside the cement board, which have a susceptibility to absorb water when submerged. Then, for samples that do not contain fiber which is 0.00 % of fibre ratio, it has the lowest water absorption value due to less space that allows water to permeate.

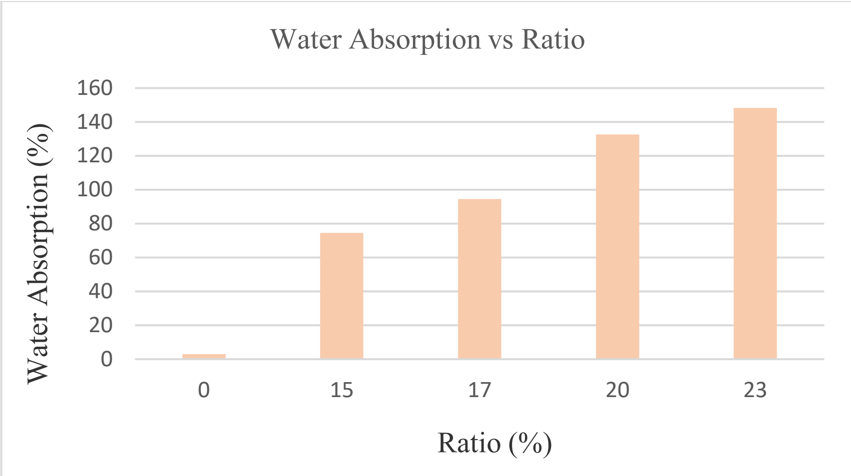

Figure 4: Water absorption of EFB cement board

3.4 Modulus of Rupture (MOR) & Modulus of Elasticity (MOE)

Based on the result obtained, it shows the modulus of rupture with different ratio of fibre. The modulus of rupture for cement board with different ratio 0.00 %, 15.00 %, 17.00 %, 20.00 % and 23.00 % of fibre is 10.05 N/mm^2, 2.93 N/mm^2, 1.13 N/mm^2, 0.82 N/mm^2 and 0.67 N/mm^2. It can be observed that the cement board with 0.00 % of fibre has the higher value of MOR. From the graphs it stated that as the amount of EFB fibre increases, the MOR values drop. The differences between the standard and test values are displayed in Figure 5. The sample that achieve MOR requirement was the ratio 0.00 % of fibre with the value 10.05 N/mm$^{2.}$ The others ratio which is 15.00 %, 17.00 %, 20.00 % and 23.00 % did not achieve the standard for cement board to be used as structural in construction. The standard requirement for MOR is 9 N/mm^2. The MOR number denotes the maximum load that the board can withstand on its surface.

