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Development of Oil Palm Empty Fruit Bunch Cement Boards Based on Different Boards Surface Alteration

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Abstract

The construction industry is currently dealing with a critical need to discover environmentally friendly alternatives to conventional building materials. Taking all of this into consideration, the application of agricultural waste in the production of cement-based boards has attracted major interest. This study focuses on the development of oil palm empty fruit bunch (OPEFB) cement boards through the application of different surface alteration techniques. The objective of this research is to the surface alteration method that can be applied for cement bonded fibre boards and evaluating the effect of surface alteration method on physical and mechanical properties of cement boards. There were two different approaches to the surface alteration that were used which is coating and sanding. The constant density and water content fixed as 1300 kg/m³ and 40% respectively. The mechanical properties, such as modulus of elastic, modulus of rupture and internal bonding while physical properties thickness monitoring and density have been specified to determine the potential of empty fruit bunch strength and to establish the research findings. The study's findings revealed that varying the surface alteration techniques altered the mechanical and physical properties of the EFB cement board. Particularly, when compared to other surface alteration approaches, the board with coating method shown excellent mechanical and physical properties, with the MOR, MOE, IB, thickness swelling, and density produced being 4.434 N/mm², 4236 N/mm², 0.35 N/mm², 1.32%, and 1185 kg/m³ respectively. These findings highlight the potential of EFB as an environmentally friendly material for sustainable construction, providing benefits in terms of environmental preservation, energy conservation, and economic viability.

1. Introduction

The passage discusses conventional cement composites, highlighting their widespread applications in construction but acknowledging drawbacks such as low tensile strength and increased shrinking. Cement boards (CB) are identified as a popular building material globally, made from a mixture of wood particles or fibers, cementitious material, water, and additives [1]. These cement boards, incorporating cement, glass, aggregate, and fiber reinforcements, find use in reinstalling ceramic, stone, worktops, and floors. They are categorized based on various conditions like binder, surface, coloration, and shape, with sizes ranging from 30 to 60 inches and thicknesses of 0.25 to 0.5 inches [2]. The physical properties of cement boards include density and thickness swelling, while mechanical properties encompass bending strength, modulus of elasticity, and internal bonding. Two main types of cement boards are highlighted: wood particle cement boards and wood fiber cement boards, the former being used for architectural, fire-resistant, and acoustic panels. The text emphasizes Malaysia's significant role in oil palm production, stressing its importance to the country's economy and rural development. The palm oil industry generates substantial waste, including oil palm empty fruit bunches (OPEFB), which are fibrous remains after oil extraction. OPEFB, composed of cellulose, hemicellulose, lignin, and other compounds, presents an opportunity for sustainable construction materials, addressing environmental concerns [3]. The Malaysian palm oil industry is exploring ways to optimize OPEFB utilization and reduce its environmental impact. The passage notes that Malaysian palm oil companies have seen substantial profits from palm oil exports, emphasizing the need for responsible practices and sustainability within the industry [4]. The interconnectedness of the cement and palm oil industries, emphasizing the potential of natural fiber composites, especially OPEFB, in sustainable construction. It links these materials with the development and properties of fiber cement boards, showcasing the evolving landscape of construction materials and the industry's efforts towards responsible and sustainable practices.

2. Previous Study

Natural fibers play a crucial role in reducing the environmental impact of polymeric composites, providing a sustainable alternative to synthetic fibers in various applications [5]. These fibers, derived from sources like plants, exhibit properties that make them suitable for composite materials, contributing to their low-energy, durability, and eco-friendly nature. Composite materials, consisting of two or more physical elements with enhanced properties, often use polymers as matrices due to their favorable characteristics such as low density, strong wetting ability, and ease of molding [1]. In comparison to synthetic fibers like glass, natural fibers offer economic and environmental advantages, being non-toxic, biodegradable, affordable, and corrosion-resistant [3]. However, they may have drawbacks such as lower workability and fiber breakdown [1]. Waste fibers from agricultural production, such as those from oil palm, coconut, bamboo, sisal, and jute, hold significant potential for use in composites due to their strength, low cost, global availability, and environmental friendliness [6].

