CEMENT BOARD FILLED WITH AGED OIL PALM TRUNK STRANDS: EFFECT OF BOARD DENSITIES AND STRAND SIZES

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Abstract

Abstract: Wood cement board (WCB) combines organic and inorganic material; wood and cement. The inclusion of wood fiber into cement allows reduction of weight for finished product and adds an amount of carbon capture character in the WCB. In this study, the WCB combined aged oil palm strands (organic) obtained from the trunk and Portland cement (inorganic). The experiments aimed to determine the physical (thickness swelling and water absorption) and mechanical (bending strength and screw withdrawal) properties of WBC at 3 densities; 1300 kg/m^3, 1100 kg/m^3 and 900 kg/m^3. Two particle sizes of 30 mm and 50mm of the oil palm trunk strands were utilized. The result showed that generally, WBC with density of 1300kg/m^3 has higher mechanical properties and better dimensional stability. The highest bending strength was presented by WCB with 1300kg/m3 density with 50mm strands size, displaying modulus of elasticity 1315.6 MPa and modulus of rupture 4.6 MPa. Therefore, it is possible to use aged oil palm strand in WCB.

Keyword: Cement board, densities, mechanical properties, physical properties, strand size

Introduction

Timber is conventionally acknowledged for its existence to be the material in aesthetic items, shelters, weapons and furniture production. Apart from being used as solid wood, by product of timber processing can also be converted to particle, chips or flakes. These forms can be composed to produce composite panel which includes particleboard, hardboard, wood plastic composite, medium density fiberboard, oriented strand board and wood cement board (WCB). Manufacturing of wood composite panel normally requires the use of different binder types for specific product properties and characters. In general, wood composite is produced by following a certain process. The first step is to mix particles or fibers with resin and other additives, followed by the panel consolidation and curing the composite under pressure and heat. Later, the steps are continued by finishing the sanding and sawing it to specific or desired dimensions.

Reduction of wood supply, directly influence the resources needs of composite producer who relies on wood off-cut. Different alternative wood species or source materials such as lignocellulosic waste are needed as substitute. Globally, a lot of efforts were contributed to search for raw material that can become eco-friendly, including the use of recycle paper, sawdust, and particles. The motif of using eco-friendly material is to save the world resources as well as aiming for zero waste. Oil palm trees are capable in supplying lignocellulosic material derived from oil palm trunks (OPT), oil palm fronds, empty fruit bunches, palm pressed fiber palm, palm shells and palm oil mill effluent palm (POME) (Norfadhilah et al., 2019; Onaja et al., 2019).

The first oil palm plantation was established in Malaysia in 1917, and currently oil palm flourished in Malaysia with more than 4 million hectares coverage. The oil palm plantation can be easily found in every state within Malaysia (Awalludin et al., 2015). Oil palm tree is felled after 15-20 years rotation, when the tree is no longer producing fruits at economically commercial level. It is estimated that in year 2015 to 2026, 4 to 9 million trunks are available as oil palm tree reached its end-cycle and replanting exercised need to be done (Anis et al., 2014). Utilization of OPT can be one of the assisting factors in upgrading to more types of composite panel product, thus adding a new source of material for wood base industry. Additionally, low-cost product may be produced by using of oil palm strands obtain from felled oil palm trunk because the oil palm trunks would otherwise be left unused in the field.

Malaysia Standard 934 (1986) has defined wood cement board (WCB) as product made from wood fiber material or source, mixed with Portland cement. This can be in the form of chips or flakes from any wood source. Other than that, a few chemical additives are added and board is cured under pressure, at room temperature condition. Using WCB can save natural resource and decrease the waste of wood resource. Wood cement board has good durability, high structural strength, fungal decay resistant, rot resistant, fire resistant and low deterioration. (Amiandamhen & Osadolor 2020; Soares et al., 2007). These characteristics enables WCB usage as permanent shuttering of concrete walls, pillar, floor and frameworks (Mohammad et al., 2014; Matthew 2008). Besides, this composite is easy to be nailed, painted and coated, and exhibits excellent screw holding capacity

