Strength improvements of wooden joints by using tough layer technique

S Jalali (INEGI, Portugal) | RJC Carbas | EAS Marques | LFM da Silva

- ***Wood as a Sustainable Material***

Wood is a renewable material appreciated for its strength, lightness, and durability, which makes it widely used in many industries. However, its variability, influenced by factors like species, growth conditions, and age, can pose challenges [1]. Densified wood, with its improved mechanical properties, provides a solution for more consistent performance in structural applications. This study investigates the strength and fracture characteristics of natural and densified pine wood, evaluating their potential as sustainable composite options for use in demanding industries [1].

- ***Densification Procedure***

The wood densification process consists of three steps. First, wood blocks are immersed in a solution of 2.5 M NaOH and 0.4 M Na_2SO_3 and boiled for seven hours to improve cell wall penetration and expand volume. Next, the blocks are boiled in deionized water to remove the catalyst. Finally, the wood is compressed in a hot press at 3 MPa and 100°C for 24 hours, increasing its density and strength while preserving the integrity of the fibers.

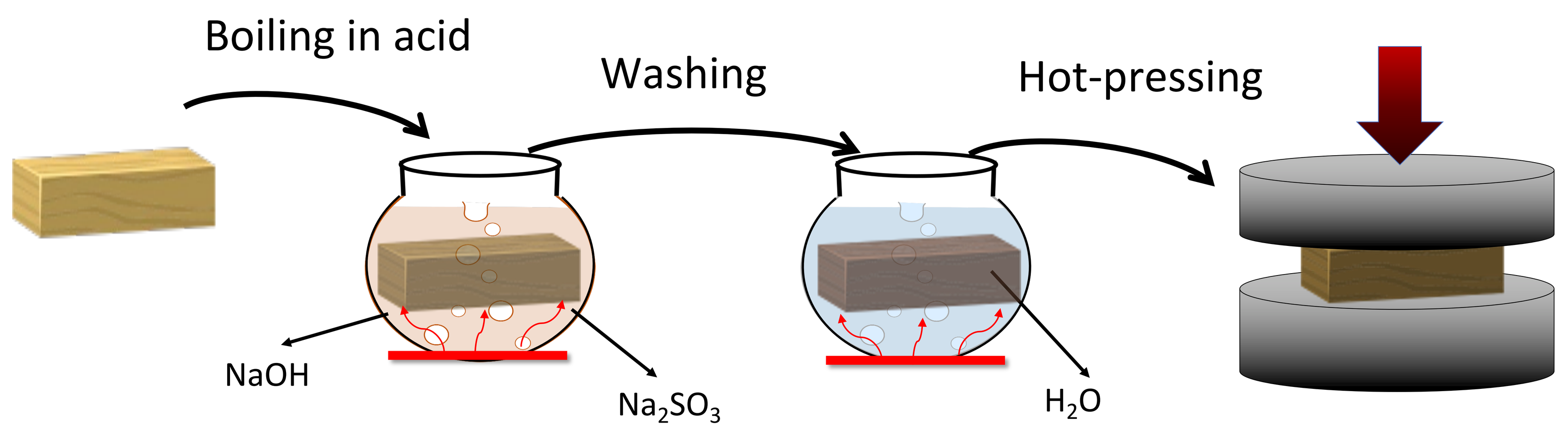

Figure 1 – Densification procedures.

- ***Joint Testing***

SLJ specimens, each 25 mm wide, were bonded with Fabricol 200 AD to ensure direct adhesion to the substrate and meet the bio-adhesive's zero-thickness requirement. The specimens were tested under static loading at a constant rate of 1 mm/min, using different densified wood thicknesses (0, 4, 5, 6 mm) to evaluate the effect of the tough layer on joint performance. The joint geometry and configurations are detailed in Figure 2.

