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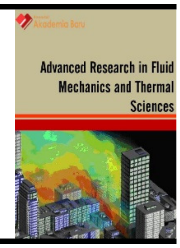

Effect of Hot Pressing Temperature and Varying Veneer Density on the Properties of Oil Palm Sandwich Board

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ABSTRACT

Abundance of oil palm trunks (OPT) can be obtained from the replanting activities that can be converted into value-added products. One of the sectors that can beneficial from this is bio-composite. Low-density sandwich board (SB) consisting of a core-board (CB) overlaid with an oil palm veneer face was produced and studied in this paper. Effect of different hot-pressing temperatures on the production of CB and layering the face and back with varying veneer density on the properties of the SB were investigated. Results showed that the use of a hot-pressing temperature of 160 ^{o}C is optimum for the production of CB. The thickness swelling (TS) and internal bond (IB) values meets the minimum standard requirement when the temperature used is at 160 ^{o}C. The CB layered with oil palm veneers (density of more than 300 kg m^{-3}) tended to improve the product quality of SB. Results show that modulus of elasticity (MOE), modulus of rupture (MOR), and IB increased by 17%, 10%, and 14% respectively. While TS was reduced about 11 %, this is due to the use of high-density veneer (300-400 kg/m^3) at the top and bottom of the CB surfaces which will prevent the absorption of water. In conclusion, the SB can be manufactured from OPT using the optimum parameters such as 12% resin content, board density 700 kgm^{-3}, particle size of more than 2 mm, hot-pressing temperature of 160 ^{o}C and high-density veneer that is more than 300 kgm^{-3}.

Keywords:
Sandwich panel-board, oil palm veneers, hot-press temperature

1. Introduction

Malaysia is the second largest producer of palm oil with 5.74 hectares of plantations [1]. Each year, an enormous amount of felled oil palm trunk (OPT) is available during the replanting activity and can be the renewable and permanent feedstock for the timber industry as reported by Khalil *et al.*, [2]. While Anis *et al.*, [3] estimated that the availability of OPT was around 13.6 million logs annually based on the replanting of 100,000 ha.

OPT is comprised of primary vascular bundles (VB) embedded in soft parenchymatous tissues. A thorough study by Lim and Khoo [4] and Sulaiman *et al.*, [5], has found that the numbers of VB

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gradually decreases from the peripheral region to the centre of the cross-section and increases from the butt end to the top of the OPT. This property will directly relate to palm wood density due to the distribution of the number and thickening of the VB varies in both radially and vertically. In addition, the author showed that the physical and mechanical property values also vary due to the variation in density which is as high as 575 kg/m^3 at the peripheral region at the bottom of the OPT to 190 kg/m^3 at the centre of the cross-section of OPT.

Therefore, to increase the value of the OPT, it can be utilized as an alternative raw material for the production of value-added products such as composite boards, fine chemicals, carbon products, pulp and paper and also animal feed. Even though OPT has a few weaknesses such as low in strength, in-consistent dimensional stability, low durability and machining properties [3], it still can be utilized as a raw material for producing value-added products. Oil palm biomass such as OPT, oil palm frond (OPF) and empty fruit bunches (EFB) contains lignocellulosic components which are suitable for producing value-added composite panels [6,7].

The conversion of oil palm biomass into composites for the non-structural applications has been studied by many researchers [2,8,9]. OPT is also being used for a wide range of products such as lumber, plywood, medium density fiberboard, particleboard and polymer composites. Studies by Anis *et al*., [3] has successfully developed technology for producing oil palm veneer and plywood. Furthermore, the OPT plywood was successfully commercialized, in which, the oil palm veneer was found suitable to be used as the core layer to be integrated with the face and back layers of tropical hardwood veneer [10].

For non-structural applications, MPOB [11] continuous to look into the possibilities of using OPT as furniture from particleboard. Particleboard is defined as a panel product manufactured under pressure and heat, from wood or lignocellulosic particles which was blended with adhesive. Structural components called sandwich board made up of a lightweight core overlaid with two stiff, strong faces also can be manufactured [12,13].

Approximately 30% of the outer part of OPT could be utilized as a lumber material, while the remaining 70% is considered as waste [14]. Based on the higher amount of waste, it shows that OPT has good potential as an alternative raw material for the production of core-board or particleboard [15]. Nevertheless, studies by Thanate *et al*., [16], has found that OPT has not yet been used effectively in particleboard manufacturing as compared with rubberwood [17]. The studies by Junidah *et al*., [18] also found that the natural sugars and other water soluble within the lignocellulosic material are also chemically transformed through the hydrolysis of hemicelluloses and softening of lignin which the sugars will act as a bonding agents and strengthen the board. The hydrolysis was performed when applying heat during the process.

According to Paridah *et al.,* [19], the polymerization rate of resin depends on the material used, influence of the temperature and duration for the particleboard manufacturing. Furthermore, Wang [20] and Apri *et al*., [21] also reported that the temperature and duration of pressing could be adjusted either increasing pressing duration at a constant temperature or increasing temperature at a constant pressing duration. A comparison study on the production of particleboard from OPT with and without resin in different thickness has been carried out by Mohana *et al*., [22].

