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The Physical and Mechanical Properties of Oil Palm Empty Fruit Bunch Fibre (OPEFB) Based on Various Fibre-Cement Ratios

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Abstract: Empty fruit bunch (EFB) is one of the potential alternative in producing cement boards due to its abundant supply and favourable physicochemical characteristics which benefit in many ways. The focus of this research is to examine natural residues which is empty fruit bunches from palm oil that have been used as reinforcing materials in the manufacture of cement boards that related to various ratio. This experimental research work conducted to explore the role of cement to EFB ratio on the mechanical performances of cement boards. Furthermore, densities of 1200kg/m^3 with a cement: EFB 2:1, 2.5:1 and 3:1 ratio were exploited to get the finest performance from this empty fruit bunch cement board (EFBCB). On the other hand, the EFBCB test, which was invented matching to BS standards, containing thickness monitoring (BS EN 3241: 1993), density test (BS EN 323: 1993), elastic modulus (BS EN 310: 1993), modulus of rupture (BS EN 310: 1993), thickness swelling (BS EN 317: 1993) and internal bonding (BS EN 319: 1993). The optimum density for EFB cement panels was discovered to be sample with ratio 3:1 at the end of this project. It displayed the last monitoring readings for thickness was 12.38 mm, highest density 1239 kg/m^3, lowest thickness swelling 3.63%, highest internal bonding 0.299 N/mm^2, highest Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) 1105.13 N/mm^2 and 3.46 N/mm^2. Simply put, the results of this study prove that EFB has a great capacity to be the most advanced material in the country's construction industry.

Keywords: Empty Fruit Bunch Cement Board, Density, Physical Properties, Mechanical Properties

1. Introduction

Excessive of palm oil residue have been increased from each year to a year. The amount of fresh fruit bunch (FFB) produced in Malaysia has increased rapidly from time to time which has produced over million tons of oil annually [1]. Oil palm fibre either from trunk or empty fruit bunch (EFB) is such

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exceptional reinforcement material as it is safe, renewable and, due to established technology it always readily available at relatively low cost to obtain the fibres vastly. Nowadays, there is a huge demand for civil engineering in Malaysia, especially building materials. Other application includes the use of EFB fibre is as insulation, wall partition, medium density fibre board, housing application and fertilizer. The product availability is very easy because it comes from many sources and access which should be fully optimize. So, there are problems with the supply of materials. Some researchers have found solutions to develop waste management strategies that can be used to replace materials with specific needs [2]. For example, coconut shells and empty palm oil palm fruit (EFB) can be exploited as fibres to replace asbestos in cement board manufacturing.

The main advantage of cement boards is that they do not swell or curl when wet, because they have excellent drying properties [3]. It is also widely used in construction because it has a longer lasting performance advantage than paper-lined gypsum products because it will not mould or physically decompose due to moisture or leakage. The properties of empty fruit bunch which have low thermal conductivity, good thermal insulation, and have also been invented for the manufacture of high-strength materials, making them suitable for use as reinforcing materials for cement boards [4]. Higher fibre content utilise in cement mixture is not impossible subsequently it will adversely affect the properties of cement products. Aside from the research attempt to make Empty Fruit Bunch Cement Board (EFBCB), there may be very limited and rarely published research on the outcome of different fibre cement ratios which will effect on the EFBCB properties. The aim of this study was therefore to investigate whether the uptake of EFB with a high fibre content from oil palm could improve the properties of cement boards. Hence, it is vital to discover and isolate the proper fibre ratios that can interject to the peak performance for the final product when completed.

2. Oil palm empty fruit bunch fibre (OPEFB) in Malaysia

Oil palm empty fruit bunch (OPEFB) got a huge demand thrust in industry because it is a lignocellulosic material which mostly include of cellulose, lignin and hemicelluloses that can be exploited to good use. Oil palm fibre obtained from oil palm's empty fruit bunch (OPEFB) within decoration process which is a non-hazardous biodegradable material. It can provide extra mechanical and structural support. Because of these special characteristics, there has been a growing attentiveness in oil palm fibre which used to utilize these natural fibres as reinforcement in construction industry.

