A novel method to evaluate a bio-based, zero thickness adhesive and its application to densified pine wood

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Introduction

Wood is a renewable resource valued for its strength, lightness, and durability, making it popular across various industries. However, its heterogeneity, influenced by factors such as species, growth conditions, and age, presents challenges [1]. Densified wood, known for enhanced mechanical properties, offers a solution for more predictable performance in structural uses. This research examines the strength and fracture properties of natural and densified pine wood, exploring their potential as sustainable composite alternatives in demanding sectors [2].

Experimental methodology

Densification procedure

The densification of wood involves a three-step process. Initially, wood blocks are treated in a 2.5 M NaOH and 0.4 M Na2SO3 solution and boiled for seven hours, enhancing cell wall penetration and volume. Subsequently, they're boiled in deionized water to extract the catalyst. The final thermo-mechanical step compresses the wood in a hot-press at 3 MPa and 100°C for 24 hours, increasing density and strength without harming the fibers.

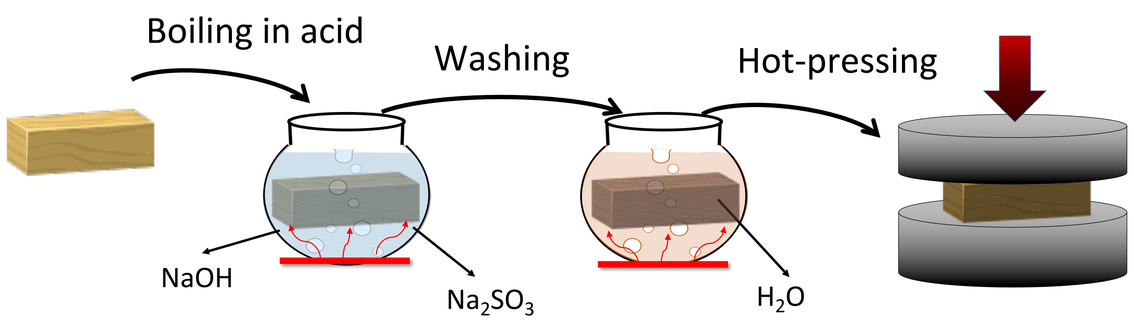

Figure 1 – Densification procedures.

Joint testing:

SLJ specimens, 25 mm wide, were bonded using Fabricol 200 AD to achieve direct substrate adhesion and fulfill the bio-adhesive's zero-thickness requirement. Tested under static loading at a steady rate of 1 mm/min, various densified wood thicknesses (0, 4, 5, 6 mm) were employed to assess the impact of the tough layer on joint performance. Details of the joint geometry and configurations are shown in Figure 2.