There is a wide range of products successfully made of WCB from other species of timber such as cement bonded composite with Populus alba strands (Papadopoulos et al., 2006), poplar strand (Ashori, Tabarsa, & Sepahvand, 2012), rubber wood (Rahim et al. 1989), Macaranga gigantea and neolamarckia cadamba (Noor Azrieda et al., 2012), arhar stalks and wheat straw (Karade 2010; Soroushian et al., 2004), coconut coir (Asasutjarit et al., 2007), rice straw, coir, hazelnut shell, oil palm residues, cork granules, bark and bagasse (Karade, 2010). However, the attempt of using oil palm trunk strands as WCB (Elaeis guineensis) surprisingly has not been widely reported. Thus, this study aims to determine the physical and mechanical properties of the cement board using oil palm strand with different densities and sizes.

Materials and Methods

The oil palm trunk strands (OPTS) utilized in this study was obtained from felled OPT from FELDA Ulu Jempul, Maran, Pahang. The trunk was debarked, chipped, air and oven dried (80%). The OPTS were prepared and kept in polypropylene bags for over two years unscreened. The aged strands were then screened to the size of 30mm and 50mm and re-dried. The Portland cement and cement additive (aluminum sulphate (1.5%) and sodium silicate (3%)) used are from commercially available sources. A completely randomized 2 by 3 factorial experimental design was adopted. The parameters tested were: particle size of 50mm and 30mm and density range of 1300 kg/m^3, 1100kg/m^3 and 900 kg/m^3. The flow of cement board production can be seen in **Figure 1**.

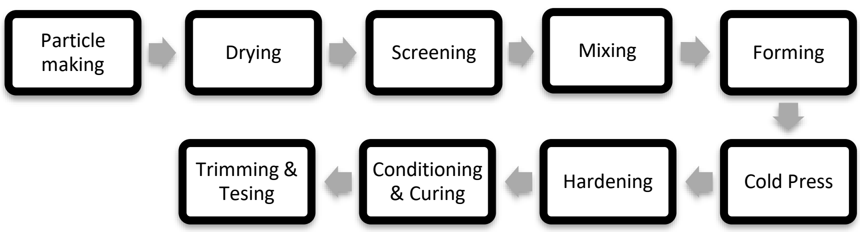


Figure 1 The process flow chart of wood cement board manufacture

The moisture content of OPTS was kept at $\leq 15\%$ for uniformity of board production. Cement mixer was used to blend weighted OPTS, cement, additives and water. The strands were placed into a cement mixer first, followed by aluminum sulphate, sodium silicate and water. The mixture was allowed to blend prior to addition of cement. Time taken to blend the material was between 10 to 15 minutes. After the blending process completed, the mixed material was poured uniformly into a mold measuring 450mm x 450mm. The mold was initially placed on a plastic lined caul plate (prevent WBC sticking). Poured mixture was compacted with cold press of 150psi to reduce the mat to desired thickness and increase contact between the particles. The compacted WBC mat was transferred to the conditioning chamber in which the cement and hardener was bonded with particles under temperature of $35 \pm 3°C$ at high humidity. This conditioning process was done for 24 hour. It was carried out to improve the strength of the bonds between the cement and mixed particle. The WCB was then placed in the cement conditioning chamber for another 28 days for curing process. In this chamber, the evaporation process of WCB was controlled.

The resulting WBC was trimmed and cut into test specimens based on MS943:1986. The WCB was tested for bending strength, screw withdrawal (SW), thickness swelling (TS) and water absorption (WA). The bending test specimen dimension was 175mm x 100mm x 12mm, with span length 150mm and load rate 6mm/min. The SW test specimen dimension was 75mm x 75mm x 12mm and pilot hole was drilled on specimen surface. Both bending and SW were tested using an Instron Test Machine. Physical properties of the sample size was 50mm x 50mm x 12mm. This process was conducted within 24-hour duration.

