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Advancing Timber for the Future Built Environment

PERFORMANCE OF PARTICLEBOARD INCORPORATING RECYCLED RUBBER FROM WASTE TYRES

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ABSTRACT: Recycling end-of-life tyres (EOLT) is a critical global challenge, aggravated by the increasing demand for tyres and their short lifespan. This study explored the effect of incorporating recycled rubber particles from EOLT into particleboard on the properties of the resulting panels. Particleboard panels were manufactured and tested for performance according to the Australian Standard AS/NZS 4266.1 (2017), and the results were benchmarked against Australian Standards (AS 1859.1 2017). These tests included bending strength and stiffness, thickness swelling, internal bond, and other key performance properties. The findings demonstrated that incorporating recycled rubber into particleboards reduced bending stiffness and strength as rubber content increased; however, panels with up to 30% rubber still met or exceeded the requirements for standard (STD) and moisture-resistant (MR) particleboard. Additionally, increasing rubber content improved moisture resistance, and all particleboards tested surpassed the moisture resistance requirements for both STD and MR classifications.

KEYWORDS: Recycled Rubber, Particleboard, Circular Economy, Sustainable Materials, Moisture Resistance

1 – INTRODUCTION

Over the past few decades, the rise in vehicle use has significantly increased tyre production, resulting in vast amounts of end-of-life tyres (EOLT) [1]. Therefore, the recycling of end-of-life tyres (EOLT) is a major concern especially as the demand for tyres is increasing and their lifetime is short. In Australia, 67 million EOLT, equating to 537,000 tonnes, are generated in 2023-2024 financial year [2]. In contrast, over 300 million tyres in the European Union and more than 10 billion tyres globally reach the end of their useful lives each year [3, 4]. Globally, about 20% of these end-of-life tyres (EOLT), or roughly 2 billion, are either stockpiled or landfilled [5, 6]. Consequently, the urgency to recycle tyre rubber has intensified over the past 25 years, driven by environmental, economic, social, and legislative pressures. The manufacturing of particleboards from recycled or waste material has increased in recent years due to a shortage in wood feedstock and attractive environmental and economic benefits. Supplementing the manufacture of particleboards with recycled rubber particles could help address this feedstock shortfall, facilitate immediate production growth and recycling opportunities for EOLT. Therefore, the objective of the project was to investigate the technical feasibility of integrating recycled rubber particles sourced from EOLT with wood in the manufacture of particleboards. The study first examined the effect of rubber content on particleboard properties by producing single-layer panels to identify an optimal rubber proportion suitable for use. Subsequently, the stiffness and strength of three-layer particleboards—comprising two face layers and one core layer—were evaluated to assess their performance in more commercially relevant configurations.

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2 – MATERIALS & METHODS

Softwood timber particles were acquired from a local particleboard manufacturer. The particles were sieved through 0.5 mm (35 mesh), 1.7 mm (12 mesh), 2.8 mm (7 mesh) and 5 mm sieves. Rubber particles were acquired from two different producers. One supplied 30 mesh rubber particles, less than 0.595 mm in size, while the other provided with particle sizes ranging from 0.5 mm to 1.5 mm and 1.5 mm to 2.2 mm, respectively. The rubber particles were produced from a mix of car and truck tyres and were classified as "Small", "Medium", and "Large". The different wood and rubber particle sizes are illustrated in Figure 1.

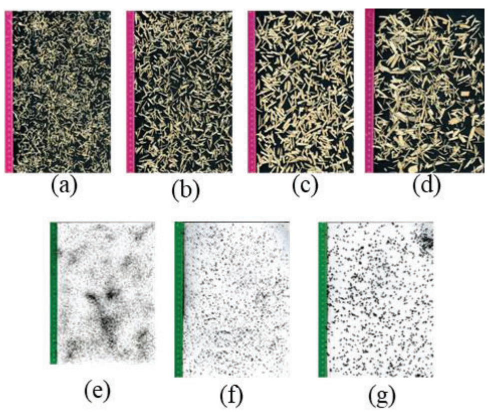

Figure 1. Particle sizes for wood (a) Small: 0.5-1.7 mm, (b) Medium: 1.7-2.8 mm, (c) Large: 2.8-5 mm, (d) X-Large: > 5 mm, and Rubber (e) Small: < 0.595 mm (30 mesh), (f) Medium: 0.5-1.5 mm, (g) Large: 1.5-2.2 mm

