

Oriented Strand Board Made from Tropical Plantation Wood with the Inclusion of Kenaf Core at Different Resin Content

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Oriented strand board (OSB) was prepared from the strands of rubberwood (RW) and *Acacia mangium* (AC), with inclusion of kenaf core (KC). The KC was used as substitution, where 5% was added with RW and AC during the manufacturing process of OSB. Considering the expected negative impact of adding KC on the performance of the OSB, various levels of PF resin content were used. This study applied phenol-formaldehyde (PF) resin contents of 7%, 9%, and 11%. The OSB samples produced were evaluated for thickness swelling (TS), water absorption (WA), modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding strength (IB). Generally, incorporation of kenaf core reduced the mechanical and physical properties of the OSB. However, its mechanical and physical properties could be improved by increasing the resin content. Based on the findings, taking into consideration the properties of OSB as well as the cost of resin, 9% resin content is recommended.

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Keywords: Resin content; *Hibiscus cannabinus*; *Acacia mangium*; Rubberwood; Phenol formaldehyde

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INTRODUCTION

Oriented strand board (OSB) is an engineered wood product made of strands that are long and thin and oriented in the same direction. The main purpose of producing OSB boards is for it to be utilized similar to plywood. However, OSB has one advantage over plywood, which is that the raw materials for OSB manufacturing could be derived from trees with smaller diameter and thus efficiently utilize the available forest biomass (Processing-Wood 2018). Another benefit of OSB is that its mechanical properties are equivalent to that of structural plywood but at a much lower cost.

Currently, OSB is still classified as “other products” in the report of trade performance of Malaysian Major Timber Products (MTIB 2023). However, OSB has gained significant importance recently especially as a sustainable alternative to traditional plywood (Cha 2023). In 2022, the global OSB market size was valued at USD 23.50 billion, and it is expected to grow at compound annual growth rate (CAGR) of 8.5% from 2023 to 2030 (Grand View Research 2023). According to the report, it was reported that construction segment held the largest revenue share of 54.0% in 2022. The trends imply

the gaining importance of OSB in the global market, particularly in the construction and building segment. The same situation was found in Malaysia, as OSB was reportedly a reliable choice for many Malaysian building projects (Cha 2023).

OSB is typically manufactured using softwood species such as spruce and pine due to their favorable mechanical properties and availability (Walker and Chapman 2006). However, certain soft hardwoods and even high-density hardwoods have also been successfully used in OSB production (Dumitrascu *et al.* 2020). In response to increasing wood shortages, the use of alternative wood species is gaining attention as a viable raw material source (Salles Ferro *et al.* 2018). To ensure structural integrity, these wood strands are bonded using synthetic adhesives, with phenol formaldehyde (PF) and polymeric methylene diphenyl diisocyanate (pMDI) being the most commonly used resins (Brochmann *et al.* 2004; Gonçalves *et al.* 2021).

OSB has been produced from oil palm biomass (Ibrahim *et al.* 2022), bamboo (Maulana *et al.* 2024), and sugar cane bagasse (Silva *et al.* 2012). Kenaf, a rapidly growing lignocellulosic resource, may also serve as an alternative material for OSB production. However, kenaf core is much lighter than the tropical hardwood normally used to produce OSB. Therefore, within a given weight unit, kenaf core would occupy a greater volume and make the formed OSB mat bulky. It tends to cause “spring back” phenomena when the mat is hot-pressed into a designated thickness. The spring back phenomena will negatively impact the functionality of the OSB boards. Therefore, kenaf core must be used only as a partial substitution, or supplement, to the current wood materials (Salles Ferro *et al.* 2018).

Moreover, because of the presence of two or more materials with different density, the bonding of the OSB could pose some serious problems (Adole *et al.* 2025). Materials with different density could have different rates of resin consumption, which might lead to a starved glue line if one of the materials absorbs more resin during the blending process (Salih *et al.* 2022). This impairs the performance of the resulting OSB. One of the methods to compensate for this drawback is to adjust the resin content used. Higher resin content may lead to a better performance of OSB boards. However, the extent of resin content used must also be controlled carefully to make sure it remains price competitive. As a result, an investigation on the effects of PF resin content on the properties of OSB boards made from a mixture of rubberwood, acacia wood, and kenaf core has to be conducted. Therefore, the main objective for this study was to determine the effects of variation PF resin content on the properties of oriented strand board (OSB) made from rubberwood (*Hevea brasiliensis*) and *Acacia mangium* with inclusion of kenaf core.