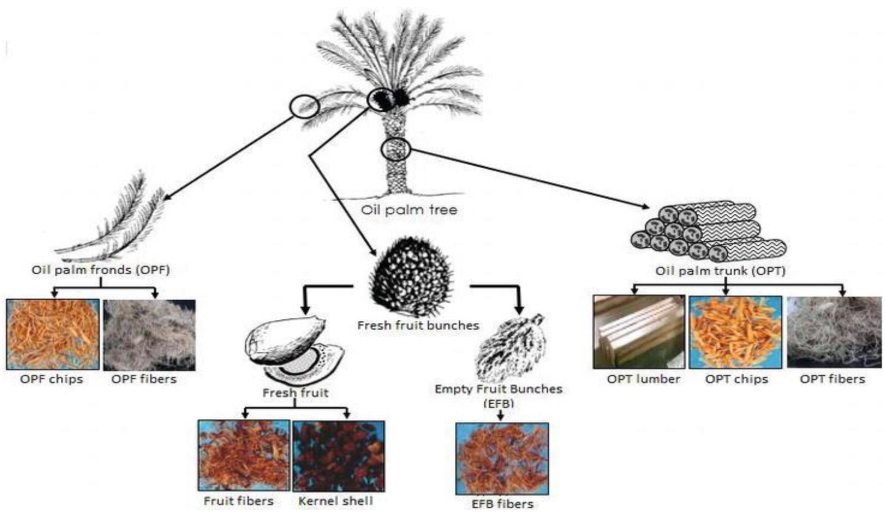

Figure 1: Total Utilisation of Oil Palm Biomass

2.1 Fibre

Natural fibres are taken from plants and are mainly composed of cellulose, hemicellulose, lignin, pectin and other waxy substances [5]. Natural fibres extracted from plants are usually used as reinforcing materials for cement boards. EFB is the bulky capacious brown bunch that left over from the palm oil factory after the sterilized fruit is extracted by the rotary thresher drum. The EFB has an irregular shape, weighs about 3.5 kg, is 130 mm thick, has a length ranging from 170 to 300 mm, and a width ranging from 250 to 350 mm [6].

Figure 2: EFB Oil Palm

2.2 Fibre Properties

Oil Palm Empty Fruit Bunch (OPEFB) is categorized by tensile strength, elastic modulus, elongation at break, density, and etc [7]. For technical purposes, oil palm fibres are processed into polymers (composites). The addition of fibres to the cement mixture has advantages such as higher fracture toughness, better module characteristics and lower density.

Figure 3: Oil Palm Empty Fruit Bunches Fibre

2.3 Physical and Mechanical Properties

The mechanical properties of the fibre, such as tensile strength, elongation and modulus of elasticity, are determined according to ASTM C1557.

Table 1: Physical-mechanical properties of natural fibres

Fibre	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)	Density (g/cm^3)
Abaca	400	12	3-10	1.5
Bagasse	290	17	-	1.25
Bamboo	140-230	11-17	-	0.6-1.1
Flax	345-1035	27.6	2.7-3.2	1.5
Hemp	690	70	1.6	-
Jute	393-773	26.5	1.5-1.8	1.3
Kenaf	930	53	1.6	-
Sisal	511-635	9.4-22	2.0-2.5	1.5
Oil palm	248	3.2	25	0.7-1.55

3. Materials and Methods

3.1 EFB fibre preparation

Empty fruit bunch (EFB) fibre is a prospective natural fibre to be explore. EFB is also an agricultural waste that produce from the oil palm industry. The empty fruit bunch (EFB) are collected at the oil palm factory in Kluang, Johor. First, OPEFB must be dried in the sun for at least one day after it has arrived at the factory and canvas is used as the liner. Then, the EFB fibre departed through the shredding process. The EFB fibre is in a loose form which can be collected manually from the shredded machine. EFB fibre reduced to particle by hammer mill machine to produce shorter EFB. Next, EFB screened with several differ size distribution in this research which is 1 x 1mm. Ratio of cement: fibre used in this research were 2:1, 2.5:1 and 3:1 with fixed density of 1200 kg/m3 in order to experiment more suitable ratios in future for more perfect mixture of cement board.

Figure 4: EFB fibre preparation

3.2 Cement binder and Ratio

In this study the ordinary Portland cement type 1 (OPC-Tasek Brand) and the density handled 1200 kg / m3 were used with different proportions, which were the cement: fiber ratio; 2: 1, 2.5: 1 and 3: 1 relative. In contrast, distilled water was used to optimize the hydration rate of the cement, with 40% water based on the weight of the cement.

