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Size Effect of Core Strands on the Major Physical and Mechanical Properties of Oriented Strand Boards from Fast Growing Tropical Species

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Abstract

Oriented strand board (OSB) is generally used for sheathing in residential walls, floors, and roofs. Because of its low pricing and utilisation of tiny diameter logs from fast-growing trees and thinning logs as raw materials, OSB is anticipated to gain popularity. In chapter, board properties of OSB using smaller strand size of *Leucaena leucocephala* as core layer had been studied. Small strand size of S3 (length = 75 mm, width = 3.2 to 6.3 mm) was located in the middle layer of the board while bigger strand sizes of S1 (length = 75 mm, width = 12.7 to 19.0 mm) and S2 (length = 75 mm, width = 6.3 to 12.7 mm) were located at the face and back layers. Utilization of smaller strands (S3) in the middle layers may yield boards that have better physical and mechanical properties. Except for MOR in the minor axis, board density and resin content were shown to have a substantial impact on physical and mechanical properties. Except for MOR in the major axis, strand size had little affected on physical and mechanical properties. The effects of board density on mechanical properties were discovered to affect significantly different. With a positive correlation, board density had a significant effect on thickness swelling. Between S1+S3 and S2+S3 strand size, there is no significant effect on bending properties, internal bond strength and thickness swelling. The effect of resin content on bending properties revealed a significant difference of MOR in major axis, as well as MOE values in both major and minor axes. Even when the resin content was as low as 5%, all treatments of OSB passed the general requirement of general purpose OSB.

Keywords: oriented strand board, strand size, core layer, physical properties, mechanical properties

1. Introduction

Leucaena leucocephala is a fast-growing tree species and can be cultivated in Malaysia. This species has potential as an alternative resource for the Malaysian

furniture and panel board industries in the coming years because of a shortage of the current frequently used raw material of rubberwood [1]. The use of a fast-growing species for wood composite production may offer some advantages, such as a shorter time required to activate production compared with other woody plants [2]. In Malaysia, the study on OSB from rubberwood was successfully carried out at the laboratory for the first time in 1996 by researchers from the Forest Research Institute Malaysia (FRIM), showed a good sign of using plantation species [3].

OSB is an engineered wood-based panel material in which long strands of wood are crushed together in layers and bonded together with a synthetic resin glue. Despite its strength, the effective performance of OSB begins immediately after it is created; OSB panels are light in weight and simple to handle and instal. Due to the coordination between the board and the adhesive to generate a strong, dimensionally stable panel, the panels also demonstrate outstanding fastener-holding, resist deflection, delamination, and warping. OSB is commonly used for flooring, roof and decking, and wall sheathing because it is uniquely acceptable for load-bearing applications in construction [4].

In order to efficiently used OSB products, it is important to understand the material and manufacturing variables that affect properties of the boards. As a result, this study will investigate the properties of OSB from *L. leucocephala* wood. This chapter describes the findings of the study conducted to evaluate the properties of the OSB produced from smaller strand size. The strand size of S3 as core material in the manufacture of OSB using eight-year-old *L. leucocephala* wood (**Figure 1**) strands was conducted in the study. Smaller strand size of S3 or fines is an additional component to this study. Any wood particles that pass through a 6.3 mm screen but remain at 3.2 mm screen are considered fines. They are a natural by-product of the stranding process and are used as filler material in the board. They add to the board's mass but are assumed to have no effect on the board's final volume. An optimal manufacturing process would use a balance of wood strands and fines to achieve the strength requirements while reducing the cost of raw materials. The S3 strand size (length = 75 mm, width = 3.2 to 6.3 mm) was found in the middle layer of the board, while the S1 (length = 75 mm, width = 12.7 to 19.0 mm) and S2 strand sizes (length = 75 mm, width = 6.3 to 12.7 mm) were found on the face and back layers (**Figure 2**). The focus of this study is to maximise recovery and to find the best combination of treatments. Perhaps, by utilisation of smaller strands (S3) in the middle layers may yield boards that have better physical and mechanical properties. By utilising S3; residue utilisation, only a small portion will be burned as waste or sent to a landfill. **Table 1** exhibit the properties of OSB according to board density, strand size and resin content.