EXPERIMENTAL

Materials

Materials used in the manufacturing of OSB were rubberwood, *Acacia mangium*, and kenaf core that had been obtained from rubber a plantation in Jengka 14, a study forest near Universiti Teknologi MARA Jengka Campus, and Lembaga Kenaf Tobacco Negara (LKTN), respectively. Meanwhile, the binder of phenol formaldehyde (PF) resins was supplied by Aica Malaysia Sdn. Bhd., Senawang.

Strands Preparation

The felled trees were debarked and flaked into strands, followed by screening. The kenaf core was cut into 75-mm-long pieces and split in half along the core. Then, it was

subjected to a cold press to obtain flat strands. Figure 1 shows the kenaf core flat strand. Rubberwood and acacia strands demonstrated a greater length, averaging between 100.25 and 125.88 mm, in contrast to the 119.5 mm average for kenaf core strands. The average thickness of kenaf core strands was greater (1.81 mm) compared to that of rubberwood and acacia strands, which ranged from 0.91 mm to 1.15 mm. In contrast, rubberwood acacia strands exhibited a broader particle size, averaging between 16.6 and 17.9 mm, whereas kenaf core strands had an average width of only 5.44 mm. All the produced strands were then dried in an oven prior to manufacturing OSB.



Fig. 1. Kenaf core flat strand

OSB Manufacturing

The wood strands were weighted on the analytical balance with the rubberwood and kenaf core with the ratio of 95% and 5%; the same applied to *Acacia mangium* and kenaf core with the ratio of 95% and 5% respectively. The PF resin was used as the binder in this study. Dried wood strands were added to the OSB mixer (customized) and rotated until sufficiently mixed. The amount of PF used was 7%, 9%, and 11% based on the oven-dried weight of the strands.

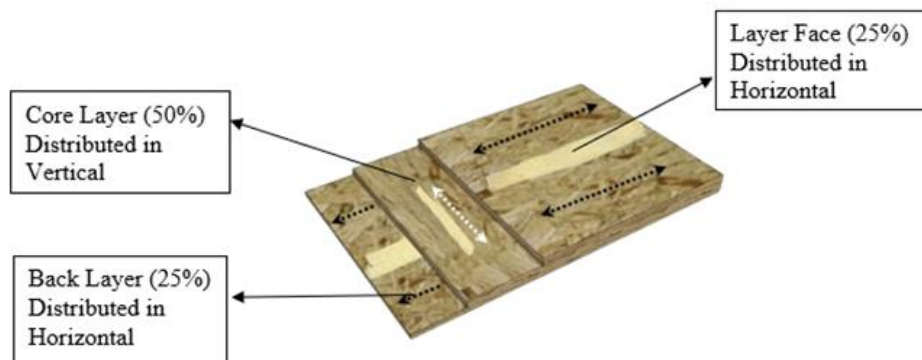


Fig. 2. Oriented strand board manufacturing

The mixture of dried wood strands and PF resin was arranged in the forming line where the cross directional layers are formed. Silicone spray was used before forming with the base metal board to withstand temperatures exerted on it and prevent the wood strands

from sticking on plates. The blended strands were divided into 3 portions by weight, which was 25% face, 50% core, and 25% back to form a three-layer OSB with a target density of 700 kg/m³. The blended strands were evenly distributed in an oriented manner with the aids of a metal forming box size 38 cm width, 38 cm length with parallel compartments. Each layer was formed perpendicularly to its adjacent layer, as shown in Fig. 2. The mats were compressed to a thickness of 2 cm at a temperature of 175 °C using a hot press, applying a pressure of 160 kg/cm² for a duration of 6 minutes (Carver CMG 100H-15, Ontario, NY, USA).

Properties Evaluation and Data Analysis

Properties, such as density, bending strength, internal bonding (IB), and thickness swelling (TS), were calculated according to European standards. Density was determined based on EN 323 (1993). Bending strength was determined based on EN 310 (1993), while IB and TS were determined using EN 319 (1993) and EN 317 (1993), respectively. The specifications of OSB referred to EN 300 (2006). The obtained data were analysed by analysis of variance (ANOVA) using Statistical Package for the Social Sciences (SPSS; IBM, version 30, Armonk, NY, USA) software. *Post hoc* test was then carried out to further separate the mean values. Tukey's honest significant difference (HSD) test was used to assess the significance of differences between pairs of group means at $p \leq 0.05$.

RESULTS AND DISCUSSION

Table 1 shows the ANOVA of the interaction between species, resin content, and the properties of OSB. Both the species and resin content were found to have a significant impact (p value < 0.05) on all properties of OSB, including modulus of rupture (MOR), modulus of elasticity (MOE), IB, and TS. Nonetheless, the density of the OSB was only affected by species and not the resin content. Meanwhile, there is no interaction between the species and resin content (p value > 0.05), indicating that the performance of OSB was affected by each of the two factors, which in this case, either species or resin content.

