Development and mechanical characterization of a high-content bio-based adhesive for sustainable cork agglomerates

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INTRODUCTION

Sustainability has become an important topic in modern manufacturing, and with it there is a growing use of bio-based materials replacing synthetic, petrochemical-based ones. Cork is a naturally renewable and biodegradable material, making the cork industry a particularly good candidate for this kind of transition. However, the adhesives commonly used to produce cork agglomerates are derived from petroleum, which significantly offsets the environmental benefits of the material itself. The main purpose of this study was to develop and validate an ecological adhesive suitable for cork agglomerate, in order to obtain more sustainable natural cork composite joints.

The research was carried out in two stages. The first involved developing the adhesive formulation through an iterative process, arriving at a composition where at least 70% of the raw materials are either natural or recycled in origin. In the second stage, the mechanical behaviour of the adhesive was evaluated using standardized compression and flexural tests, complemented by joint configuration assessments such as single lap joint (SLJ) testing, in order to compare stiffness and strength. Overall, the results show that this bio-based adhesive performs in terms of mechanical properties and structural integrity, making it a good and practical eco-friendly option for the industry.

EXPERIMENTAL DETAILS

SLJ specimens, 25 and 50 mm wide, were bonded using adhesive developed by Professor João Bordado, from Instituto Superior Técnico. It is a polyurethane-based bio-adhesive, with 70% of its content derived from natural sources. It is known to provide good adhesion to both wood and cork, and fulfil the bio-adhesive's zero thickness requirement.

The SLJ's were tested under static loading at a steady rate of 1 mm/min. Details of the joint geometry and configurations are shown in Figure 1.

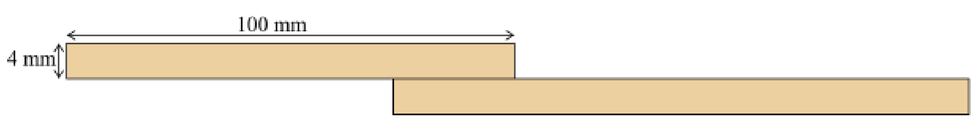


FIGURE 1. SLJ specimen geometry.

The geometry of the single lap joint is illustrated in Figure 2. For the cork-coated specimens, the cycle lasted double the time, because the process of bonding the coating to the wood substrate required the same curing cycle used in joint preparation. The thickness of the adhesive layer was not controlled, because the bio-adhesive in use can only be successfully cured in a zero thickness condition due to its very low viscosity.