Boards made from S1S3 with 9% resin content gave the best value of physical and mechanical properties in the fabrication of boards with a target board density of 700 kgm^{-3} (MOR major axis; 43.57 MPa, MOE major axis; 7377 MPa, MOR



Figure 1.
Leucaena leucocephala logs.



Figure 2.
Strand size.

Target density (kgm ⁻³)	strand size	Resin (%)	Actual density (kgm ⁻³)	Major axis		Minor axis		IB (MPa)	TS (%)
				MOR (MP)	MOE (MPa)	MOR (MP)	MOE (MPa)		
700	S1S3	5	699	38.11	6455	15.94	1444	0.64	15.75
700	S1S3	7	695	40.70	6703	16.84	1485	0.79	14.11
700	S1S3	9	707	3.57	7377	16.26	1597	1.20	12.05
700	S2S3	5	697	36.00	6684	14.41	1444	0.57	20.43
700	S2S3	7	695	39.73	6929	14.29	1483	0.90	15.19
700	S2S3	9	703	41.05	7013	14.71	1569	0.98	12.30
800	S1S3	7	793	52.12	7324	18.22	1624	0.92	19.42
800	S1S3	9	797	56.24	8555	20.66	2024	2.06	12.93
800	S2S3	7	792	46.08	7663	18.67	1804	1.34	15.34
800	S2S3	9	799	51.03	7783	19.76	2003	1.92	15.07
Min. req.				18 MPa	2500 MPa	9 MPa	1200 MPa	0.28 MPa	<25%
Type OSB/1: General purpose EN Standard				EN 310: 1993	EN 310: 1993	EN 310: 1993	EN 310: 1993	EN 319: 1993	EN 317: 1993

Note: MOR = Modulus of Rupture, MOE = Modulus of Elasticity, IB = Internal Bond, TS = Thickness Swelling.

Table 1.
Properties of OSB.

minor axis; 16.26 MPa and MOE minor axis; 1597 MPa, Internal Bond; 1.20 MPa and thickness swelling; 12.05%). However, boards produced from S2S3, with a density of 700 kgm⁻³ and 5% resin content, had the lowest mechanical properties in both major and minor axes, with the exception of MOE in major axis. The board also had the highest percentage of thickness swelling (20.43%), yet it still met the



a) S1S3

b) S2S3

Figure 3.
Spring back phenomena.

EN standard's minimal requirements. The highest MOR values in the major axis were 2.4 times higher than the EN standard specification. Furthermore, MOR in the major axis performed 37.32% better than MOR in the minor axis. MOE values in the major axis perform tremendously with 3 times greater than minimum requirement. By raising the resin content from 5–9%, the internal bond values of OSB board improved significantly. Internal bond improvements were 1.7 to 1.8 times better than the internal bond with 5% resin content. The boards with 9% resin content had the best thickness swelling overall. Physical and mechanical properties were determined to comply with EN 300 standard [5] for general purpose (type OSB/1) even at the lowest resin content of 5%, according to the study's findings.

In the major and minor axes, the boards with a target board density of 800 kgm^{-3} and a combination of strand sizes S1S3 at 9% resin content had the highest MOR and MOE values. In the major axis, the MOR and MOE values are 56.24 MPa and 8555 MPa, respectively. MOR had the highest minor axis value of 20.66 MPa and MOE had the highest minor axis value of 2024 MPa. The board also had the highest internal bond values, at 2.06 MPa, which was 7 times higher than the EN standard's specification. The board's thickness swelling was also lower, at 12.93%. Boards constructed from target density of 800 kgm^{-3} with strand size of S1S3 and 7% resin content, on the other hand, had the lowest values for mechanical properties in major and minor axes, with the exception of MOR in major axis. This board likewise has the highest percentage of thickness swelling (19.42%), yet it still meets the maximum requirement of 25% and below. The findings of this study revealed that boards with a resin content of 7% exhibit spring back phenomena, resulting in a thickness increase of more than 12 mm (**Figure 3**). The 'spring back' effect was reduced by reducing the board density and increasing the resin amount. As a result of the performance at 7% resin content, the fabrication of boards with 5% resin content was not conducted. Because the board specimens blow in the core layer, no data from the treatment of S1S3 and S2S3 at board density of 800 kgm^{-3} with 5% resin content was acquired. In general, boards with strand sizes of S1S3 perform better than boards with strand sizes of S2S3, and all boards fulfil the EN 300 minimum criteria.