Based on previous investigations, on low density and variation of density along the OPT, this study was conducted to manufacture a core board (CB) and layered with different veneer density with the effect of hot-pressing temperature to produce the board with the minimum standard quality requirement. Therefore, the main aim of this research is to evaluate the suitability of OPT as a material to produce sandwich board (SB). The influence of hot-pressing temperature and varying veneer density on the physical and mechanical properties of the SB were also evaluated.

2. Methodology

2.1 Raw Material Preparation

Oil palm trees were obtained from the replanting area at Sungai Kahang Estate which is located in Kluang, Johor. In order to produce a good quality veneer, the selection of the logs is very important. The log was selected based on the straightness and the uniformity of the top and bottom diameter. In general, the length of oil palm bole is about 5.5 to 6.0 m with an average diameter of 39 cm. The volume of oil palm bole of 6 m long is approximately 0.71 cm^3.

2.2 Preparation of OPT Particle

In this study, the fresh OPT from the bottom and top portion were used for the preparation of the chips. The OPT were sawed using a band saw to remove the outer layers (bark). The portion without bark was further sawed into lumber with dimensions of 15 cm (H) x 30 cm (W) x 64 cm (L). The lumber was then fed into the chipper to crush into chips. The chips were then dried in the kiln dryer until the moisture content is less than 10% before proceeding into the hammer mill. The particles obtained were screened using a vibrator screen to get the particle size of more than 2 mm.

2.3 Preparation of Core-Board

In this study, particles used were obtained from the bottom portion of the OPT. The particle sizes used was more than 2 mm and the targeted density of 700 kg m^{-3} were fabricated. The particles were bonded with urea-formaldehyde (UF) resin which was available from Dongwha Fiberboard, Nilai. The resin content used in this study was 12% with 1% wax and was blended in drum type glue blender. After spraying, the particles with resin were then manually laid in a wooden mould over a caul plate with a dimension of 300 mm X 300 mm. The mat will be pre-pressed at a pressure of 3.5 Mpa for 30 seconds to initiate bonding and avoid disintegration of particles.

Subsequently, the mat was pressed in a single opening hydraulic hot press at a platen temperature between 140^{0}C to 180^{0}C for 6 minutes. The silicone release agent was spray on to the caul plate to avoid boards from sticking. The stoppers from the steel bars of 12 mm thickness will be placed on both sides of the assembled mat to control the board thickness. After hot pressing, the board will be left to cool down before trimming to the required size. All the boards will be condition for a week at 20^{o}C and 65% relative humidity (RH) before being tested using British Standard [23].

2.4 Preparation of Sandwich Board

In this study, the sandwich board (SB) was prepared using the CB as a center core and layered with dry veneer at the bottom and top of the surfaces (Figure 1). The CB was prepared using particles from the bottom portion of the OPT. The dry veneer for layering the top and the bottom of the CB will be selected from the three different density ranges from 200 to 300 kg/m^3, 300 to 400 kg/m^3 and > 400 kg/m^3. UF resin was evenly distributed onto the top and bottom veneers.

The resonated oil palm veneers were laid onto the CB, followed by cold pressing for 5 minutes. This would allow even distribution of resin onto the surface of the CB. Two pieces of 12 mm thick steel bar stoppers will be placed on both sides of the assembled board to control the final thickness of the board during pressing. The assembled board will be pressed at 160 ˚C for 6 minutes. The boards produced will be stabilized to equilibrium conditions at the temperature 20 ± 2 ˚C and 65 ± 5 % of relative humidity for a week before testing using British Standard [24].

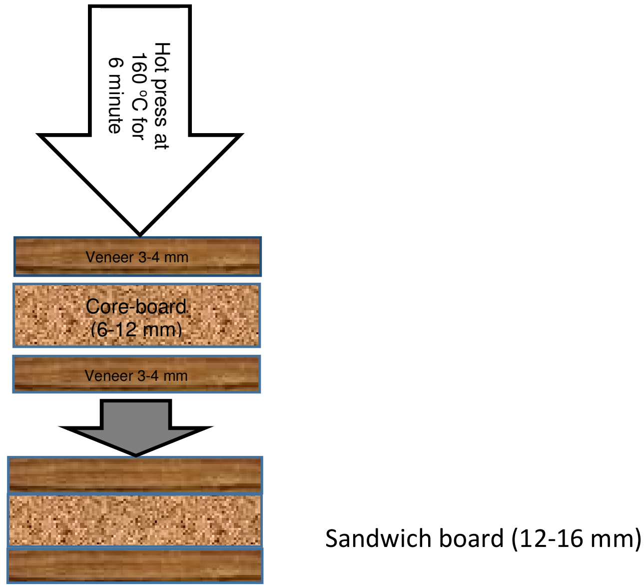

Fig. 1. Process flow for the production of sandwich board

2.5 Determination of Physical Properties of CB

2.5.1 Thickness swelling

Thickness swelling test is carried out to determine the total amount of water a material takes up from immersion. The test pieces measured 50mm x 50mm x 12mm in size were used for this test. The thicknesses of the piece were measured by a digital calliper. The swelling in thickness was then calculated by using the formula below [25].

