Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 290-299
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RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Forming Empty Fruit Bunch Cementboards (EFBCB) Using Hand and Hand Plus Vibration: Effect on Density, Thickness Swelling, Thickness Monitoring and Internal Bonding

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DOI: https://doi.org/10.30880/rtcebe.2022.03.01.031
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Natural fiber reinforced cement-based materials are becoming increasingly applicable especially for residential building components meanwhile oil palm empty fruit bunches (EFB) fibres are considered one of the natural fibres providing advantages such as availability, renewability, low cost and proven fibre extraction technology. Therefore, the objective of this research is to study the effect of hand and hand plus vibration forming on density, thickness swelling, thickness monitoring and internal bonding of empty fruit bunch cement boards (EFBCB) and to propose the most suitable forming method in fabrication of EFBCB that contribute to the optimum properties of cement board. Experimental sample of size 350 x 350 x 12 mm has been fabricated based on the target density 1300 kg/m^3. The testing method were carried out according to the BS EN 317:1993, BS 323:1993 and BS EN 319:1993. The result showed that the average density that were four tested sample meet the requirement British Standard, 1291.67 kg/m^3, 1315.33 kg/m^3, 1324.67 kg/m^3 and 1349.67 kg/m^3 respectively. Hand plus vibration of 2 minutes is the only method that achieved the requirement of British Standard with the value of 1.48%. Thickness monitoring shows an increasing in every sample, 12.91, 13.16, 13.76 and 14.10. Result for internal bonding shows that hand forming have a lower value compared to the hand plus vibration. The nearest value that complied BS EN 319:1993 was 0.4808 N/mm^2. In overall, 2 minutes hand plus vibration is the best method to produce EFBCB because if the sample undergoes more than 2 minutes, the mixing will be inbalance between fibre and cement and this will affect the strengths and durability of the cement boards.

Keywords: Empty Fruit Bunch (EFB), Empty Fruit Bunch Cement Board (EFBCB), Hand and Hand Plus Vibration

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1. Introduction

In the building industry, the idea of using natural fibre is not new, as the use of fibre in materials and construction can be traced back to several centuries ago. Natural fiber-based composites are becoming an important composite material in the construction and civil engineering fields because of their light weight, strong chemical resistance, corrosion resistance and high strength to weight ratio [1]. The integration of fibres into the concrete will increase concrete strength, ductility, flexural damage tolerance and energy absorption ability [2]. Other than that, the fibre addition slows the propagation of cracks and increases the distribution of stress in the matrix at the time of loading [3]. Using these fibres as a reinforcement will enhance the composite's properties at a relatively low cost. Natural fibre or wood in cement composite roles as the reinforcement that can increase the work ability of composite and fracture development. In building construction, the application of cement boards required the composite material that had to be good in bending, flexural strength and internal bonding. Hence, combination of natural cellulosic fibre with a cement binder capable of producing composite properties to meet the requirements of cement bonder fibreboards or particleboards as defined in BS EN 634-2[4]. Cement bonded composite production consists of wood wool of cement bonded, cement bonded fibreboard and cement bonded particleboard. The cement bonded`s physical and mechanical characteristics were derived from varied particle sizes and geometries.

Fibre cement board characteristics as a building components make it an ideal for usage as a ventilated, exterior covering for new and refurbished structures, interior wall cladding, balcony railing board, pedestal and chimney cladding and enclosure soft-fit lining [5]. The rapture mechanism that can occur in construction medium is complicated since the stresses are not consistently scattered all along the rapture especially in crack-prone areas [5]. The cellulose and polyvinyl alcohol fiber reinforcements in the currently used fiber cement boards are designed to carry mechanical loads [6]. The fibers only strengthen the fibre cement board element when they are applied in a particular amount and are evenly distributed all over the cementitious matrix. Some of the experiments that have been carried out that were testing on EFBCB shows the board was insulation, mold, termite attack and fire resistant [6]. Therefore, EFBCB was suitable for roofing, separation wall or tile wall replacement. The purpose of this research is to study the difference of physical properties EFBCB that are formed using hand and hand plus vibration. There are two methods in this stage which is hand and hand plus vibration and this will determine the optimum that contribute to the properties of the EFBCB. Method of hand forming is the method that were used a hand for the moulding process while hand plus vibration is addition in the moulding process where used a vibration table to level the material to the rest of the section. For the hand plus vibration, it will vibrated with different times. Fiber cement board or FCB is a flexible, environmentally friendly, and extensively used construction substance.