Table 1. ANOVA Summary at $p \leq 0.05$ of the Interaction Between Species, Resin Content, and the Properties of OSB

SOV	Density	MOR	MOE	IB	TS
Species	0.000**	0.000**	0.000**	0.000**	0.000**
RC	0.304 ns	0.000**	0.000**	0.000**	0.000**
SP*RC	0.996 ns	0.917 ns	0.879 ns	0.668 ns	0.560 ns

Notes : Source of variance (SOV) ** - highly significant $p < 0.01$ * - significant $p < 0.05$ ns – not significant $p > 0.05$

Physical Properties Evaluation of OSB

The density, TS, and water absorption (WA) of the OSB samples produced in this study after 24 h water immersion are shown in Table 2. The density of the OSB panels produced in this study ranged from 570 to 723 kg/m³. OSB made of 100% RW has higher density than that of OSB made of 100% AC. At the same resin content of 7%, the inclusion of 5% KC reduced the density of the OSB boards (Type 1 and Type 4) when compared with their 100% RW and AC counterparts (Type 7 and Type 8). However, the density increased along with increasing resin content, though no statistical difference was detected.

Kenaf is light weight and spongy in nature and therefore it occupied a larger volume per unit weight. Based on our observations, owing to the larger volume of KC that prevent complete compressing of the mat, the resulting panel exhibited larger thickness than those of 100% RW and 100% AC. Therefore, reduction in density was observed. Other the other hand, the OSB made from 100% RW bonded with 7% PF resin (type 7) had TS and WA values of 26.26% and 35.47%, respectively. Meanwhile, OSB made with 100% acacia bonded with 7% PF (type 8) had TS and WA values of 33.68% and 45.54%, respectively. The OSB manufactured using RW exhibited lower TS and WA compared to the OSB made from AC wood strands. This observation can be ascribed to the juvenile nature of the acacia wood utilized in this study. The acacia trees used in this study were one year old and classified as juvenile wood. According to a report by Bao *et al.* (2001), juvenile wood has been found to have a greater capacity for absorbing and diffusing moisture compared to mature wood. Furthermore, Nazerian *et al.* (2011) found that juvenile wood exhibited almost tenfold greater swelling and shrinkage compared to mature wood. This explains why OSB made from juvenile wood had higher values for TS and WA than OSB made from mature wood.

In contrast, the addition of 5% KC during the manufacturing process of OSB resulted in an increase in both the TS and WA of the OSB. Based on the information provided in Table 2, it is evident that OSB made with 95% RW (type 1) and 95% AC (type 4) showed an increase in TS and WA when the PF resin content was maintained at 7%. Type 1 OSB had TS value of 27.56% and WA value of 37.8%, while type 4 OSB had TS value of 34.9% and WA value of 47.9%. The reason for this is that KC is a lignocellulosic material with high hygroscopicity, meaning that it can absorb a significant amount of water (Yu *et al.* 2020). As a result, the board's TS and WA were increased. The increase in TS value of the OSB is undesirable as it indicates a low level of dimensional stability. This limitation restricts its use in various applications that require high dimensional stability.

Table 2. TS and WA of the OSB Produced in this Study

Type	Ratio	Resin Content (%)	Density (kg/m ³)	Thickness Swelling (%)	Water Absorption (%)
1	95%RW:5%KC	7	645.2 ± 8.3 ^{cd}	27.56 ± 1.50 ^{bcd}	37.76 ± 2.16 ^{cd}
2	95%RW:5%KC	9	676.8 ± 7.6 ^{de}	22.22 ± 0.51 ^{ab}	28.60 ± 1.83 ^{bc}
3	95%RW:5%KC	11	701.4 ± 7.4 ^{ef}	18.45 ± 0.80 ^a	19.97 ± 1.27 ^a
4	95%AC:5%KC	7	570.4 ± 12.7 ^a	34.94 ± 4.71 ^e	47.87 ± 6.31 ^f
5	95%AC:5%KC	9	598.2 ± 13.3 ^{ab}	28.06 ± 2.03 ^{cd}	36.10 ± 3.22 ^{cd}
6	95%AC:5%KC	11	620.2 ± 11.4 ^{bc}	23.33 ± 2.68 ^{abc}	25.30 ± 3.33 ^{ab}
7	100% RW	7	722.8 ± 32.8 ^f	26.26 ± 1.03 ^{bc}	35.47 ± 2.14 ^{cd}
8	100% AC	7	638.8 ± 32.0 ^{bcd}	33.68 ± 4.24 ^{de}	45.54 ± 6.24 ^{de}

Note: Means followed by the different superscript letters in the same column are significantly different at $p \leq 0.05$; RW = rubberwood; KC = kenaf core; AC = acacia

