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Relationship between Density and Mechanical Properties of oil Palm Empty Fruit Bunch Cement Fibreboards After Using Vibration Table during Fabrication

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Abstract: Oil palm empty fruit bunch fibre has been studied for its applicability and potential replacement for wood fibres in producing cement fibreboards as Malaysia has abundant of these biomasses from the oil palm industry. Modification and method of improvement for the properties of empty fruit bunch cement fibreboard (EFBCB) was needed to match the properties of wood fibre cement board, and application of vibration table during the moulding process in the fabrication stage of EFBCB was introduced. This method applied the technique of compaction of concrete through vibration which was common in construction practices. A research was conducted to study the relationship between density and mechanical properties of EFBCB after using vibration table during fabrication. 18 samples were fabricated from 3 cement: EFB fibre ratio of 2:1, 2.5:1 and 3:1, of which 9 samples applied vibration and the other 9 were manually hand formed. Results shown that vibration table has effect on the density distribution across the EFBCB samples, which the density across the board are more evenly and uniformly distributed, however difference of average density between hand plus vibration table formed (HF+VT) EFBCB with hand formed (HF) EFBCB was not significant. The mechanical properties of HF+VT EFBCB increased compared to HF EFBCB. HF+VT EFBCB of ratio 3:1 possess the highest mechanical properties values (MOE 4888 N/mm^2, MOR 11.40 N/mm^2, IB 0.37 N/mm^2). Hence, applying vibration table can be regarded as a new and effective method to improve the qualities and properties of EFBCB.

Keywords: Oil Palm Empty Fruit Bunch Cement Fibreboard, Vibration, Density, Mechanical Properties

1. Introduction

Cement board is made up of Portland cement and reinforcing fibres or particles that act as construction materials such as interior wall panel, floor panel, cladding and more. Cement fibreboard is

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the most manufactured type of cement board globally, and it contains cellulose fibre of which mostly comes from wood. In Malaysia, demand for wood has been increasing and has led to rapid deforestation. One of the alternative materials to replace wood in the production of cement fibreboard is oil palm empty fruit bunch (EFB) fibres, and Malaysia has abundant of oil palm resources, in fact it has generated massive lignocellulosic biomass. Utilise these biomass by-products to produce cement fibreboards potentially replaces wood as reinforcing fibre at the same time maintaining sustainability and environmental friendliness.

Cement fibreboard made from wood fibre are durable, resistant to fire, decay and moisture, impact resistant and possess superior physical and mechanical properties [1]. The properties of EFB fibre should behave even or superior as compared to wood fibre. Research has been done on the strength performance of EFB made products to determine its functionality and value in structural applications. Kolop et al. [2] has shown that EFB fibre cement blocks can be categorized as lightweight blocks suitable to be used at load restricted structure. There is a need for new methods to be discovered in order to improve the qualities and properties of EFB made products. Dullah [3] has founded that combination of different distribution of EFB fibre size, appropriate pre-treatment concentration and addition of cement accelerators produced board samples with greater physical and mechanical properties. For this research, vibration of the mixture during the moulding process in fabrication stage is introduced. Idea of the method follows the vibration of concrete, with the purpose of consolidate the concrete to reduce the porosity and increase the density along with strength, which is already commonly used in construction practices.

The objective of this research is to determine; (a) the improvement of density of oil palm empty fruit bunch cement fibreboard (EFBCB) using vibration table in fabrication compared to manual hand forming; and (b) the mechanical properties of hand formed empty fruit bunch cement fibreboard (HF EFBCB) and hand plus vibration table formed empty fruit bunch cement fibreboard (HF+VT EFBCB) and the correlation with its respective density. There are very limited findings about how the vibration of mixture actually improves or affects the properties of EFB cement fibreboard, hence this research is necessary to be carried out.

2. Materials and Methods

2.1 Materials preparation

In this study, oil palm empty fruit bunch (EFB) was obtained from Ban Dung Palm Oil Industries Sdn Bhd at Parit Sulong, Batu Pahat, Johor. The EFB was already in form of loose fibres and sun dried for 2 days to reduce the moisture. Then, the loose EFB fibres went through the hammer mill process to produce shorter fibres [4]. The EFB fibres that was processed through the hammer mill was then screened using a sieve with opening size of 1 mm (18 mesh). The sieve was put on top of the vibration table and vibrate for 1 minute. This process separates most of the fibre dust from the fibres while retaining some of the shorter length fibres. Then, the EFB fibres was pre-treated by soaking with sodium hydroxide (NaOH) solution of 0.4% concentration based on water weight for 24 hours. After that, the fibres were washed using tap water to remove the presence of alkali due to NaOH soaking and sun dried until minimum moisture as possible before undergo heat treatment by oven-drying at a temperature of 100°C for 24 hours.