3.3 EFB cement board fabrication

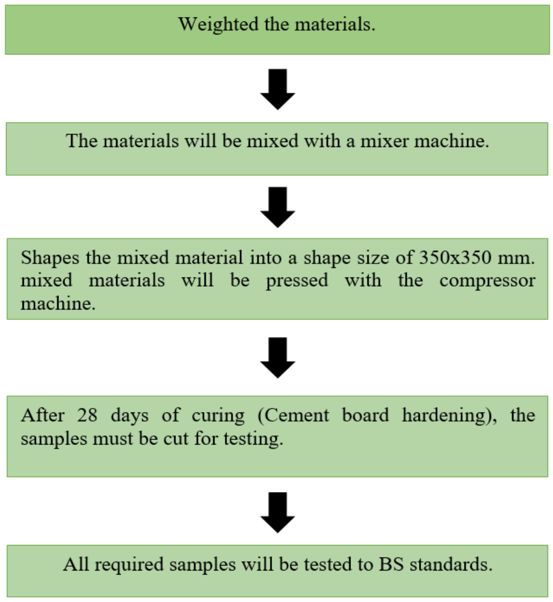

Figure 5: EFB cement board fabrication

3.4 EFB-CB Physical and Mechanical Properties Testing

A sample test was conducted to determine the properties of certain cement board samples. Four property tests were carried out for the cement board EFB; Thickness swelling(TS), Modulus of Rupture (MOR), Modulus of Elasticity (MOE) and Internal Bonding (IB), while two stability tests were carried out for the EFB cement board; Thickness monitoring and density. These tests have been performed according to BS EN 317: 1993 [13], BS EN 310: 1993 [12], BS EN 319: 1993 [14], BS EN 364: 1995 [16] and BS EN 323: 1993 [15]. EFB-cement bonded fiberboard samples were cut as shown in Figure 2.

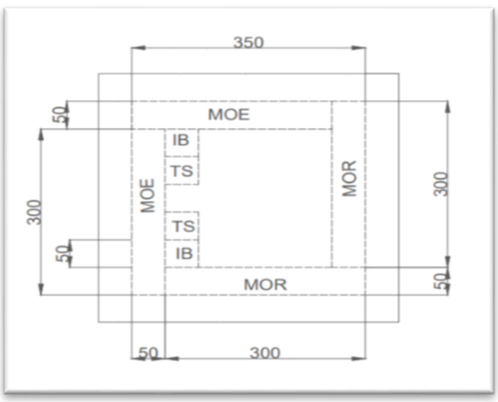

Figure 6: Cutting dimension for EFB cement board samples

4. Results and Discussion

4.1 Results

From the results obtained, the EFB fibre ratio with differential mixture can produce a different physical appearance, durability, strength and special characteristics to the cement board.

4.1.1 Thickness monitoring

The monitoring of the thickness is a test which is conducted out in order to observe the elastic effect of the cement board with different fibre cement content. Testing of this thickness control began after the sample was released from the steel clamp. Thickness monitoring is recorded every two days until 28 days after cure. This study was done to see the increase in the thickness of the empty fruit bunch cement board which leads to the rebound effect. The design thickness for this study is 12mm, with + 1mm allowed (BS EN 364: 1995) [16], the thickness of which should be in the range of 11mm to 13mm where possible to be acceptable for use as a structure in the construction industry being. Figure 4.2 also show the thickness monitoring for the 3:1 ratio increased from day 2 to day 28 from 12.00 mm to 12.38 mm due to the high cement content in empty fruit bunch. This happen due to the content of the highest proportion of mixed cement in the sample [8]. The main binder for binding EFB fibres in EFBCB samples is cement [9]. The weight of the sample was reduced every 2 days. Referring to Figure 7, the thickness control for the 2.5:1 ratio has been increased from 11.70 mm to 11.76 mm even from start to mid-month data record a little bit not constant and the weight has been reduced slightly.