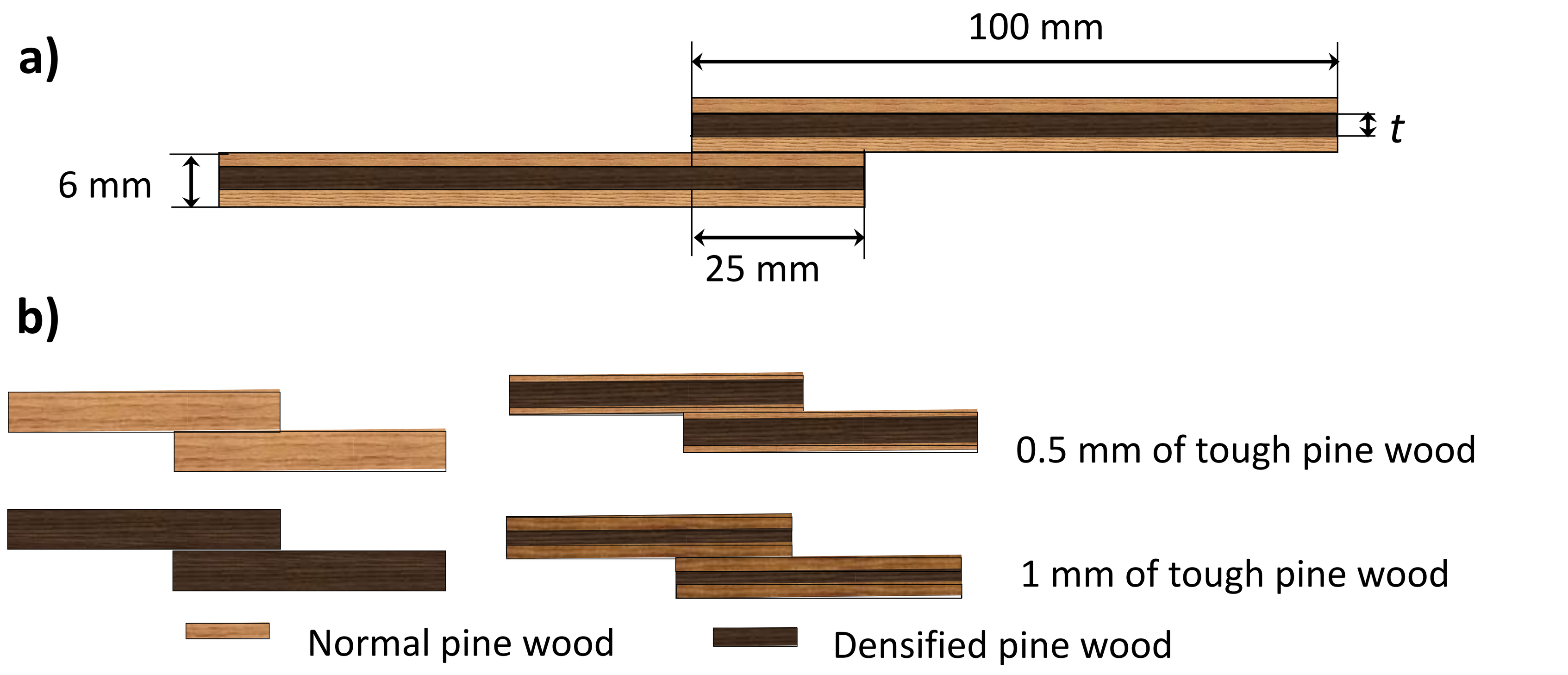

Figure 2 – SLJ geometry, *t* is the densified wood thickness (0,4,5,6 mm) a), tested joint configurations b).

- ***Discussion***

The development of toughened adherends has been a major breakthrough in materials engineering, enabling the creation of joints with enhanced energy absorption properties. This advancement is further improved with the use of hybrid toughened-densified adherends, which have shown a significant increase in joint strength. Compared to traditional joints made with standard pine substrates, these hybrid adherends exhibit over an 85% increase in strength, representing a notable improvement in the durability and performance of these materials.

- ***Peel Stress Analysis***

The analysis of peel stress distributions emphasizes the role of substrate modification in improving adhesive-bonded joint performance. Toughened joints show high peel stresses but risk early failure due to stress concentrations, while densified joints offer more uniform stress distribution and better durability.

Hybrid joints, combining densified cores and toughened outer layers, provide optimal performance by reducing stress concentrations, with 1 mm thick outer plies offering a slight advantage in load distribution.