2.2 EFB cement fibreboard fabrication

The samples of size 350mm × 350mm × 12mm with targeted density of 1300 kg/m^3 was produced total of 18 samples. Ordinary Portland Cement (OPC), EFB fibres and water were needed to fabricate the samples. The cement: fibre mixing ratio was 2:1, 2.5:1 and 3:1 respectively and water weight was 40% based on cement weight plus 30% of EFB fibre weight [3]. The EFB fibres was placed in the mixing machine and added water according to its cement: fibre mixing ratio for 2 minutes. Then, cement was added gradually to mix with the wetted EFB fibres in the machine for 8 minutes [3,5].

For the HF EFBCB samples, the mixture was then taken out from the mixing machine and dispersed evenly using hand spreading motion into a wooden mould with a 10×10mm wire mesh. Initially, a steel plate with a polythene sheet on top of it was placed under the wooden mould. After finished dispersing the mixture, it was hand pressed using a plywood plate to pre-form the HF EFBCB sample and reduce the initial sample thickness. After that, the wooden mould and plywood plate was removed replaced by another polythene sheet and steel plate [3,5].

For the VT+HF EFBCB samples, the moulding process was similar. The mixture was taken out from the mixing machine and dispersed using hand spreading. The placement of the wooden mould and the bottom steel plate with the polythene sheet was the same. However, after finished dispersing the mixture, the wooden mould with the bottom steel plate was placed on top of the vibration table and tighten using strings to prevent the wooden mould and steel plate from moving vigorously and out of alignment. The table was set to vibrate for 2 minutes. After the vibration completes, the strings were removed and the mixture was hand pressed using the plywood plate. After that, the wooden mould and plywood plate was removed and polythene sheet was placed on top followed by steel plate.

Table 1 shows the number of samples needed for HF EFBCB and HF+VT EFBCB for each ratio. The pre-formed HF EFBCB and HF+VT EFBCB samples that was placed between the steel plates was then put in the hydraulic cold-press machine to compress until it reaches thickness of 12 mm limited by the steel spacer. Then, the pre-formed samples were bolted and kept compressed for 24 hours. After 24 hours of compression, the sample was de-clamped and stacked vertically under ambient temperature for 28 days for air curing [3,5].

Table 1: Number of HF EFBCB and HF+VT EFCB samples for each ratio

Cement: fibre ratio	2:1	2.5:1	3:1
HF EFBCB	*3	*3	*3
HF+VT EFBCB	*3	*3	*3

Note: *3 samples

Figure 1: Fabrication process for HF+VT EFBCB

2.3 Density and Mechanical Properties Testing

The samples must meet the minimum requirements of mechanical properties (MOE $\geq$ 4000N/mm^2, MOR $\geq$ 9N/mm^2, IB $\geq$ 0.5N/mm^2) and density at least 1000 kg/m^3 after the 28 days of curing. The measurement of density and mechanical properties testing were carried out based on BS EN 323-1993 for density, BS EN 310-1993 for MOE and MOR and BS EN 319-1993 for IB [6,7,8]. Guideline by

Malaysian Standard specification (MS 934 1984) and British Standard (BS EN 326-1-1994) shows how the EFB cement fibreboard was cut to conduct the respective tests [9,10] as in Figure 2.