2. Materials and Methods

2.1 Materials Preparation

Materials preparation for EFBCB consists of Portland cement, EFB fibre and water based on predetermined ratio. The EFB fibre has undergone several process which is hammer mill process, screening process and pre-treatment process before mixing with cement. The sample size of the cement board for this study is 350 x 350 x 12 in millimeter. Figure 1 show the sample size of cement board while Figure 2 show the flowchart for the material preparation.

2.1.1 Portland cement

The cement that were used in this study is the standard Portland cement that produced by Associated Pan Malaysia Sdn. Bhd. Malaysian Standard specification MS 522: Part 1:2003 describes cement as for concrete work. Portland cement is commonly used in concrete mixture.

2.1.2 EFB fibre

The raw material that were used in this project were oil palm empty bunches that were obtained from Ban Dung Oil Industries Sdn Bhd. This factory were located at Jalan Muar, Parit Sulong

2.1.3 Hammer Mill Process

EFB fibre that were obtained need to sun dry first before going through process hammer mill. This is because to eliminate moisture content that were exist in the fibre. EFB fibre from the oil palm mill will initially in coil condition with an approximate length of 50 mm to 200 mm. Thus, to minimize the fibrous fiber to chip particles, the hammer mill process must be carried out. Shear and impact behavior in hammer mills may reduce the particle size of EFB fiber.

2.1.4 Screening Process

The primary goal of this procedure were to separate dust that could have an effect on the performance of the cement board. Sample grinds were placed on top of a stack of sieves that were placed in descending order of opening size. EFB fibre and particle were screening with size distribution around 20.5% passing 4 retained 7 mesh, 33.8% passing 7 and retained 14 mesh, 35.3% passing 14 and retaining 80 mesh and the remainder indicate dust passing through 80 mesh for the next 10.4%

2.1.5 Pre-treatment Stage

The EFB fibre then were immersed for 24 hours in sodium hydroxide (NaOH) with a concentration of 0.4% based on water weight. The purpose of this treatment are to eliminate residual oil and any impurities on the fibre. After being soaked for 24 hours, the fibres were washed about several times under running water to remove the excess of NaOH from the fibre surfaces. Then, the treated fibre were dried under the sun to remove any moisture content and oven dried at temperate 100ºC to ensure it completely dried before adding into concrete mixture.