$$\text{Thickness swelling (\%)} = \frac{(t_2 - t_1)}{t_1} \times 100 \qquad (1)$$

where,
t_1: thickness (mm) before water absorption
t_2: thickness (mm) after water absorption

2.5.2 Moisture content

Moisture content (MC) was determined in accordance with [25] procedures. The veneer samples were stored in a plastic bag. This was carried out in order to ensure its MC will remain unchanged during storage. Test samples were weighed individually to the nearest 0.01 g to obtain the green weight. After weighing, the samples were dried in an electric oven (Memmert, UFE 600) at 103 ± 2 ˚C until constant dry weight to be nearest 0.01 g is obtained. The samples were further weighed at hourly intervals until no weight loss was detectable. The MC was calculated as follows.

$$MC_{od} (\%) = \frac{W_g - W_{od}}{W_{od}} \times 100 \qquad (2)$$

where,
MC_{od}: MC on an oven-dry basis in percentage
W_g: weight of the sample before drying (in grams)
W_{od}: weight of the sample after drying (in grams)

In this study, MC is expressed as a percentage of the oven-dry weight rather than as a percentage of original weight.

2.6 Determination of Mechanical Properties
2.6.1 Modulus of rupture and modulus of elasticity

Prior to testing, the sample board was conditioned in an ambient condition of 20 ± 3 °C and relative humidity of 65 ± 3% for 7 days in order to release the drying stresses with uniform MC throughout the sample board. Strength and thickness in bending are generally expressed as modulus of rupture (MOR) and modulus of elasticity (MOE). These properties were determined by three-point bending in accordance with [27].

Testing was performed in an ambient condition at 20 ± 3 °C and relative humidity of 65 ± 3% using Zwick Testing Machine (Model NNM 356). The surface of the test sample was perpendicular to the direction of loading. The loading head was moved at a speed of 5 mm min^{-1} on the centre of a test span of 280 mm. The MOR and MOE were calculated using the following equations.

$$\text{MOR (Mpa)} = \frac{3P_{max} \times L}{2b \times h^2} \tag{3}$$

$$\text{MOR (Mpa)} = \frac{P \times L^3}{4\Delta \times b \times h^3} \tag{4}$$

where,
P: Bending load at proportional limit (N)
P_{max}: Maximum bending load (N)
b: Width or breadth of the test specimen (mm)
h: Thickness of the test specimen (mm)
Δ: deflection measurement at proportional limit
L: Span length (mm)

2.6.2 Internal bond test

The internal bond (IB) test was done using Zwick Testing Machine (Model NNM 356). Metal blocks were glued to the surface of the test samples. The force or load perpendicular to the plane was applied until failure occurred. The IB strength perpendicular to the plane of the pieces was calculated using the following equation [27].

$$\text{IB } (Nmm^{-2}) = \frac{P'}{b \text{ X } L} \tag{5}$$

where,
P’: maximum load (N) at the time of failing force
b: width (mm) of test piece
L: length (mm) of test piece

2.6.3 Statistical analysis

Calculations were performed using Microsoft Office Excel 2007 and SAS 9.4 for Windows. Statistical comparisons between means of mechanical properties from different pressing temperatures were conducted using an analysis of variance (ANOVA). Tukey's Honest Significant Different (HSD) was used to conduct a post-hoc test to compare them further.

3. Results and Discussion

3.1 Physical Properties of Oil Palm Veneer

3.1.1 Moisture content

One of the drawbacks of using oil palm stems as a source of veneers is the high variation in density and moisture found in the stems. Figure 2 illustrates the MC distribution in the core towards periphery zone for a different portion of the peeler log. The curves indicate the changes in MC value for veneer samples from the bottom, middle and top portion of OPT.

Results showed that veneers obtained from the inner portions of the logs have higher MC than veneers obtained from the outer portions of the logs. In general, veneers near the peeler core from the top portion of peeler log have higher moisture than veneers from the middle and bottom portion. The veneers obtained from the bottom portions had MCs ranging from 50.5% to 270.3% while the veneers obtained from the top portion had MCs ranging from 50.5% to 370.4%.