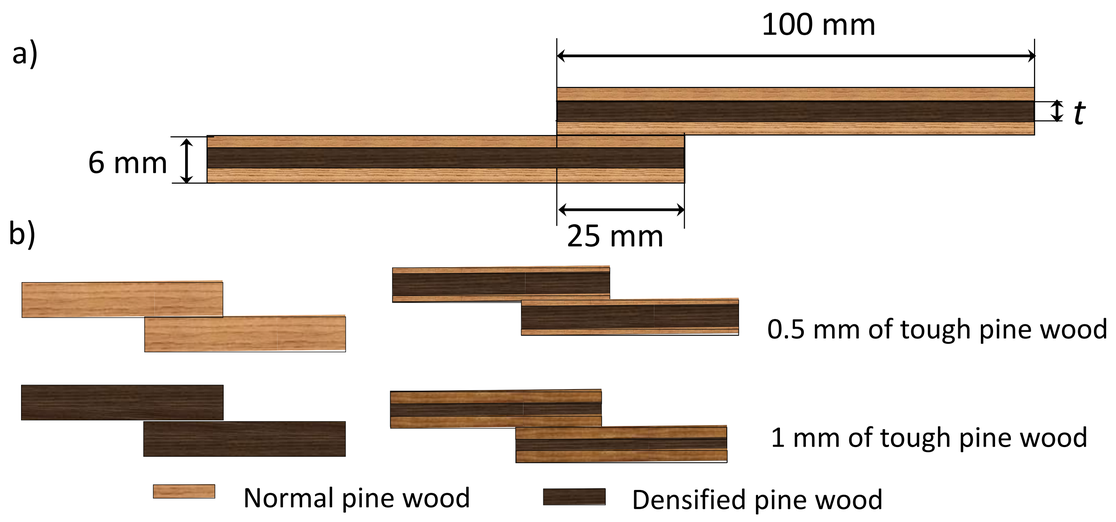

Figure 2 – SLJ geometry, *t* is the densified wood thickness (0,4,5,6 mm) a), tested joint configurations b).

Discussion

The development of toughened adherends has been a significant advancement in materials engineering, allowing for the creation of joints characterized by their superior energy absorption capabilities. This innovation is further enhanced through the use of hybrid toughened-densified adherends, which have demonstrated a remarkable increase in joint strength. When compared to conventional joints made with regular pine substrates, these hybrid adherends have shown an increase in strength of more than 85%, marking a substantial improvement in the durability and performance of such materials.

Experimental results

Under quasi-static conditions, the experimental results in Figure 3 reveal the load-displacement behavior of the joints. Additionally, Figure 4 presents digital images of the fracture surfaces, providing insight into the joint behavior.

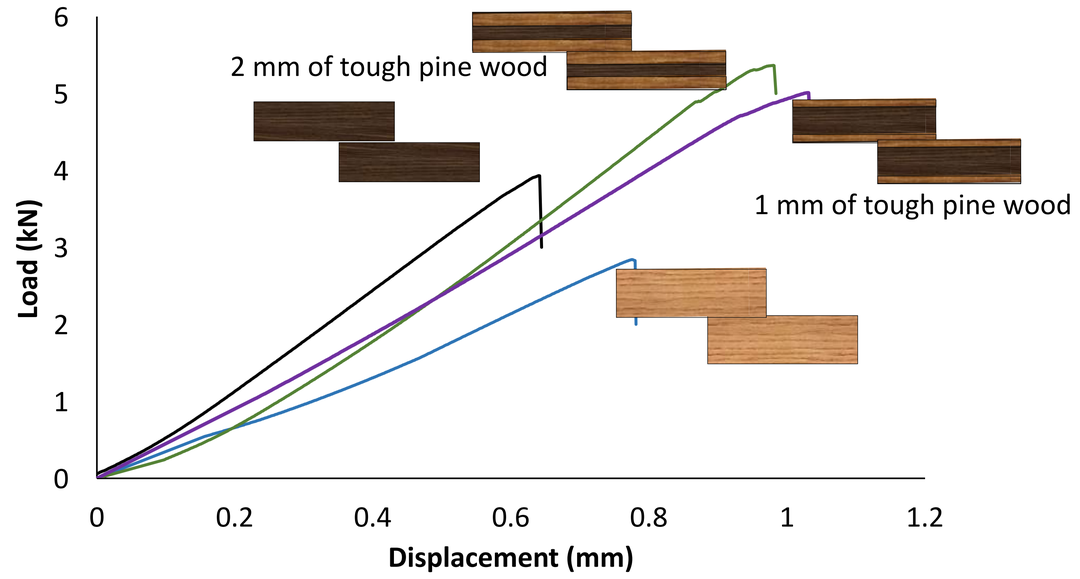

Figure 3 – Load displacement behavior of the single lab joints.