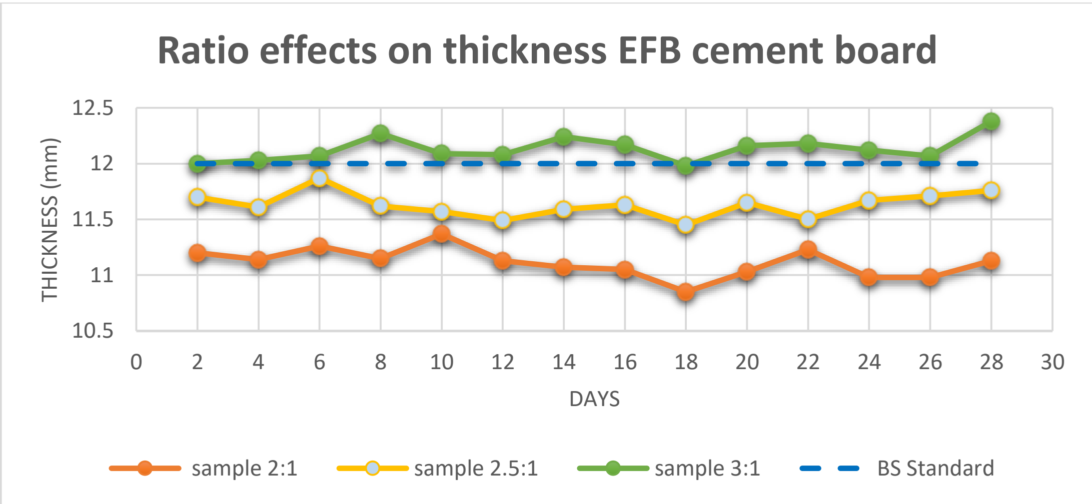

Figure 7: The thickness Monitoring for the 2:1, 2.5: 1 and 3:1 ratio cement board sample

4.1.2 Density Test

Density of the cement board was observed on the basis of the different proportions of the cement boards. The design density for this study is 1200 kg / m³. The tests were executed according to BS EN 323-1993 standard [15]. Figure 8 shows the density results obtained based on different proportions.

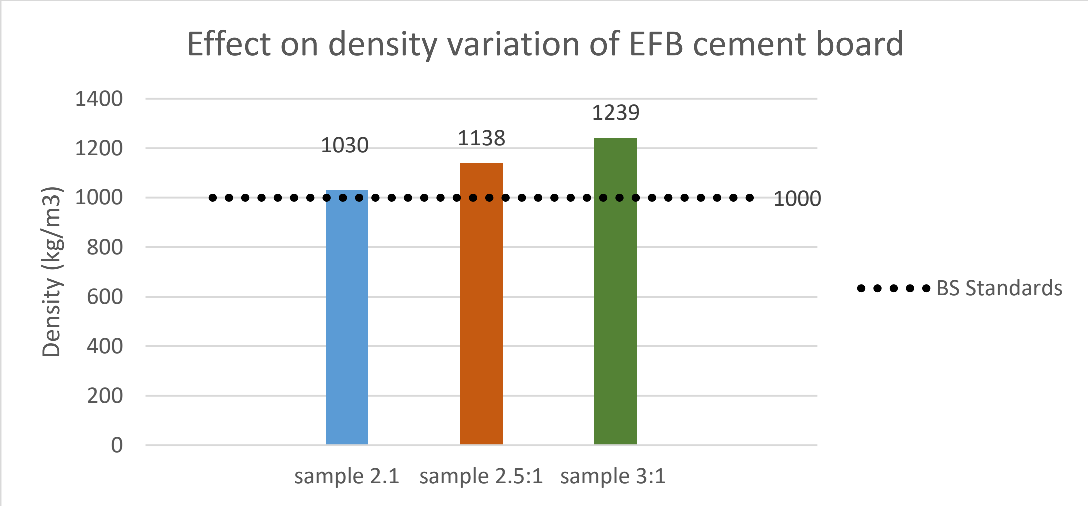

Figure 8: Density of Cement Board results based on various ratios

In figure 8 above shows that all density values exceed and meet the "BS standard" reference value of 1000 kg / m3 which is given in the "BS standards". From these graph, the highest density value recorded is in the 3: 1 ratio category of the cement mix: EFB. With the highest value of 1239 kg / m3, it shows that the most perfect EFBCB density in this research is the 3: 1 ratio. In fact, the all these 3 ratio showed, all of them meet the BS standards too.

4.1.3 Thickness Swelling Test based on different ratio

The EFB fibre cement board sample was immersed in tap water for 24 hours with certain level. The thickness of the sample will be recorded prior to soaking. The sample was cut into 50 mm x 50 mm according to the specifications of BS EN 317: 1993 [13]. Figure 9 shows the thickness swelling result versus fibre cement ratio.