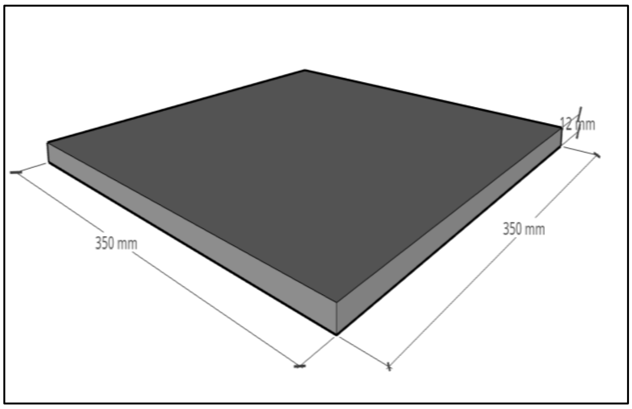

Figure 1: The sample size of cement board

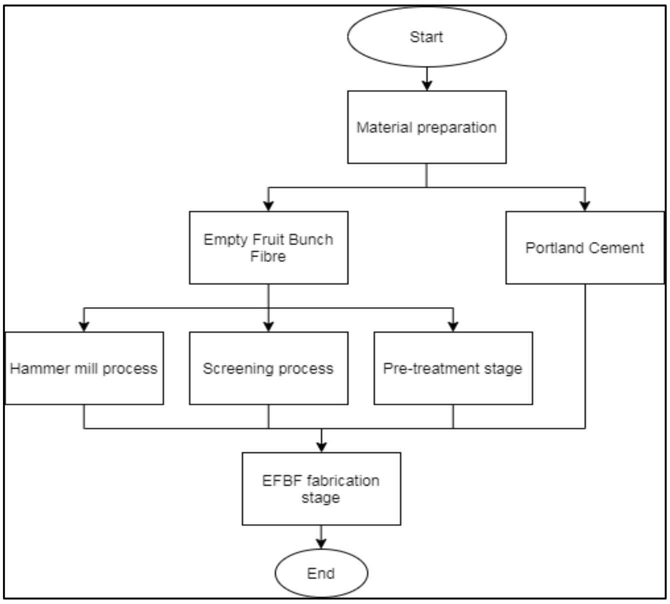

Figure 2: The flowchart of material preparation

2.2 Methods

The procedures of the EFBCB consist of the mixing the materials with hand and hand plus vibration, moulding, cold press compacting and lastly is curing. In order to produce EFBCB, cement and water were measured in specific ratio and used as a binder. EFB fiber, cement and tap water were mixed using a mixer or blender. The cement and fibre were weight before combining according to the mix design. The mixture was uniformly blended before being placed to a 10 x 10 mm wooden mould. To create a cement board sample, the mixture was uniformly poured into a wooden mould and flattened by hand.Then, to pre-compact the mat, a plate of plywood was laid on top of it and the wooden mould were removed. The pre-formed mats on both sides (top and bottom) were covered with polythene sheets and the steel mould were laid on the top of mat. The moulding process were repeated again but with addition hand plus vibration technique. The hand plus vibration were vibrated with different times which is 1 minutes, 2 minutes and 3 minutes. The steel mould containing the blended material was compressed at a particular pressure of 40 tonnes using a hydraulic cold-press machine to minimize its height. A 12 mm thick spacer were inserted between the steel moulds before the mixed materials was compacted. The moulds were distributed with a cold press until the required 12 mm thickness was obtained. After bolting the two steel moulds together, the pressed mats were held under compression for 24 hours. After 24 hours, the mats is then de-clamp, stack and condition at ambient temperature 28±1°C with relative humidity of 65±5% for 28 days in order to allow the composite cement-EFB to cure thus raising the strength. The process of the fabrication process can be seen in Figure 3.

