THE SPRING BACK EFFECT OF OIL PALM EMPTY FRUIT BUNCH FIBRE ON PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT BOARD

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ABSTRAK

Penggunaan serat tandan kosong kelapa sawit (EFB) di dalam penghasilan papan simen telah menyebabkan peningkatan tekanan dalaman yang dipanggil lantunan semula (SpB). Secara teorinya SpB akan menyebabkan berlakunya pertambahan ketebalan dan mengurangkan ketumpatan sampel yang pada akhirnya akan menyebabkan penurunan terhadap sifat fizikal dan mekanikal papan simen serat tandan kosong kelapa sawit (EFBCB). Kajian ini dijalankan bagi mencadangkan kaedah yang paling berkesan dalam mengurangkan kesan SpB ke atas sampel EFBCB, seterusnya langkah pembetulan dapat diambil dengan lebih cepat terutamanya semasa tempoh pengawetan sampel. Tiga kumpulan sampel telah disediakan iaitu berdasarkan panjang serat EFB, nisbah antara serat EFB dan simen serta peratus kepekatan NaOH yang digunakan semasa proses rawatan EFB. Empat ujikaji utama yang terlibat iaitu modular keanjalan (MOE), modular kerapuhan (MOR), ikatan dalaman (IB) dan pengembangan ketebalan (TS). Dapatan kajian mendedahkan gabungan panjang purata EFB yang terdiri 65% daripada 25.72 mm, 64% daripada 14.37 mm dan 20% daripada 4.32 mm bersama-sama dengan nisbah simen kepada EFB sebanyak 3:1 dan kepekatan NaOH sebanyak 3% telah menghasilkan sifat-sifat fizikal dan mekanikal yang optimum. Gabungan ini telah mengurangkan kesan SpB yang ketara ke atas sampel EFBCB dengan nilai MOE, MOR, IB dan TS masing-masing 6098 N/mm^2, 11.92 N/mm^2, 0.53 N/mm^2, and 1.22%. Selain itu,model regresi garis lurus mendedahkan bahawa peratusan maksimum pertambahan ketebalan kesan dari SpB terhad kepada 3.2% atau 0.4 mm dalam mengekalkan kepatuhan kepada piawaian. Had peratusan pertambahan ketebalan ini digunapakai dalam meramal kesan SpB oleh EFB dalam sampel-sampel EFBCB. Oleh itu, langkah-langkah pembetulan dapat dilakukan lebih awal terutamanya semasa tempoh pengawetan untuk sampel dengan ketebalan melebihi 12.4 mm (3.2% ketebalan reka bentuk). Ianya dapat disimpulkan bahawa, pengurangan pengaruh SpB ke atas sample EFBCB dapat meningkatkan prestasi sample dengan ketara serta sampel-sampel yang gagal dapat dikenalpasti seawall semasa tempoh pengawetan untuk tujuan pembentulan ke atas rekabentuk campuran.

ABSTRACT

The inclusion of oil palm empty fruit bunch fibre (EFB) in cement board has promoted the internal stress development called spring back (SpB). Theoretically SpB has increased the thickness and decreases the density of the sample, and eventually decline the physical and mechanical properties of empty fruit bunch cement board (EFBCB). The main factors that have identified to contribute SpB are the length of fibres used, the ratio of cement to fibres and incompatibility between fibres and cement. Hence, this study was conducted to propose an effective approach to mitigate the effect of SpB on EFBCB samples to expedite corrective action especially along curing period. Three groups of samples namely EFB length, cement-EFB ratio and percentage NaOH concentration for EFB treatment were prepared, where each of design mixed consists of 5 repeated samples. Modulus of elasticity (MOE), modulus of rupture (MOR), internal bonding (IB) and thickness swelling (TS) are the properties that were investigated for EFBCB sample. The results revealed that combination EFB length of 16% of 25.72 mm, 64% of 14.37 mm and 20% of 4.32 mm with cement to EFB ratio of 3:1 and 3% NaOH concentration for EFB treatment has yielded optimum physical and mechanical properties. This combination has significantly diminished the SpB effect and produced MOE, MOR, IB, and TS values of 6098 N/mm^2, 11.92 N/mm^2, 0.53 N/mm^2, and 1.22%, respectively. On top of that, the linear regression prediction model based on cement to EFB ratio and percentage of NaOH concentration for EFB treatment discovered that the maximum percentage of thickness increment due to SpB is found to be limited to 3.2% or 0.4 mm in sustaining the standard requirement. Therefore, the limit of percentage thickness increment (3.2%) has been incorporated in new laboratory technique to mitigate the SpB effect of EFB on EFBCB sample. Thus, the corrective measures can be done as early as day 2 to day 15 during the curing period for the samples with a thickness exceeding 12.4 mm (3.2% of design thickness). It can be concluded that, the reduction in thickness increment due to SpB significantly improve the performance of EFBCB samples as well as failed of EFBCB samples can be identified as earlier as during curing period purposely for design mix correction.

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LIST OF SYMBOLS AND ABBREVIATION

EFB	:	Oil Palm Empty Fruit Bunch Fibre
EFBCB	:	Empty Fruit Bunch Fibre Cement Boards
WPCB	:	Wood Particle Cement Boards
WFCB	:	Wood Fibre Cement Boards
MOR	:	Modulus of Rupture
MOE	:	Modulus of Elasticity
IB	:	Internal Bonding
TS	:	Thickness Swelling
CB	:	Cement Boards
SpB	:	Spring Back
NLT	:	New Laboratory Technique
NaOH	:	Sodium Hydroxide
SEM	:	Scanning Electron Microscope
XRF	:	X-ray Fluorescence
I_i	:	Inhibition Index
R7M	:	Passed 4 mesh, retained 7 mesh size
R14M	:	Passed 7 mesh, retained 14 mesh size
R30M	:	Passed 14 mesh, retained 30 mesh size
T_{max}	:	Maximum Hydration Temperature
t_{max}	:	Time taken to reach max hydration temperature

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CHAPTER 1

INTRODUCTION

1.1 Research background

Wood cement boards (CB) are one of the construction materials that have been used thoroughly in Europe, Russia, and Asia, mainly for roofs, floors, and walls. It is fabricated based on the combination of wood particles or fibres, cementitious material, water, and chemical additives. According to MS 934 (1986) and BS EN 634-1 (1995), CB is a sheet of materials manufactured under pressure based on wood or other vegetable particles bound with hydraulic cement and possibly containing additives. CB products are classified based on several conditions such as according to the binder (bonded with ordinary Portland cement or magnesium-based cement), to the state of surface (as pressed plain or pattern, sanded surface, coated, and surface with sheets material), to coloration (integrally coloured or no added coloration) and lastly according to the shape (with a flat surface and square edge or profiled surface and profile edged). The physical properties of CB are density and thickness swelling (TS), while its mechanical properties consist of bending strength/modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding (IB).