Various studies have explored the reinforcement potential of fibers from coir, flax, sisal, hemp, bamboo, jute, and empty fruit bunch. One notable source of natural fiber is the empty fruit bunch of the oil palm (OPEFB), known for its polymer-reinforced composite properties. EFB fiber, extracted from oil palm's empty fruit bunch, consists mainly of cellulose, lignin, and hemicelluloses, making it a non-hazardous and biodegradable substance. Research indicates that EFB-reinforced polymer composites exhibit superior characteristics compared to other materials. While natural fibers offer clear benefits such as lower energy requirements and cost-effectiveness, they also present challenges related to inconsistent properties, moisture absorption, and lower processing temperatures [7]. Experiments involving the soaking of fiber particles in solutions, such as hot water, and the addition of chemicals like magnesium chloride and calcium chloride aim to enhance the compatibility of fiber and cement in construction materials [7]. Natural fibers contribute significantly to sustainable composite materials, offering a range of advantages, including environmental friendliness, affordability, and strength. Despite challenges, ongoing research explores new fiber sources and processing techniques, fostering the continued development and application of natural fibers in various industries.

2.1 Cement board with the physical and mechanical properties

The study investigates various types of cement boards, each with distinct physical and mechanical properties. Notably, fiber-cement boards exhibit the highest density, while plywood has the lowest. The thickness of the surface material plays a crucial role in determining weight and density, with plywood offering advantages in both aspects due to its thin surface. Water resistance is evaluated based on water absorption after a day of soaking, revealing that commercial wood-composite boards differ in this characteristic. Fiber-cement boards demonstrate the highest resistance to water compared to plywood. Physical stability is assessed through thickness swelling after a 24-hour soak, with plywood exhibiting the lowest stability and fiber-cement board showing the highest. Bending characteristics, measured by Modulus of Rupture (MOR) and Modulus of Elasticity (MOE), are essential strength features. Plywood demonstrates the highest MOR, indicating superior strength-to-weight and strength-to-thickness ratios compared to other materials. The enhanced fiber orientation in the longitudinal direction during manufacturing contributes to plywood's increased bending strength. Cement particleboard exhibits the highest MOE, surpassing fiber-cement board. The chemical composition of cement and wood influences the interfacial binding strength between the materials. The refining process, involving high pressure, temperature, and wood-degrading refining, leads to wood deterioration, impacting the quantity of extractives in fiber-cement board. Despite the lower MOE value of fiber-cement board compared to cement particleboard, the study highlights the intricate relationship between material composition, manufacturing processes, and resulting mechanical properties

2.2 Surface Alteration Techniques

Surface alteration have focused on surface alteration techniques to enhance the properties of oil palm empty fruit bunch (EFB) cement boards. These modifications aim to improve the compatibility between EFB fibers and cement matrices, resulting in enhanced mechanical properties and water resistance of the cement composites. Common techniques like coating and sanding play a crucial role in preparing durable fiber cement boards for applications in construction, such as roofing and siding. Sanding processes involve the use of coarse-grit sandpaper initially, progressing to finer grits for a smoother finish. Hand sanding with a block or pad ensures even pressure for smaller areas, while power sanders like random orbit or palm sanders are effective for larger surfaces, provided they are equipped with the appropriate grit sandpaper. Safety precautions, including dust extraction equipment or protective masks, are essential to mitigate potential health risks associated with fiber cement dust during sanding. After sanding, a thorough inspection of the fiber cement board is necessary to identify and repair any defects. Cleaning the surface from dust and debris is crucial before moving on to subsequent phases like coating or finishing. Adhering to manufacturer guidelines and safety precautions is paramount during the sanding process. The study emphasizes the importance of coating techniques for fiber cement boards, outlining the significance of proper surface preparation, including cleaning, and priming [2]. Various coatings, such as paint, stains, and sealers, serve aesthetic and protective purposes. The application process, including spraying methods, rollers, or brushes, impacts the overall success of the coating. Strict adherence to drying and curing times, according to manufacturer specifications, and implementation of quality control procedures ensure optimal performance and durability of the coating. To comprehend the long-term performance of coatings on fiber cement boards, it is recommended to explore studies evaluating durability, weather resistance, and maintenance requirements. This multidimensional approach ensures comprehensive research into the complexities of coating techniques and their influence on the overall performance of fiber cement boards in various applications.