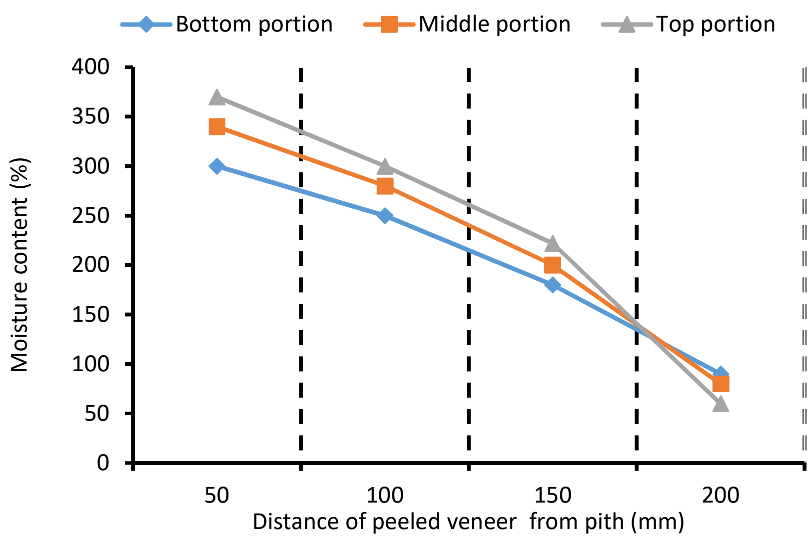

Fig. 2. Distribution of moisture content in the veneer from the core to the periphery zone of the oil palm peeler log

Veneers obtained from the bottom inner layers of the logs had 70% more moisture than veneers obtained from the bottom outer layers while veneers from the top inner layers of the logs had 78% more moisture than veneers obtained from the top outer layers. This may be due to the presence of more parenchyma tissues compared to the outer zone [28]. Killmann and Lim [29] also observed that an initial MC of similar value (ranging from 100% to 500%), where the highest value is near the core and the lowest value is at the periphery.

3.1.2 Veneer density

Figure 3 shows the bulk density (BD) distribution of the veneers across the radial section (from outer to inner) of the oil palm trunk of both the bottom and top portion of the oil palm stem. All veneers tend to show a gradual decrease in BD values from the periphery towards the core. In general, veneers from the top portion seemed to have lower BD value than those veneers taken from the middle and bottom portion of the peeler log, particularly in the region of 120 mm radius from the core.

The density of veneers taken from the bottom outer portion of the palm stem was higher (400 kg/m^3) than that taken from the bottom inner portion (230 kg/m^3). Inner veneers had an average density of 223 kg/m^3 while outer veneers had an average density of 280 kg/m^3. The outer portion consistently shows higher density than the inner layers, irrespective of the height of the tree.

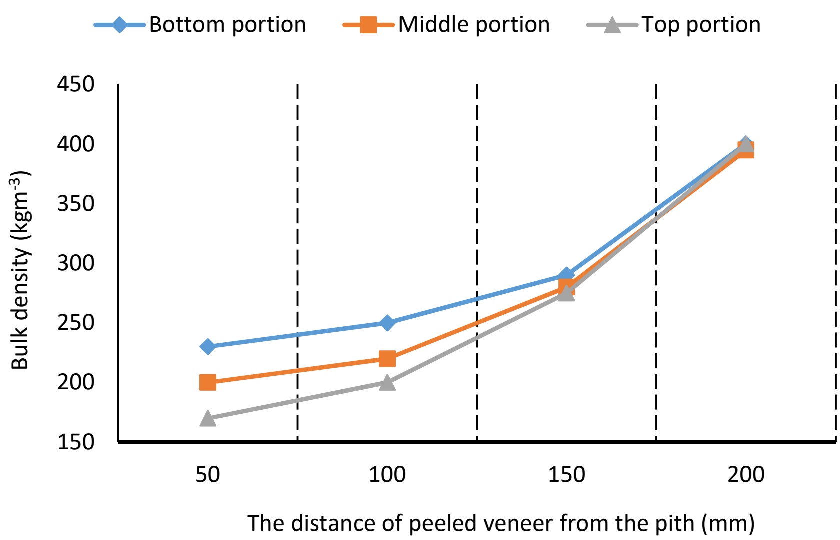

Fig. 3. Distribution of bulk density in the veneer from the core to the periphery zone of the oil palm peeler log

3.2 Effect of Hot Pressing Temperature on The Physical and Mechanical Properties of Core-Board

Hot pressing plays an important role in overall CB properties. It provides the thermal energy and mechanical force of compression to consolidate the mat [30].This process is complex and involves heat and mass transfer inside the mat of the boards [31]. Heat is transferred from the hot plate to the mat surfaces by conduction [32]. Then, the moisture at the mat surface vaporizes and generates vapour pressure with increasing temperature. The vapour flows vertically and transfers the heat from the surface to the centre of the mat panels. When the temperature of the mat centre reaches the boiling point of water (100 ^{o}C), water vaporization accelerates and the increased pressure makes the vapour flow horizontally to the edges of the mat panel boards. Several parameters affect hot pressing, such as press temperature, mat moisture content, press closing speed and resin characteristic [33]. According to Cai *et al.,* [34], these parameters affect the rate and degree of adhesive cure, the density gradient, bond quality and, consequently the physical and mechanical properties of the board. Additionally, these parameters influence energy consumption and manufacturing cost [30].