Generally, CB composites are categorised into two types: wood particle cement boards and wood fibre cement boards. Wood particle cement boards are used in architectural, fire resistance, and acoustic panels. The boards are normally produced with a range density of 300 to 1300 kg/m^3, and the maximum bending strengths are often limited to less than 10 N/mm^2. As for wood fibre cement boards, they were developed to replace asbestos cement as it affects human health. Usually, this type of CB was developed based on 5 to 15% of cellulose fibre by weight, has a density in the range of 1100 to 1800 kg/m^3, and has a bending strength ranging up to 30 N/mm^2 (Wolfe & Gjinolli, 1997).

As the CB products are based on cement binder, the composites have advantages in durability and fire resistance compared to conventional resin-bonded wood particles composites. Unlike the resin-bonded particleboards, CB meets the requirements of fire resistance and durability for outdoor applications. Thus, CB products are not limited to indoor conditions, but it is also applicable for outdoor usage (Gong, 2010).

The most popular material that has been incorporated as CB reinforcement is wood fibres/particles. Previous studies have successfully incorporate wood fibres/particles (various species) as a CB reinforcement (Adelusi *et al.*, 2019; Marteinsson & Gudmundsson, 2018; Amel *et al.*, 2020; Ogunjobi *et al.*, 2019; Ashori *et al.*, 2011; Babatunde O & Adepegba, 2015; Del Menezzi, Castro, & Souza, 2007; Semple & Evans, 2004; Sotannde *et al.*, 2012). Other materials including oil palm waste such as frond and empty fruit bunch (Hermawan, Subiyanto, & Kawai, 2001; Omoniyi, 2019; Onuorah *et al.*, 2015), coconut fibre (Asasutjarit *et al.*, 2007; Erakhrumen *et al.*, 2008), and household waste (Ashori *et al.*, 2011; Parichatprecha *et al.*, 2013). The studies were focused on manufacturing methods, CB properties, the effect of material properties, and the effect of various wood/natural fibre and cement ratios on CB performance. Moreover, waste materials have become a popular choice among researchers as there are no/less additional costs for acquiring the raw materials, and most of the waste materials used are environmentally friendly and beneficial to society.

The Malaysian oil palm industry is the second-largest producer and exporter in the world after Indonesia. Therefore, the industry has produced a massive amount of waste in both plantation and oil palm mill activities. The waste produced in this sector includes oil palm frond (OPF) and oil palm trunk (OPT) from plantation activities. Whereas waste produced from oil palm mill activities are empty fruit bunch fibre (EFB), palm pressed fibre (PPF), and palm oil mill effluent (POME) (Abdullah & Sulaiman, 2013; Basiron, 2007). From the total waste produced by oil palm mill activities, 18,022 kilotonnes represent EFB, 11,059 kilotonnes represent palm press fibre/mesocarp (PPF), and the rest 4,506 kilotonnes are palm kernel shells (PKS) (Goh *et al.*, 2010). Thus, the EFB waste is the potential to utilised as CB reinforcement. At the same time, it transforms waste into valuable products and reduces disposal issues.

However, further research is needed to understand the properties of EFB to what extent it will influence the physical and mechanical properties of CB.

Physically, EFB is hard and tough and having a similarity to coconut coir (Sreekala *et al.*, 1997). Some research attempt to utilise coconut coir as CB reinforcement (Asasutjarit *et al.*, 2007; Zuraida *et al.*, 2011) have revealed that the use of coconut coir in the manufacturing of CB has resulted in a reduction of physical and mechanical properties of the samples due to spring back (SpB) of the fibre. As reported in the research, the coconut fibres tend to ‘ball up’ the sample thickness, thus reduced the sample density. Eventually, the physical and mechanical properties of CB samples declined. Furthermore, the sample thickness is getting higher when they used the longer and untreated coconut coir fibre. Since both fibres (coconut coir and EFB) have similarities in physical properties, the EFB SpB might have a similar effect as coconut coir fibre.

Based on the data that obtained from previous finding, none of the studies emphasized the effect of SpB on cement boards produced from EFB although its effect on the performance of the samples was quite significant. Therefore, the novel findings of this study is to analyse the causes and solutions to the effect of SpB on EFBCB which it is not covered by previous researches. Eventually, the new laboratory technique was introduced to mitigate the effect of SpB on EFBCB sample during curing process to speed up the detection of failed sample due to SpB as well as corrective action can be done earlier.

1.2 Problem statement

The SpB of fibre will influence the cement boards sample by several ways namely cement to fibre ratio, length of fibre used and application of untreated fibre in cement boards mixture. Earlier, research by Moslemi & Pfister (1987), Adelusi *et al.* (2019) and Amel *et al.* (2020) revealed that the SpB for wood particle CB has caused the fabricated samples with less amount of cement to have a non-uniform density. On top of that, Fabiyi (2004) found that SpB had effectively reduced the internal bonding of CB sample, which the sample was fabricated based on low cement to fibre ratio.

Most researchers agreed that sugar, water-soluble extractive, and hemicellulose are the primary factors that inhibit the normal setting and strength development of cement-wood/natural fibre composite (Ashori *et al.*, 2011; Ferreira, 2004 & Lertwattanaruk & Suntijitto, 2015). Therefore, the use of untreated wood fibres has recorded an increase in final thickness up to 0.16% due to internal stress development cause by SpB of fibre used (Fan & Dinwoodie, 2008). Fan & Dinwoodie (2008), Sarkar *et al.* (2012) and Asasutjarit *et al.* (2007) claimed the sample thickness had markedly increased after long water immersion due to SpB of fibre caused by poor bonding between untreated fibre and cement matrix. Furthermore, damage to the specimens was detected due to SpB when pressure on the sample was released (Marteinsson & Gudmundsson, 2018).

Asasutjarit *et al.* (2007) and Zuraida *et al.* (2011) revealed that the longer and untreated coconut fibre used had caused an increment in sample thickness for about three times of designed thickness, thus reduced the physical and mechanical properties of the sample. The recent research by Omoniyi (2019) and Onuorah *et al.* (2015) revealed that, incorporation of EFB as cement boards reinforcement has increase the performance of CB sample. However, the SpB of EFB in cement boards samples has not been rigorously investigated. Therefore, further research on EFBCB is essential, particularly on the SpB effect of the CB sample as well as the method to quantify the SpB effect of EFB on EFBCB sample.

1.3 Research question

Past studies have discovered the potential of incorporating oil palm EFB as CB reinforcement. Recent research by Omoniyi (2019) and Onuorah *et al.* (2015) had revealed that incorporating the EFB in manufacturing CB had significantly increased the bending properties of the sample. However, the SpB effects on the EFBCB samples were not highlighted in the research. Although some sample properties have met the minimum requirements, the SpB effects on dimensional stability should be evaluated comprehensively, especially on the thickness and density, as it affected the sample performance. The increase in the sample thickness that differs from the designed thickness will significantly change the overall sample properties. Based on the literature review and respective research problems as in Section 1.2, three points sparked the research questions. The questions to be addressed in this research are as follows:

(i) To what extent the spring back properties of EFB will affect the physical and mechanical properties of EFBCB?