3. Materials and Procedure

3.1 Materials Preparation

The research focuses on utilizing Oil Palm Fibre (OPF) sourced from the empty fruit bunches (EFB) processed at Pamol Kluang Palm Oil Mill. The raw material undergoes a meticulous preparation process before being used in the production of EFB cement boards. The initial step involves sun-drying the EFB for at least one day to reduce moisture levels to less than 10%. The sorted and uniformly spread EFB is crucial for proper drying. The study revolves around the utilization of Oil Palm Fibre (OPF), sourced from the processing of empty fruit bunches (EFB) at Palm Oil Mill. Prior to its incorporation into EFB cement boards, the raw material undergoes a meticulous preparation process. Initially, the EFB is subjected to sun-drying for a minimum of one day, ensuring moisture levels drop below 10%. The sorted and uniformly spread EFB during this drying phase is essential for optimal results. Following sun drying, the EFB undergoes shredding, where a specialized machine reduces the dried oil palm EFB into shorter lengths, creating discrete fibrous pieces. This material is then fed into a hammer mill machine, further reducing its size and obtaining loose EFB in a hair-like form. The operation of the hammer mill involves impacting hammers and gears, stringing together fibers of different lengths and diameters to create clean and dense fibrous strings. The subsequent sieving process serves to eliminate dust and achieve the desired fiber sizes for the board. The sieving process utilizes a vibration table with nominal apertures of 1mm (30 mesh), ensuring efficiency in separating particles of varying sizes. In this study, the EFB fiber length selected is 7 mm, with a retention mesh size of 14 mm. Before hydration, a critical pretreatment step is implemented, involving soaking the fibers in a water bath at temperatures reaching up to 90°C for an extended period. This pretreatment, maintaining a consistent temperature, prepares the fibers for subsequent treatments. Following soaking, the fibers undergo rinsing in tap water to remove unwanted particles, and excess water is drained off through a twenty-four-hour oven-drying process. The below shows Table 1 estimation of fibre required and table 2 design mixture of EFBCB.

Table 1 *Estimation of fibre required*

No Samples	9
Temperature	90°C
Soaking Period	60 minutes

Sample Size	(350 x 350 x12) mm
Cement-Fibre Ratio	3.5: 1
Volume of Sample	1.47 × 10-3 m3
Dry Weight	1911 g
Fibre for One Sample	424.667 g

Table 2 *Design Mixture*

Sample Size	(350 x 350 x12) mm
Cement-Fibre Ratio	3.5: 1
Volume of Sample	1.47 × 10-3 m3
Dry Weight	1911 g
Fibre for One Sample	424.667 g
Cement	1274 g
Water required	637g

3.2 Fabrication

A set of nine cement board samples, each measuring 350mm x 350mm x 12mm and possessing a density of 1300 kg/m3, is meticulously crafted for the study. The composition of these boards includes regular Cement, water, and EFB fiber, with a water-cement ratio of 40% and a cement-fiber ratio of 3.5:1 based on cement weight. The cement is utilized in powdered form, diluted in water, and thoroughly mixed with dry EFB fiber in a mixer, ensuring comprehensive coating on every fiber surface. The initial step in creating oven-dried fiber cement involves weighing the cement, water, and oven-dried fiber. The weight ratio of cement to fiber is maintained at 3.5:1, signifying that the cement is three and a half times the weight of the fiber. The total water required is determined as 0.3 times the weight of the EFB and 0.4 times the weight of the cement. Loading the fiber into the mixer, water is gradually drizzled over it in a slow, even manner. The wetting process involves three minutes of mixing, allowing the mixer to thoroughly incorporate all ingredients. This process capitalizes on the ability of liquids to create interfaces with solid surfaces, facilitating adhesion benefits. The resulting EFB cement board has a density of 1300 kg/m3, maintaining a cement-fiber ratio of 3.5:1 for each sample. The mixing procedure commences by introducing the EFB fiber into the mixer, where it is mixed for approximately 2 minutes. Subsequently, water and cement are gradually added, and the mixture undergoes a 10-minute mixing process before being poured into wooden molds.