2. Statistical significance

The analysis of variance (ANOVA) and correlation analyses are presented for discussion. The ANOVA of the effect of board density, strand size and resin content

SOV	Df	Major axis		Minor axis		IB (MPa)	TS (%)
		MOR (MPa)	MOE (MPa)	MOR (MPa)	MOE (MPa)		
Density (D)	1	51.90**	40.57**	22.97**	21.03**	115.48**	6.76*
Strand Size (S)	1	5.66*	0.0 ns	1.91 ns	0.08 ns	1.58 ns	0.69 ns
Resin Content (RC)	1	5.80*	17.51**	0.84 ns	6.19*	74.26**	13.25**
D x S	1	3.36 ns	0.35 ns	1.29 ns	0.24 ns	6.90*	2.38 ns
D x RC	1	0.06 ns	0.10 ns	1.03 ns	1.37 ns	21.72**	0.24 ns
S x RC	1	0.35 ns	10.01**	0.02 ns	0.38 ns	7.67**	1.33 ns
D x S x RC	1	0.41 ns	0.01 ns	0.55 ns	0.19 ns	0.14 ns	0.99 ns

Note: SOV = Source of variance, Df = Degree of freedom, ns = not significant at $p > 0.05$.
* significant at $p < 0.05$.
**highly significant at $p < 0.01$.

Table 2.
Summary of the ANOVA on the properties of S1S3 and S2S3 board.

and their interactions on the OSB properties are shown in **Table 2**. Mechanical properties and thickness swelling were both affected by density, according to statistical analysis. Except for MOR in the major axis, strand size did not affect mechanical properties and thickness swelling. Except for MOR in the minor axis, all mechanical properties and thickness swelling were found to be affected significantly by resin content. Except for internal bond, there is no significant difference in the interaction between board density and strand size. The interaction between board density and resin content showed a similar pattern. Despite this, there was no significant difference in the interaction between strand size and resin, with the exception of MOE in the major axis and internal bond strength. In the interaction of all main factors, no significant effect was found.

3. Effects of board density

The effect of board density on mechanical properties are given in **Figure 4**. The mechanical properties showed higher value with increase in board density. The mechanical properties are significantly different at $p < 0.05$, according to the t-test comparison. With increasing board density, the values of MOR and MOE in major and minor axes of each board increased almost linearly. The MOR in the major axis was approximately 2.6 times that of the minor axis. In MOE, a similar trend in density effects was seen. According to [6] the values of MOR and MOE determined in the parallel direction are approximately 40–50% greater than the values determined in the perpendicular direction. MOR major axis, MOE major axis, MOR minor axis, MOE minor axis, and internal bond increased with increased board density ($r = 0.68^{**}$, 0.59^{**} , 0.56^{**} , 0.50^{**} , and 0.61^{**} , respectively) according to correlation analysis (**Table 3**). According to [7], board density was one of the most critical elements influencing particleboard mechanical properties. In wood composites, board density is the most important component for board structure to sustain load, so increasing density means increasing material resistance to outside forces and achieving strong composite unit contacts for improved bonding strength. Study by [8] investigated three different board densities (0.53 , 0.66 and 0.78 gcm^{-3}) and found that mechanical properties increased as panel specific gravity increased for douglas-fir flakeboards.