(ii) Is there any possibility to reduce the effect of EFB SpB by introducing various cement-EFB ratios, various combinations of EFB length percentage, and modification of EFB using the chemical treatment?

(iii) What is the possible method to predict the effect of SpB against EFBCB, especially during the fabrication and testing stages, to shorten the time taken to perform the corrective action on failed samples regards the SpB effect?

1.4 Objective of study

The primary objective of recycling EFB as CB reinforcement is to improve the sample's physical and mechanical properties, thus fulfil the minimum requirements as in standard. However, the SpB issues of EFB in CB composite should be understood and provide the necessary methods to overcome them. Therefore, the research objectives are as follows:

i. To identify an appropriate EFB length composition that contributes to the optimum physical and mechanical properties of EFBCB and reduces the effect of SpB.

ii. To determine an optimum cement-EFB ratio that can be used in the fabrication of EFBCB by complying with thickness tolerance as stipulated in the BS EN 634-1:1995 and optimize the physical and mechanical properties.

iii. To propose a simple NaOH treatment method to improve the compatibility of EFB in the cement matrix thus reduces the SpB effect on EFBCB and enhances physical and mechanical properties.

iv. To develop a linear regression prediction model for physical and mechanical properties of EFBCB based on percentage thickness increment of the samples due to SpB.

v. To develop a new laboratory technique to quantify the effect of SpB on physical and mechanical properties of EFBCB based on thickness increment for different cement-EFB ratios and various percentages of NaOH treatment for EFB.

REFERENCES

Abdul Khalil, H. P. S., Nurul Fazita, M. R., Bhat, a. H., Jawaid, M., & Nik Fuad, N. a. (2010). Development and material properties of new hybrid plywood from oil palm biomass. *Materials and Design*, *31*(1), pp. 417–424.

Abdullah, N, & Sulaiman, F. (2013). Biomass Now – Sustainable Growth and Use. *The oil palm wastes in Malaysia*. School of Physic, Universiti Sains Malaysia. (pp. 75–100).

Abdullah, Nurhayati, & Sulaiman, F. (2013). The properties of the washed empty fruit bunches of oil palm. *Journal of Physical Science*, *24*(2), pp. 117–137.

Adelusi, E. A., Olaoye, K. O., & Adebawo, F. G. (2019). Strength and Dimensional Stability of Cement-bonded Boards Manufactured from Mixture of Ceiba pentandra and Gmelina arborea Sawdust. *Journal of Engineering Research and Reports*, *8(1)*, pp. 1–10

Aggarwal, L. K., Agrawal, S. P., Thapliyal, P. C., & Karade, S. R. (2008). Cement-bonded composite boards with arhar stalks. *Cement and Concrete Composites*, *30*(1), pp. 44–51.

Ajayi, B., & Badejo, S. O. O. (2005). Effects of board density on bending strength and internal bond of cement-bonded flakeboards. *Journal of Tropical Forest Science*, *17*(2), pp. 228–234.

Amel, B. A., Paridah, M. T., Rahim, S., H'Ng, P. S., Zakiah, A., & Hussein, A. S. (2017). Physical-mechanical characteristics of cement-bonded kenaf bast fibres composite boards with different densities. *Journal of Engineering Science and Technology*, *12(8)*, pp. 2254–2267.

Amel, B. A., Paridah, M. T., Rahim, S., & Hussein, A. S. (2020). Effects of kenaf bast fibre and silica fume content on bending strength and dimensional stability of cement bonded kenaf composite boards. *Journal of Engineering Science and Technology*, *15(2)*, pp. 1124–1138.

Amiandamhen, S. O., & Izekor, D. N. (2013). Effect of wood particle geometry and pre-treatments on the strength and sorption properties of cement-bonded particle boards. *Journal of Applied and Natural Science, 5(2),* pp. 318-322.

Amiandamhen, S. O., Agwu, C. U. & Ezenwaegbu, P. N. (2021). Evaluation of Cement-Bonded Particleboards Produced from Mixed Sawmill Residue. *Journal Indian Academy Wood Science, 18(1),* pp. 14-19

Ariffin, H., Hassan, M., Umi Kalsom, M., Abdullah, N., Shirai, Y., Ariffin, H., … Shirai, Y. (2008). Effect of physical, chemical and thermal pretreatments on the enzymatic hydrolysis of oil palm empty fruit bunch (OPEFB). *J. Trop. Agric. and Fd. Sc*, *36*(2), pp. 1–10.

Asasutjarit, C., Hirunlabh, J., Khedari, J., Charoenvai, S., Zeghmati, B., & Shin, U. C. (2007). Development of coconut coir-based lightweight cement board. *Construction and Building Materials*, *21*(2), pp. 277–288.

Ashori, A., Tabarsa, T., Azizi, K., & Mirzabeygi, R. (2011). Wood–wool cement board using mixture of eucalypt and poplar. *Industrial Crops and Products*, *34*(1), pp. 1146–1149.

Ashori, A., Tabarsa, T., & Sepahvand, S. (2012). Cement-bonded composite boards made from poplar strands. *Construction and Building Materials*, *26*(1), pp. 131–134.

Ashori, A., Tabarsa, T., & Valizadeh, I. (2011). Fiber reinforced cement boards made from recycled newsprint paper. *Materials Science and Engineering A*, *528*(25–26), pp. 7801–7804.

American Society for Testing and Materials (2013)STM D1037. ASTM D1037-13 Standard test methods for evaluating properties of wood-base fiber and particle. United States: ASTM D1307.

Awalludin, M. F., Sulaiman, O., Hashim, R., & Aidawati, W. N. (2015). An overview of the oil palm industry in Malaysia and its waste utilization through thermochemical conversion , specifically via liquefaction. *Renewable and Sustainable Energy Reviews*, *50*, pp. 1469–1484.

Azni, M. E., Norhan, A. S., & Lofflad, H. (2015). Feasibility Study On Empty Fruit Bunch (Efb) Cement. *Proceeding of ISER 9th International Conference, Berlin, Germany*, pp. 33–37.

Babatunde, A., B, O., Fuwape, J. ., & Badejo, S. . (2008). Effect of Wood Density on Bending Strength and Dimensional Movement of Flake Boards from Gmelina Arborea and Leuceana Leucocephala. *11th International Inorganic-Bonded Fibre*

Composites Conference. Madrid, Spain. pp. 260–266.

Babatunde O, O., & Adepegba, J. A. (2015). Cement Bonded Particle Board from Musa paradisiaca Stalk . *The Pacific Journal of Science and Technology*, *16*(1), pp. 12–20.