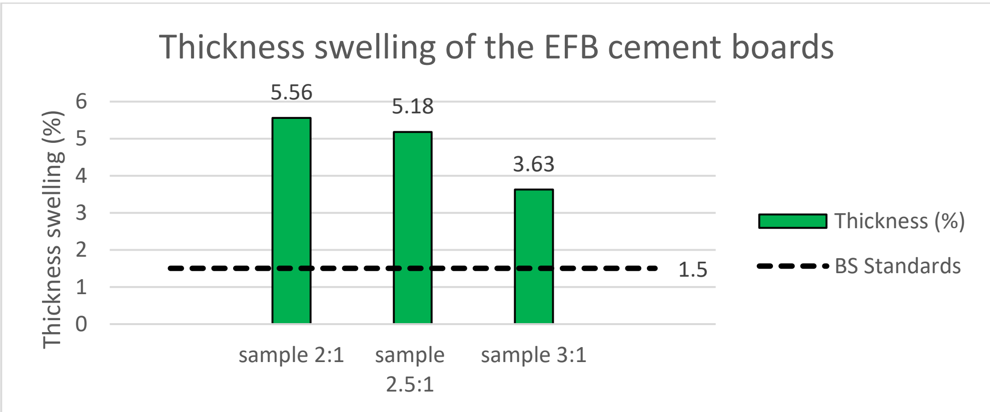

Figure 9: shows the thickness swelling result versus fibre cement ratio

Based on the analysis of the thickness swelling graph in Figure 9 above, the fibre cement ratio for the 2:1 sample was 5.56%, a higher thickness swell than the sample, 2.5:1 and 3:1 which are 5.18% and 3.63%. The high content of fibre cement boards in the sample mixture were not fully compressed and there were voids that prevented water from easily penetrating the cement board. A more frequent voids on low density particle board with respect to the high density particle board, creating areas for greater water absorption in the result [10]. According to BS EN 317: 1993 [13], the standard swelling thickness for the cement boards used is 1.5% of their initial thickness. The swell thickness for each type of fibre cement board ratio tested and reported in the graphical analysis above meet the requirement successfully.

4.2 EFB cement board mechanical properties based on different ratio.

The mechanical characteristics of EFBCB based on wide-ranging densities on EFBCB were clarified and reviewed in terms of Modulus of Rupture (MOR), Modulus of Elasticity (MOE), and Internal Bonding (IB). All testing performed involving British Standards BS EN 310:1993 [12], and BS EN 319: 1993 [14] respectively.

4.2.1 Internal Bonding (IB)

The internal bond test in the cement board sample is used to observe the strength of the cement board until it breaks. Internal Bonding also known as tensile strength. The tensile strength is computed by dividing the maximum stress at the time of catastrophe by the cross-sectional area of the sample. The test is based on BS EN 319: 1993 [14]. Figure 10 shows the result of the internal bond (IB) with different proportions of EFB cement.