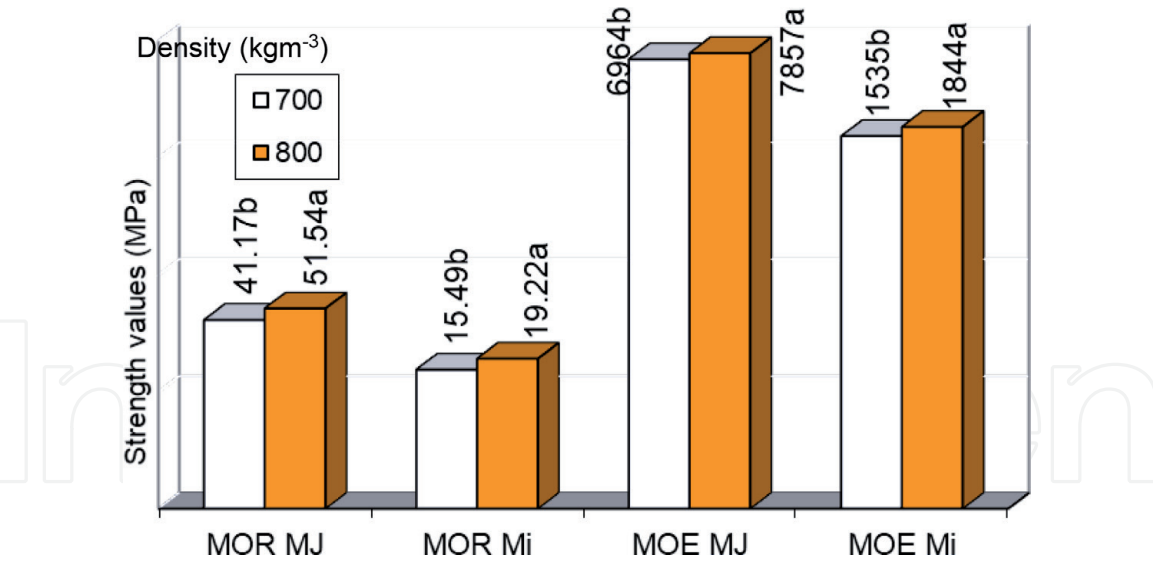


Figure 4.
Effect of board density on bending properties.

Variable	Major axis		Minor axis		IB (MPa)	TS (%)
	MOR (MPa)	MOE (MPa)	MOR (MPa)	MOE (MPa)		
Density	0.68**	0.59**	0.56**	0.50**	0.61**	0.30*
Strand Size	−0.18 ns	−0.04 ns	−0.18 ns	0.06 ns	−0.01 ns	−0.02 ns
Resin	0.27*	0.40**	0.09 ns	0.29*	0.52**	−0.40**

Note: ns = no significant correlation.
*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

Table 3.
Correlation coefficients of the effect of Strand size, resin content and density on board properties for S1S3 and S2S3.

The internal bond follows a similar pattern to bending properties and has a significant effect (**Figure 5**). A positive correlation between board density and internal bond strength ($r = 0.61^{**}$) was revealed in the correlation analysis (**Table 3**). Because the core layer’s strand size (S3) is smaller, it’s easier to increase the core density, which leads to more intimate contact between strands and hence stronger internal bonding. Higher amount of materials in a board density of 800 kgm^{-3} resulted in a stiffer board. Board density has been studied as one of the elements that affect the internal bonding of strand composite panels, according to [9].

Figure 5 also revealed a significant difference in board thickness swelling. Thickness swelling has a positive correlation with board density ($r = 0.30^{*}$) according to correlation analysis (**Table 3**). A probable reason for this behaviour is that when immersed in water, the greater density zone and finer particles in the core rebound to swell more. When both were constructed with the same wood supply, greater density boards had more compression set than lower density boards, but expanded more following immersion in water, according to [10]. According to [11] in their study found a good linear correlation between density and thickness swelling values. According to [12], OSB thickness swelling not only causes aesthetic problems in some applications, but it is also linked to a reduction in the material’s strength and stiffness. However, decreasing board density could increase board dimensional stability [8].