Badejo, S. O. O. (1988). Effect of flake geometry on properties of cement-bonded particleboard from mixed tropical hardwoods. *Wood Science and Technology, 22*, pp. 1982–1983.

Basiron, Y. (2007). Palm oil production through sustainable plantations. *European Journal of Lipid Science and Technology*, *109*(4), pp. 289–295.

Bediako, M., & Amankwah, E. O. (2015). Analysis of Chemical Composition of Portland Cement in Ghana : A Key to Understand the Behavior of Cement. *Advance in Materials Science and Engineering*, *2015*, pp. 1-5.

Bejó, L., Takáts, P., & Vass, N. (2005). Development of Cement Bonded Composite Beams. *Acta Silv. Lign. Hung.*, *1*, pp. 111–119.

Benyahia, A., Merrouche, A., Rokbi, M., & Koudri, Z. (2013). Study the effect of alkali treatment of natural fibers on the mechanical behavior of the composite unsaturated Polyester-fiber Alfa. *21st Congress Francais de Mecanique*, 1–6.

Bonnet-Mosimbert, P. A., Gauvin, F., Brouwers, H. J. H. & Amziane, S. (2020). Study of Modification on the Chemical and Mechanical Compatibility Between Cement Matrix and Oil Palm Fibre. *Result in Engineering, 7(2020),* pp. 100-150.

Brandt, A. M. (2009). *Cement Based Composites: Materials,Mechanical Properties and Performance.* Second Edition. United Kingdom: Taylor and Francis Ltd.

Briggs, R. J., Nicholson, R., Vazvaei, F., Busch, J., Mabuchi, M., Mahesh, K. S., … Abbott, R. W. (2014). Method transfer, partial validation, and cross validation: Recommendations for best practices and harmonization from the global bioanalysis consortium harmonization team. *AAPS Journal, 16(6)*, pp. 1143–1148.

British Standard Institution. *Wood-based panels — Determination of modulus of elasticity in bending and of bending strength*. London, BS EN 310. 1993

British Standard Institution. *Particleboards and fiberboards – Determination of tensile strength perpendicular to the plane of board.* London, BS EN 319. 1993.

British Standard Institution. *Wood-based panels — Determination of density*. London, BS EN 323. 1993

British Standard Institution. *Wood-based panels — Determination of dimensions of* *boards.* London, BS EN 324-1. 1993

British Standard Institution. *Cement-bonded particleboards Specifications —Part 2: Requirements for OPC bonded particleboards for use in dry, humid and external conditions*. London, BS EN 634-2. 2007

British Standard Institution. *Selection and application of particleboard , oriented strand board (OSB), cement bonded particleboard and wood fibreboards for specific purposes*. London BS 7916. 1998

British Standard Institution. *Particleboards and fiberboards – Determination of swelling in thickness after immersion in water*. London, BS EN 317.1993

British Standard Institution. *Cement-bonded particle boards — Specification —Part 1: General Requirement*. London, BS EN 634-1. 1995

Castro, V., Parchen, C., & Iwakiri, S. (2018). Particle Sizes and Wood / Cement Ratio Effect on the Production of Vibro-compacted Composites. *Wood Science and Technology*. *25*(4), pp. 1–8.

CIDB (2010). *Construction Industry Standard-Manual For IBS Content Scoring System (IBS Score).* Malaysia: Lembaga Pembangunan Industri Pembinaan Malaysia.

CIDB (2016). *Industrialised Building System Vol 3*. Malaysia: Lembaga Pembangunan Industri Pembinaan Malaysia.

Del Menezzi, C. H. S., Castro, V. G. De, & Souza, M. H. De. (2007). Production And Properties Of A Medium Density Wood-Cement Boards Produced With Oriented Strands And Silica Fume. *Maderas. Ciencia y Tecnologia*, *9*(2), pp. 105–115.

Engineering Service Division (2010). *Drinking Water Quality Surveillance Programme.* Malaysia: Ministry of Health.

Erakhrumen, A. A., Areghan, S. E., Ogunleye, Larinde, S. L., & Odeyale. (2008). Selected physico-mechanical properties of cement- bonded particleboard made from pine (Pinus caribaea M.) sawdust-coir (Cocos nucifera L.) mixture. *Scientific Research and Essay*, *3*(5), pp.197–203.

Eusebio, D. A., Soriano, F. P., Cabangon, R. J., & Evans, P. D. (2000). Manufacture of Low-cost Wood–Cement Composites in the Philippines Using Plantation-grown Australian Species: II. Acacias. *Aciar Proceedings*, pp. 115–122.

Fabiyi, J. S. (2004). Effects of chemical additive concentrations on strength and sorption of cement-bonded board. *Journal of Tropical Forest Science*, *16*(3), pp. 336–342.

Faizi, M. K., Shahriman, A. B., Majid, M. S. A., Shamsul, B. M. T., & Ng, Y. G. (2017). An overview of the Oil Palm Empty Fruit Bunch (OPEFB) potential as reinforcing fibre in polymer composite for energy absorption applications. *MATEC Web of Conference 90*. *01064.* pp. 1-9.

Fan, M., & Dinwoodie, J. (2008). Dimensional Stabilisation of Cement Bonded Particleboard. *11th International Inorganic-Bonded Fibre Composites Conference*, (November), pp. 180–187.

Fan, M., Dinwoodie, J. M., Bonfield, P. W., & Breese, M. C. (1999). Dimensional instability of cement-bonded particleboard: Behavior of cement paste and its contribution to the composite. Wood and Fiber Science, 31(3), 306–318.

Fatra, W., Helwani, Z., Muchtar, Z., & Asmura, J. (2016). Effect of Alkaline Treatment on the Properties of Oil Palm Empty Fruit Bunch Fiber-reinforced Polypropylene. *International Journal of Technology*, *6*, pp. 1026–1034.

Ferraz, J. M., Del Menezzi, C. H. S., Souza, M. R., Okino, E. Y. A., & Martins, S. A. (2012). Compatibility of pretreated coir fibres (cocos nucifera L.) with Portland cement to produce mineral composites. *International Journal of Polymer Science*, *2012*, pp. 1-8.

Ferreira, F. C. J. C. P. J. M. F. (2004). Wood-cement composites : A review. *Holz Roh Werkst*, *62*, pp. 370–377.

Frybort, S., Mauritz, R., Teischinger, A., & Muiler, U. (2008). Cement bonded composites – a mechanical review. *BioResource*, *3*(2), pp. 602–626.

Goh, C. S., Tan, K. T., Lee, K. T., & Bhatia, S. (2010). Bio-ethanol from lignocellulose: Status, perspectives and challenges in Malaysia. *Bioresource Technology*, *101*(13), pp. 4834–4841.

Gong, A. (2010). *Wood-Cement Particleboards: Improved Manufacturing, Material Characterization And Potential Application In Concrete Crash Barriers.* Michigan State university: Ph.D. Thesis.

