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To Study the Effect of Oil Palm Empty Fruit Bunch (OPEFB) Fibre Ratio on The Mechanical Properties of EFB Cement Board for Panelling

Izzah Basiran[1], Azman Ja'afar[1]*

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, University Tun Hussein Onn Malaysia, 84600, Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: Oil Palm Empty Fruit Bunch (OPEFB) is one of the biomasses produced in oil palm agriculture. It is important to acknowledge the physical and mechanical properties of the Empty Fruit Bunch (EFB) before being utilised in the suitability of fabrication of the cement board fibre. However, there are compatibility issues within the EFB fibre with the cement mixtures. This is because fibres contain residual oil and sugar that prevent cement setting and its hydration. Thus, this study was directed to perform the compatibility assessments in order to improve the cement board fibre mixture. The fabrication of cement board fibre samples was done by incorporating pretreatment of 4.00 % sodium hydroxide (NaOH) concentration EFB having different percentage ratios which are 5.00 %, 7.00 %, 10.00 % and 12.00 %. This is to find the effect of fibre percentage ratio addition on cement board fibre. The test sample performed to measure the mechanical and physical properties were Modulus of Elasticity (MOE), Modulus of Rupture (MOR), density, Thickness Swelling (TS), and water absorption (WA). The results showed that OPEFB fibre affected the mechanical and physical properties of the cement board after it had gone through tests. The optimum weight percentage of EFB fibre ratio is when the result from the test achieved BS EN standard which is 12.00 % of OPEFB fibre. This study found that the increase of fibre percentage and its contribution to the mechanical properties is largely affected by its changes in the cement board fibre. Contrary to what has been assumed, the findings indicate that the rise of fibre percentage causes lower mechanical properties than the standard but different in physical properties where it's achieved the standard.

Keywords: OPEFB Fibre, Cement Board, Mechanical Properties

1. Introduction

Nowadays, development of agriculture is rising due to the awareness of effective materials in agriculture rather than using conventional materials. These have attracted researchers and building specialists to explore more regarding products or wastes of agriculture to be implied in other sectors

*Corresponding author: azman@uthm.edu.my

like construction. This is because of the lack of resources or necessities to find an alternative way that more economical. Hence, to find a better solution, researchers have found and studied several raw materials from waste production which can be in the form of trunks, fronds, fibres, shells, and empty fruit bunches that can be used in construction. This will eventually increase the growth of local materials and bring benefits to the local social economy.

One of the main agricultural activities in Malaysia is crude palm oil production. In the long term, this activity can lead to a vast production of biomass products. When efforts were put into retrofitting this product into a valuable reason, this consumption of waste agricultural product in construction will help to reduce biomass waste. This study will be focus on the usage of biomass products on the production of cement boards fibre which is one of the cement composites that are mostly produced. Previously, cement bonded composite has undergone various changes; cement bonded wood wool, cement bonded fibre boards and cement bonded particle boards. In fact, natural fibre cement composite has been used widely in construction materials and processes especially as insulating, noise barriers, layering, and house building.

[1] mentioned that, materials being commonly used in the production of cement board nowadays are calcium silicate and gypsum board. However, these two materials have high moisture content that is not suitable for high humidity areas. The main problem of common cement boards nowadays is it is not durable as it is high in unit weight and moisture content. Therefore, researchers have found potential to retrofit these materials into fibre usage. They have found out that fibre cement boards have low unit weight and low moisture content. This study intends to focus on addition of different ratios of OPEFB fibre which are 5.00 %, 7.00 %, 10.00 %, and 12.00 % to examine the mechanical strength properties of the EFB cement board and to determine the optimum ratio of EFB compared to conventional cement board stated in BS EN Standard.

1.1 Cement board

Back in 1900, Czech engineer Ludwik Hatschek developed the technology of damp roof and nonflammable lightweight, strong and durable asbestos cement sheets. Unfortunately, due to legal regulations of considering harmful asbestos which is then replaced with safer cellulose fibre [8]. Processes that include cement board of fibre in construction materials are included in house building, panelling, noise barriers, cladding and insulating [16]. Fibre cement boards are manufactured from natural raw materials such as limestone, cellulose fibres, cement, and water. It is also stated that fibre cement boards are exposed to changes in temperature, humidity, and sunlight radiation, making them suitable for exterior building construction as a foundation for exterior plaster systems or as finishing systems. Researchers discovered that Organic Waste Fibre (OWF) aids in reducing the raw materials cost and it's processing along with reducing the primary materials and energy. OWF can be easily obtained because it is worldwide accessible, environmentally friendly, and biodegradable [10].