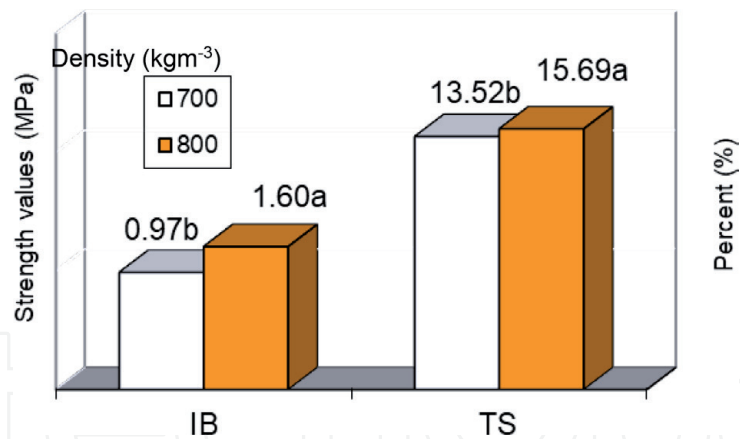


Figure 5.
Effects of board density on internal bond and thickness swelling.

4. Effects of strand size

Figure 6 shows the effect of strand size on bending properties. There is no significant difference on bending properties between combination of strand size of S1S3 and S2S3. Study by [13] discovered that the length of flakes between 5.0 and 7.5 cm had no significant effect on MOR and MOE. This is because smaller strand sizes provide denser structures between strands in the core part, whereas larger strand sizes of S1 and S2 act as stress supporters on the board's face and back. The lower value of bending properties could be due to the distribution of large wood strands. Large strands that should improve bending strength may be heavily disoriented, according to [14], whereas smaller strands that have less influence on bending strength may be well orientated. Due to additional space or void in the core layer and adjacent layers of face and back (**Figure 7**), boards with S1S3 strands have a higher spring back. Boards with S2S3 strands, on the other hand, had less spring back because the S2 strand size was smaller, resulting in less void between the S2 and S3 strands. According to [15], the presence and distribution of macro-voids are governed by the bigger and longer strand, which could be filled by smaller strand size to close the gap. Increased proportions of smaller strands had a negative impact on the mechanical properties of the board in general. The mechanical properties had an insignificant ($r = -0.18$ ns, -0.04 ns, -0.18 ns, and 0.06 ns) correlation

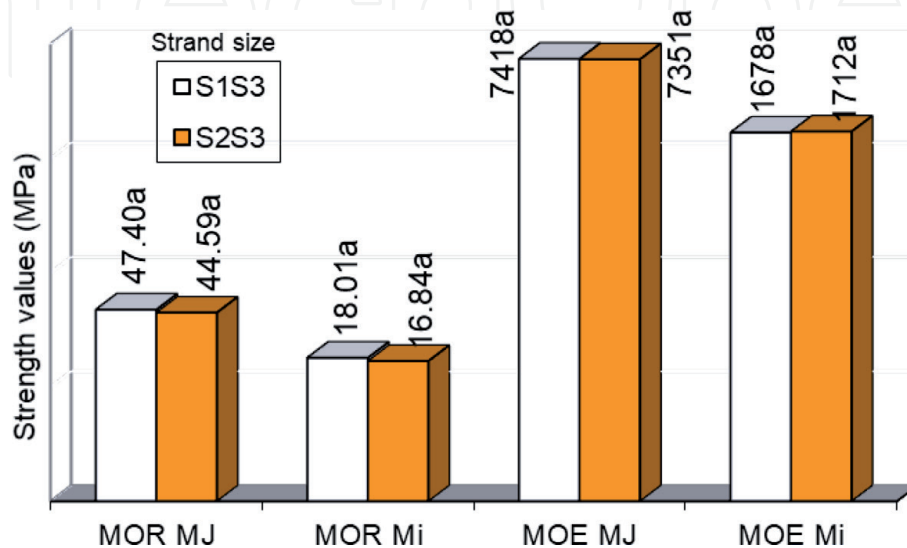


Figure 6.
Effects of Strand size on bending properties.