Govin, A., Peschard, A., Fredon, E., & Guyonnet, R. (2005). New insights into wood and cement interaction. *Wood Research and Technology*, *59*(3), pp. 330–335.

Gunawan, F. E., Homma, H., Brodjonegoro, S. S., Hudin, A. B. B., & Zainuddin, A. B. (2009). Mechanical Properties of Oil Palm Empty Fruit Bunch Fiber. *Journal of Solid Mechanics and Materials Engineering*, *3*(7), pp. 943–951.

Harsono, Mulyantara, L. T., Rizaluddin, A. T., Nakagawa izumi, A., & Ohi, H. (2015). Properties of Fibers Prepared from Oil Palm Empty Fruit Bunch for Use as

Corrugating Medium and Fiberboard. *J—STAGE Advance*, *1148*, pp. 1349–1159.

Hasan, K. M. F., Horváth, P. G., & Alpár, T. (2021). Development of lignocellulosic fiber reinforced cement composite panels using semi-dry technology. *Cellulose, 28(6)*, pp. 3631–3645

Hassan, C. S., Chellaiah, N. R., Sahari, B., Salit, M. S., & Abdul Aziz, N. (2016). Effect of Chemical Treatment on Oil Palm Empty Fruit Bunch (OPEFB) Fiber on Water Absorption and Tensile Properties of OPEFB Fiber Reinforced Epoxy Composite. *Key Engineering Materials*, *701*, pp. 295–299.

Hassan, N. S., & Badri, K. (2016). Thermal behaviors of oil palm empty fruit bunch fiber upon exposure to acid-base aqueous solutions. *Malaysian Journal of Analytical Sciences*, *20*(5), pp. 1095–1103.

Hermawan, D., Subiyanto, B., & Kawai, S. (2001). Manufacture and properties of oil palm frond cement-bonded board. *Journal of Wood Science*, *47*(3), pp. 208–213.

Ibrahim, Z., Ahmad, M., Aziz, A. A., Ramli, R., Jamaludin, M. A., Muhammed, S., & Alias, A. H. (2016). Dimensional Stability Properties of Medium Density Fibreboard (MDF) from Treated Oil Palm (Elaeis guineensis) Empty Fruit Bunches (EFB) Fibres. *Open Journal of Composite Materials*, *06*(04), pp. 91–99.

International Standard. *Cement-Bonded Particleboards - Boards of Portland or Equivalent Cement Reinforced with fibrous Wood Particles*. Switzerland, ISO 8335. 1987

Jaafer, B. S., Majeed, A. H., & Kadhim, M. J. (2020). Physical and Mechanical Properties of Reed Fibre Cement Boards. *IOP Conference Series: Materials Science and Engineering*, 928 (2020), pp. 022-054

James M, G. (2012). *Overview of X-Ray Fluorescence*. Retrieved from University of Missouri Research Reactor website on July 25, 2017, from http://archaeometry.missouri.edu/xrf_overview.html

Jawaid, M., Abdul Khalil, H. P. S., & Abu Bakar, a. (2010). Mechanical performance of oil palm empty fruit bunches/jute fibres reinforced epoxy hybrid composites. *Materials Science and Engineering A*, *527*(29–30), pp. 7944–7949.

John, M. J., & Anandjiwala, R. D. (2008). Recent Developments in Chemical Modification and Characterization of Natural Fiber-Reinforced Composites. *Polymer Composites*, pp. 187–207.

Joseph, S., Joseph, K., & Thomas, S. (2006). Green Composites from Natural Rubber and Oil Palm Fiber : Physical and Mechanical Properties. *International Journal* *of Polymeric Materials*, *55*, pp. 925–945.

Juenger, M. C. G., & Jennings, H. M. (2002). New insights into the effects of sugar on the hydration and microstructure of cement pastes. *Cement and Concrete Research*, *32*, pp. 393–399.

Karade, S. R. (2011). Developments in Cement-Bonded Composite Material Technology. *National Seminar on Modern Trends in Architectural and Civil Engg. Practices*, (November 2007), pp. 57–64.

Khalil, H. P. S. A., Jawaid, M., Hassan, A., Paridah, M. T., & Zaidon, A. (2012). Oil Palm Biomass Fibres and Recent Advancement in Oil Palm Biomass Fibres Based Hybrid Biocomposites. in INTECT. *Composites And Their Applications.* Universiti Sains Malaysia: School of Industrial Technology.

Kochova, K., Schollbach, K., Gauvin, F., & Brouwers, H. J. H. (2017). Effect of saccharides on the hydration of ordinary Portland cement Effect of saccharides on the hydration of ordinary Portland cement. *Construction and Building Materials*, *150*, pp. 268–275.

Kow Chong, M. (2017). *Ibs Scoring In Malaysia.* Setia Precast Sdn Bhd.

Kwei, N. L., Wan Daud, W. R., & Ghazali, A. (2007). Morphological And Chemical Nature Of Fiber Strand Of Oil Palm Empty-Fruit-Bunch (Opefb). *BioResource*, *2*(3), pp. 351–362.

Lertwattanaruk, P., & Suntijitto, A. (2015). Properties of natural fiber cement materials containing coconut coir and oil palm fibers for residential building applications. *Construction and Building Materials*, *94*, pp. 664–669.

Li, W., Shupe, T. F., & Hse, C. Y. (2004). Physical and mechanical properties of flakeboard produced from recycled CCA-treated wood. *Forest Products Journal*, *54*(2), pp. 89–94.

Ma, L. F., Yamauchi, H., Pulido, O. R., Sasaki, H., & Kawai, S. (2000). Production and properties of oriented cement-bonded boards from Sugi (Cryptomeria japonica D. Don). *Wood Cement Composites in The Asia Pacific Region - ACIAR Proceeding, Canberra, Australia*. pp. 140–147.

Malaysian Standard (1986). *Specification For Wood Cement Board*. Malaysia: MS 934.

Marteinsson, B., & Gudmundsson, E. (2018). Cement Bonded Particle Boards with Different Types of Natural Fibres—Using Carbon Dioxide Injection for Increased Initial Bonding. *Open Journal of Composite Materials*, *08*(01), pp. 28–

42.

Malaysia Biomass Industries Confederation (2020). Malaysia Biomass Industries Review 2019/2020-*Green Ocean Business Model, Market and Funding Opportunities.*

Miller, D. P., & Moslemi, A. A. (1991). Wood-Cement Composites: Effect of Model Compounds on Hydration Characteristics and Tensile Strength. *Wood and Fiber Science*, *23*(4), pp. 472–482.

Mohamed Yusoff, M. Z., Salit, M. S., & Ismail, N. (2009). Tensile Properties of Single Oil Palm Empty Fruit Bunch (OPEFB) Fibre. *Sains Malaysiana*, *38*(4), pp. 525–529.