However, this undesirably high TS could be compensated by applying higher PF resin content. When 9% and 11% PF resin were applied, the TS and WA of the OSB for both RW and AC were reduced, indicating better dimensional stability. Among these, OSB made with 95% RW and 5% KC, bonded with 11% phenol-formaldehyde (PF) resin (type 3), showed a significantly lower TS value compared to the other types of OSB (as shown by the different grouping of a, b, c, d and e), except for type 2. Type 2 OSB was similar to type 3 in composition, but it was bonded with a lower PF content of 9%. This suggests that using a 9% PF content in applications may be enough to achieve satisfactory TS values,

which are not significantly different from the previous values. The enhanced dimensional stability of the OSB can be ascribed to the incorporation of resin content, which is the primary determinant in regulating the TS and WA of any wood composite (Boruszewski *et al.* 2022). Increasing the resin content allows for a greater amount of resin to come into contact with the wood fibers, resulting in the formation of a strong crosslinked structure when the resin cures. The robust composition of this structure provides excellent resistance to moisture, resulting in improved dimensional stability of the boards (Hong *et al.* 2017).

Results for the TS and WA of the OSB samples produced in this study after 24 h water immersion are shown in Figs. 3 and 4, respectively. According to Fig. 3, it is evident that the TS value of all the OSB produced in this study did not meet the requirement of a maximum allowable TS value of less than 15% as specified in EN 300 (2006) for Type OSB/3 (Load-bearing Boards for Use in Humid Conditions). All the OSB produced had a TS value greater than 15%.

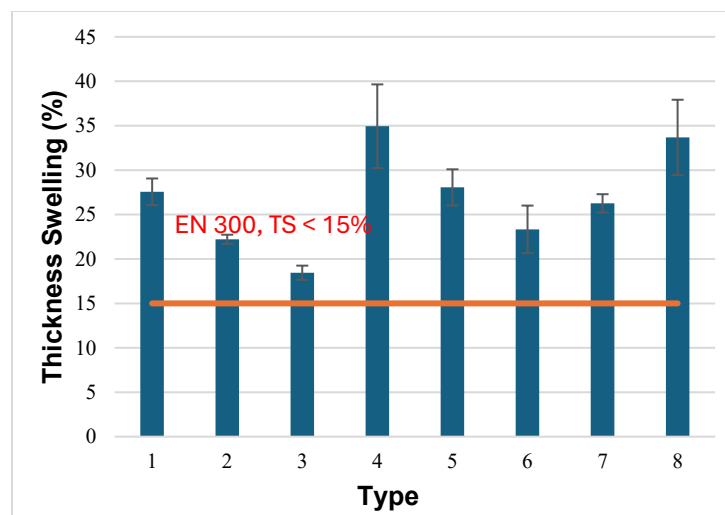


Fig. 3. TS of the OSB produced in this study and its maximum allowable TS value according to EN 300 (2006)

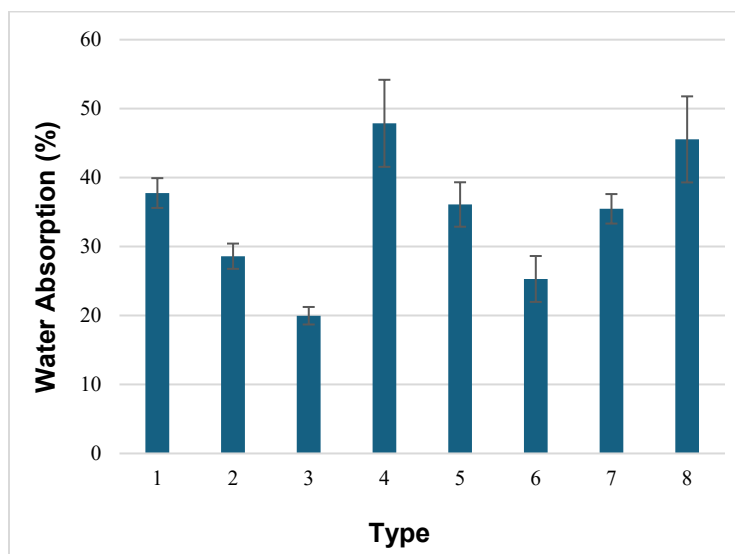


Fig. 4. WA of the OSB produced in this study

OSB type 3 exhibited a TS value that closely aligned with the specified requirement. This suggests that increasing the PF content can serve as a partial remedy for reducing the TS value of the OSB. Achieving a thickness swelling (TS) of 15% or lower is indeed challenging. According to previous studies, OSB bonded with melamine resin showed a TS of 15.3% under exposure to 100% relative humidity (Böhm *et al.* 2019). It's important to note that this condition is less severe than the water immersion used in the current study, yet the OSB still did not meet the maximum allowable TS limit of 15%. Despite that, OSB type 3 met requirements of Type OSB/2 (Load-bearing Boards for Use in Dry Conditions) as specified in EN 300 (2006), which states the maximum allowable TS value shall be less than 20%. As for WA, there is no requirement specified in the EN 300 (2006) but the trend of WA is highly mirrored that of the trend of TS.