Particle type also determines mat structure and the temperature behaviour inside the mats during hot pressing. The porous structure of the mat panels is necessary to understand the heat and mass transfer inside the mat panels, as water vapour flows through the panels and influences the rate of vertical and horizontal mass transfer [30].

Five samples of CB are produced at temperature 140 °C, 150 °C, 160 °C, 170 °C and 180 °C. Meanwhile, during the CB manufacturing, the initial parameters, namely, resin content (12%), pressing time (6 minutes), board thickness (12mm) and particle size (more than 2mm) were kept constant.

Thickness swelling (TS) of CB with the variation of hot pressing temperature ranging from 140 °C to 180 °C are shown in Figure 4. As the temperature increases from 140 °C to 160 °C, the value of TS decreases from 25% to 15%, but when the temperature increases from 160 ˚C to 180 °C, the TS value slightly increases from 15% to 17%. It means that if we further increase the temperature up to 180 °C, the TS value will move in ascending order and the strength of PB will be reduced. The optimum and acceptable temperature range for CB is from 160 °C to 170 °C. TS value also depends upon the natures of the resin curing used as a binder and hot pressing time [35]. TS is also affected by the OPT material which is highly hygroscopic and can absorb higher moisture from the surroundings [36]. Use of low temperature and high temperature are strictly prohibited from manufacturing CB in the normal case of resin curing. Meanwhile, the standard minimum requirement value of TS for CB is less than 16%.

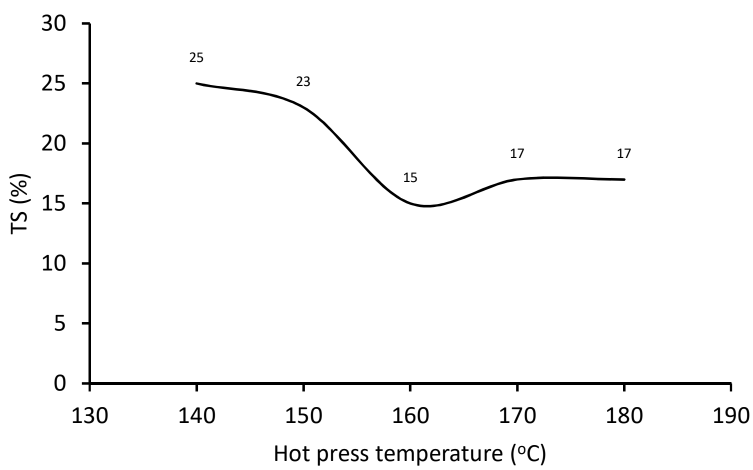

Fig. 4. Effect of hot-press temperature on swelling in the thickness of CB. [Resin content: 12%, board density, 700 kg/m^3, board thickness, 12 mm]

The value of internal bond (IB) is ranging from 0.6 Nmm^{-2} to 1.0 Nmm^{-2} of a temperature range from 140 °C to 180 °C as shown in Figure 5. The IB value at temperature (140 ˚C) is 0.3 Nmm^{-2}, while the value that meets the minimum standard requirement is more than 0.45 Nmm^{-2}. Hence, from 140 °C to 150 °C, the particleboard has a poor IB. But when the temperature increased from 160 °C to 180 °C, the IB value reaches a value of more than 0.45 Nmm^{-2}. This means that at 160 °C, the particleboard meets the value of the minimum standard requirement of 0.45 Nmm^{-2}. According to Nemli [37] increased pressing temperature, duration, pressure and adhesive ratio caused a significant improvement in board strength and IB. This may be due to the relationship with resin curing, the reduced wettability of the particle surface, the limitation of diffusion, and/or the spreading of the adhesive within the particles and over the particle surface [36].

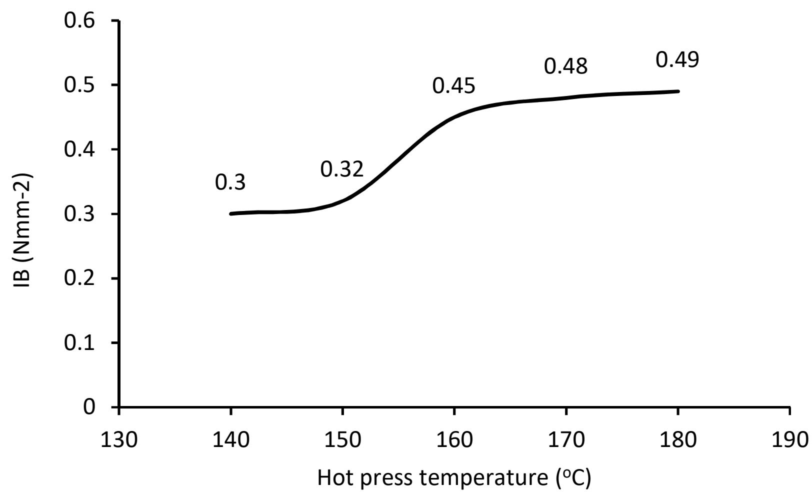

Fig. 5. Effect of hot-press temperature on an internal bond of CB [Resin content: 12%, board density, 700 kgm^{-3}, board thickness, 12 mm]

This phenomenon can be explained by two approaches firstly, the temperature will influence the adhesion ability of the resin to wood material. The pressing temperature will influence water flow in wood, which causes the diffusion of adhesive molecules into the voids of the wood. The low temperature used will cause low adhesive diffusion into the wood, and it will decrease the mechanical bonding strength. Secondly, the chemical bonding change at the surface of the material with the effect of temperature, e.g., the melting of lignin or the degradation of hydrogen bonds has an important role in bond strength.