For the single layer particleboard manufacturing, small wood particles and medium rubber particles were used. To investigate the effect of proportion of rubber on particleboard properties, the rubber content was varied from 0 to 50% with 10% increment. For three layers particleboard, the core and face materials were supplied by industry were used without sieving. Two types of structural adhesives, MDI (Methylene Diphenyl Diisocyanate) and MUF (Melamine Urea Formaldehyde), were used in the manufacturing process. For all single layer panels 10% adhesive was used. Three-layer panels were manufactured with 10% adhesive in the face and core except one configuration, which had 10% adhesive in the face and 7% in the core, to be used as a comparison. The rubber content in the face varied between 0 - 10% for a core rubber content of 20%. For a core rubber content of 30%, rubber content in the face ranged from 0 - 20%. The measured moisture content during manufacturing across the batches in the core and face ranged between 0.69 - 2.92% and 7.98 - 10.21%, respectively.

Rubber and wood particles were mixed in a custom-made mixer for 4 minutes to achieve a homogeneous blend. Adhesive was then slowly introduced over 30 seconds to 1 minute while mixing continued, followed by an additional 10 minutes of blending to ensure uniform particle coating. The prepared material was then weighed to achieve the desired target density and placed into a 300 mm × 200 mm wooden mould for cold press. The mixture was cold pressed at 1 MPa for 30 seconds.

The partially pressed mat and aluminium frame (12mm thick for single layer and 16mm thick for three layers panels) were then transferred to a hot press, where sufficient pressure was applied to bring the platen into full contact with the frame, forming panels approximately 12 or 16mm mm thick. Pressing temperature and time varied depending on the specific sample conditions. After hot pressing, the particleboards were cooled on a rack and conditioned at 20°C and 65% relative humidity prior to mechanical and physical testing.

The thickness swelling, internal bond and bending Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) were measured for each manufactured sample following the methodology in the AS/NZS 4266.1 (2017) [7]. The results were benchmarked against the Australian Standards AS 1859.1 (2017) [8] that classifies particleboards into three types, namely standard (STD), moisture resistance (MR) and high performance (HP).

3 – RESULTS & DISCUSSION

Figure 2 and Figure 3 shows the influence of the percentage of rubber content on the MOE and MOR, respectively, of particleboard samples manufactured using MDI and MUF adhesives. Increasing rubber content adversely affected MOE and MOR, however, samples containing up to 30% rubber met the requirements for standard (STD) and moisture resistant (MR) particleboards. None of these panels fully met the MOE requirements for HP particleboards for these single-layer panels.

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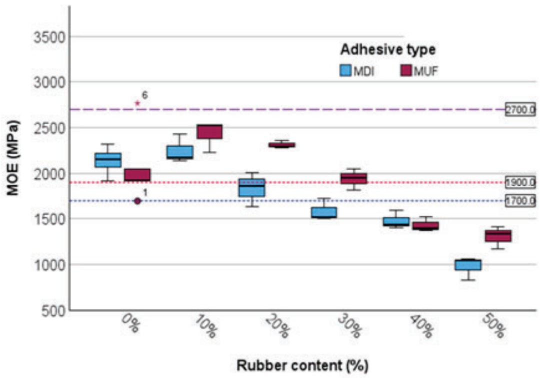

Figure 2. Influence of glue type and rubber percentage on MOE of particleboard samples. The broken horizontal lines from the bottom represent STD, MR, and HP particleboard standards requirement, respectively.

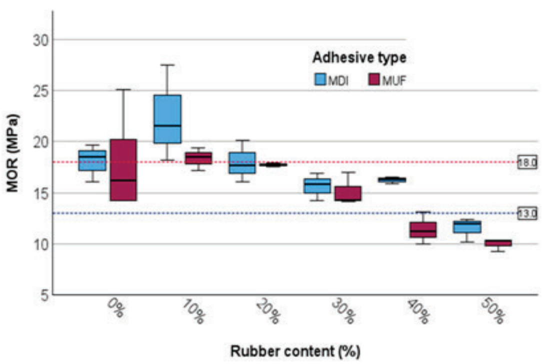

Figure 3. Influence of glue type and rubber percentage on MOR of particleboard samples. The broken horizontal lines from the bottom represent STD/MR and HP particleboard standards requirement, respectively.

Figure 4 shows that an increased percentage of rubber positively impacted the thickness swelling of both MDI and MUF bonded samples, with all samples surpassing the requirements for MR particleboards. All MDI and MUF samples containing 30% - 50% rubber, had passed the MR and HP requirements. The test results indicate the thickness swelling observed between 30% and 50% rubber percentages for both adhesives was similar. Unlike the MOR and MOR, the samples manufactured using MDI typically performed better in terms of thickness swelling. Rubber improved moisture resistance, with samples containing 30% or more rubber meeting or exceeding MR and high performance (HP) requirements.