3.2.1 Molding Process

The molding process for the EFB cement board involves several essential steps. First, the mixed substance, consisting of regular Cement, water, and EFB fiber, is poured into a 350 mm × 350 mm wooden mold. This mixture is then evenly distributed and pressed flat by hand. To ensure uniformity, a 10 mm by 10 mm wooden mesh is placed over the formwork, and a wooden comb is used to evenly spread the fiber mixture across all corners and edges. The pre-compact process follows, where a plywood plate is positioned on top of the combined materials to initiate the pre-compression process. Subsequently, a transparent polyethylene sheet is placed over the samples to smooth out any uneven areas on the surface. A metal plate mold is then positioned atop this layer, and the entire assembly is moved to a hydraulic compressor machine. The cement board undergoes compression until it reaches a thickness of 12mm, securing the mold with bolts and nuts. After a 24-hour waiting period, the board and molds are set aside for rest. Following the molding and clamping processes, the curing stage begins. After 24 hours, the EFB cement board is considered toughened, and the specimens are carefully removed from the board. These specimens are allowed to cure at room temperature to prevent moisture loss during the process. For this study, the optimal curing time for each sample is determined to be 28 days.

Fig. 1 *Molding Process*

3.2.2 Surface Alteration Techniques

Following a 28-day curing period, surface alteration techniques were applied to three cement board samples, commencing with the sanding method. The surface preparation involved meticulous cleaning to eliminate dust and debris. Employing varying grits of sandpaper, starting with coarser options and progressing to finer grits, ensured a smooth finish without compromising the board's integrity. Careful attention was paid to avoid over-sanding. After achieving the desired texture, the surface underwent thorough cleaning to eliminate any residual dust. This sanding process served as a crucial primer, enhancing the adhesion properties of the cement board for subsequent surface alteration techniques, ultimately resulting in an improved final appearance. For another set of three cement board samples, the coating method was employed after the 28-day curing period. Before this, a water-based acrylic coating called Fibercote, free from lead or mercury, was applied to the surface. The coating process consisted of systematically applying three layers, with each layer requiring an hour for application. Special care was taken to ensure even coverage and uniform thickness. Following the application, the cement board with three layers underwent a 14-day drying period to achieve full and robust dryness. This multi-layered coating not only enhanced the aesthetic appeal of the cement board but also contributed to its durability and protection, preparing it effectively for its intended use. These surface alteration techniques, whether through sanding or coating, showcase the commitment to refining the appearance and performance of the cement board, demonstrating versatility and suitability for various applications.

(a) (b)

Fig. 2 *Surface Alteration Techniques (a) Sanding Method (b) Coating Method*

3.3 Mechanical and Physical Properties

The sample was carried out to assess the qualities with achieve the minimum criteria for mechanical and physical properties. The following minimum criteria (MOR ≥ 9N/mm^2, MOE≥ 4000N/mm^2, IB ≥ 0.5N/mm^2) while (TS 1.5 % from initial thickness and density ≥ 1000 kg/m3). The measurements of the EFB cement board samples will be cut in various shapes for testing purposes since the surface would be uneven and unclean, then the board was cut approximately.

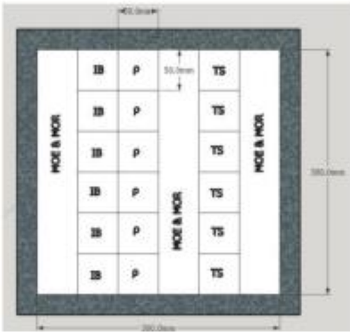

Fig. 3 *Cutting of fibre according to the dimension process*

4. Results and Discussion

4.1 Physical Properties

4.1.1 Density

To investigate the influence that density has on the spring back of cement board, different surface alternation techniques applied to the fibre were taken into consideration. The density that was determined to be the aim for this study was 1300 kg/m^3, whereas the lowest density that was required was 1000 kg/m^3. The testing that was done method was carried out according with the guidelines specified in BS EN 323-1993. Following the cautious and precise cutting of each sample to the desired dimensions, the vernier caliper was used to weigh the samples and measure their length, breadth, and thicknesses. The results of the density tests performed on different surface alternation techniques are presented in Fig. 4