Mechanical Properties of OSB

The MOR, MOE, and IB strength of the OSB samples produced in this study is shown in Table 3. In term of MOR, OSB made from 100% RW bonded with 7% PF resin (type 7) had a MOR and MOE value of 18.0 MPa and 3100 MPa, respectively. Meanwhile, OSB made with 100% acacia bonded with 7% PF (type 8) had a MOR and MOE value of 16.0 MPa and 2740 MPa, respectively. It is evident that the OSB manufactured with RW exhibits greater flexural strength compared to the OSB made with AC. The utilization of juvenile AC wood may have contributed to the aforementioned observations, which are consistent with the physical properties of OSB discussed earlier. This is because, when compared to mature wood, juvenile wood is known to have a rapid growth rate and lower density and strength (Passialis and Kiriazakos 2004). A similar trend was also observed for IB strength, where type 7 OSB had higher value (0.87 MPa) than type 8 OSB (0.77 MPa).

Table 3. MOR, MOE, and IB Strength of the OSB Produced in this Study

Type	Ratio	Resin Content (%)	MOR (MPa)	MOE (MPa)	IB (MPa)
1	95%RW:5%KC	7	16.10 ± 0.98 ^{cb}	2768 ± 153 ^b	0.80 ± 0.04 ^{ab}
2	95%RW:5%KC	9	19.18 ± 0.96 ^{cd}	3251 ± 50.67 ^d	0.94 ± 0.06 ^c
3	95%RW:5%KC	11	20.66 ± 0.72 ^d	3555 ± 82.50 ^e	1.25 ± 0.06 ^e
4	95%AC:5%KC	7	14.23 ± 0.96 ^a	2477 ± 149 ^a	0.71 ± 0.04 ^a
5	95%AC:5%KC	9	16.95 ± 0.86 ^{bc}	2874 ± 54.04 ^b	0.83 ± 0.05 ^{abc}
6	95%AC:5%KC	11	18.27 ± 0.88 ^{bc}	3143 ± 104 ^c	1.11 ± 0.07 ^d
7	100% RW	7	18.06 ± 0.88 ^{bc}	3101 ± 192 ^{cd}	0.87 ± 0.05 ^{bc}
8	100% AC	7	15.97 ± 0.55 ^{ab}	2742 ± 156 ^{ab}	0.77 ± 0.03 ^{ab}

Note: Means followed by the different superscript letters in the same column are significantly different at $p \leq 0.05$

At the same resin content of 7%, adding 5% KC has reduced the mechanical strength of the OSB. When 5% KC was added, the type 1 OSB experienced a decrease of 10.8% in MOR and a decrease of 10.7% in MOE compared to type 7 OSB. Comparatively, the MOR and MOE of type 4 OSB decreased 10.9% and 9.7%, respectively, compared to type 8 OSB. A similar observation was also made in the IB strength of the OSB where 5% KC addition reduced the IB strength of the board. The KC is a light lignocellulosic material. Therefore, within a given weight unit, kenaf core would occupy a greater volume and made

the formed OSB mat very bulky. The bulkiness will prevent the board from obtaining an appropriate compaction ratio and therefore lower MOR, MOE, and IB values (Lee *et al.* 2015).

To compensate for the loss of mechanical strength, higher PF resin content can be employed. As the resin content increased to 9 and 11%, the MOR, MOE, and IB of the OSB surpassed that of their respective control board (types 7 and 8). Overall, OSB type 3 (95% RW and 5% KC bonded with 11% PF) has significantly higher MOR than the other type of OSB, except for type 2. Type 3 OSB also has significantly higher MOE and IB than the other type of OSB. The results indicate that the decrease in mechanical properties caused by the addition of KC can be counterbalanced by increasing the PF resin content to 9 and 11%. Specifically, regarding MOR, a 9% PF appears to be adequate in producing satisfactory outcomes for the resulting OSB.