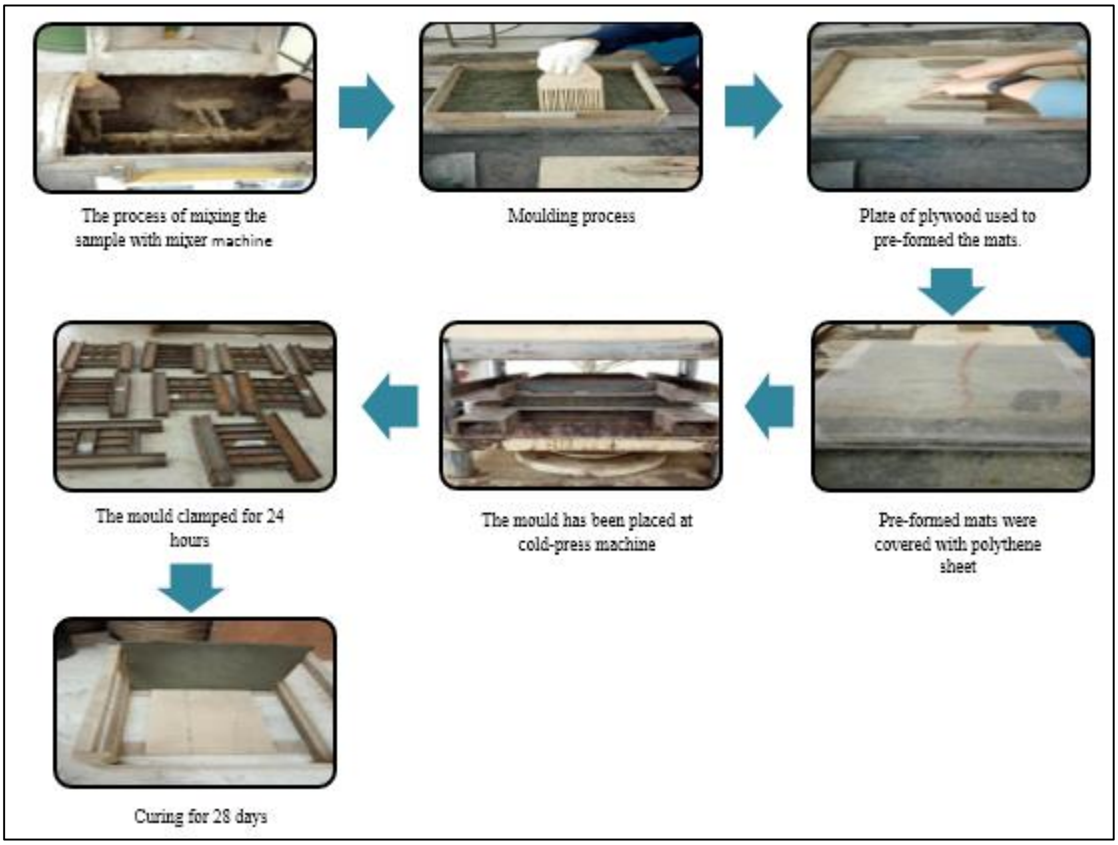

Figure 3: The fabrication process

2.3 Testing

2.3.1 Density

The density values of prepared composite samples were target with 1300 kg/m^3 after 28 days of hardening. The composite cement fibre density is measured in compliance with the requirements of BS EN 323:1993 and Table 1 shows all the requirements that needed in testing method. The test was carried out on the specimens with compressive strength before they were compress into failure. With an increase in NaOH concentration, the densities rose until a substantial decrease are achieve at 8% concentration. This may be attribute to a higher NaOH concentration contributing to excess delignification, softer, or weaken fibres. The equation below were used to determine the density. Table 1 shows the requirements that needed for the cement board.

$$\rho = \frac{\mathrm{m}}{\mathrm{b_1 \times b_2 \times t}} \times 10^6 \quad Eq\ 1$$

Where,

m = The mass of the pieces (g)

$\mathrm{b_1, b_2, t}$ = Measure in (mm)

2.3.2 Thickness Swelling (TS)

Thickness swelling is measured by calculating the thickness rise in the test piece after full soaked in water. This test was conducted in accordance to the British Standard BS EN 317:1993 with the size of specimen is 50 x 50 x 12 in millimeters. The vernier clippers were used to determine specimen thickness before and after immersion in water, with a time period of 24 hours. The swelling of thickness (TS) was determined using the formula:

$$TS = \frac{T2 - T1}{T1} \times 100\% Eq\ 2$$

Where,

T1 = the thickness before soaking

T2 = the thickness after soaking

2.3.3 Thickness Monitoring

For thickness progression, the readings were taken from 4 positions of the sample starts on the first day of the curing. The vernier clippers were used to determine the specimen thickness progression. For every sample, the thickness value that were obtained will be divided into four until it get an average results. This progression were continued until the end of the curing day.

2.3.4 Internal Bonding (IB)

Internal bonding of the specimen was determined by the tensile that perpendicular to the surface area. The specimen of this test are 50 x 50 x 12 in millimeter as accordance to BS EN 319:1993. Prior to gluing on both surfaces, the sizes and weight of each specimen examined were taken which were then sandwiched between two metal blocks. The specimens were then stored for 24 hours in a conditioning room to testing. The following is the equation that used to determine internal bonding.

$$\mathrm{IB} = \frac{\mathrm{p}}{\mathrm{w} \times \mathrm{l}} Eq\ 3$$

where,

IB = Internal Bonding (N/mm^2)

P = Peak Load or Maximum Load (N)

w = width (mm)

l = length (mm)

Table 1: Minimum requirement for specified cement board

Properties	Standard Requirement	Unit	Requirement
Density	BS EN 323:1993	kg/m^3	1300
Thickness Swelling	BS EN 317:1993	%	1.5
Thickness Monitoring	BS EN 317:1993	m	12
Internal Bonding	BS EN 319:1993	N/mm^2	0.5

3. Results and Discussion

The panels were cut into various parts for the test, as shown in Figure 4. Several tests, including Density, Thickness Swelling, Thickness Progression and Internal Bonding were carried out to determine the performance of cement board and the result of the test were shown in Table 2. These tests were conducted in accordance to BS 317:1993, BS 323:1993 and BS 319:1993.