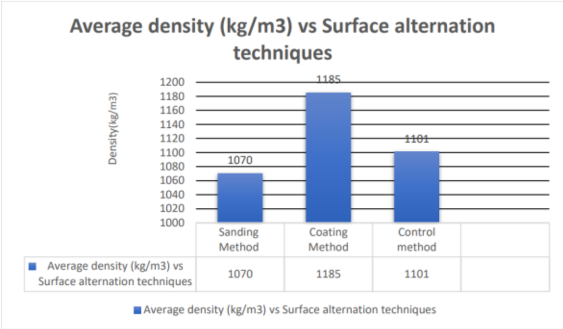

Fig. 4 *Result of density test*

The examination of the different surface modification methods applied to the panels exposed significant variations in panel density. The investigation of several surface modification techniques used on boards revealed considerable differences in density. Among the methods tested, coating techniques had the highest density, reaching 1185 kg/m^3, exceeding the control method's density of 1101 kg/m^3. Meanwhile, boards that were exposed to sanding techniques had the lowest density of 1070 kg/m^3. Particularly, all three techniques fulfilled the minimum density criteria of 1000 kg/m^3, showing basic compliance. Understanding the causes guiding decreased density in boards subjected to sanding processes should advise sanding process changes for improved results. Overall, this thorough investigation gave useful insights into the various results of different surface altering procedures.

4.1.2 Thickness Swelling

The samples of EFB fiber-cement board were submerged in distilled water for a period of twenty-four hours as part of this test. Prior to the soaking procedure, the initial thickness of the sample was measured and recorded. The sample was cut 56 dimensions of 50 mm × 50 mm to meet to the criteria of BS EN 317: 1993.

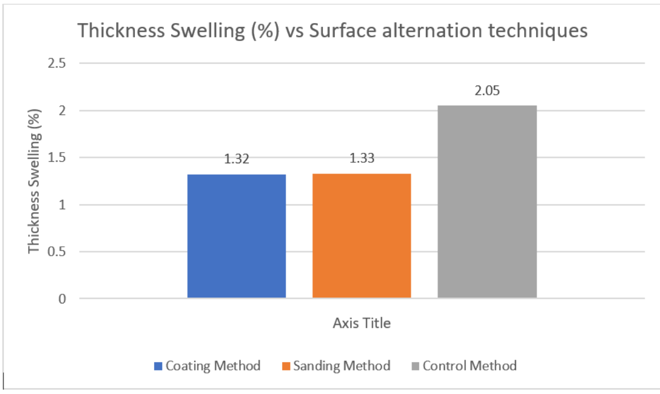

Fig. 5 *Result of Thickness Swelling*

The study of the acquired findings reveals considerable differences in thickness swelling across samples treated with different Surface Alternation Techniques. The coating approach resulted in the least thickness swelling at 1.32%, followed closely by the Sanding method at 1.33% and the Control method with no surface application at 2.05%. On the contrary, samples treated with the Control technique without surface application showed the greatest thickness swelling at 2.05%, with Sanding method□treated samples trailing close behind at 1.33%. Notably, fibres treated with the coating approach had 1.32% less thickness swelling than samples handled with the Sanding method and the Control method with no surface application. With the standard BS EN 317:1993, the requirement thickness swelling for cement boards is established at 1.5% of their initial thickness. Nevertheless, as shown in the graph, the analysis of the tested fibre-cement board ratios reveals that the Surface alternation techniques with coating and sanding method of the samples met this requirement for thickness swelling, whereas the no Surface alternation techniques control method did not meet this requirement for thickness swelling.

4.2 Mechanical Properties

4.2.1 Modulus of Rupture (MOR)

The primary aims of this test are to determine the maximum load bearing capacity of the cement boards and to quantify the stress at which the material fractures or breaks. We were able to determine the entire strength of the cement boards using this test, which we performed. Using this test, we were able to ascertain the ultimate strength of the cement boards, as opposed to the modulus of elasticity, which only provides information regarding deflection. Fig. 6 shows the results of the modulus of rupture tests for EFB cement board.