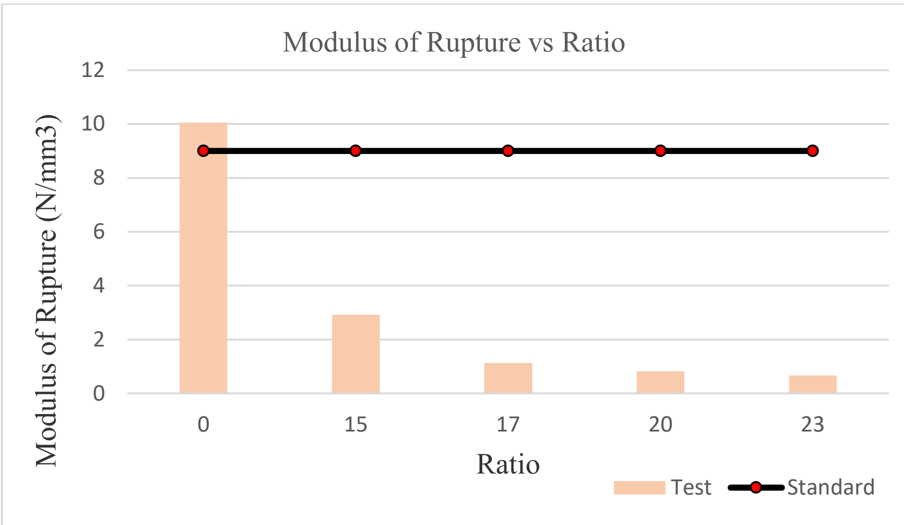

Figure 5: Modulus of Rupture results with various fibre ratio

Based on the result obtained, it can be seen that the optimum modulus of elasticity (MOE) for fibre with ratio 0.00 %, 15.00 %, 17.00 %, 20.00 % and 23.00 % are 4176.07 N/mm^2, 1901.24 N/mm^2, 1379.89 N/mm^2, 1624.56 N/mm^2, and N/mm^2. So, the optimum MOE is ratio 0.00 %. The MOE value for the mix ratio of 23.00 % is extremely low, while the maximum value is for the ratio of 0.00 %. However, the fibre ratio 17.00 % has higher cement content but lower MOE value than 20.00 %. As we all know, fibre acts as a reinforcement in cement boards to boost strength, but cement boards with a fibre ratio of 17.00 % have a high cement content that is less than the value of fibre. As a result, the cement is fragile. So, it is reasonable to conclude that the higher fibre content, the lower value MOE of that cement board. Based on the BS EN 301: 1993 standard requirements, the value of Class 1 is 4500 N/mm^2 and for Class 2 is 4000 N/mm^2. The study has shown that the criteria in MOE achieve the BS requirements for fibre with ratio 0.00 %, while the others ratio did not achieve.

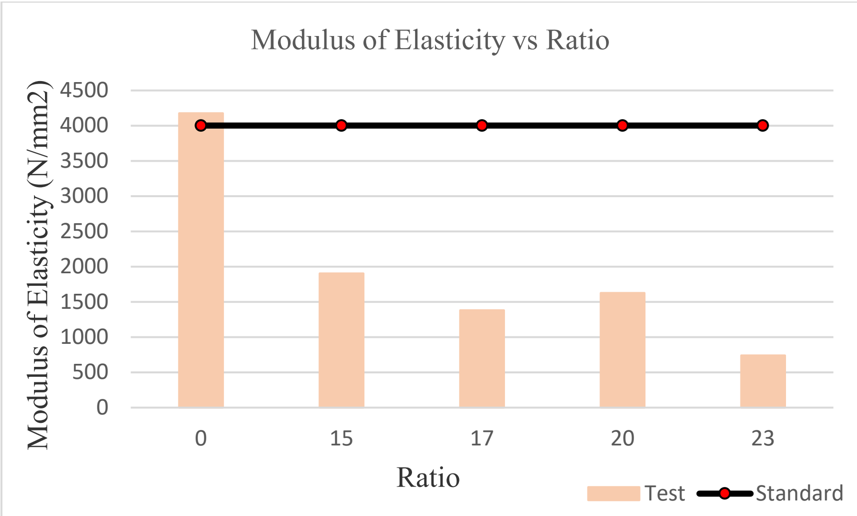

Figure 6: Modulus of Elasticity with various of fibre ratio.

According to previous research [12], particle size influences MOE and MOR strength, implying that particle surface area is significant in defining MOE and MOR strength. As a result, the fibre size used in this study ranges from 0.50 cm to 1.00 cm. However, due to a variety of factors, including a lack of a suitable cutting equipment that compelled the fibre to be cut manually with a scissors, the desired particle size for particular fibre proportions was not met which is not more than 1.0cm. As a result, the MOE values desired were not obtained, and it appeared that the more fibre inserted in the board, the weaker the board became. The mechanical characteristics and water absorption of composite boards will be reduced if substantially larger particle sizes are used [13]. Aside from that, the fibre, water, and cement mixture should be consistent. Because of the improper mixing procedure, the bonding between the fibres and the cement is not consistent, the strength of the cement board is not uniform at each place.

Other than that, when the EFB fibres were washed with NaOH, they seemed to flock together with the others. Even though attempts were made to separate the fibres, some were unable to do so. The experimentally determined strength of natural fibres tends to rise when the test length is lowered and the number of flaws in the test region is reduced [14]. According to Das et al. (1999) [15], when compressed fibre absorbs water, it not only swells, but it also relieves the compressive stress imparted to the fibre board during processing due to the recovery of the fibre's original shape via previous memory (fibre spring-back action). The spring-back action of compressed EFB fibre causes the adhesive connections between the EFB fibres to break. As a result, the prepressing process should be extended to ensure that the forming is well attached. If a shorter time period is required to pre-press the board, another additive, such as carbon dioxide, should be used, but only with correct press schedules and unique procedures [16].