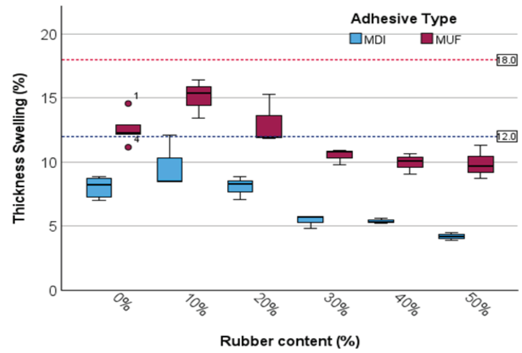

Figure 4. Influence of glue type and rubber percentage on thickness swelling of particleboard samples. The broken horizontal lines from the bottom of the graph represent HP and MR standards, respectively.

Figure 5 shows the results for the three-layer particleboard with various rubber content combination in the face and core layer. The three-layer particleboard panels indicate significant variations in mechanical properties based on different rubber and adhesive content configurations. As expected, the control panels with no rubber (0% F, 0% C, 10% A) exhibited the highest mean MOE compared to all other panels and the mean MOE decreased as the rubber content increased.

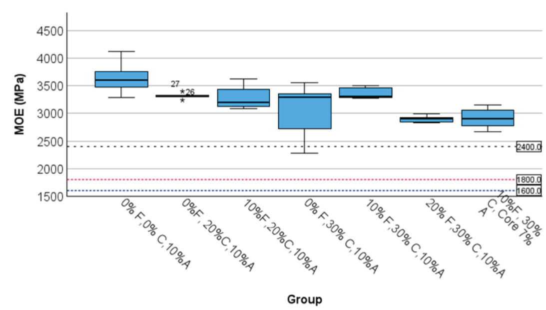

Figure 5. Influence of varying levels of rubber particle contents in the face and core layers and amount of adhesive on MOE of three-layer particleboard samples. The broken horizontal lines from the bottom of graph represent STD, MR, and HP particleboard standards requirement, respectively.

The panel with 10% face and 30% core rubber content and 10% adhesive (10% F, 30% C, 10% A) displayed the second-highest mean MOE that differs not significantly from all other rubber containing panels except those containing 10% face rubber content and 7% core adhesive (10% F, 30% C, 7% A) and 20% face and 30% core rubber content with 10% adhesive (20% F, 30% C, 10% A).

Panels containing 20% face rubber content and 30% core rubber content (20% F, 30% C, 10% A), as well as those with decreased adhesive content (10% F, 30% C, 7% A), exhibited the lowest average MOE. However, all samples passed STD/MR/HP standard requirements.

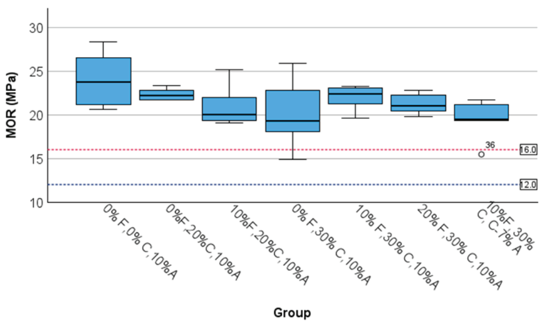

Figure 6. Influence of varying levels of rubber particle contents in the face and core layers and amount of adhesive on MOR of three-layer particleboard samples. The broken horizontal lines from the bottom of graph represent STD/MR and HP particleboard standards requirement, respectively.

MOR of the particleboard panels across various configurations is presented in Figure 6 . As expected, panels with no rubber content and 10% adhesive (0% F, 0% C, 10% A) demonstrated the highest average MOR, which did not significantly differ from all other groups except for samples containing either 0% or 10% face rubber content and 30% core rubber content with 10% and 7% adhesive percentages, respectively. The panels with different proportions of rubber particles in the face and core layers did not show statistically significant differences from each other.

4 – CONCLUSION

The results demonstrate that rubber particleboard can be manufactured without significant change in the standard manufacturing process and meet market regulations for STD and MR particleboard. Increasing rubber content negatively impacted MOE and MOR, and positively impacted thickness swelling. However, samples with less than 30% rubber met STD and MR particleboard requirements. Further investigations on market analysis, financial analysis, fire resistance, and regulatory testing are recommended to advance the product's development and adoption in collaboration with industry partners.

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