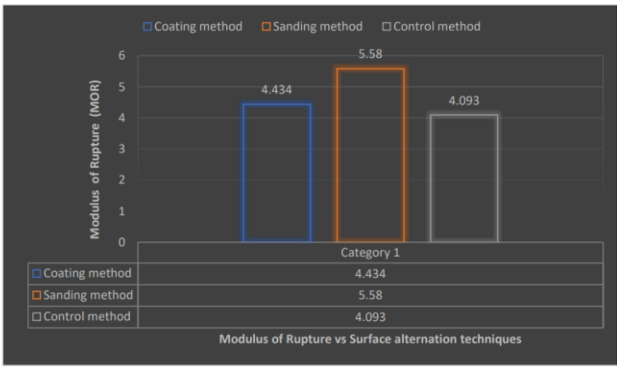

Fig. 6 *Average Modulus of Rupture (MOR) value Surface alternation techniques of Empty Fruit Bunch (EFB)Cement Boards*

Fig. 6 demonstrates significant variations in the Modulus of Rupture (MOR) strength of Empty Fruit Bunch (EFB) fibers subjected to different surface alteration techniques. The sanding method proves most effective, yielding the highest average MOR strength at 5.58 N/mm^2. This suggests that sanding enhances the structural integrity of EFB fibers more effectively than other techniques. Throughout the study, a consistent trend emerges: MOR values decrease with the application of various surface alteration techniques. The control procedure, without any surface alterations, exhibits a range of MOR values with an average of 4.093 N/mm^2, indicating that any surface alteration technique influences fiber strength. In the realm of fiber cement boards, the coating method emerges as noteworthy for providing higher MOR strength compared to boards without surface modifications. The average MOR value for coated fiber cement boards is 4.434 N/mm^2, surpassing the normal control approach. These findings underscore the varied impact of surface modification on EFB fiber and fiber cement board MOR strength, with sanding and coating methods being particularly effective. Recognizing these variations is crucial for informed decision-making in selecting the most appropriate surface alteration method based on desired strength outcomes in practical applications. While the MOR strength values in this research did not meet the BS EN 310:1993 requirement of 9 N/mm^2 or above for cement boards, various factors, including the fiber's crumpled state during sun drying after pre-treatment, may contribute to this deviation. Optimizing the fiber size through crushing or separating before the oven-drying process could enhance the composite boards substantially. Additionally, the fiber's effectiveness, influenced by factors like composition, structural integrity, and moisture content, plays a role in its ability to withstand applied stress and sustain strength. This study suggests that the size of fiber particles significantly influences the characteristics of fiber-cement composites when combined with cement.

4.2.2 Modulus of Elasticity (MOE)

To determine the EFB cement board's resistance to bending and its capacity to restore its original form when the load that was applied to it was removed, the modulus of elasticity (MOE) of the board was determined. An Instron Universal Testing Machine was used in the testing process, which took place at the Structural Laboratory. The measurement consisted of assessing the sample's capacity to withstand deformation when it was exposed to a force. The testing procedure followed the requirements outlined in BS EN 310-1993. The outcomes of the MOE are presented in Fig. 7. for different surface alternation techniques.

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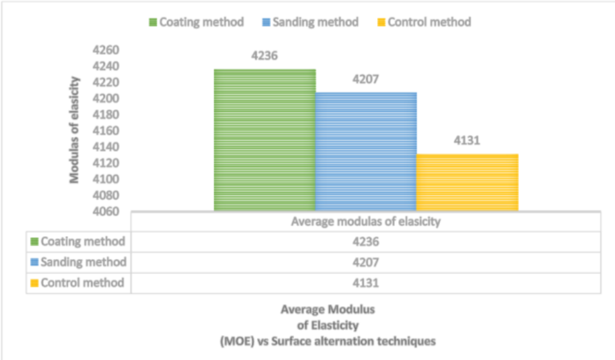

Fig. 7 *The average Modulus of elasticity (MOE) value for Surface alternation techniques of Empty Fruit Bunch (EFB) Cement Boards*