Test data were analyzed by using Statistical Social Science (SPSS) package. Analysis of variance (ANOVA) was carried out to determine the effects of variable studied.

Result and Discussion

By appearance, the 30mm strands basically produced smoother and more uniformed surface WCB. Voids are more apparent with the 50mm strands because packing is harder for the longer strands as spring back occurs. The mean values for physical and mechanical testing of OPTS WCB are summarized in **Table 1**. The analysis of variance for density and size influence are presented in **Table 2**. The relations were measured in terms of Modulus of Rupture (MOR), Modulus of Elasticity (MOE), and SW was determined for mechanical properties, while physical properties were measured via TS and WA.

Table 1 Physical and Mechanical Properties of Wood Cement Board

Density, kg/m^3	**Size, mm**	**MOE, MPa**	**MOR, MPa**	**SW, N**	**TS %**	**WA %**
1300	50	2105 $\pm$ 683	7.37 $\pm$ 2.44	451 $\pm$ 195	0.77 $\pm$ 0.57	14.3 $\pm$ 5.2
	30	1955 $\pm$ 293	5.81 $\pm$ 1.45	213 $\pm$ 55	1.03 $\pm$ 0.57	10.8 $\pm$ 2.1
1100	50	1985 $\pm$ 624	5.01 $\pm$ 0.79	173 $\pm$ 34	2.05 $\pm$ 3.02	19.1 $\pm$ 3.3
	30	1285 $\pm$ 137	5.36 $\pm$ 0.33	225 $\pm$ 45	0.95 $\pm$ 0.50	14.4 $\pm$ 3.5
900	50	1667 $\pm$ 416	5.30 $\pm$ 1.00	175 $\pm$ 43	1.69 $\pm$ 1.12	11.1 $\pm$ 4.1
	30	1642 $\pm$ 549	5.18 $\pm$ 0.94	216 $\pm$ 42	12.37 $\pm$ 6.75	14.8 $\pm$ 9.6
MS934 (1984)		3000	9	400	2	-

Table 2 ANNOVA of Physical and Mechanical Properties of Wood Cement Board

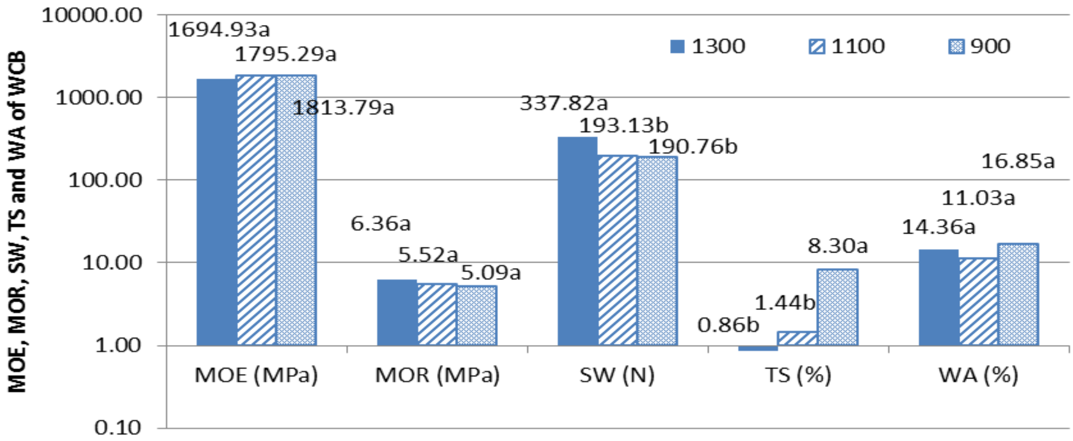
	MOE	**MOR**	**SW**	**TS**	**WA**

Density	0.184	2.109	7.346^{s}	21.784**	2.410
Size	6.599^{ns}	2.197	4.725^{s}	18.416**	0.168**
Density*Size	0.858	1.538	4.457*	14.639**	0.188

Note : ** p≤0.01 highly significant, * P ≤0.05 significant, ns – not significant

Effects of density

Figure 2 shows the effects of densities on WBC properties. The MOE variation is not significant. Modulus of rupture and SW value observed is proportional to the density**.** As density decreases, the MOR and SW decreases. This is expected as there is less material to be bonded thus making it more brittle. The TS reflects the porosity reduction as density increases. The reduction in TS is also associated with the degree of coverage of the strands used when closer contact of strand and cement is promoted by the higher density. However, the water absorption over 24hr showed unstable results.