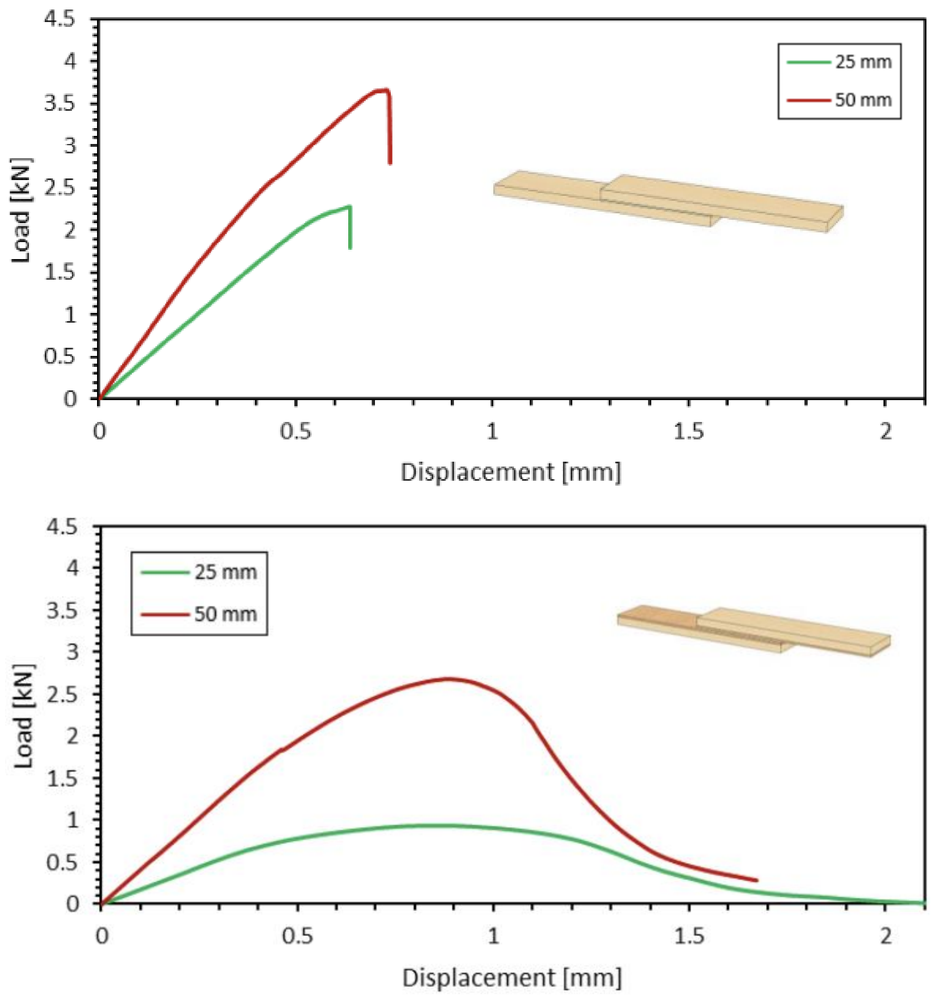
Wood SLJ

Wood/Cork SLJ

FIGURE 2. SLJ specimen configurations.

RESULTS

The joints were manufactured and subjected to quasi-static (1 mm/min) test conditions using an Instron 3360 universal testing machine. Figure 3 shows the load-displacement failure load as a function of overlap length and the failure mechanism.



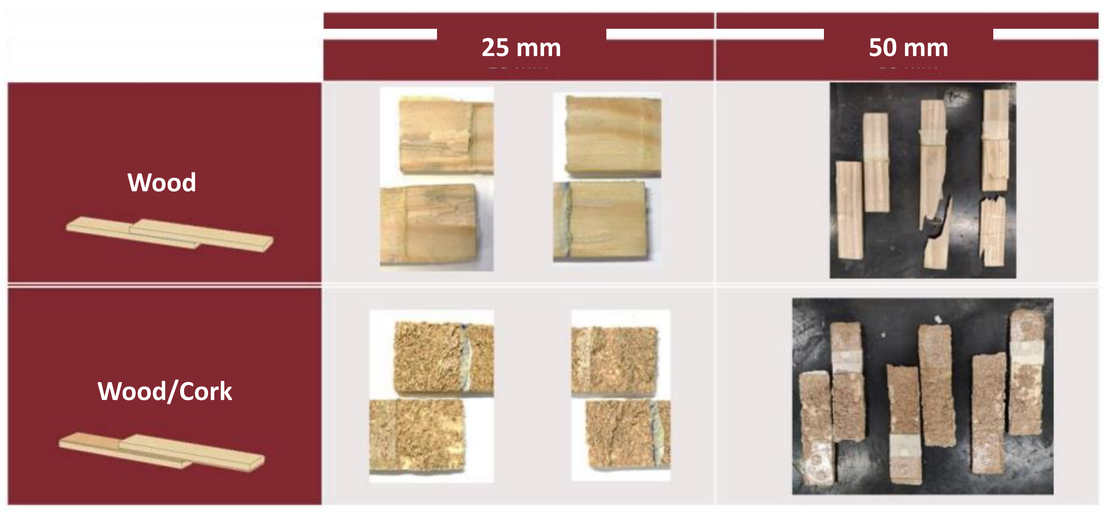


FIGURE 3. Load-displacement curves and failure mechanisms for both type of joints and overlaps.

CONCLUSION

- Joint testing demonstrated that increasing the overlap length from 25 mm to 50 mm had the most significant impact on wood/cork samples, which outperformed others in energy absorption due to a more favorable stress field provided by the larger overlap.
- For the 50 mm overlap, the energy absorption of wood/cork joints increased by 85% compared to natural wood substrate joints and by 45% compared to densified wood substrate joints, indicating that cork can introduce advantageous properties for high-energy absorption applications.
- Only the wood/cork samples exhibited a consistent failure mode, whereas increasing the overlap length promoted wood failure in both the natural wood and densified wood samples.

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