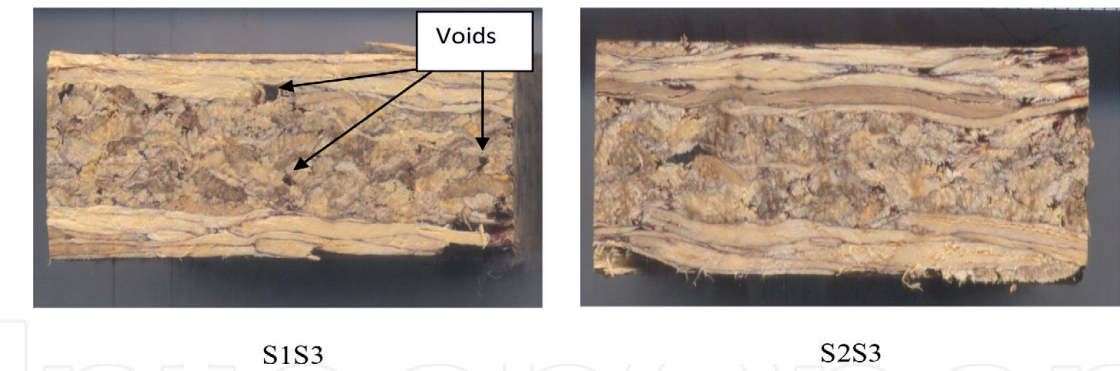


Figure 7.
Voids within the board.

with strand size, according to the correlation analysis (**Table 3**). Study by [16] reported that the MOR and MOE of the boards were not affected greatly with increase in strand size.

One of the important mechanical properties is internal bond strength. The majority of failure in the internal bond test on boards manufactured from S1S3 and S2S3 strand size happened in the wood part, not at the adhesive or glue line (**Figure 8**). The strand size used in the study had no effect on the internal bond strength of the boards, according to the statistical analysis (**Figure 9**). The internal bond strength showed an insignificant ($r = -0.01$ ns) correlation with decreasing strand size, according to the correlation analysis (**Table 3**). Internal bond strength did not increase for boards with 30% fines content, and even reduced as fines content was increased to 45%, according to [17]. This is likely owing to poor bonding, resulting in less resin covering on the surfaces of wood fines. According to [18], wood elements are deposited randomly over the horizontal plane in a more or less layer-by-layer way throughout the hand-forming process, and voids can result between any adjacent elements in any layer. The number of these voids decreases in a unit area within one layer as flake size rises, whereas void size increases.

The strand size showed no significant effect on thickness swelling readings after a 24-hour soak at a 95% significant level (**Figure 9**). The results demonstrate that S2S3 boards with a combination of strand sizes outperformed S1S3 boards with a



Figure 8.
Failure occurred in the wood portion.