Mohammadkazemi, F., & Doosthoseini, K. (2015). Rice Husk and Old Corrugated Container Container Cement Boards: Performance of Nano-SiO2 on Strength and Dimensional Stability. *Iran.J.Chem.Chem.Eng*, *34*(3), pp. 91–98.

Mohr, B. J. (2005). *Durability of Pulp Fiber-Cement Composites.* Georgia Institute of Technology. Ph.D. Thesis.

Morrissey, F. E., Coutts, R. S. P., & Grossman, P. U. A. (1985). Bond between cellulose fibres and cement. *International Journal of Cement Composites and Lightweight Concrete*, *7*(2), pp. 73–80.

Morteza, N., Mohammad Dahmardeh, G., & Ebrahim, G. (2011). Effect of wood species, particle size and dimension of residue obtained from trimming of wood-cement composite on physical and mechanical properties of cement-bonded particleboard. *Wood Materials Science and Engineering*, *6*(2011), pp. 196–206.

Mosier, N., Charles, W., Bruce, D., Richard, E., Lee, Y. Y., Holtzapple, M., & Ladisch, M. (2005). Features of promising technologies for pretreatment of lignocellulosic biomass. *Bioresource Technology*, *96*(March 2019), pp. 673–686.

Moslemi, A. A. (1999). Emerging Technologies in Mineral-Bonded Wood and Fiber Composites. *Advanced Performance Materials*, *6*(1999), pp. 161–179.

Moslemi, A. A. (2008). Technology and Market Considerations for Fiber Cement Composites. *11th International Inorganic-Bonded Fibre Composites Conference.* Madrid, Spain. pp. 113-129.

Moslemi, A. A., Garcia, J. F., & Hofstrand, A. D. (1983). Effect of Various Treatments and Additives on Wood-Portland Cement-Water Systems. *Wood and Fiber Science*, *15*(2), pp. 164–176.

Moslemi, A. A., & Pfister, S. C. (1987). The Influence of Cement Wood Ratio and

Cement Type on Bending Strength and Dimensional Stability of Wood-Cement Composite Panels. *Wood and Fiber Science*, *19*(2), pp. 165–175.

Na, B., Wang, Z., Wang, H., & Lu, X. (2014). Wood-cement compatibility review. *Wood Research*, *59*(5), pp. 813–826.

Nafu, Y. R., Foba-tendo, J., Njeugna, E., Oliver, G., & Cooke, K. O. (2015). Extraction and Characterization of Fibres from the Stalk and Spikelets of Empty Fruit Bunch. *Journal of Applied Chemistry,2015,* pp. 1-10.

Nasser, R. A., Alshahrani, T. S., Al-Mefarrej, H. A., & Abdel-Aal, M. A. (2014). Effects of tree species and wood particle size on the properties of cement-bonded particleboard manufacturing from tree prunings. *Journal of Environmental Biology*, *35*(September), pp. 961–971.

Ndazi, B. S., Karlsson, S., Tesha, J. V., & Nyahumwa, C. W. (2007). Chemical and physical modifications of rice husks for use as composite panels. *Composites Part A: Applied Science and Manufacturing*, *38*(3), pp. 925–935.

Noor Azrieda, A.R., Razali, A.K., Izran, K., Rahim, S., & Adbul Aziz, M. (2009). Hydration permormance of cement-bonded wood composites: compatibility assessment of six pioneer forest species. *Borneo Science*, *25*(September), pp. 47–58.

Norul Izani, M. A., Paridah, M. T., Anwar, U. M. K., Mohd Nor, M. Y., & H'ng, P. S. (2012). Effects of fiber treatment on morphology , tensile and thermogravimetric analysis of oil palm empty fruit bunches fibers. *Composites Part B, 2012,* pp. 1-7.

Norul Izani, M.A., Paridah, M.T., Anwar, U.M.K., & Mohd Nor, M.Y. (2013). Properties of Medium-Density Fibreboard (Mdf) Made From Treated Empty Fruit Bunch of Oil Palm. *Journal of Tropical Forest Science*, *25*(2), pp. 175–183.

National Ready-Mixed Concrete Association of Malaysia (2018). *Technology In Practice What, Why and How?: TIP 17 - Drying Shrinkage of Concrete*. Malaysia: NRMCA

Nurul Hazira, C.M., Masturah, M., Shuhaida, H. & Osman, H. (2016). The Effect Of Various Pretreatment Methods On Empty (Kesan Kaedah Prarawatan Berbeza Terhadap Tandan Kosong Kelapa Sawit Bagi Penghasilan). *Malaysian Journal of Analytical Science, 20(6),* pp. 1474–1480.

Ogunjobi, K. M., Ajibade, M. A., Gakenou, O. F. & Gbande, S. (2019). Physical and Mechanical Properties of Cement-bonded Particle Board Produced from

Anogeissus Leiocarpus Guill and Perr Wood Species. *African Journal of Agriculture Technology and Environment, 8(1),* pp. 192-199.

Ogunjobi, K. M., Falayi, T. B., Gakenou, O. F., Ayanleye, S. O., & Thompson, O. E. (2019). Effect of Boards Density and Mixing Ratio on The Physio-Mechanical Properties of Cement-Bonded Particle board Produced from *Ceiba Petandra* Sawdust. *Agriculture and Forestry Journal, 3(2).* pp. 58-63.

Okino, E. Y. A., Souza, M. R. de, Santana, M. A. E., Sousa, M. E. de, & Teixeira, D. E. (2004). Wood Cement-Agglomerated Chapel Of Hevea Brasiliensis Müll. *Revista Árvore*, *28*(3), pp. 451–457.

Olorunnisola, A. O. (2002). Effects Of Particle Geometry And Chemical Accelerator On Strength Properties Of Rattan – Cement Composites. *African Journal of Science and Technology, 8(1),* pp. 22–27.

Omar, F.N., Mohammed, M A.P., & Baharuddin, A.S. (2014). Effect of Silica Bodies on The Mechanical Behaviour of Oil Palm Empty Fruit Bunch Fibres. *BioResources, 9(4),* pp. 7041–7058.

Omar, F.N., Mohammed, M.A.P., & Baharuddin, A.S. (2014). Microstructure modelling of silica bodies from oil palm empty fruit bunch (OPEFB) fibres. *BioResources, 9(1),* pp. 938–951.

Omoniyi, T. E., & Akinyemi, B. A. (2013). Hydration Characteristics of Bagasse in Cement-*Bonded Composites*. *3(1),* pp. 1–6.

Omoniyi, T. E. (2019). Potential of Oil Palm (Elaeisguineensis) Empty Fruit Bunch Fibres Cement Composites for Building Application. *AgriEngineering, 2019 (1),* pp. 153-163.