Same trend was found by Valenzuela *et al.*, [38], where the IB value continuously increased with the increase in the hot-press temperature. At the maximum temperature of 180 ^{o}C, the IB value of 0.49 Nmm^{-2} was obtained. If we further increase the temperature, the surface may lead to a high-temperature difference and ultimately the CB may become brittle. The rate of temperature increase has a significant effect on the rate of adhesive cure. This is a critical factor not only for the total press duration but also in the development of the vertical density gradient [39]. Lin *et al.*, [40] noted that the combination of high temperature, moisture content occasionally leads to the excess gas pressure inside the mat and cause a blow upon press opening.

The modulus of elasticity (MOE) value of CB varied between 1551 Nmm^{-2} to 2335 Nmm^{-2} as shown in Figure 6. The minimum standard requirement for CB is more than 2300 Nmm^{-2}. It was found that increasing the pressing temperature to 160 ^{o}C increased the value of MOE. At a lower temperature (140 ^{o}C), results to a lower strength because the resin did not cure. Also, at a high temperature (more than 160 ^{o}C), the value of MOE decreased, resulting the resin to be over-cured. Both of those conditions will reduce the bonding strength in the adhesive bond. In this study, the board meets the minimum standard requirement (more than 2300 Nmm^{-2}) when the temperature of hot pressing was 160 ^{o}C.

The modulus of rupture (MOR) of the CB was also analyzed. The trend of the MOR curve was similar with that of the MOE curve. The value of MOR for the temperature from 140 ^{o}C to 180 ^{o}C are shown in Figure 7. Results showed that the MOR value had increased from the lower temperature (140 ^{o}C) to 160 ^{o}C but the value decreased with the increase of temperature. Saari *et al.*, [41] reported similar findings on the increased of MOR by increasing the hot-pressing temperature. Pressing at 160 ^{o}C resulted the MOR value in meeting the minimum standard requirement that is less than 17 Nmm^{-2}. Even at low temperature (140 ^{o}C), the MOR value still meets the minimum standard requirement.

However, with further temperature increase from 160 °C to 180 °C, the MOR behaves in a reverse manner. The result from Analysis of variance (ANOVA) shows that there is a significant effect of temperature on all mechanical properties of CB namely MOR, MOE and IB (Table 1).

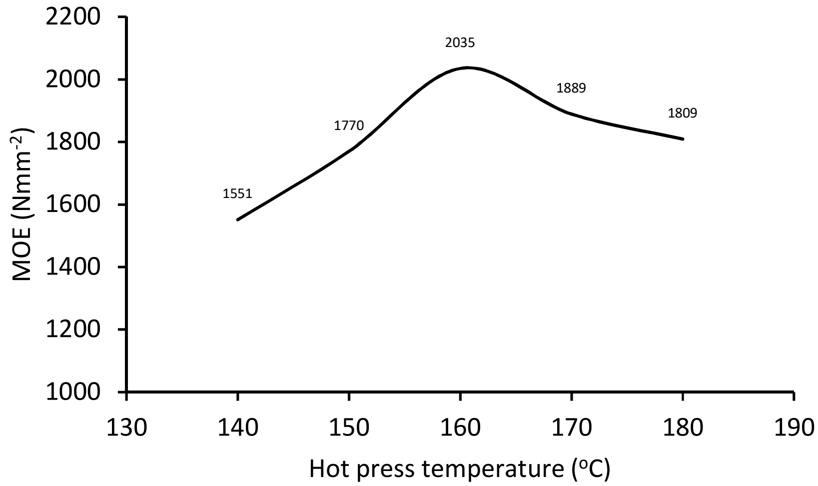

Fig. 6. Effect of hot-press temperature on the modulus of elasticity of CB [Resin content: 12%, board density, 700 kgm^{-3}, board thickness, 12 mm]