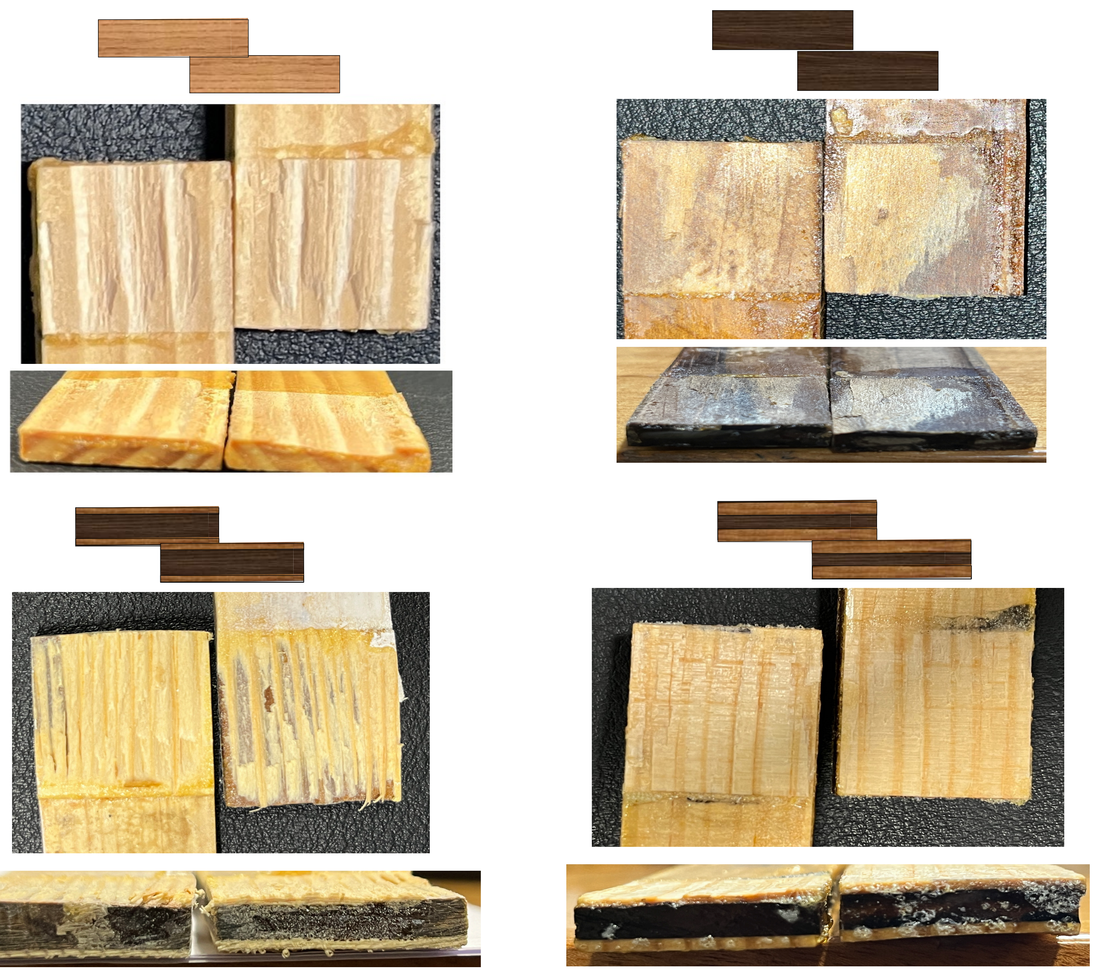

Figure 4 – Single lap joints fracture surfaces.

Conclusions

The toughened adherends allowed to obtain a joint with highest energy absorption. The hybrid toughened-densified adherends increased the joint strength more than 85% compared to regular pine substrates.

References

[1] Jalali, S., Borges, C., Carbas, R., Marques, E., Akhavan-Safar, A., Barbosa, A., Bordado, J. and da Silva, L., 2024. A Novel Technique for Substrate Toughening in Wood Single Lap Joints Using a Zero-Thickness Bio-Adhesive. *Materials*, *17*(2), p.448.

[2] Jalali S, Borges CD, Carbas RJ, Marques EA, Bordado JC, da Silva LF. Characterization of Densified Pine Wood and a Zero-Thickness Bio-Based Adhesive for Eco-Friendly Structural Applications. Materials. 2023 Nov 13;16(22):7147.

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