1.2 Oil Palm Empty Fruit Bunch (OPEFB) fibres

Process of palm-oil extraction and milling ended with solid oil-palm biomass. OPEFB fibre is then produced. OPEFB fibre used in both industrial and farming applications. For instance, its particle and fibre boards are used as a material for wood-based products, composite panels, pulp and paper, soil stabilization and gardening applications [18]. OPEFB advantages in its suitability, availability, renewability, low cost and established technology in obtaining fibre. [16] stated that fibre cement board are versatile and environmentally friendly material used as a brick substitute in construction. Most of the fibres used to reinforce fibre cement composites are derived from wood resources and are mainly obtained from the kraft pulping process.

Sisal and crops from agricultural wastes are of interest for fibre cement composite research due to their low prices and availability. In addition, preparation and characterization of cementitious composites have also been investigated to represent a classification of natural fibre based on their origin [16]. This will help future study to continue the effort in searching for the best retrofit material in producing better cement board fibre. Typically, Fresh Fruit Bunch is composed of palm oil, palm kernel, Empty Fruit Fibre, Palm Kernel Shells, Mesocarp Fibres and Palm Oil Mill [15]. According to [16], fibre strength properties and easily dispersed in water is the basic fibre cement composite preparation. The benefits of having a natural fibre composite can be widely used in building materials and processes such as insulation, siding, noise barriers, and house construction [14].

1.3 Natural fibre-cement compatibility

Cellulose helps the plant remain stiff and rigid, while hemicellulose helps strengthen the cell wall, and lignin covers the structural support and protects it from chemical or biological attack, etc. As a result, lignocellulose contains cellulose, hemicellulose and lignin that bond together. The cell had to be broken before it could be used in the next process.

In straw rice fibres, as mentioned by [9], pretreatment by steam explosion and chemical 1-allyl-3-methylimidazolium chloride is effective for isolation of cellulose except lignin. The study of [11], on pine needles showed that pretreatment with 2.00 % NaOH solution, boiling water or unheated water can result in fibre reinforced concrete composite due to its ability to dissolve lignin.

1.4 Physical and mechanical properties of cement boards

This study only focuses on several basic physical and mechanical properties. Density, water absorption (WA), and thickness swelling (TS) while mechanical properties focus on Modulus of Elasticity (MOE) and Modulus of Rupture (MOR).

MOE of concrete is defined as the ratio of applied stress to strain. It demonstrates the ability of concrete to withstand deformation and its stiffness caused by applied force. It represents concrete's capacity to bend elastically. High MOE shows the material is stiff, low MOE shows the material is easily bent [2]. According to [18], the MOE value rises as the fibre loading coconut coir rises.

MOR refers to the amount of strength of the concrete before it is ruptured; how much compression and force it can withstand. It is also known as flexural strength, bending strength, or ultimate strength. According to [3], in their study, 9 wt.% of fibre reached its optimum MOR but further than that MOR declined showing that the higher the fibre content, the lower the MOR.

According to [18], a high positive relationship exists between density and MOE. This indicates that the denser the board is, the higher the MOE it produces. Density predicts MOE, implying that the density of cement board has an impact on the MOE value. Figure 1 shows the association between MOE and cement board density in this investigation [2].

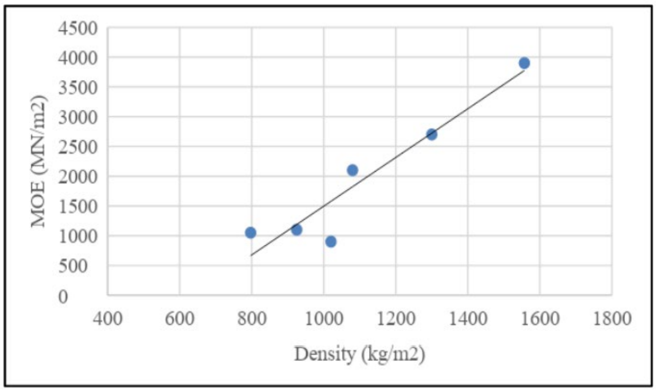

Figure 1: Connection between density and MOE [2]

In [6], the WA increased with increasing fibre content. This is due to the creation of micro void when being introduced to the coconut husk fibres and also due to the hydrophilic nature of the fibre. Thickness swelling measured when the specimen finished its completion of immersion in water. According to [14], composites made with pretreatment fibres will cause low sorption properties that show its suitable for outdoor applications. Generally, with low TS and WA value, the boards with treated fibres are stable, hence the suitability to be used for interior and exterior applications are good.