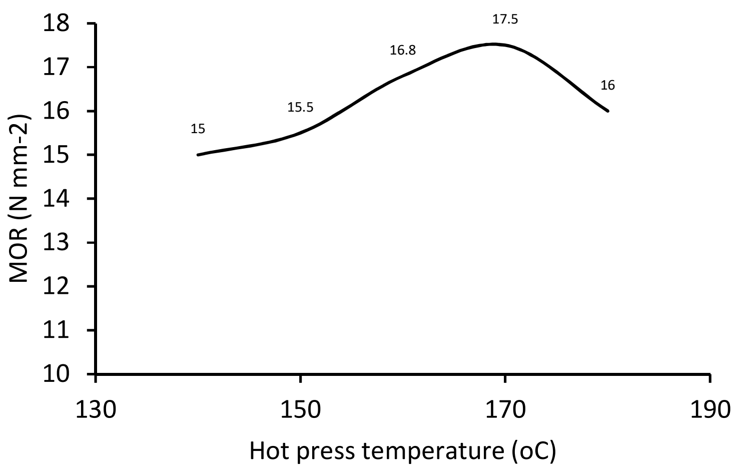

Fig. 7. Effect of hot-press temperature on the modulus of rupture of CB. [Resin content: 12%, board density, 700 kgm^{-3}, board thickness, 12 mm]

Table 1
ANOVA analysis of Mechanical properties of CB

Source	MOE		MOR		IB	
	F	Pr > F	F	Pr > F	F	Pr >F
Temperature	59.85	<.0001*	8.34	0.0004*	71.84	<.0001*

Note: *significant at α = 5%

Further analysis was conducted using Tukey's Honest Significant Different (HSD) at 5% significant level. The result suggested that 160°C is the optimum pressing temperature which produces significantly higher MOE as compared to the higher and lower pressing temperatures. At the higher pressing temperature (170 °C and 180 °C) the MOE reduced significantly. The same issue is observed at a lower pressing temperature (150 °C and 160 °C).

There is no significant effect on MOR at the pressing temperature of 150 °C, 160 °C, 170 °C, and 180 °C. The results also indicate that there is no significant differece of MOR at pressing temperatures 140 °C, 150 °C, and 180 °C, but has a significant difference between both pressing temperature groups. Therefore, the pressing temperature of 150 °C is preferable because it requires less energy to achieve the minimum standard requirement in the context of MOR. For IB, the optimum pressing temperature is at 160 °C, at lower temperature results to a weaker IB due to the uncured resin. Therefore, increasing the pressing temperature will not affect IB significantly (Table 2). Based on the analysis, it shows that 160 ˚C is the ideal temperature to be applied during the hot-pressing process in the production of CB.

Table 2
Tukey's HSD test for Mechanical properties of CB

Temperature	MOR	MOE	IB
140	13.54^{c}	1551.0^{b}	0.65^{c}
150	$14.4a^{b}$	1777.6^{ab}	0.726^{b}
160	16.07^{a}	2035.4^{a}	0.98^{a}
170	14.14^{b}	1889.4^{a}	1.01^{a}
180	13.38^{c}	1809.2^{ab}	1.02^{a}

Note: within the same column, means value by different letters is significantly different at P<0.05. MOR: Modulus of rupture, MOE: Modulus of elasticity, IB: Internal bonding.

3.3 Mechanical and Physical Properties of The Sandwich Board

For the production of SB, the parameters used were hot-press temperature 160 °C, at 6 minutes pressing time. The results on the mechanical and physical properties of the SB are shown in Figure 8 and 9. The SB prepared with veneer density ranges from 300 kg m^{-3} to more than 400 kg m^{-3} meets the minimum standard requirement. The MOR and IB had increased about 24% and 31% respectively when using high-density veneer (more than 40 kg m^{-3}). This shows that veneer with higher density is suitable for manufacturing SB.

It was found that, by applying the higher veneer density, the water absorption (WA) reduced about 3% and TS decreased about 1.1% (Figure 10). This is because the CB sandwiched with high density veneer will reduce the absorption of water in the PB at the centre. The properties of the CB sandwiched with veneer are shown in Table 3. The result shows that MOE, MOR and IB value for the CB has improved if it was layered with higher density veneer.

Table 3
Improvement of the physical and mechanical properties of CB layered with oil palm veneer

Samples	Modulus of elasticity (N mm^{-2})	Modulus of Rupture (N mm^{-2})	Internal bond (N mm^{-2})	Thickness swelling (%)
CB from OPT	2020	16.2	1.2	18
Sandwich board from OPT	2440	18.0	1.4	16

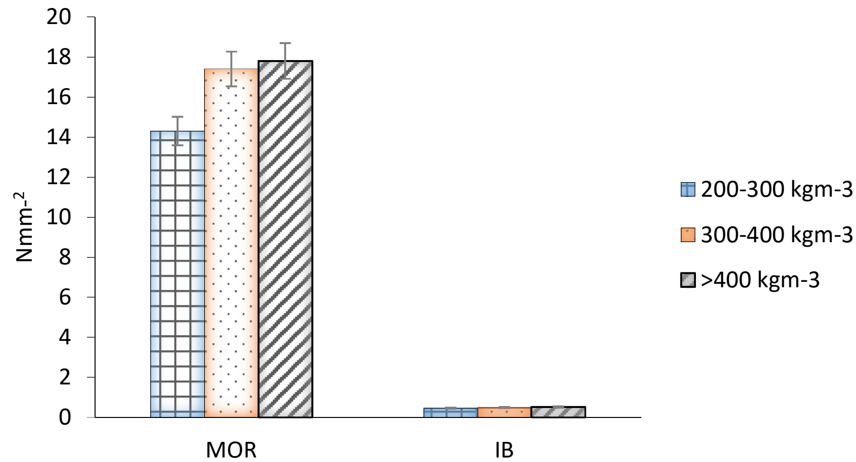

Fig. 8. Effect of veneer density on the MOR and IB of the SB. [MOR = modulus of rupture and IB= Internal bond]