Based on Fig. 7, the EFB fibre treated with surface alteration techniques using the coating method has the highest modulus of elasticity (MOE) strength when compared to the Sanding method and the control method with no surface alterations. The average MOE strength for the EFB fibre treated to the coating technique is reported to be 4236 N/mm^2, above both the Sanding method, which registered an MOE value of 4207 N/mm2, and the control method with no surface applied surface alteration. Surface alternation techniques that use the Sanding method reveal higher strength in the domain of fibre cement boards when compared to the no Surface alternation techniques control approach. The fibre cement board treated with the Sanding method has an average MOE value of 4131 N/mm^2, indicating that this specific surface alteration approach improves the modulus of elasticity above the control method with no applied modification. It is reasonable to conclude that the findings of the study met the BS Standard criterion of Class 2: 4000 N/mm^2.All the three surface alternation techniques achieve in reaching the standard with Class 2: 4000 N/mm^2. These studies illustrate the effect different surface alteration approaches on the MOE strength of EFB fibres and fibre cement boards. The coating approach is particularly successful in increasing the MOE strength of EFB fibres, whereas the Sanding method outperforms in the context of fibre cement boards. Understanding these variations is critical for making educated judgements when selecting acceptable surface modification techniques in practical applications based on required strength characteristics.

4.2.3 Internal Bonding (IB)

Internal bonding tests are done on cement board samples to determine the strength of the boards by applying force until the boards break. Tensile strength is the term used to describe this sort of strength. To calculate the tensile strength of a sample, divide the maximum load at failure by the sample's cross-sectional area. These tests are carried out in compliance with BS EN 319-1993 requirements. Fig. 8 show the results of internal bonding (IB) tests performed on EFB cement boards treated with various Surface Alteration techniques.

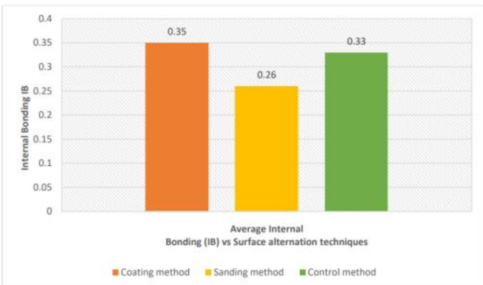

Fig. 8 *The average Internal Bonding (IB) results of EFB Cement boards for Surface alternation techniques of Empty Fruit Bunch (EFB) Cement Boards*

The outcomes obtained give a thorough understanding of the internal bonding strength of Surface Alternation Techniques across various surface types, using the coating technique, sanding method, and a control approach with no surface changes. Internal bonding values recorded were 0.35 N/mm^2, 0.26 N/mm^2, and 0.33 N/mm^2. Particularly, the EFB cement board treated with the coating method has the strongest internal bonding strength, showing a strong strength of 0.35 N/mm^2. This data indicates that the coating approach greatly improves the internal bonding strength of the cement board, surpassing the sanding and control methods. According to BS EN 319:1993, cement boards should have an internal bonding strength of 0.5 N/mm^2 or above. However, this study did not achieve the BS level, it was observed that the failure of the boards was due to failure of fibre-to-fibre bond. This happened in compaction procedure, there was unsuitable compaction. Inadequate compaction can result in uneven fibre distribution and insufficient fibre contact, compromising internal bonding strength. Research done by Nor Asmalyana Kamaruddin in 2022 supports this finding, indicating that prepressing process should be extended to ensure that the forming is well attached. These findings play an important role in determining the effectiveness of different Surface Alternation Techniques in changing the internal bonding strength of materials. The coating method's excellence in this context suggests its potential for increasing the cohesive forces inside the cement board. Understanding these variances allows for educated decision-making when selecting surface alteration procedures, taking into consideration the individual needs and desired attributes in real applications.

5 Conclusion

This study aimed to comprehensively explore surface alteration strategies for cement-bonded fiber boards derived from oil palm empty fruit bunches (EFB), with a primary focus on identifying optimal methods for enhancement. Through meticulous examination, coating and sanding methods emerged as particularly beneficial in improving the structural qualities of these boards, providing practical significance for commercial applications. The findings not only summarize major discoveries but also establish a tangible link between research outcomes and potential real-world applications, paving the way for breakthroughs in material efficiency within the construction sector. Additionally, the research yielded significant insights into the influence of various surface alteration techniques on the physical and mechanical characteristics of cement boards. The analysis highlighted the critical role of the coating process in enhancing the compatibility of EFB fiber-cement composites. EFBCB samples subjected to the coating method exhibited improved performance, particularly in modulus of elasticity, modulus of rupture, and internal bonding, compared to the effects observed with sanding and the control method without surface alteration techniques. These findings underscore the significant efficacy of the coating method in optimizing both the physical and mechanical properties of cement boards made from oil palm empty fruit bunches.

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