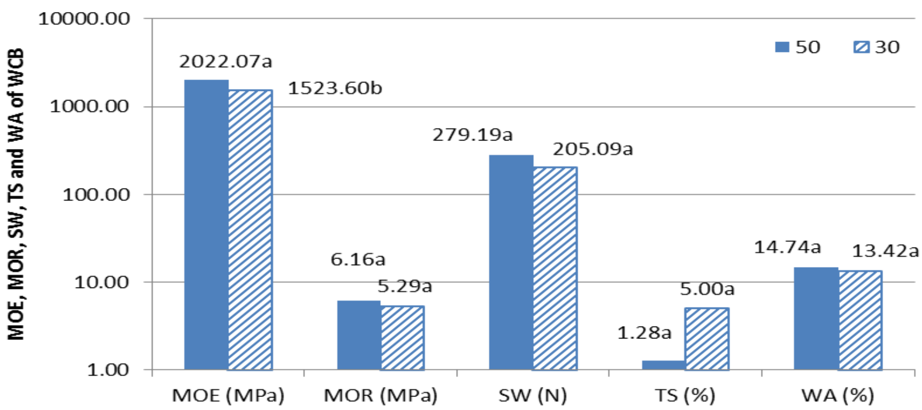


Note: For different alphabets, value significant at p<0.05

Figure 2 Effects of Densities of Wood Cement Board: Comparison of Mechanical and Physical Properties

Effects of strand size

The impact of 50 mm strands size is shown to be significantly different for MOE (**Figure 3**). Longer strands encourage interlocking and tangling of strands which promote better flexibility to the WCB. The MOR and SW are higher for 50mm size, where the improvement of MOR and SW are 16% and 36% respectively. Here, the impact of strand interactions is seen again. Despite of the large differences in MOR and SW values, they are still not significant at p<0.05. Variation in the standard deviation as seen in **Table 1** could also explain the non-significant outcome statistically for TS (74% reduction) when using strands of size 50mm versus 30mm. Water absorption has given insignificant difference at p<0.05.

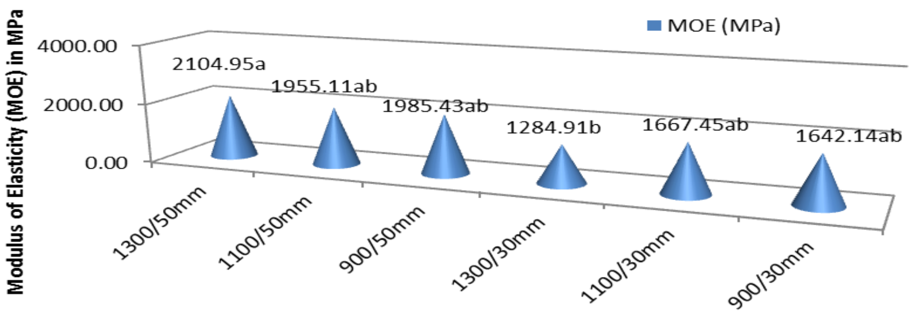


Note: For different alphabets, value significant at p≤0.05

Figure 3 Effects of Wood Strand Size on Wood Cement Board: Comparison of Mechanical and Physical Properties

Effects of density and strand size combinations

The six combinations were separately compared and analyzed. **Figure 4** shows wood cement board with density of 1300kg/m^3 and the strand size 50mm has the highest value of 2104.95 MPa. As density decreases, the MOE decreases proportionally for strands at 50mm. This is expected as there is less material to be bonded, leading to weaker MOE. However, the values for 1300kg/m^3 by ANNOVA remain similar and are not significantly different from 1100kg/m^3 and 900kg/m^3 density of WCB. For 30mm fiber, the 1100 and 900kg/m^3 density have almost the same MOE. In fact, the ANOVA has shown no significant difference within any of the densities. Only 1300kg/m^3 with 50mm combination and 900kg/m^3 with 30mm show significant difference at p≤0.05.