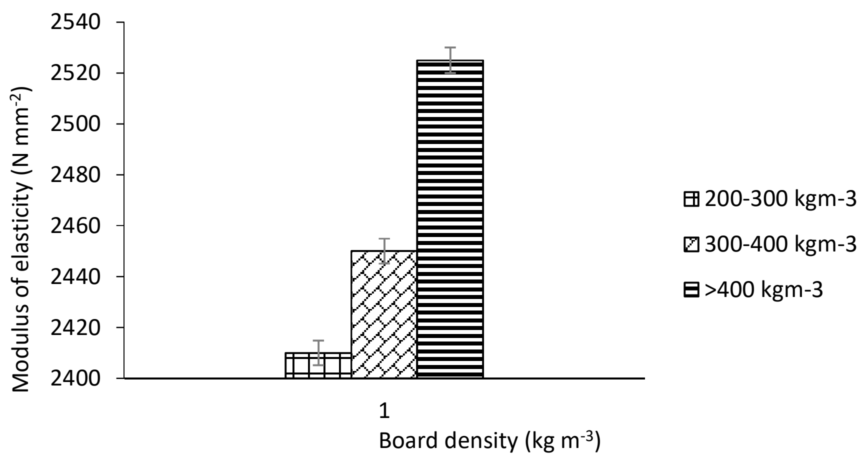

Fig. 9. Effect of veneer density on the MOE of the SB. [MOE=modulus of elasticity]

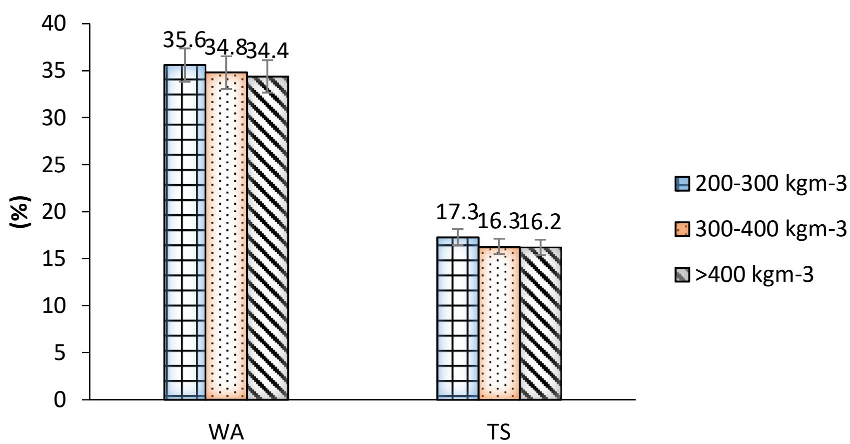

Fig. 10. Effect of veneer density on the WA and TS of the SB. [WA= water absorption & TS= thickness swelling]

Table 3
Improvement of the physical and mechanical properties of CB layered with oil palm veneer

Samples	MOE (N mm^{-2})	MOR (N mm^{-2})	IB (N mm^{-2})	TS (%)
CB from OPT	2020	16.2	1.2	18
Sandwich board from OPT	2440	18.0	1.4	16

Note: MOE= Modulus of elasticity, MOR= Modulus of Rupture. IB= Internal bond and TS=Thickness swelling

4. Conclusions

In this study, the CB can be manufactured from oil palm trunk. The effect of hot pressing temperature on the physical and mechanical properties of CB has been evaluated. In CB manufacturing, pressing temperature is one of the important factors that influence the board properties. The strength and TS of CB improved with the increase of hot pressing temperature from 140 ^{o}C to 160 ^{o}C; the MOR increased by 12%, the IB increased by 50%, the TS decreased by 40%. This is because, with the rise of the hot-pressing temperature, the elapse of the temperature on the surface and CB will increase. So, the resin can flow better and be evenly distributed between the particles; thus, it can be thoroughly solidified. But if the temperature is continuously risen up to 180 ^{o}C, the strength and TS of the board decreased, which might be caused by the degradation and brittleness of the resin.

Results on the improvement of mechanical and physical properties of CB layered with veneer shows that MOE, MOR, and IB increased by 17%, 10%, and 14% respectively. While TS reduced about 11%, this is due to the use of high-density veneer (300-400 kg m^{-3}) at the top and bottom of the CB surfaces which will prevent the absorption of water. In conclusion, the SB can be manufactured from the bottom section of OPT using the optimum parameters such as 12% resin content, board density 700 kg m^{-3} and particle size of >2 mm and high-density veneer of more than 300 kg m^{-3}.

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