Bio-based approaches to enhance the joint strength of wood single-lap joints

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Bio-adhesives are sustainable, but are they tough enough for real service?

A moisture-curing polyurethane bio-adhesive (70 % natural resources) bonds wood well.

This work toughens the wood substrates themselves and tests single-lap joints under repeated low-energy impacts.

Why wooden bonded joints fail

Single-lap joints combine shear and peel at the overlap ends, and wood is weak across its grain. Key factors include:

Weak across the grain
Radial and tangential strength is far below longitudinal.

Peel stress at the overlap ends
Eccentric loading drives delamination between plies.

A toughening strategy

Two wood types—pine and oak—were used to evaluate a bio-based polyurethane adhesive. Four configurations were tested.



Ref. pine
6 mm pine

Ref. oak
6 mm oak

Hybrid pine
pine | oak | pine
1 + 4 + 1 mm

Hybrid oak
oak | pine | oak
1 + 4 + 1 mm

Experimental results

The specimens were assembled into single-lap joints (25 mm overlap) and cured at 100°C under 30 bar. At least three repetitions per test.

Instron 3367 · 1 mm/min

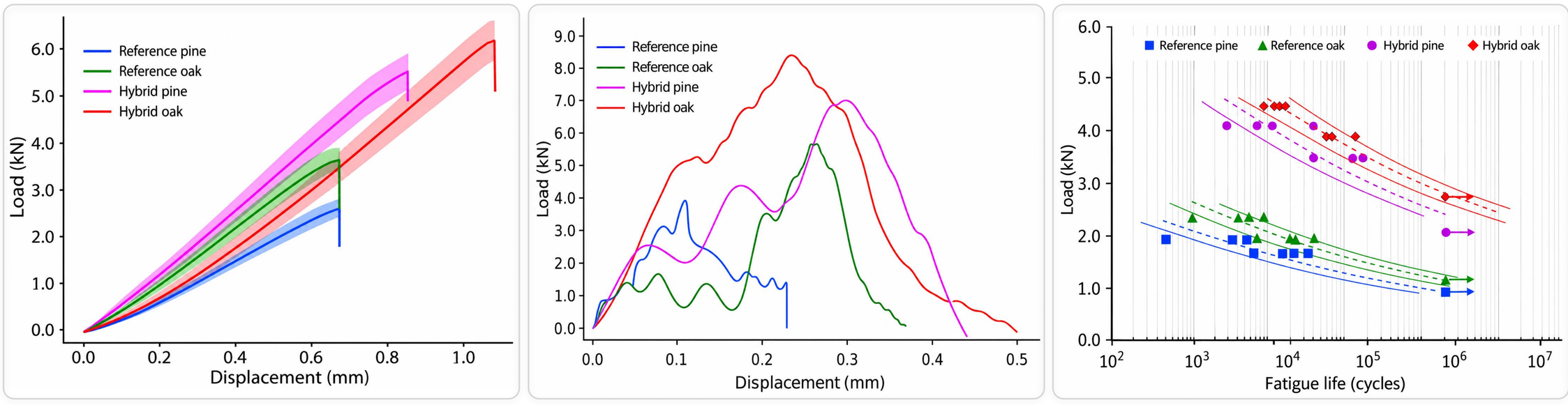
Quasi-static
A 30 kN load cell capacity was utilized to determine the static strength of the joints.

Drop weight · 10 kg · 3 m/s

Impact
A 50 kN load cell and high-speed data acquisition recorded impact force–time.

Instron 8801 · square wave · R = 0

Impact fatigue
Pmax at 80, 70, 60 % of static strength, then residual strength after 10^6 cycles at 50 %.



Key results

The hybrid oak joint outperformed the reference configurations across all evaluated mechanical tests.

2.4× strength
6.0 kN vs 2.5 kN for ref. pine.

2.1× strength
8.5 kN vs 4.0 kN for ref. pine.

+25 % load ratio
vs ref. pine and +15 % vs ref. oak.

Conclusions

- **Best design:** oak outer layers on a pine core gave the highest strength, impact energy and fatigue resistance.
- **Mechanism:** stiff, toughened hardwood skins spread stress; the softer core dissipates energy.
- **Failure shift:** interlaminar wood cracking at high loads becomes cohesive adhesive failure at long lives.

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