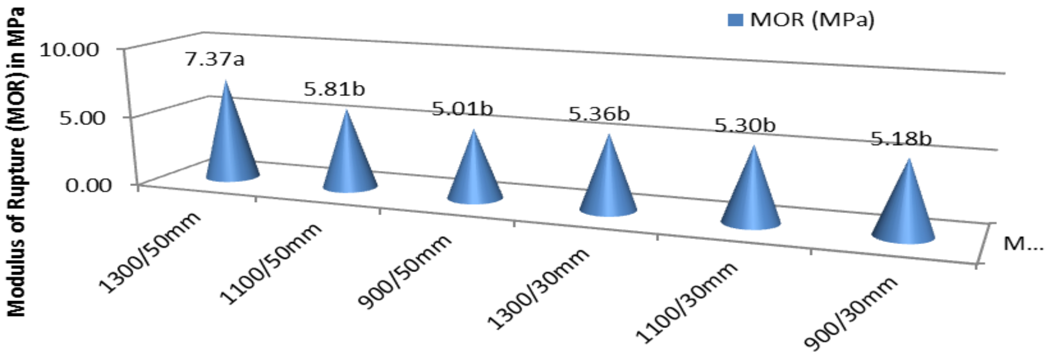


Note: For different alphabets, value significant at p≤0.05

Figure 4 Effects of Combinations on Wood Cement Board on Modulus of Elasticity

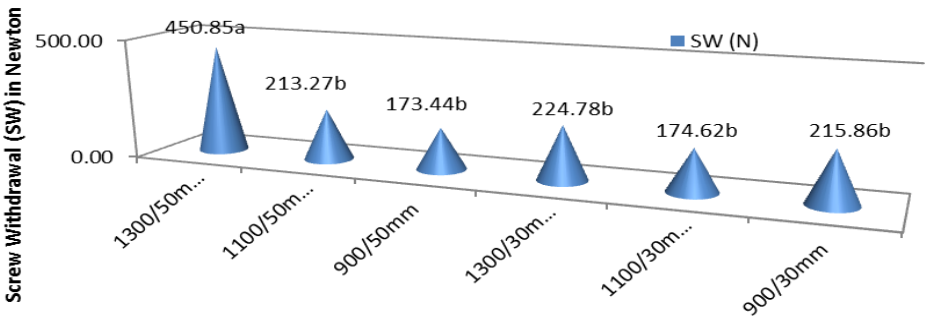
As illustrated in **Figure 5**, density of 1300kg/m^3 and the size 50mm exhibits the highest MOR. With the rise in density interface for contact increase, the strength of board increases as well. The strength value showed a decreasing trend for density of 1100kg/m^3 to 900kg/m^3. This is true because the material become less with lower density and leads to less contact which is required for good bonding. Furthermore, MOR is affected by space compaction. The interaction of cement and 30mm strands is equally good at all different densities. Individual combination observations indicate that higher density gives higher MOR for both 50mm and 30mm strands. However, strand size of 30mm does not show the same trend as

50mm strands. The MOR reading is almost the same for all densities. The advantage of similarity in MOR behavior with lower density would be the potential to form lower density bricks. Both 30mm and 50mm boards are not significant different at P ≤ 0.05.