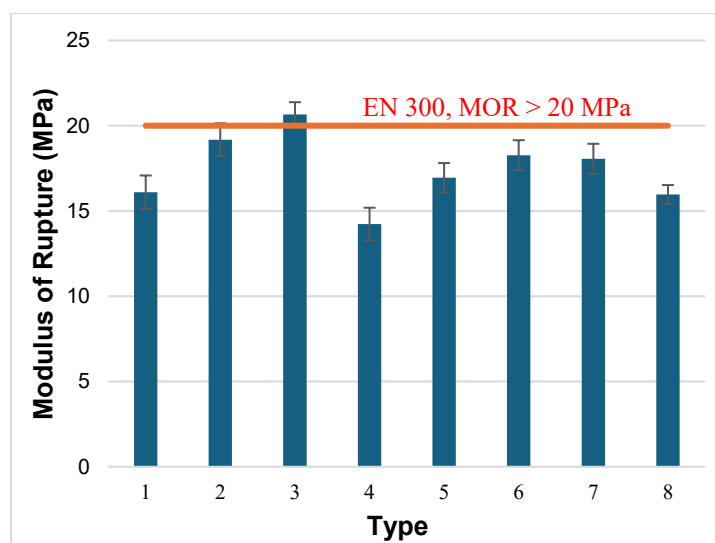


Fig. 5. MOR of the OSB produced in this study and its minimum MOR value requirement according to EN 300 (2006)

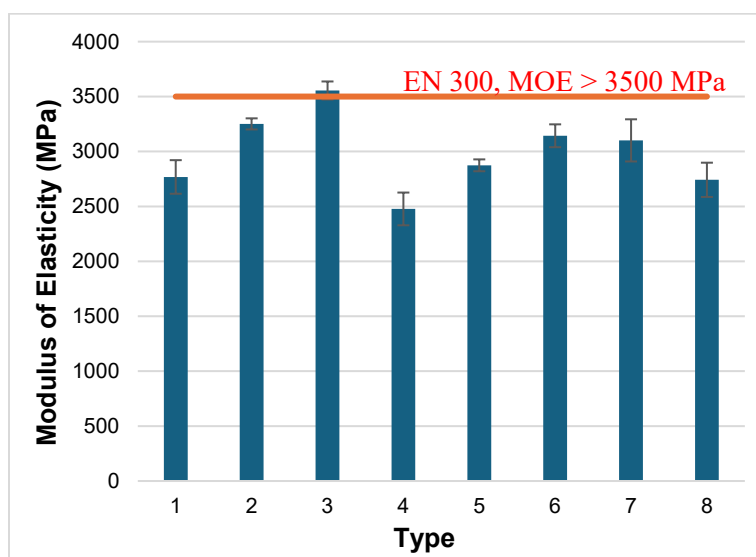


Fig. 6. MOE of the OSB produced in this study and its minimum MOE value requirement according to EN 300 (2006)

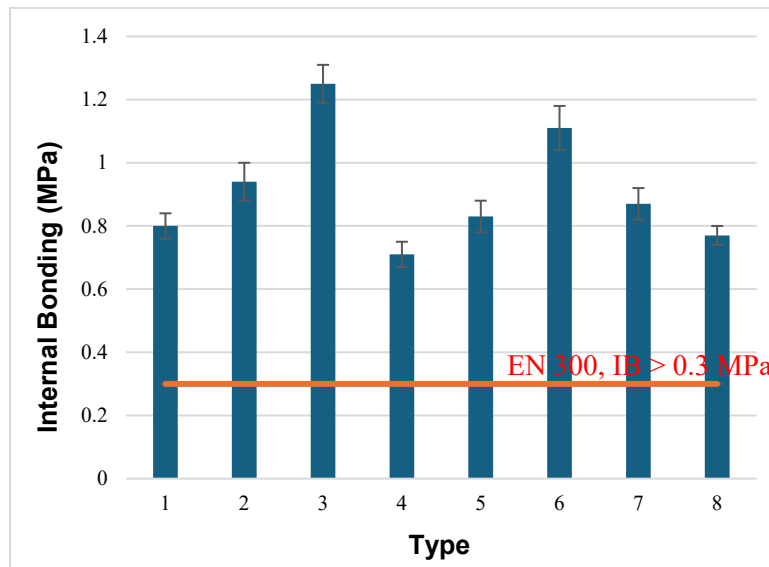


Fig. 7. IB of the OSB produced in this study and its minimum IB value requirement according to EN 300 (2006)

Figures 5 through 7 depict the MOR, MOE, and IB strength of the OSB samples produced in this study, along with the minimum requirement value specified in EN 300 (2006). According to Fig. 5, all the OSB boards, except for OSB type 3, did not meet the minimum MOR value of 20 MPa required for Type OSB/3 (Load-bearing Boards for Use in Humid Conditions). Figure 5 demonstrates that the minimum requirements stated in EN 300 (2006) are 3500 MPa. Only type 3 OSB was able to fulfil this requirement. Regarding the IB strength, the minimum threshold is 0.3 MPa, and all the OSB manufactured in this study has satisfactorily met this requirement.