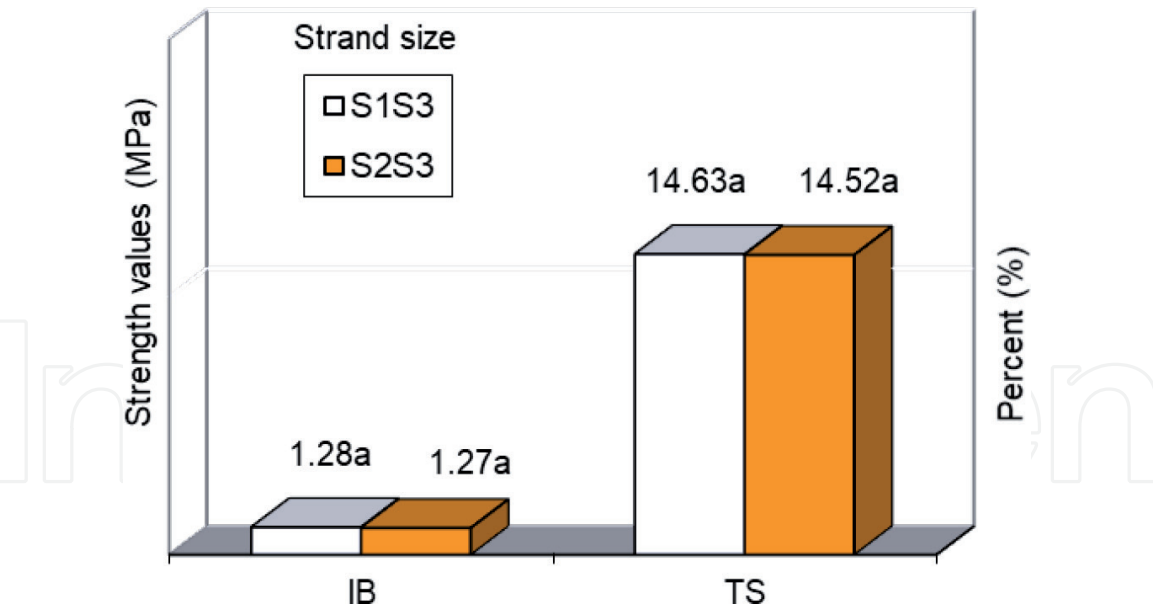


Figure 9.
Effects of Strand size on internal bond and thickness swelling.

variety of strand sizes. The statistical analysis revealed that bigger strand size of S1 and S2 strand sizes in the face and back layers had an excellent role in preventing the board from swelling further, with no significant different between boards manufactured with S1S3 and S2S3 strands. The use of strand sizes of S1, S2, and S3 to maximise recovery without jeopardising board attributes was demonstrated in this treatment technique. The thickness swelling values showed insignificant ($r = -0.02$ ns) correlation with strand size, according to the correlation analysis (**Table 3**). The thickness swelling of smaller strand size at the core center of the OSB was higher than that in the surface region, according to [19].

5. Effects of resin content

The influence of resin content on bending properties is shown in **Figure 10**. MOR values in major axis and MOE values in both major and minor axes shows significant difference according to the statistical analysis. With increased resin content, however, MOR exhibits no significant difference in minor axis. The bending properties of MOR in major axis, MOE in major axis, MOR in minor axis, and MOE in minor axis all show a positive association with increased of resin content ($r = 0.27^*$, $r = 0.40^{**}$, $r = 0.09$ ns, and $r = 0.29^*$, respectively) according to the correlation analysis (**Table 3**). Insufficient resin is available to bond smaller strand sizes, resulting in lower performance by 7% resin content, especially for S2 and S3. Because smaller strand sizes absorb more resin and create uneven resin distribution among smaller strands during the blending process, higher board density and the presence of smaller strand sizes resulted in less bonding contact. Smaller strand sizes or particles resulted in insufficient resin coverage on the surface, resulting in poor strength [20–23]. Nonetheless, in terms of rupture property, the boards with 7% resin content are comparable to boards with 9% resin content. As a result, it might be possible to make the boards with a lower resin level. According to [24], high-cost resin adhesives must be applied at appropriate rates to ensure both the product’s exceptional qualities and its economic viability. When considering reduced application rates, the composite’s improved performance and quality must be maintained.

Figure 11 indicates that increasing the resin content shows a significant difference on internal bond strength. A positive correlation between resin content and