One Steel Manufacturing (2014). *Hot Rolled And Structural Steel Products-Seventh Edition*. Australia: One Steel Catalogue

Onuorah, E. O., Okeke, C. A., Neabanne, J. T., Nnabuife, E. L. C., & Obiorah, S. O. (2015). The effects of production parameters on properties of single and 3-layer cement-bonded composites made from oil palm empty fruit bunch and tropical hardwood sawmill residue. *World Journal of Engineering*, *12*(6), pp. 577–590.

Oyagade, A. O. (1990). Effect Of Cement / Wood Ratio On The Relation- Ship Between Cement Bonded Particle- Board Density And Bending Properties. *Journal of Tropical Forest Science, 2*(2), pp. 211–219.

Pang, X. (2015). The effect of water-to-cement ratio on the hydration kinetics of Portland cement at different temperatures. *The 14th International Congress on*

Cement Chemistry, October. pp. 1-12.

Parichatprecha, R., Paoleng, P., Phenrat, T., & Jitsangiam, P. (2013). Mechanical Properties Of Cement-Bonded Composite Board Produced From Aseptic. *Sustainable Construction Materials and Technology*. pp. 1-8.

Pomeranz, Y., & E. Meloan, C. (2013). *Food Analysis-Theory And Practice*. Third Edition. New York, London : Chapman & Hall.

Purwanto, D. (2016). The Physical and Mechanical Properties of Cement Board Made from Oil Palm Empty Fruit Bunches Fibres. *Jurnal Riset Industri Hasil Hutan, 8(2)*. pp. 43-52

Ramli, R., Shaler, S., & Jamaludin, M. A. (2002). Properties of Medium Density Fibreboard From Oil Palm Empty Fruit Bunch. *Journal of Oil Palm Research*, *14*(2), pp. 34–40.

Rocha, R. (2002). Utilization of the coconut shell of babacu to produce cement-bonded particleboard. *Bioresource Technology*. *85(2002)*, pp. 159–163.

Ronald, E. W., Raymond, H. M., Sharon, L. M. & Keying, Y. (2007). *Probability and Statistics for Engineers and Scientists.* 8th Edition. New Jersey: Pearson Prentice Hall.

Rosa, T. S. D, Schweitzer, V. R., Trianoski, R. & Iwankiri, S. (2017). Physical and Mechanical Properties of Oriented Wood-Cement Boards Produced With Five Eucalyptus Species, *Floresta, Curitiba. 47 (3)*, pp. 317-322.

Sarkar, M., Asaduzzaman, M., Das, a K., Hannan, M. O., & Shams, M. I. (2012). Mechanical properties and dimensional stability of cement bonded particleboard from rice husk and sawdust. *Bangladesh J. Sci. Ind. Res*, *47*(3), pp. 273–278.

Šavija, B., & Luković, M. (2016). Carbonation of cement paste: Understanding, challenges, and opportunities. *Construction and Building Materials, 117(August)*, pp. 285–301.

Semple, K. E., & Evans, P. D. (2004). *Wood-cement composites — Suitability of Western Australian mallee eucalypt, blue gum and melaleucas: A report for the RIRDC/Land & Water Australia/FWPRDC/MDBC - Joint Venture Agroforestry Program*. Australia: Rural Industries Research and Development Corporation (RIRDC).

Sen, S., & Rao, K. B. (2017). Effect of Water Cement Ratio on the Workability and Strength of Low Strength Quarry Dust Concrete. *International Journal of Civil Engineering and Technology (IJCIET)*, *8*(10), pp. 1448–1455.

Senawi, R., Alauddin, S. M., Saleh, R. M., & Shueb, M. I. (2013). Polylactic Acid/Empty Fruit Bunch Fiber Biocomposite:Influence of Alkaline and Silane Treatment on the Mechanical Properties. *International Journal of Bioscience, Biochemistry and Bioinformatics*, *3*(1), pp. 59–61.

Shareef, E. T. D., & Ramli, M. B. (2009). Study The Effect Of Using Palm Fiber On The Properties Of High Strength Flowable Mortar Study The Effect Of Using Palm Fiber On The Properties. *34th Conference on Our World in Concrete & Structure*. Singapore. pp. 1-9.

Shinoj, S., Visvanathan, R., Panigrahi, S., & Kochubabu, M. (2011). Oil palm fiber (OPF) and its composites: A review. *Industrial Crops and Products*, *33*(2011), pp. 7–22.

Sia, C. V., Nakai, Y., Shiozawa, D., & Ohtani, H. (2014). Statistical Analysis of the Tensile Strength of Treated Oil Palm Fiber by Utilisation of Weibull Distribution Model. *Open Journal of Composite Materials*, *4*(January), pp. 72–77.

Sihabut, T., & Laemsak, N. (2010). Feasibility of producing insulation boards from oil palm fronds and empty fruit bunches. *Songklanakarin Journal of Science and Technology*, *32*(1), pp. 63–69.

Soom, R. M., Hassan, W. H. W., Top, A. G. M., & Hassan, K. (2006). Thermal Properties of Oil Palm Fibre. *Journal of Oil Palm Research*, *18*, pp. 272–277.

Sotannde, O. A., Oluwadare, A. O., Ogedoh, O., & Adeogun, P. F. (2012). Evaluation Of Cement-Bonded Particle Board Produced From Afzelia Africana Wood Residues. *Journal of Engineering Science and Technology*, *7*(6), pp. 732–743.

Soydan, A. M., Sari, A. K., Duymaz, B., Akdeniz, R. & Tunaboylu, B. (2018). Characterization of Fibre-Cement Composites Reinforced with Alternate Natural Cellulosic Fibres. *Eskisehir Tech. Univ. Journal of Sci.and Tech. A Applied Sci. and Eng. 19(3)*, pp. 721-731.

Sreekala, M. S., Kumaran, M. G., & Thomas, S. (1997). Oil palm fibers: Morphology, chemical composition, surface modification, and mechanical properties. *Journal of Applied Polymer Science*, *66*(5), pp. 821–835.

Sreekala, M. S., Kumaran, M. G., & Thomas, S. (2002). Water sorption in oil palm fiber reinforced phenol formaldehyde composites. *Composites - Part A: Applied Science and Manufacturing*, *33*(6), pp. 763–777.

Sudin, R., & Swamy, N. (2006). Bamboo And Wood Fibre Cement Composites For Sustainable Infrastructure Regeneration. *Journal of Materials Science*, *41*(69), pp. 17–24.

Sulaiman, F., Abdullah, N., Gerhauser, H., & Shariff, a. (2011). An outlook of Malaysian energy, oil palm industry and its utilization of wastes as useful resources. *Biomass and Bioenergy*, *35*(9), pp. 3775–3786.

Suradi, S. S., Yunus, R. M., Beg, M. D. H., & Yusof, Z. A. M. (2009). Influence Pre-Treatment on the Properties of Lignocellulose Based Biocomposite. *National Conference on Postgraduate Research (NCON-PGR) 2009*. Malaysia: Universiti Malaysia Pahang. pp. 67–78.