CONCLUSIONS

1. Oriented strand board (OSB) produced from rubber wood (RW) exhibited superior strength and dimensional stability compared to OSB made from acacia.
2. At the same resin content level of 7%, incorporation of 5% kenaf core reduced the mechanical and physical properties of the OSB. However, it can be compensated by increasing the resin content from 7% to 9 and 11%.
3. The study showed that 9% phenol formaldehyde (PF) resin was the most optimum resin level, taking into consideration the properties of OSB as well as the cost of resin.
4. In the context of the EN 300 (2006) standard, only type 3 OSB (95%RW:5%KC bonded with 11% PF) satisfactorily complied with the criteria for load-bearing boards intended for humid circumstances based on the parameters evaluated in this study.
5. Therefore, higher PF resin is needed to meet the requirements specified by the standard.

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REFERENCES CITED

- Adole, A. M., Anum, I., Jamaludin, M. Y., and Suhaimi, A. R. (2025). “Mechanical characterization of green sandwich composites from kenaf fiber skins and sawdust core,” *Discover Civil Engineering* 2(1), 1-19. DOI: [10.1007/s44290-025-00241-9](https://doi.org/10.1007/s44290-025-00241-9)
- Bao, F. C., Jiang, Z. H., Jiang, X. M., Lu, X. X., Luo, X. Q., and Zhang, S. Y. (2001). “Differences in wood properties between juvenile wood and mature wood in 10 species grown in China,” *Wood Science and Technology* 35, 363-375. DOI: [10.1007/s002260100099](https://doi.org/10.1007/s002260100099)
- Böhm, M., Kobetičová, K., Procházka, J., Černý, R. (2019). “Moisture sorption and thickness swelling of wood-based materials intended for structural use in humid conditions and bonded with melamine resin,” *IOP Conference Series: Materials Science and Engineering* 549, article 012042. DOI: [10.1088/1757-899X/549/1/012042](https://doi.org/10.1088/1757-899X/549/1/012042)
- Boruszewski, P., Borysiuk, P., Jankowska, A., and Pazik, J. (2022). “Low-density particleboards modified with blowing agents—characteristic and properties,” *Materials* 15(13), article 4528. DOI: [10.3390/ma15134528](https://doi.org/10.3390/ma15134528)
- Brochmann, J., Edwardson, C., and Shmulsky, R. (2004). “Influence of resin type and flake thickness on properties of OSB,” *Forest Products Journal* 54(3), 51-55.
- Cha, W. S. (2023). “OSB: Redefining structural strength in Malaysian building projects,” Available from: <https://www.montco.com.my/osb-redefining-structural-strength-in-malaysian-building-projects/>, Accessed 12 Nov 2024.
- Dumitrascu, A. E., Lunguleasa, A., Salca, E. A., and Ciobanu, V. D. (2020). “Evaluation of selected properties of oriented strand boards made from fast growing wood species,” *BioResources* 15(1), 199-210. DOI: [10.15376/biores.15.1.199-210](https://doi.org/10.15376/biores.15.1.199-210)
- EN 300 (2006). “Oriented strand boards (OSB) – Definitions, classification and specifications,” European Committee for Standardization, Brussels, Belgium.
- EN 310 (1993). “Wood-based panels – Determination of modulus of elasticity in bending and of bending strength,” European Committee for Standardization, Brussels, Belgium.
- EN 317 (1993). “Particleboards and fibreboards – Determination of swelling in thickness after immersion in water,” European Committee for Standardization, Brussels, Belgium.
- EN 319 (1993). “Particleboards and fibreboards – Determination of tensile strength perpendicular to the plane of the board,” European Committee for Standardization, Brussels, Belgium.
- EN 323 (1993). “Wood-based panels – Determination of density,” European Committee for Standardization, Brussels, Belgium.
- Gonçalves, D., Bordado, J. M., Marques, A. C., and Galhano dos Santos, R. (2021). “Non-formaldehyde, bio-based adhesives for use in wood-based panel manufacturing industry—A review,” *Polymers* 13(23), article 4086. DOI: [10.3390/polym13234086](https://doi.org/10.3390/polym13234086)