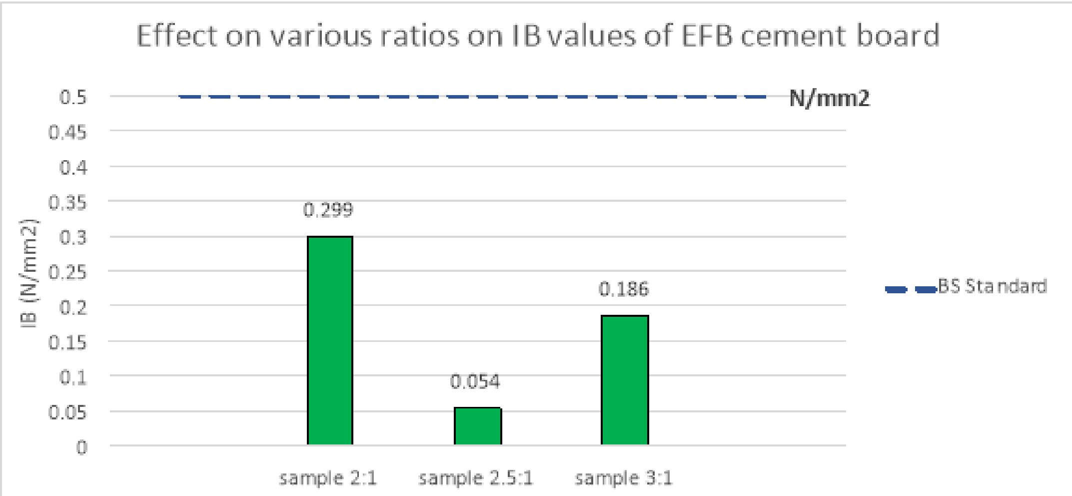

Figure 10: Internal bonding (IB) result with different proportions of EFB cement

The 2:1 ratio showed the highest performance value with a reading of 0.299 N / mm2, which more nearly the 'Standard BS' reference value of 0.5 N / mm2 even not achieved it. Although all samples under the target standard of the 'BS Standard', this shows that the bond strength between cement: EFB still ok but maybe need develop more research on more ratios from this scope.

4.2.2 Modulus of Elasticity (MOE)

The modulus of elasticity is the degree of elasticity of the empty EFB cement board after the applied tension has been relieved and durable to flexural strength. A specimen with a certain resistance to deformation elasticity is measured when a force is applied to the specimen, the test was carried out with the Instron Universal Testing Machine in the Structural Laboratory. The test is based on the specifications of BS EN 310: 1993 [12]. Figure 11 shows the result for the Young's modulus (MOE).

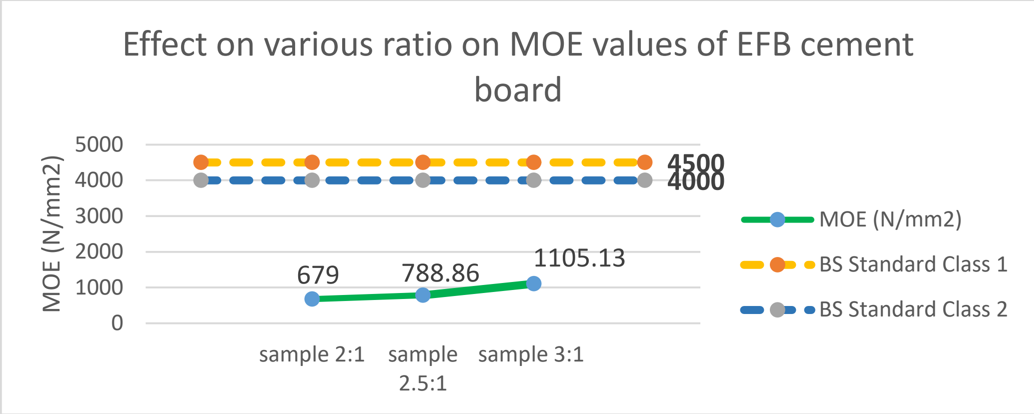

Figure 11: the result for the Young's modulus (MOE)

Based on the result obtained, it can be seen that the optimum modulus of elasticity (MOE) for fibre cement with a ratio of 2:1, 2.5:1, 3:1 increase ascendingly due to proportion. The optimal MOE is therefore the ratio 3:1. The MOE value for the mixing ratio of sample 2: 1 is very low compare to ratio of 2:1 and 3:1. As we know, the fibre in a cement board acts as a reinforcement to increase strength, but the cement board with a mix ratio of 6: 1 contains a high cement value less than the value of the dietary fibre. So, Cement has brittle properties, so it can be assumed that the higher the fibre content, the lower the modulus of elasticity. At a high MOE value, the plates appear brittle, at a low value they tend to be ductile or flexible [11]. According to the specification requirement set out in BS EN 310: 1993 [12], the value for Class I is 4500 N / mm² and for Class 2 is 4000 N / mm². The study has shown that the MOE criteria do not meet the BS requirements.

4.2.3 Modulus of rupture (MOR)

Modulus of Rupture (MOR) is measured by the maximum load-bearing capacity observed from the applied stress at which the specimens break. The test serves to determine the total strength of the cement board in comparison to the modulus of elasticity, which only measures the deflection but not the breaking strength of the EFB cement boards itself. The MOR test is based on the specifications of BS EN 310: 1993 [12]. Figure 12 shows the result of the rupture modulus with various fibre ratio.