2. Materials and Methods

The method used to study the compatibility of OPEFB cement boards with different percentages of EFB fibres is explained. This part discusses briefly fibres process, pretreatment of OPEFB, the determination of the mechanical properties of the OPEFB cement board.

2.1 Materials

- OPEFB Fibre

The OPEFB fibre supplied from an oil palm mill factory was in a bulk pile. The pretreatment of OPEFB fibres with 4.00 % NaOH without the addition of an accelerator. The fibre soaked several times to remove inhibitory substances and oil residues that could affect the hydration of the cement. It was then washed with running water. The EFB fibers are then dried using an industrial oven with 105° temperature for 24 hours to completely dry. The OPEFB fibre was then subjected to a cutting process, ranging from 5 mm to 10 mm in length. The longer the length, it may cause too much entanglement during the mixing process.

- Cement

Ordinary Portland Cement (BS: 12: 1996) is the primary binder in cementitious fibreboard. Which was then combined with water and EFB fibres to produce cementitious fibreboard.

- Water

Water is the main cause used to mix all materials (fibres and cement). Normally, tap water in Malaysia has a H value of 7.5 which meets the quality requirements of the Malaysia government [4].

2.2 Methods

The fabrication process of OPEFB fibre cement board in Figure 2 based on previous literature researchers [4]; [17]; [5] and guidelines in laboratory.

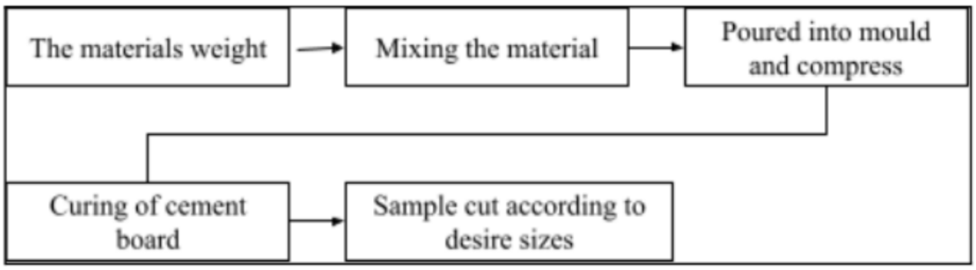

Figure 2: Cement board fabrication method

The materials proportion required for this part had to be weight. Treated OPEFB fibre added to the cement portion in weight percentages of 5.00 %, 7.00 %, 10.00 % and 12.00 % from the cement weight as shown in Table 1 below. To obtain the best mixture for the OPEFB fibre cement board, the mixing proportions were determined through trial and error. Material quantity based on weight percentage of total. The cement and water content are fixed, and the mixture without the OPEFB fibre serves as a control sample. The mixing process is repeated. For this proportion, a constant water cement ratio of 0.50 is used.

The fibre needed to segregate first to make sure all the surface areas of fibre are thoroughly mixed with cement and water because it tends to clump between each other. The combinations are then mixed manually by adding water gradually until it meets its homogenous mix. The mixed material is placed in a wooden mould measuring 210 mm x 210 mm x 12 mm covered with oil to make sure the mixture is not sticking to the surface and to make the demoulding process easier.

After the formation, the mixture was then pre-compressed by using a wooden plate covered with oiled aluminium to reduce the height and obtain a height of 12 mm. The boards were exposed to air for several minutes and then plastered with cement mortar to obtain a smoothed surface evenly. Curing methods of OPEFB fibre cement board based on previous literature research [4] has been done after 24 hours, stacked and conditioned for 28 days minimum at an ambient temperature of 28±1 °C and a relative humidity of 65±5 %. Cement board cut into small sample compliance with the Malaysian standard (MS934:1986) [12] and British Standard (BS EN 326) [7] to test sample specimens in Figure 3.