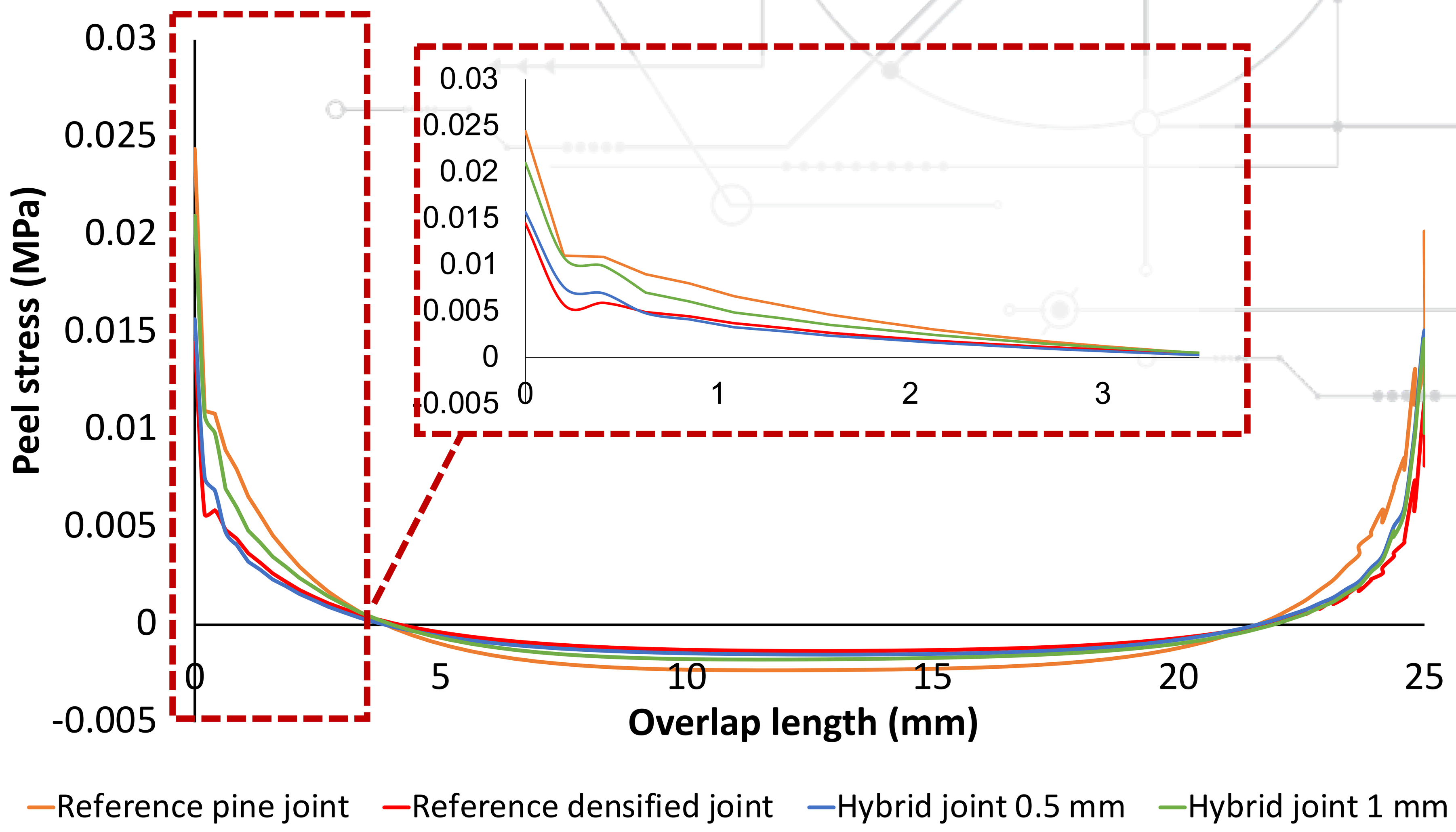

Figure 3 – Peel stress distribution along the overlap length

- ***Load-Displacement behaviour***

Under quasi-static conditions, the experimental results shown in Figure 4 illustrate the load-displacement behavior of the joints and digital images of the fracture surfaces, offering a closer look at the joint behavior.