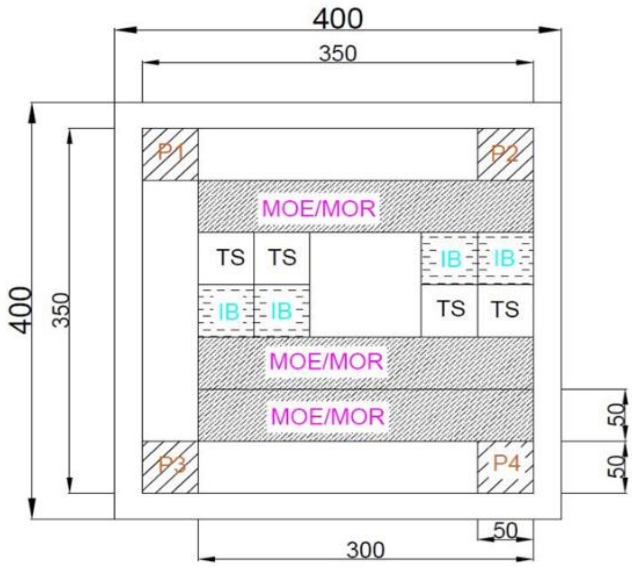

Figure 2: Cutting dimension of EFB cement fibreboard sample

3. Results and Discussion

3.1 Effect of vibration table on the density of EFBCB

Vibration table was applied during the moulding process in the fabrication stage of EFBCB to determine the sample's density and was compared with the EFBCB of using hand forming only during the moulding process. According to BS EN 634-2:2007 [11], the minimum allowable density for cement bonded particleboards is 1000 kg/m^3. All the samples have fulfilled the minimum allowable density. Figure 3, Figure 4 and Figure 5 shows the graph of density against HF EFBCB and HF+VT EFBCB of different cement: fibre ratio. From the 3 figures, the average density of HF+VT EFBCB samples are only slightly higher compared to average density of HF EFBCB. However, the standard deviation of HF+VT EFBCB samples are very small compared to standard deviation of HF EFBCB. The density of HF+VT EFBCB samples are distributed uniformly across the board because the measurement of density at the four locations (P1, P2, P3, P4) are consistent and differ very less. Using the vibration table during moulding process in the fabrication stage helps disperse the cement and fibre more evenly, hence decrease the porosity inside the mixture thereby improve the mechanical properties [12]. Decreasing the porosity have allowed to achieve possible maximum density across the board sample uniformly, which greatly reduces the deviation of mechanical properties values at different location of measurement across the board sample.