Table 1: Design mix proportion of cement board fibre mixture in weight

No.	Cement (g)	Fibre (g)	Water (ml)	No. of boards
1	500	0	250	2
2	500	25	250	2
3	500	35	250	2
4	500	50	250	2
5	500	60	250	2

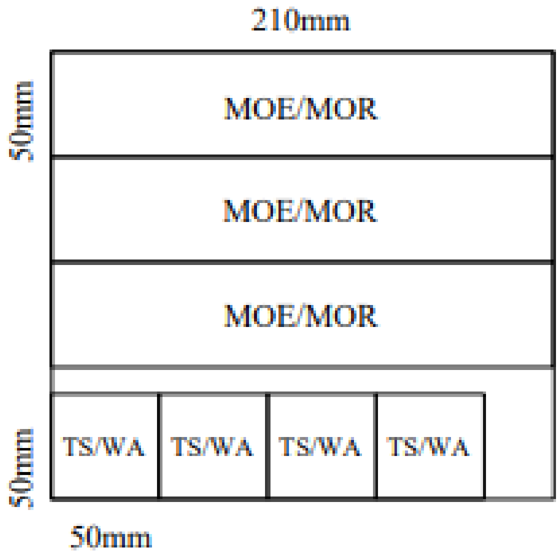

Figure 3: OPEFB fibre sample cutting dimensions

3. Results and Discussion

Table 3 is the final product of the physical and mechanical properties of cement board fibre test that must meet the minimum requirements of Specification for Wood-based panels (BS EN 310:1993) as in Table 2 below. The OPEFB fibre cement board product characteristics are then determined from the analysis result obtained from the implemented tests. The focus of this part was to find out the optimum fibre percentage to produce a lightweight cement board and the affect performance of the cement board on its mechanical properties. Previous published articles mention that the fibre percentage in cement board manufacturing knowingly affected the cement board performance.

Table 2: Standard value of tests conducted

Properties	MOE (N/mm^2)	MOR (N/mm^2)	TS (%)	WA (%)	Density (kg/m^3)
Requirement (All thickness)	Class 1:4500 Class 2:4000	9	1.5 (from initial thickness)	60*	less than 1500

* = based on industrial requirement

Table 3: OPEFB fibre cement board average tests value

Fibre percentage (%)	MOE (N/mm^2)	MOR (N/mm^2)	TS (%)	WA (%)	Density (kg/m^3)
0	1770.57	10.05	0.24	3.07	1925.25
5	306.47	1.83	0.80	13.70	1462.24
7	391.95	1.62	1.04	24.07	1473.35
10	476.61	1.33	1.08	41.63	1257.83
12	105.74	0.34	1.63	48.54	1099.69

3.1 Discussions

Based on the result obtained in Table 3, all fibre percentages did not achieve the BS EN standard as in Table 2. The highest MOE with the strength of 1770.57 N/mm^2 at 0.00 % fibre percentage. While the lowest strength was 105.74 N/mm^2 at 12.00 % of fibre percentage. Comparison between these two can be seen that fibre initially were to act as addition for reinforcement in a cement board to increase its strength but consequently it adds the brittle properties in the cement board. This analysis brings two incomes which are; as the fibre percentage increases, the MOE strength is reduced. Next is, the addition of fibre only in cement board products did not give effect to MOE strength shows it needs other reinforcement material to make it stronger.

Generally, all the mean values of the MOR result did not achieve the standard value in BS standard which is minimum 9.00 N/mm^2 except the highest and the nearest to the standard was 0.00 % fibre percentage with MOR mean value of 10.05 N/mm^2. From this figure, it appears that by increment of fibre percentage in the cement board, the mean value of MOR reduced.

As reported by [2], particle size influenced the result value of MOE and MOR. Particle size is prior to the surface area of the cement board sample as it is affecting the strength of MOE and MOR. This study was initially planned to use a length of fibre ranging from 5 mm to 10 mm. Yet, due to inefficient methods of cutting fibre, such as manually cutting with scissors, some fibre proportions are not obtained. The size of the fibre gives effect to the particle size formation; the bigger the particle size, the lower the strength of the mechanical properties. Other than that, the distribution mixture into the mould should be even and uniform to prevent non-uniform density and strength of cement board at each part.

All mean fibre percentage achieved standard of industrial requirement which is less than 60.00 % of water absorption. The analysis shows that increasing fibre addition causes an increase in the mean value of WA. Generally, when WA is more, the thickness swells more. The greatest percentage of TS is 12.00 % of fibre percentage with the amount of 1.63 % where the cement board sample did not achieve the requirement whilst the least TS percentage is 0.00 % fibre percentage with amount of 0.24 %. In general, the TS of this study reached the standard value of TS in BS EN standard of cement fibreboard; less than 1.50 %. Overall, it appears that increasing fibre addition causes an increase in the mean percentage value of TS.