- Grand View Research (2023). "Oriented strand board market size & trends," Grand View Research, Available from: (<https://www.grandviewresearch.com/industry-analysis/oriented-strand-board-market>), Accessed 12 Nov 2024.
- Hong, M. K., Lubis, M. A. R., and Park, B. D. (2017). "Effect of panel density and resin content on properties of medium density fiberboard," *Journal of the Korean Wood Science and Technology* 45(4), 444-455. DOI: [10.5658/WOOD.2017.45.4.444](https://doi.org/10.5658/WOOD.2017.45.4.444)
- Ibrahim, N. I., Saiful Azry, S. O. A., Sultan, M. T. H., Fajobi, A. O., Lee, S. H., and Ilyas, R. A. (2022). "Oriented strand board from oil palm biomass," in: *Oil Palm Biomass for Composite Panels*, Elsevier, pp. 267-281. DOI: [10.1016/B978-0-12-823852-3.00006-4](https://doi.org/10.1016/B978-0-12-823852-3.00006-4)
- Lee, S. H., Ashaari, Z., Chen, L. W., San, H. P., Peng, T. L., Chow, M. J., Chai, E. W., and Chin, K. L. (2015). "Properties of particleboard with oil palm trunk as core layer in comparison to three-layer rubberwood particleboard," *Journal of Oil Palm Research* 27(1), 67-74.
- Li, W., Chen, C., Shi, J., Mei, C., Kibleur, P., Van Acker, J., and Van den Bulcke, J. (2020). "Understanding the mechanical performance of OSB in compression tests," *Construction and Building Materials* 260, article ID 119837. DOI: [10.1016/j.conbuildmat.2020.119837](https://doi.org/10.1016/j.conbuildmat.2020.119837)
- Malaysian Timber Industry Board (MTIB) (2023). "Trade performance summary, January – December 2022," Available from: (<https://www.mtib.gov.my/en/information/sources/statistics>), Accessed 14 Nov 2024.
- Maulana, S., Suwanda, A. A., Murda, R. A., Antov, P., Komariah, R. N., Maulana, M. I., Augustina, S., Lee, S. H., Mahardika, M., Rianjanu, A., and Taher, T. (2024). "Performance of oriented strand board made of heat-treated bamboo (*Dendrocalamus asper* (Schult.) Backer) strands," *Polymers* 16(12), article 1692. DOI: [10.3390/polym16121692](https://doi.org/10.3390/polym16121692)
- Nazerian, M., Ghalehno, M. D., and Kashkooli, A. B. (2011). "Effect of wood species, amount of juvenile wood and heat treatment on mechanical and physical properties of laminated veneer lumber," *Journal of Applied Sciences* 11, 980-987. DOI: [10.3923/jas.2011.980.987](https://doi.org/10.3923/jas.2011.980.987)
- Passialis, C., and Kiriazakos, A. (2004). "Juvenile and mature wood properties of naturally-grown fir trees," *Holz als Roh-und Werkstoff* 62, 476-478. DOI: [10.1007/s00107-004-0525-7](https://doi.org/10.1007/s00107-004-0525-7)
- Processing-Wood.com (2018) "Production of OSB boards," Available from: (<https://processing-wood.com/processes/panels/osb/>), Accessed 8 Nov 2024.
- Salih, R. F., Hamad, E. M., and Ismail, T. N. (2022). "Commercial and field factors of selecting kenaf fibers as alternative materials in industrial applications," *Malaysian Journal of Sustainable Agriculture (MJSa)* 6(2), 85-89. DOI: [10.26480/mjsa.02.2022.85.89](https://doi.org/10.26480/mjsa.02.2022.85.89)
- Salles Ferro, F., Magalhães Souza, A., de Araujo, I. I., Van Der Neut de Almeida, M. M., Christoforo, A. L., and Rocco Lahr, F. A. (2018). "Effect of alternative wood species and first thinning wood on oriented strand board performance," *Advances in Materials Science and Engineering* 2018(1), article ID 4603710. DOI: [10.1155/2018/4603710](https://doi.org/10.1155/2018/4603710)
- Silva, A. J. P., Lahr, F. A. R., Christoforo, A. L., and Panzera, T. H. (2012). "Properties of sugar cane bagasse to use in OSB," *International Journal of Materials Engineering* 2(4), 50-56. DOI: [10.5923/j.ijme.20120204.04](https://doi.org/10.5923/j.ijme.20120204.04)

- Walker, J. C., and Chapman, K. M. (2006). "Wood-based panels: Particleboard, fibreboards and oriented strand board," in: *Primary Wood Processing: Principles and Practice*, J. C. Walker (ed.), Springer, Dordrecht, Netherlands, pp. 427-475. DOI: [10.1007/1-4020-4393-7_12](https://doi.org/10.1007/1-4020-4393-7_12)
- Yu, W., Xu, B., Fan, B., Zhang, Y., and Wang, X. (2020). "Effects of saturated steam treatment on the cell-wall mechanics and moisture sorption properties of kenaf fiber," *BioResources* 15(1), 159-171. DOI: [10.15376/biores.15.1.159-171](https://doi.org/10.15376/biores.15.1.159-171)

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