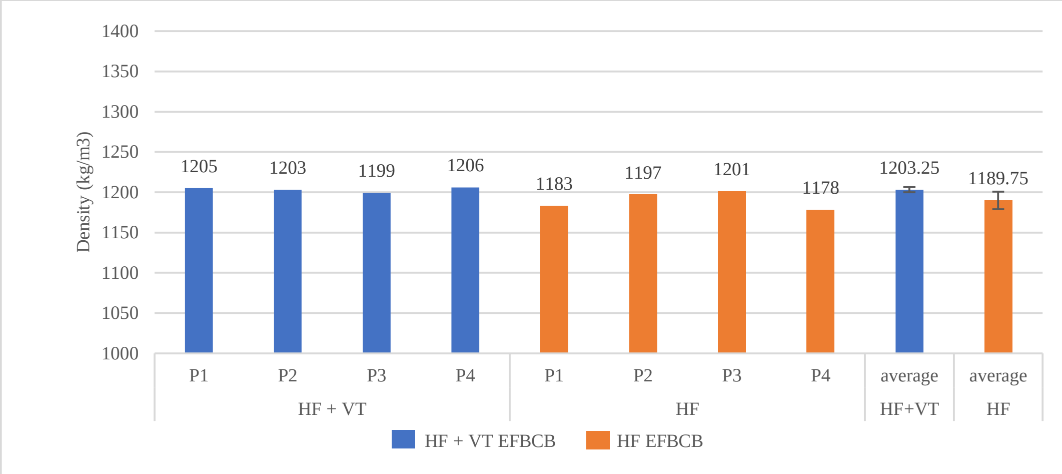

Figure 3: Graph of Density vs Ratio 2:1

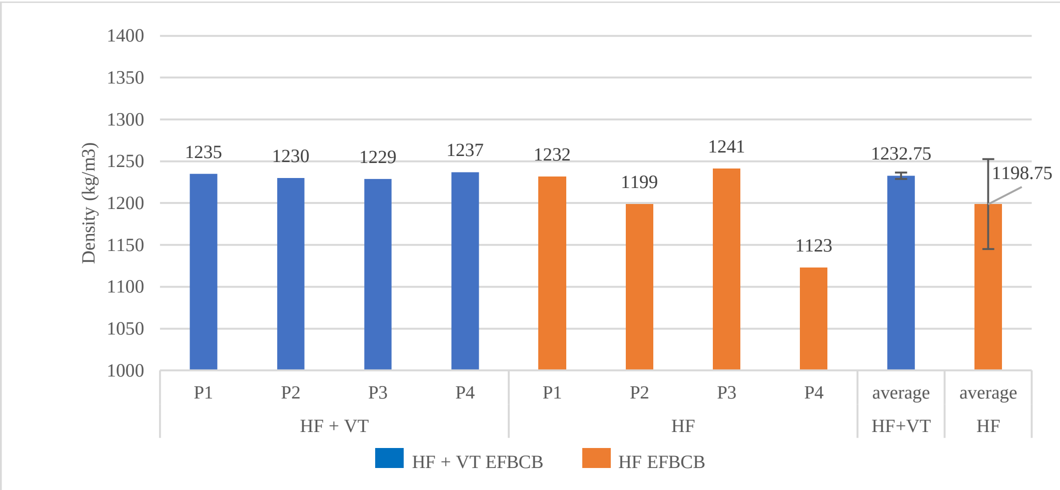

Figure 4: Graph of Density vs Ratio 2.5:1

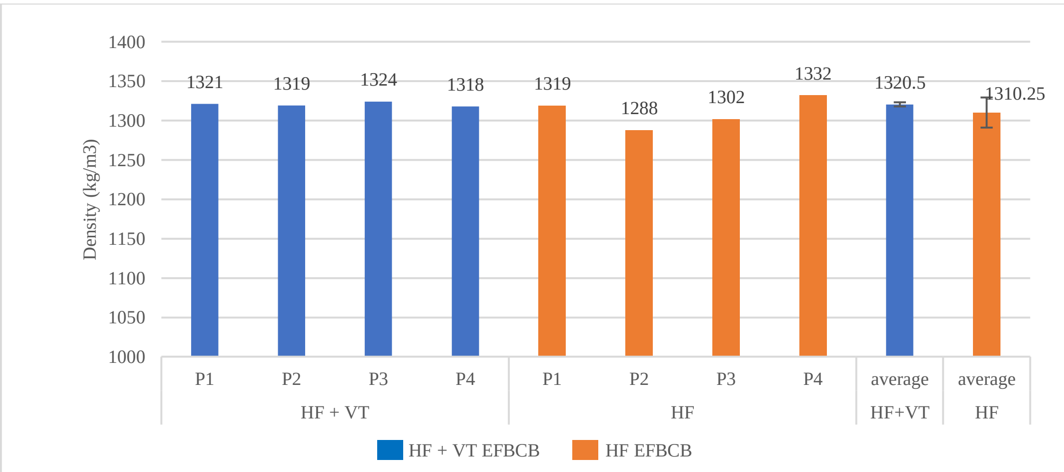

Figure 5: Graph of Density vs Ratio 3:1

3.2 Correlation of mechanical properties of HF+VT EFBCB and HF EFBCB with density

The samples are tested for Modulus of Elasticity (MOE) using the Universal Testing Machine (UTM) by conducting bending test based on BS EN 310:1993 [7]. From Figure 6, HF+VT EFBCB of every ratio has higher MOE values compared to HF EFBCB. The difference of MOE value between the samples is 298 N/mm^2 for ratio 2:1, 348 N/mm^2 for ratio 2.5:1 and 277 N/mm^2 for ratio 3:1. Based on BS EN 634-2:2007 [11], the minimum requirement of MOE is 4000 N/mm^2, however both HF EFBCB and HF+VT EFBCB for ratio 2:1 and 2.5:1 did not fulfil the MOE minimum requirements.

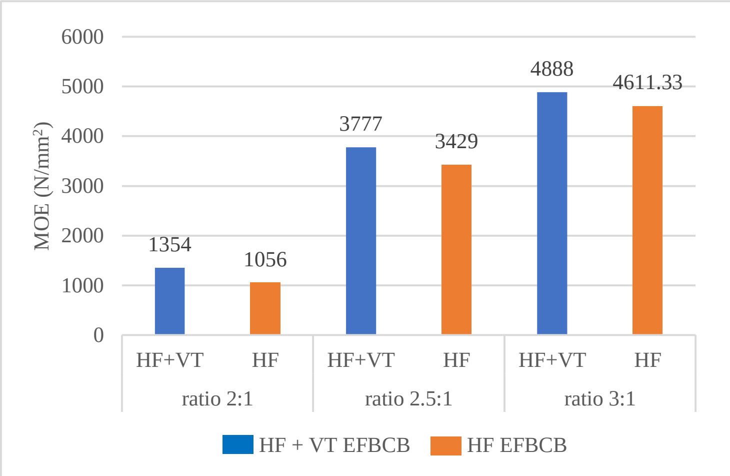

Figure 6: Graph of Average MOE vs Ratio

The samples were tested for Modulus of Elasticity (MOR) using the Universal Testing Machine (UTM) by conducting bending test based on BS EN 310:1993 [7], simultaneously with MOE. From Figure 7, HF+VT EFBCB of every ratio has higher MOR values compared to HF EFBCB. The difference of MOR value between the samples is 0.39 N/mm^2 for ratio 2:1, 1.27 N/mm^2 for ratio 2.5:1 and 1.81 N/mm^2 for ratio 3:1. It can be seen that when the cement: fibre ratio increases, the difference of MOR value of VT+HF EFBCB with HF EFBCB increases along. Based on BS EN 634-2:2007 [11], the minimum requirement of MOR is 9 N/mm^2, however both HF EFBCB and HF+VT EFBCB for ratio 2:1 and 2.5:1 did not fulfil the MOR minimum requirements.