It can be clearly seen that TS and WA are closely corresponding to each other. Figure 4 shows the connection where when WA increases, TS also will be increased. Theoretically, cement board samples with low fibre content mixture are compressed completely and that lessens the presence of void that brings in water to enter cement board easily. In [13], influence of the TS percentage is due to the presence of void in cement boards which enhance the water absorption. According to [4], the OPEFB fibre sample will increase in thickness as it is characterised as hydrophilic which refers to its high tendency to absorb water. Overall, the higher the swelling thickness, the higher the water absorption value.

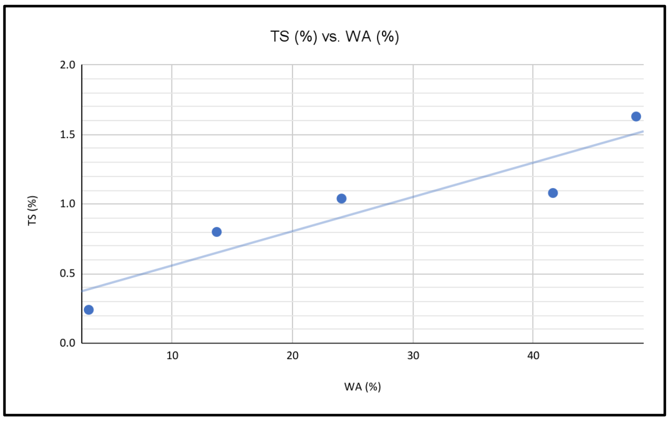

Figure 4: TS and WA relationship

Roughly, most cement boards in this study have achieved the targeted standard which is less than 1500 kg/m^3. The value density for boards with no fibre addition is the highest whereas the density of the boards decreased as the addition of the fibre increased as in the 12.00 % fibre addition. From this result, it appears that increasing fibre addition causes decrease in the mean value of density. Consequently, the density of 0.00 % fibre addition is beyond the targeted value, which is 1925.25 kg/m^3. As stated by [2], density affected the mechanical properties of the cement board; the increment of density increased the MOE value, in other words density able to predict MOE as in Figure 5.

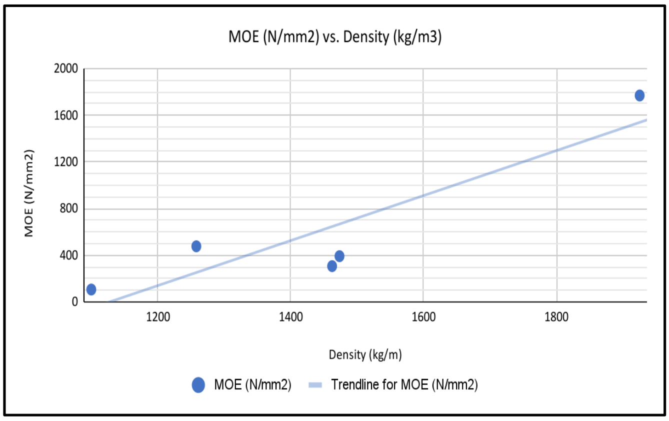

Figure 5: Correlation between Density and MOE

4. Conclusion

The focus of this study is on some basic mechanical properties of cement board fibre. The percentage fibre being used in the study were 0.00 %, 5.00 %, 7.00 %, 10.00 %, and 12.00 % where it was an addition of the cement weight. The study has resulted in an identification for optimum fibre percentage to be used in OPEFB fibre cement board is 12.00 %; 60 g for fibre and 500 g for cement. This is because the results analysis shows that this ratio had a substantial difference with the properties that were studied. However, the MOE and MOR result from this study did not achieve the minimum standard specification in the BS EN Standard of Wood-based panels. It was discovered that OPEFB fibre does not crucially give impact to the MOE and MOR of cement board fibre.

Overall, this study showed that it is possible to fabricate cement boards out of OPEFB fibre. However, the material is still subjected for further studies as to improve in every board property till obtained the optimum condition in all criteria. Future work is prior to evaluating the mechanical and physical properties of panelling products and assisting in deciding the operation parameters for fabricating procedure.