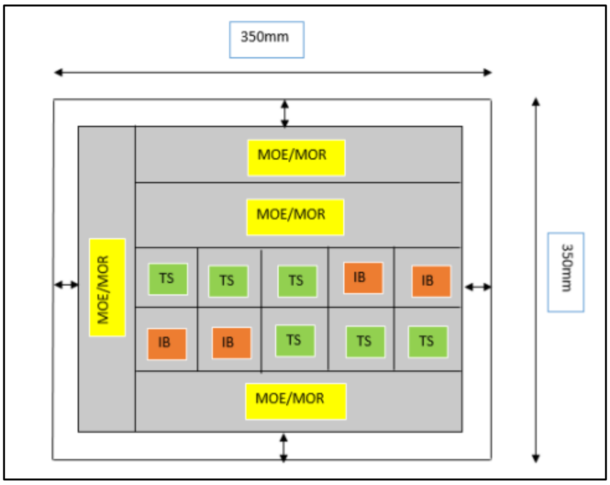

Figure 4: The cut of the board for exposure test pieces

Table 2: Results of the Density, Thickness Swelling, Thickness Monitoring and Internal Bonding

	Density (kg/m^3)	**Thickness Swelling (%)**	**Thickness Monitoring**	**Internal Bonding (N/mm^2)**
3:1 (1 minutes vibration)	1291.67	1.69	12.91	0.3684
3:1 (2 minutes vibration)	1315.33	1.48	13.16	0.4808
3:1 (3 minutes vibration)	1324.67	1.60	13.76	0.3724
3:1 (Hand mix)	1349.67	1.71	14.10	0.332

3.1 Density

Figure 5 shows the graph that were obtained from the test. The lowest density can be seen in vibration table within the time 1 minute which is the average was 1291.67 kg/m^3 and this value does not meet the requirement of the British Standard that were larger than 1300 kg/m^3. For 2 minutes and 3 minutes of hand plus vibration, the value that were obtained was 1315.33 kg/m^3 and 1324.67 kg/m^3 respectively while for the hand mix method, the value of the density was 1349.67 kg/m^3. All the methods except 1 minute of hand plus vibration shows that the best method and meet the requirement of the British Standards. Previous research found that the density of composite board impacted its mechanical characteristics [7].

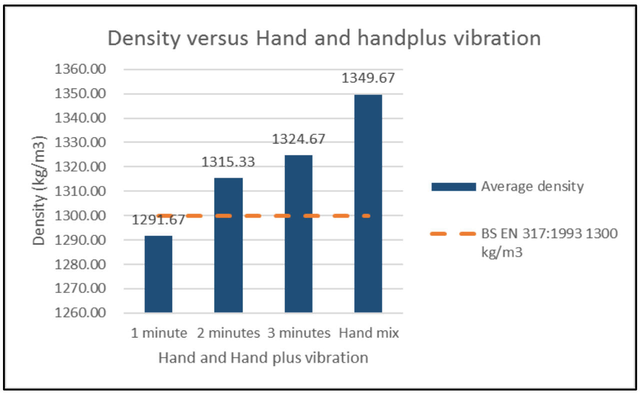

Figure 5: Density with hand and hand plus vibration method

3.2 Thickness Swelling (TS)

The graph of analysis for TS can be seen in Figure 6. According to the BS EN 317:1993, the requirement of TS were lower than 1.5%. The percentage of thickness swelling of EFBCB that were 1 minute hand plus vibration, 1.69 % does not meet the requirement British Standard where the value obtained were largest than 1.5 %. However, EFBCB that 2 minutes hand plus vibration achieved thickness swelling of 1.48% respectively. These result were lower than the BS recommended maximum thickness swelling value. For hand forming, it shown that the thickness swelling have an average TS of 1.71 % and this clearly shown that the result does not meet requirement British Standard. From the result, 2 minute hand plus vibration, 1.48% achieved the requirement of BS which were lower than 1.5%. Previous researcher state the lower of thickness swelling values indicate greater uniformity between fibers, resulting in better structural stability and, in general, stronger internal bonding values[8].