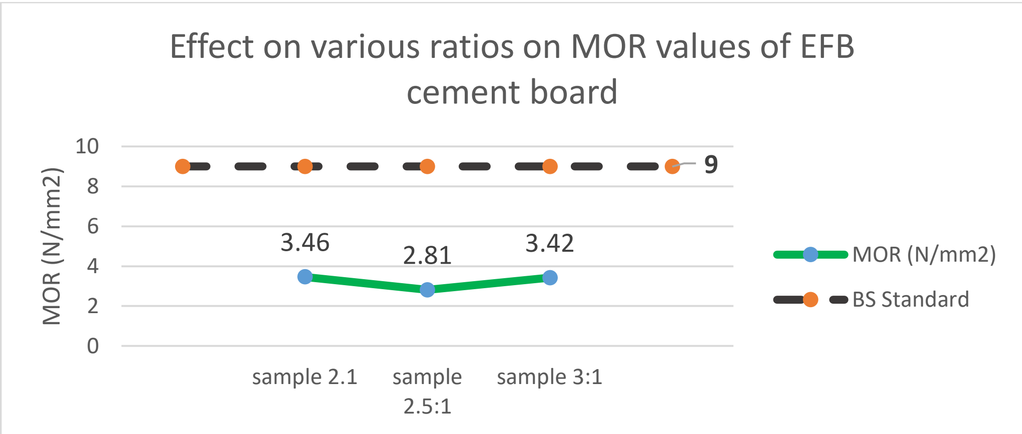

Figure 12: the result of the rupture modulus with various fibre ratio

The diagram in Figure 12 shows that the fibre cement with a ratio of 2:1 is 3.46 N / mm² larger than the value with a ratio of 2.5:1, 3:1 which relatively 2.81 N/mm and 3.42N / mm. This explains why the modulus of rupture that occurs in the cement board is lower when the thicker the cement board is. The standard requirement for MOR is 9 N / mm². The MOR for the total fibre cement ratio did not meet the requirement at all from this result which very far from requirement standards. The performance of the

MOR could be attributed to the mismatch of the EFB fibre with the cement mixes due to the density of the EFB cement board [8].

5. Conclusion

From the analysis, the appropriate ratio of cement: fibre which contributes to optimal physical and mechanical properties can solely be determined from the tests, which was ratio of 3:1 sample. The result of the density tests in Figure 8 clearly shows that the density value for panels with a ratio of 3: 1 (1239 kg/m3) is higher and contains less fibres and also a high cement content compared to 2:1 (1030 kg/m3) and 2.5:1 ratio (1138 kg/m3). The higher the density, the better the physical properties of the cement board. The other tests such as the thickness swelling, also contributed to the fact that the fibre cement ratio 3:1 (3.63%) contains high values of cement components and a lower fibre content, which means that the water absorption of the cement boards is reduced when compare to 2:1 (5.56%) and 2.5:1 (5.18%). The MOR for cement boards with cement / fibre ratios 2:1 (3.46%) showed significantly higher MOR values than others due to the elastic recovery and the increased amount of fibre in figure 12. For the internal bond test of cement boards, it acted as an adhesive and increased the strength of the cement board in a ratio of 2:1, which is shown in the test results in Figure 9. Based on the result, only three test meet the standards, while the others not meet the standards. So, this indicated that advance study is crucial to develop the mechanical properties of cement board to the higher level. The precise cement to fibre ratio that influenced to the optimal physical and mechanical properties is readily apparent from the tests. In summary, it is suggested to use higher various cement: fibre ratios once the amount of the particles affects the prospective and performance of the mechanical and physical properties in cement boards. The volume of particles at different cement: fibre contents also has a straight effect on TS, MOR and MOE.

A few recommendations for future research on the effect of the various ratio for empty fruit bunch cement boards (EFBCB) to physical and mechanical properties such as "Vernier calliper" used to measure thickness for 28 days in the Thickness Monitoring Test is considered less than appropriate to get a really accurate measurement. This is because the daily measured reading record directly not consistent from day before and afterward. In order to resolve this problem, a "micrometer" tool may be able to solve this problem. The "spindle" and "anvil" parts of the "micrometer" tool can go directly to the thickness monitor location marked on the EFBCB surface samples without any problem. Lastly, Chemical additives necessary to be added to the current fibre and cement elements during mixing process. Chemical additives such as NaOH or MgCl are essence to advance the physical and mechanical properties of cement boards for more promising result and product.

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