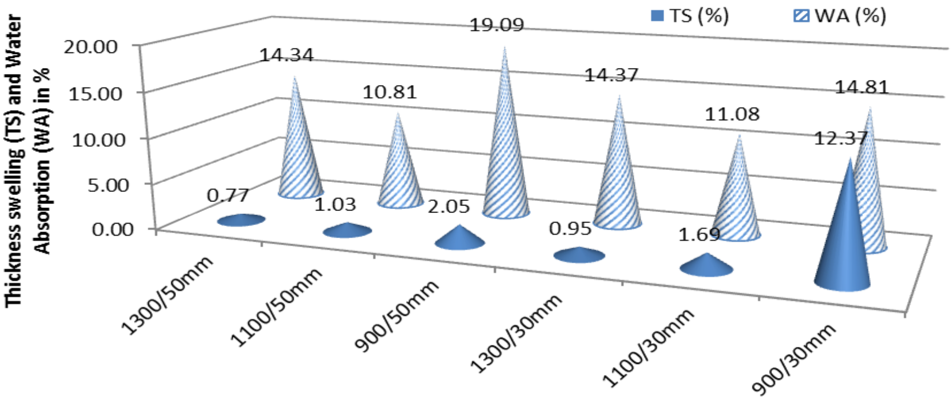
Note: For different alphabets, value significant at p≤0.05
Figure 5 Effects of Combinations on Wood Cement Board on Modulus of Rupture

The SW test is performed in searching for suitability of fastener on WCB. **Figure 6** displays the behavior of SW on the WCB. The density of 1300kg/m^3 and 50mm strands gives the best screw withdrawal of 451 N. This result hinges on the compact nature of cement to strand binding. Higher density can easily hold the screw, coupled with the strands tangling, thus resulting in high strength. The reductions in SW for 50mm strand are 52% and 68% for 1100kg/m^3 and 900kg/m^3 respectively. The low value explains that the fastener can be easily dislodged upon usage. This large drop shows the loose nature of the 50mm strand packing as the density lowered. Nevertheless, despite 50mm strand WCB has lot of voids, the SW overall strength is higher as compared 30mm strand. The thread on the screw may have contributed as a role to anchor the screw onto WCB. The impact of low density is not really declared in the 30mm strands WCB.



Note: For different alphabets, value significant at p≤0.05
Figure 6 Effects of Combinations on Wood Cement Board on Screw Withdrawal

The trending of TS and WA shows reciprocal behavior (**Figure 7**). TS of all WBC except for 900kg/m^3 density board with size 30mm, have shown value below 1.6%. This is normal for WCB as cement helps to reduce expansion if it has proper coverage on strands. The 900kg/m^3 with 30mm strands WBC has produced the highest TS. Its value is the only one that is significantly different from other combinations. A higher value for 30mm strand WCB is expected as more exposed surface area of strands occurs when the amount of cement available for bonding is lower due to smaller sized strand has higher surface area volume ratio. This will expose the wood strands, which are hydroscopic and can attract water. The surface area volume ratio effect is more prominent as the WCB density is reduced. This will cause to more voids which would allow capillary action to occur. Capillary action allows easier movement of water in the cement composite. The water absorption can cause the wood component in composite to bulk, thus resulting in higher TS.



Note: For different alphabets, value significant at $p \leq 0.05$

Figure 7 Effects of Combinations on Wood Cement Board on Thickness Swelling and Water Absorption

Conclusion

Based on the analysis of different combinations, the result has revealed that mechanical properties of WCB for the modulus of elasticity (MOE), modulus of rupture (MOR), and screw withdrawal (SW) is significantly different only for 1300kg/m3 density and size 50mm as compared to others. Significant difference is seen in SW and TS for the impact of density. When the size of strands effects is compared, only the MOE values showed significant difference. The best performance in mechanical strength is for 1300kg/m3 density along with 50mm strand size with MOE 2105 MPa, MOR 7.37 MPa and SW 450N. There is a prospective in producing WCB by using oil palm strands even after 2 years of storage. Low density of 900kg/m3 WCB has the capacity to be a low cost with high strength good product. Different formulation and addition of different chemical additives are potential for further study.

Conflict of interests

The authors declare no conflicts of interest in this research.

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