3.5 Density

The cement content directly influenced the density of the samples. The mixes 0.00 % of fibre ratio had a higher cement content resulted in higher value of density which is 1924.99 kg/m^3 compared to others ratio. High cement content enhanced the cohesion of the new mix, allowing for higher compaction quality, provided a stronger link between EFB fibres, and filled the space in the mix for smaller particles. The density difference across mixes decreased from 1924.99 kg/m^3 to 625.55 kg/m^3 when EFB fibre content increased from 0.00 % to 23.00 %. This might be related to the fresh mixtures poor cohesive strength. As demonstrated in Figure 7, the density of the specimen reduced as the EFB fibre concentration increased. EFB fibre was a cellular structure with many micropores and a large amount of vacant space. As a result, the void in the mix expanded as the EFB fibre percentage increased.

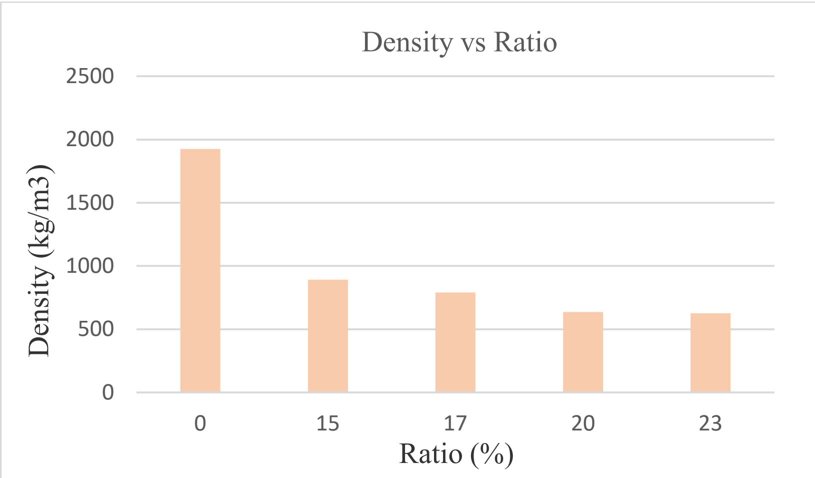

Figure 7: Graph for density

The density of the boards achieved from this investigation is roughly in line with the goal density of less than 1000kg/m^3 which is based on BS EN 323:1993. However, the density of 0.00 % fibre ratio is higher than the intended value of 1924.99 kg/m^3. A prior study found that the density of composite board affects its mechanical capabilities [11]. However, it has no effect on the stability of the product [18].

4. Conclusion

In conclusion, all the tests give a different effect on mechanical strength properties of EFB fibre cement board. This might be happened due to improper mixing process and the size of fibre used in this study was not as required which is 0.50 cm to 1.00 cm. All of this problem happened because lack of machine at our laboratory so, we need to do all the process manually as example the EFB were cut manually using scissors into the required size of length for the mixes. From this study, had identified that the optimum fibre ratio is 15.00 % to produce the cement board by using empty fruit bunch (EFB). The cement board produced by using EFB fibre did not satisfy the requirement standard in case of MOR, MOE and water absorption. It can be concluded that EFB fibre can be regarded as a potential material in the manufacturing of EFB fibre cement board for pressure-free products such as internal wall and ceiling. The lack of MOE and MOR value causing the product not suitable to be used for load bearing application. The usage of oil palm EFB, on the other hand, is still undergoing research to determine the best conditions for improving board qualities. More research is needed to identify the physical and mechanical qualities of the panel product, as well as the best operating parameters for the production process. Hopefully, the research will be maintained and expanded in the future, considering the most appropriate methods and techniques, as well as the most up-to-date technology, to create cement boards of the highest quality, cost-effectiveness, and compliance with the standards.

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