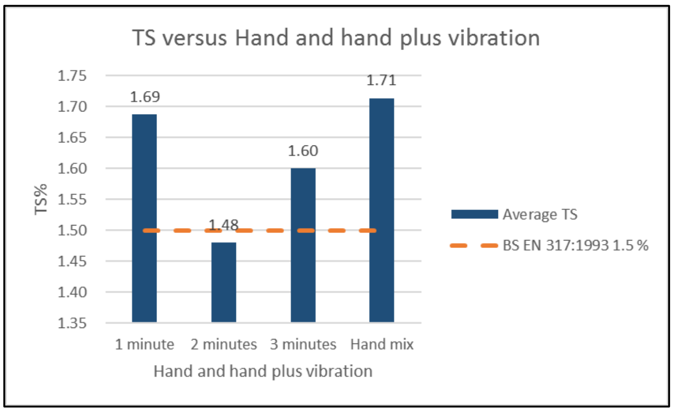

Figure 6: TS with hand and hand plus vibration method

3.3 Thickness Progression

There are increasing in thickness progression and it can be seen in Figure 7. Hand plus vibration for 1 minute show the lowest average value, 12.91 followed by 13.16 from 2 minutes hand plus vibration. Hand plus vibration for duration 3 minutes and hand forming appeared to be the largest average values for the thickness progression which is 13.76 and 14.10 respectively. All the results shown in increasing of the thickness and this does not meet the requirement of British Standard which lower than 12 m.

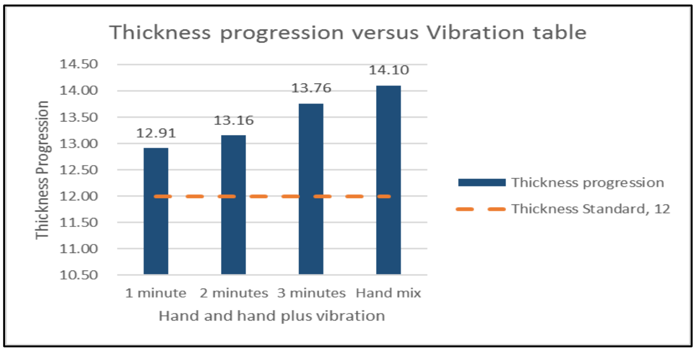

Figure 7: Thickness Progression versus vibration table

3.4 Internal bonding (IB)

The graph that were obtained in Figure 8 shown that hand forming have a lower value compared to the hand plus vibration. The vibration period of 2 minutes had the nearest value of internal bonding among the three vibration time duration with an average 0.4808 N/mm^2. For 1 minutes and 3 minutes hand plus vibration, it shown 0.368 N/mm^2 and 0.3724 N/mm^2. All these result of method does not meet the requirement BS where the minimum IB is 0.5 N/mm^2.. Despite the fact that the strength characteristics improved, the internal bonding was considerably reduced [9].

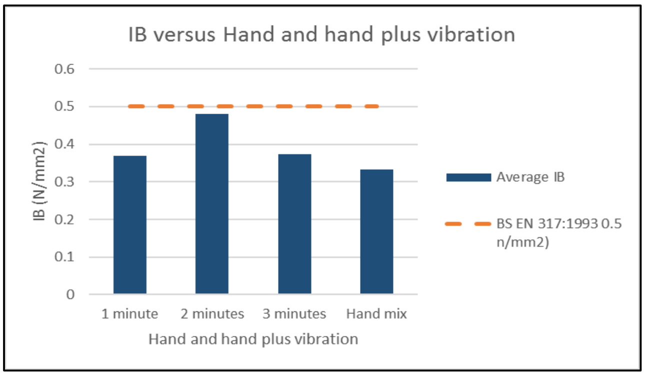

Figure 8: IB with hand and hand plus vibration method

4. Conclusion

It is concluded that EFBCB properties were affected by the method hand and hand plus vibration. Method for hand mix will not uniformly distribute as it use a hand to moulding the samples. Hand plus vibration within the time 2 minutes could contribute to the optimum properties of the sample. For 1 minute hand plus vibration, the sample was not uniformly distributed. The sample for 3 minutes hand plus vibration was not encouraged to be used because after vibration took place, the fibre will be layered to the below while the cement to the upper of the sample. Therefore, 2 minutes hand plus vibration is the best method to produce EFBCB because if the sample undergoes more than 2 minutes, the mixing will be inbalance between fibre and cement and this will affect the strengths and durability of the cement boards.

Acknowledgement

The authors would like to thank the Faculty of Civil Engineering and Built Environment, UniversitiTun Hussein Onn Malaysia for its support.

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