Tang, K., Ibrahim, W., & Kadir, W. (2016). Towards Environmental and Economic Sustainability via the Biomass Industry: The Malaysian Case Study. In (pp. 162-183). doi:10.1017/9781316337974.009

Teixeira, D. E. (2012). Recycled Old Corrugated Container Fibers for Wood-Fiber Cement Sheets. *ISRN Forestry*, *2012*, pp. 1–8.

Tibor L., A., Matyas, S., Ildiko, H., & Laszlo, B. (2012). Developing Building Materials from Cement-bonded Reed Composite Based on Waste Materials. *International Scientific Conference on Sustainable Developement & Ecological Footprint*. Sopron, Hungary. pp. 1–7.

Tittelein, P., Cloutier, A., & Bissonnette, B. (2012). Design of a low-density wood–cement particleboard for interior wall finish. *Cement and Concrete Composites*, *34*(2), pp. 218–222.

Tolêdo Filho, R. D., Scrivener, K., England, G. L., & Ghavami, K. (2000). Durability of alkali-sensitive sisal and coconut fibres in cement mortar composites. *Cement and Concrete Composites*, *22*(2), pp. 127–143.

Wei, J. (2014). *Durability of Cement Composites Reinforced with Sisal Fibere.* Columbia University. Ph.D. Thesis.

Wei, Y. M., Tomita, B., Hiramatsu, Y., Miyatake, a, & Fujii, T. (2002). Study of hydration behaviors of wood-cement mixtures: compatibility of cement mixed with wood fiber strand obtained by the water-vapor explosion process. *Journal of Wood Science*, *48*(5), pp. 365–373.

Wertz, J.-L., Bedue, O., & Mercier, J. P. (2010). *Cellulose Science and Technology*. Switzerland: Taylor & Francis Group, LLC.

Wolfe, R. W., & Gjinolli, A. (1997). Cement-Bonded Wood Composites as an Engineering Material. *The Use of Recycled Wood and Paper in Building Application. USDA Forest Service and Forest Products Society Society*

Proceeding No. 7286, pp. 84–91.

Yusoff, S. (2006). Renewable energy from palm oil e innovation on effective utilization of waste. *Journal of Cleaner Production*, *14(2006)*, pp. 87-93.

Zawawi, I., Astimar, A. A., & Ridzuan, R. (2015). Effect Of Treatment On The Oil Content And Surface Morphology Of Oil Palm (Elaeis Guineensis) Empty Fruit Bunches (Efb) Fibres. *Wood Research*, *60*(1), pp. 157–166.

Zuraida, A Norshahida, S Sopyan, I Zahurin, H. (2011). Effect of Fiber Length Variations on Mechanical and Physical Properties of Coir Fiber Reinforced Cement-Albumen Composite (CFRCC). *IIUM Engineering Journal*, *12*(1), pp. 63–75.

APPENDIX E

Appendix E 1: List of Publication and Achievement

PUBLICATION

I. Nik Soh, N.M.Z., Akasah, Z.A., Dullah, H., Abdul Aziz, A., & Aminudin, E. (2018). Alkaline Treatments on EFB Fibre: The Effect on Mechanical-Physical Properties and Fibre-Cement Hydration Rate. *Malaysian Construction Research Journal (MCRJ), Vol. 4(2), 117-128.* ***Indexed by Scopus (Q4)***

II. Akasah, Z.A., Nik Soh, N.M.Z., & Dullah, H. (2019). The Influence of Oil Palm Empty Fruit Bunch Fibre Geometry on Mechanical Performance of Cement Bonded Fibre Boards. *International Journal of Mechanical Engineering and Robotic Research (IJME), Vol. 8(4), 547-552.* ***Indexed by Scopus (Q4)***

III. Peter, P., Nik Soh, N.M.Z., Akasah, Z.A., & Mannan, M.A. (2020). Durability Evaluation of Cement Boards Produced From Untreated and Pre-treated Empty Fruit Bunch Fibre Through Accelerating Ageing. *In IOP Conference Series: Materials Science and Engineering 713 (2020) 012019.* ***Indexed by Scopus***

IV. Dullah, H., Akasah, Z.A., Nik Soh, N.M.Z., & Mangi, S.A. (2017). Compatibility Improvement Method of Empty Fruit Bunch as a Replacement Material in Cement Bonded Boards: A Review. *In IOP Conference Series: Materials Science and Engineering, 271(1), 012076****. Indexed by Scopus***

V. Akasah, Z.A., Dullah, H., Nik Soh, N.M.Z., & Guntor, N.A.A. (2019). Physical and Mechanical Properties of Empty Fruit Bunch Fibre-Cement Bonded Fibreboard For Sustainable Retrofit Building. *International Journal of Materials Science and Engineering, Vol. 7(1), 1-9.* ***Indexed by Ulrich's Periodical Directory, Google Scholar, Crossref***

VI. Akasah, Z.A., Dullah, H., Nik Soh, N.M.Z., & Peter, P., (2017). The Effect of Different Concentration of Sodium Hydroxide Treatment of Oil Palm Empty Fruit Bunch on Surface Morphology and Cement-EFB Fibre Hydration Rate. *E-Proceeding iCompex17.* ***Published in Google scholar***

ACHIEVEMENT

I. GOLD MEDAL award for innovation product of Unsanded Empty Fruit Bunch Cement Boards (EFB-CB) in National Innovation and Invention Competition Through Exhibition 2017 (iCompex'17)

II. BRONZE MEDAL award for innovation product on Unsanded Empty Fruit Bunch Cement Boards (EFB-CB) in FKAAS Innovation Festival 2017 (InnoFEST'17)

VITA

Nik Mohd Zaini Bin Nik Soh was born in Mac 2, 1982, in Jerteh, Terengganu. He went to Sekolah Menengah Teknik Besut, Terengganu, Malaysia, for his secondary school and pursued his degree at the University of Technology MARA, Shah Alam, Malaysia, and graduated with the B.Eng. (Hons) in Civil Engineering in 2007. Upon graduation, he worked as a Civil and Structure Designer Engineer in the consultant firm at Kuala Lumpur for three years. In December 2009, he joined Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia as an Instructor Engineer. He has almost 10 years' experience in lecturing for Building and Construction courses. He received the M.Sc. degree in Civil Engineering from Universiti Tun Hussein Onn Malaysia in 2012, and pursued doctoral in civil engineering at the Universiti Tun Hussein Onn Malaysia in year 2015. His current research interest includes major discipline of construction and building materials and green building. The innovation field of his interest are the utilization of natural waste fibre as part of building components such as natural fibre cement boards, fibreboards and insulator boards from natural fibre. Mr. Nik Mohd Zaini is graduate member of the Board of Engineer Malaysia and member of Concrete Society of Malaysia.