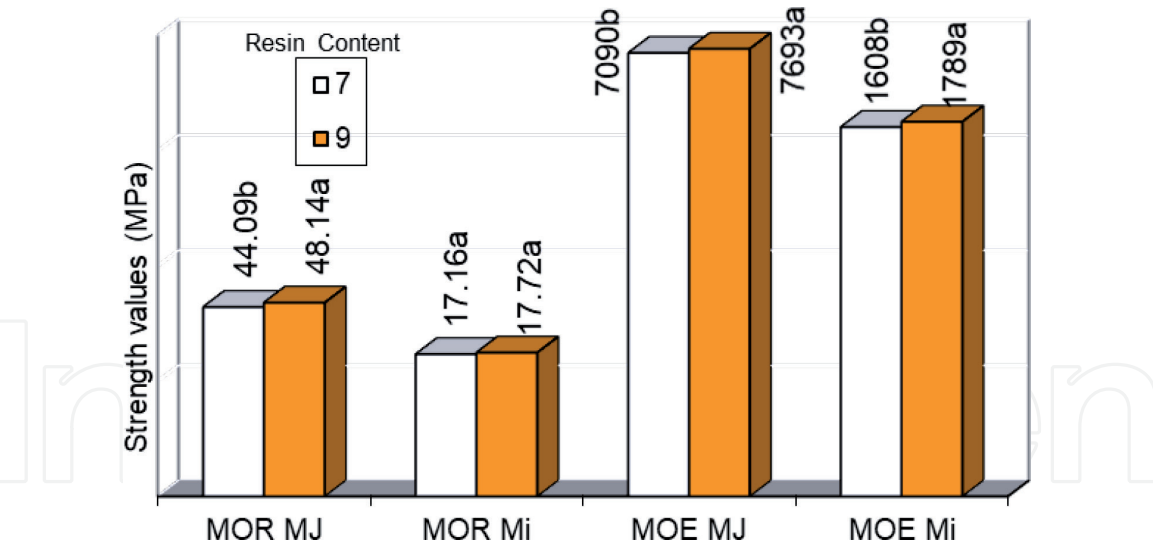


Figure 10.
Effects of resin content on bending properties.

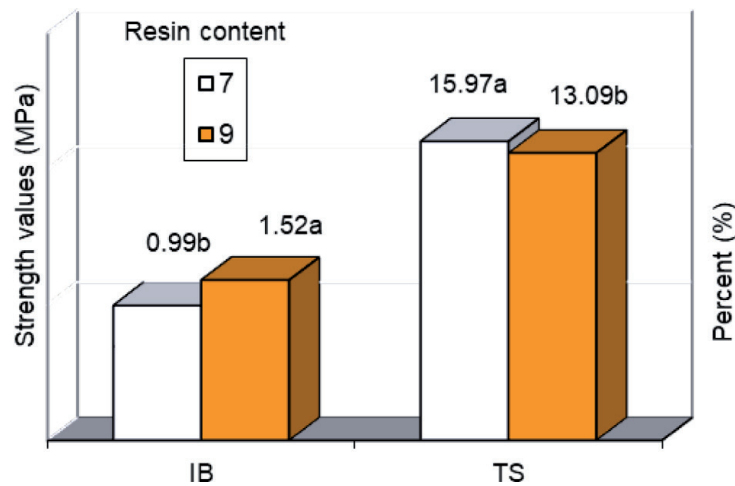


Figure 11.
Effects of resin content on internal bond and thickness swelling.

internal bond strength ($r = 0.52^{**}$) was also discovered in the correlation analysis (**Table 3**), indicating that increasing resin content improved bonding performance. According to the findings, a high resin content is required for successful bonding, particularly for small strand geometry (S3; core layer). When insufficient resin content is employed, high levels of wood fines in the core layer might contribute to lower internal bond strength, according to [17]. According to a study by [20], finer particles in high-density surface zones required far less resin than coarser particles in lower-density core sections. This finding highlights the need of good bond formation, which may be achieved with the right board forming parameters.

After 24 hours of immersion in water, boards with 9% resin content show significantly lower thickness swelling (**Figure 11**). The thickness swelling was reduced by increasing the resin content. When the resin content was increased to 9%, the dimensional stability of the boards was significantly improved (19%). The correlation analysis (**Table 3**) also demonstrated that resin content and thickness swelling have a negative relationship ($r = -0.40^{**}$). When the board is immersed in water, it becomes dimensionally unstable, and increasing the resin content improves the board's resistance to water exposure. According to [25] normally, board decreases in thickness-swell with the increase of resin content.

6. Conclusions

Based on the findings of this study, OSB made from smaller strands size of *Leucaena leucocephala* as core layers demonstrated good physical and mechanical properties. All boards produced were complied with the standard requirement values MOE, MOR, internal bond strength and thickness swelling in accordance to EN 300 Standard for general purpose (type OSB/1) which are used as the sheathing materials for walls, floors, roofs, general construction and renovation work.

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