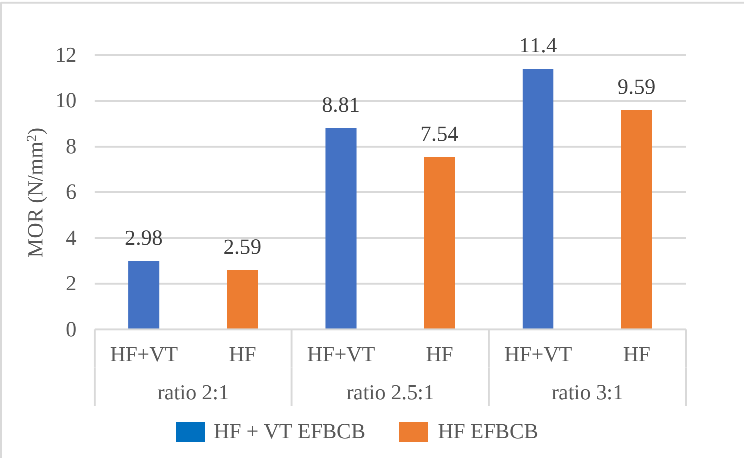

Figure 7: Graph of Average MOR vs Ratio

The samples were tested for internal bonding (IB) using the Universal Testing Machine (UTM) by applying tensile force perpendicular to the surface of the sample based on BS EN 319-1993 standard [8]. From Figure 8, HF+VT EFBCB of every ratio has higher IB values compared to HF EFBCB. The difference of IB value between the samples is 0.01 N/mm^2 for ratio 2:1, 0.04 N/mm^2 for ratio 2.5:1 and 0.03 N/mm^2 for ratio 3:1. Based on BS EN 634-2:2007 [11], the minimum requirement of IB is 0.5 N/mm^2, however all the HF EFBCB and HF+VT EFBCB of every ratio did not fulfil the IB minimum requirements.

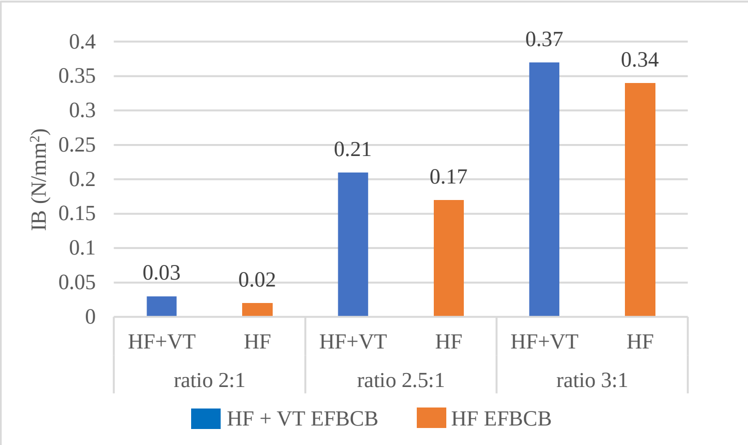

Figure 8: Graph of Average IB vs Ratio

The increase in mechanical properties of HF+VT EFBCB compared to HF EFBCB are relatable to the density distribution across the board samples. EFBCB with more uniformed distributed density has lower porosity inside the mixture, which can be achieved using vibration technique during moulding process [12]. Similarly, the presence of voids inside the board sample will result in lower IB strength due to insufficient contact area of the mixtures for an effective bonding, thus can relate to the use of vibration table to counter this issue [13].

4. Conclusion

Applying vibration table during the moulding process in fabrication stage has proven effective in maintaining the density distribution across oil palm empty fruit bunch cement fibreboard (EFBCB) samples, however not much difference of density is recorded between EFBCB samples with manual hand forming only compared to samples with applied vibration table. The mechanical properties of EFBCB are proven affected by the density distribution across the board sample. HF+VT EFBCB of cement: fibre ratio 3:1 possess the highest mechanical properties values (MOE 4888 N/mm^2, MOR 11.40 N/mm^2, IB 0.37 N/mm^2) as the standard deviation is the lowest. The results indicated that applying vibration table can be regarded as a new and effective method to improve the qualities and properties of EFBCB. However, cement: fibre ratio is the more important factor to consider compared to the application of vibration table as it affects the density and mechanical properties of EFBCB even more.

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