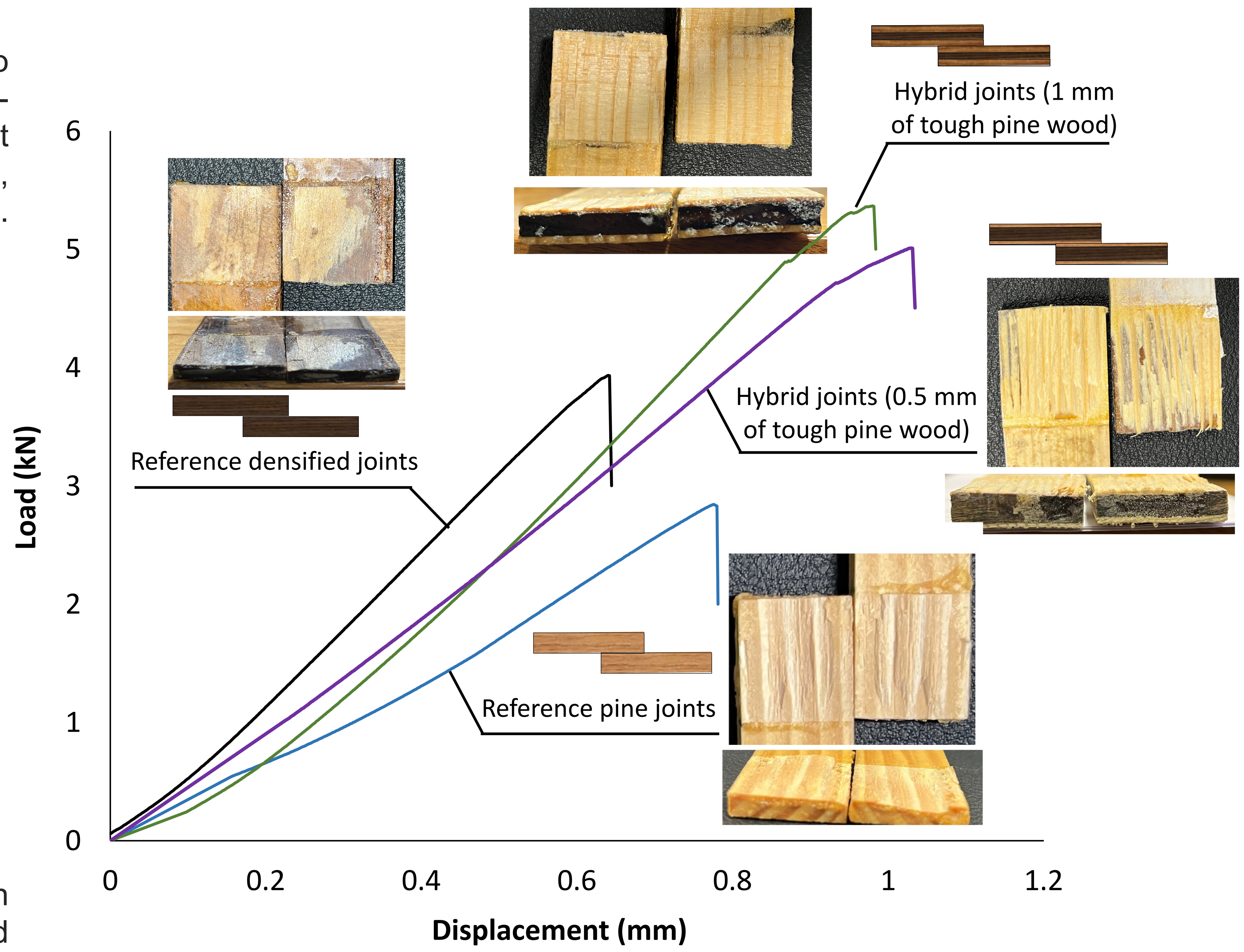

Figure 4 – Load displacement behavior of the single lab joints.

- ***Conclusions***

This study highlights the significant impact of a novel toughening method on the performance of wood joints bonded with bio-adhesives. Toughened adherends demonstrated superior energy absorption, while hybrid toughened-densified adherends enhanced joint strength by over 85% compared to standard pine. The toughening method improved failure load, absorbed energy, and stiffness under various loading conditions. Fracture analysis indicated a shift in failure mechanisms from delamination to fiber breakage, revealing the joint's superior strength. These findings advance the development of durable, sustainable wood joints for high-performance applications.

- ***Acknowledgements***

The authors would like to thank FCT for funding this work through grant 2022.12426.BD and Project No. PTDC/EME-EME/6442/2020 "SmartEcoStruct ".

- ***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.

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
BJ 2024 1ST INTERNATIONAL CONFERENCE ON BIO-JOINING
FCT Fundação para a Ciência e a Tecnologia