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References

[1] Y. W. Liu, & H. H. Pan, Properties of natural fiber cement boards for building partitions. In Challenges, Opportunities and Solutions in Structural Engineering and Construction (pp. 617-622). CRC Press (2009)

[2] N. H. Abas, A. Jaafar, & A. S. B. M. Seman, *Some Basic Properties of Cement Board Produced By Using Oil Palm* (2018)

[3] A. Abdullah, S. B., Jamaludin, M. M. Noor, & K. Noor, Composite cement reinforced coconut fiber: Physical and mechanical properties and fracture behavior. *Australian Journal of Basic and Applied Sciences*, *5*(7), 1228–1240 (2011)

[4] Z. A. Akasah, N. M. Z. N. Soh, H. Dullah, A. A. Aziz, & E. Aminudin The influence of Oil Palm Empty Fruit Bunch Fibre Geometry on mechanical performance of cement bonded fibre boards. *International Journal of Mechanical Engineering and Robotics Research*, *8*(4), 547–552. https://doi.org/10.18178/ijmerr.8.4.547-552 (2019)

[5] M. E. Azni, A. S. Norhan, L. Hans, & S. N. Roslan *Feasibility Study on Empty Fruit Bunch (EFB) Cement Board Feasibility Study on Empty Fruit Bunch (EFB) Cement Board*. *October* (2017)

[6] O. A. Babalola, & A. O. Olorunnisola Evaluation of Coconut (Cocos nucifera) Husk Fibre as a Potential Reinforcing Material for Bioplastic Production. *By-Products of Palm Trees and Their Applications*, *11*, 195–200. https://doi.org/10.21741/9781644900178-14m (2019)

[7] BSI. (1996). *BS EN 310:1993*.

[8] T. Chady, K. Schabowicz, & M. Szymków, Automated multisource electromagnetic inspection of fibre-cement boards. *Automation in Construction*, *94*(February), 383–394. https://doi.org/10.1016/j.autcon.2018.07.018 (2018)

[9] M. Jiang, M. Zhao, Z. Zhou, T. Huang, X. Chen, & Y.Wang, Isolation of cellulose with ionic liquid from steam exploded rice straw. *Industrial Crops and Products*, *33*(3), 734–738. https://doi.org/10.1016/j.indcrop.2011.01.015 (2011)

[10] K. Kochova, F. Gauvin, K. Schollbach, & H. J. H. Brouwers, Using alternative waste coir fibres as a reinforcement in cement-fibre composites. *Construction and Building Materials*, *231*, 117121. https://doi.org/10.1016/j.conbuildmat.2019.117121 (2020)

[11] W. Long, & Y. Wang, Effect of pine needle fibre reinforcement on the mechanical properties

of concrete. *Construction and Building Materials*, *278*, 122333. https://doi.org/10.1016/j.conbuildmat.2021.122333 (2021)

[12] M. Suffian, W.S. Hashim, A.L .Mohd Yusouf, R. R. & T. S. N. A.. Compliance of Malaysian Wood-Based Panels To International Requirements. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699 (2019)

[13] W. A. Maynet, *The Effect Of Cement -Efb Ratio For Empty Fruit Bunch Cement Boards (EFBCB) On Physical And Mechanical Properties*. 1–82 (2015)

[14] T. E. Omoniyi, Potential of Oil Palm (Elaeisguineensis) Empty Fruit Bunch Fibres Cement Composites for Building Applications. *AgriEngineering*, *1*(2), 153–163. https://doi.org/10.3390/agriengineering1020012 (2019)

[15] E. Onoja, S. Chandren, F. I. Abdul Razak, N. A. Mahat, & R. A. Wahab, Oil Palm (Elaeis guineensis) Biomass in Malaysia: The Present and Future Prospects. *Waste and Biomass Valorization*, *10*(8), 2099–2117. https://doi.org/10.1007/s12649-018-0258-1 (2019)

[16] Y. K. Peng, Unbleached Ethanolamine Empty Fruit Bunch (EFB) Pulp As Partial Substitution For Production of Autoclave Fibre Cement Composite. 1–46 (2019)

[17] P. Peter, N. M. Z. Nik Soh, Z. A. Akasah, & M. A. Mannan, Durability Evaluation of Cement Board produced from Untreated and Pre-treated Empty Fruit Bunch Fibre through Accelerating Ageing. *IOP Conference Series: Materials Science and Engineering*, *713*(1). https://doi.org/10.1088/1757-899X/713/1/012019 (2020)

[18] N. A. Sulaiman, and F., The Oil Palm Wastes in Malaysia. *IntechIvanova, Nadezhda*, *i*(tourism), 13 (2016)