# Unlocking physical and mechanical properties of Japanese knotweed for bio-composite applications

## Introduction

Japanese Knotweed (*Fallopia japonica*) represents a significant ecological and economic challenge across the UK, yet its rapid proliferation and abundant biomass also present compelling opportunities for sustainable material innovation. This study investigates the mechanical properties of this invasive species to assess its potential as a feedstock for bio-composite materials. We performed compression, three-point bending, shear, and tension tests on stem sections, systematically evaluating variations in mechanical behaviour across different heights and nodal locations along the stem's vertical axis. These tests were conducted using methodologies adapted from ISO 22157 – a standard protocol established for bamboo characterisation – to ensure robust data acquisition and comparability. The results will contribute to a more comprehensive understanding of Japanese Knotweed's mechanical properties and inform future research into optimised bio-composite formulations.

## Methodology

To characterise the mechanical properties of Japanese Knotweed stems, we collected over 300 samples from a single site in Gateshead, stratified into top, middle, and bottom sections representing varying heights. All mechanical testing was conducted using adapted procedures based on ISO 22157 to ensure standardised data acquisition.

**Bending Testing**

Three-point bending tests were conducted using a hybrid method, combining the loading procedure outlined in ISO22157 with the apparatus specifications described in ISO178. To minimise the risk of kinking, outer nodes were aligned with the support points, while the central load was applied directly over the central node. Testing was performed on an Instron 5585H, beginning with a 5 N preload, followed by a loading rate of 3 mm/min until 80% of the specimen's ultimate load was reached post-failure. Bending strength and bending modulus were later calculated.

**Compression Testing**

Knotweed specimens were cut into 40 mm segments and placed beneath a self-levelling device accompanying the Instron 5585H loading platen to ensure only vertical forces were applied. An initial preload of 5 N was applied, followed by a loading rate of 0.6 mm/min until the specimens reached 35 % of their post-failure ultimate strength. Compressive strength, modulus of elasticity and stiffness parallel to fibres were subsequently calculated after testing.

**Tensile Testing**

Samples were shaped into a modified "dog-bone" configuration to promote central failure and affixed with softwood end tabs to avoid crushing. Tests were performed using an Instron 5585H universal testing machine, with failure load and displacement recorded at high resolution. Tension strength and modulus of elasticity were calculated based on cross-sectional area and stress-strain behaviour at 20 - 60 % of peak load.

**Shear Testing**

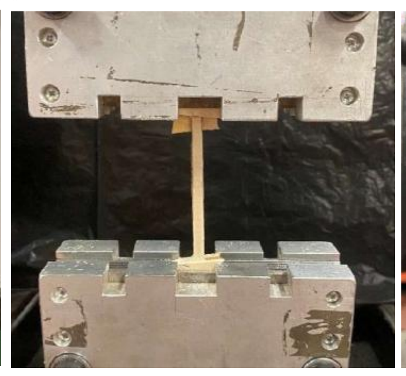
Shear tests were conducted using a custom-fabricated shear plate and followed ISO22157 criteria, modified to account for the smaller diameter of knotweed. Specimens were cut to 30 mm to encourage shear failure. Tests were again conducted using the Instron 5585H, and results were processed to derive conservative estimates of shear strength based on failure load and cross-sectional geometry.

**Moisture Content**

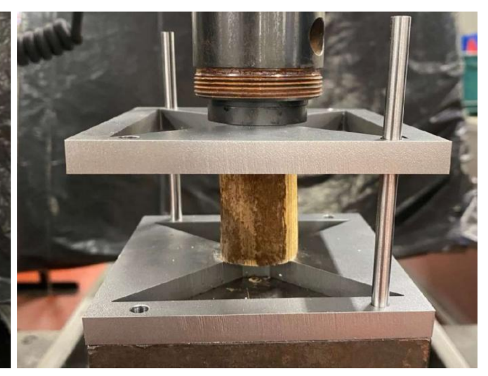
Post-test specimens were oven-dried at 105 °C until mass stabilisation. Moisture content was calculated using the difference between initial and final mass, as per ISO22157.

Bending

Compression



Tensile



Shear

## Bending Test Results

33 bending tests were completed on knotweed specimens with varying lengths, all containing 3 nodes. Testing procedures followed ISO22157 supplemented by the apparatus set up laid out in ISO178.

- **Bending strength** and **bending modulus** were found to have mean values of **15.91 MPa** and **2.67 GPa** respectively
- Failure generally occurred due to bending however, some samples experienced kinking or complete fracture. These samples were removed from the bending strength analysis yet could remain for bending modulus.
- **Sample B23** with its unique origin from the **upper section of the stem**, exhibited **significantly higher strength** compared to the more common lower sections.

Additionally, Figure 1 shows **no correlation** between knotweed's **bending properties** and **moisture content**. The Ashby chart reveals knotweed has relatively low bending strength when compared to other wood species however, sample B23 suggests upper sections could exceed that of balsa wood.

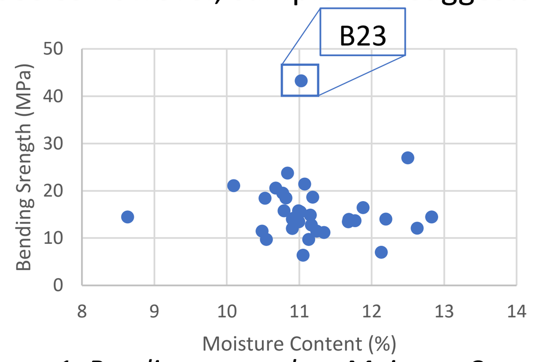



*Figure 1: Bending strength vs Moisture Content.*

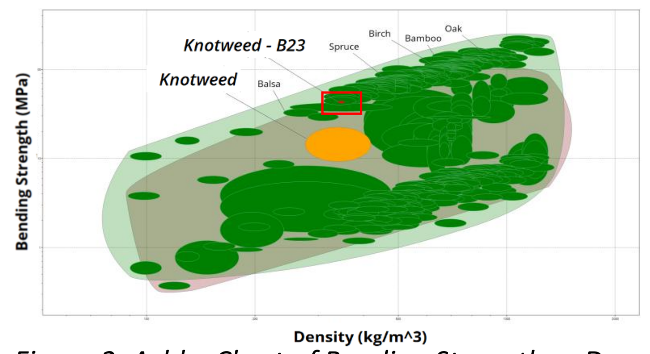



*Figure 2: Ashby Chart of Bending Strength vs Density.*

## Compression Test Results

A total of 95 compression tests were conducted on samples spanning the top, middle and bottom of the stem, including nodal and internodal sections.

- **Top internodal sections** displayed the greatest compressive strength and modulus of elasticity with **average values of 31.87 MPa and 2.165 GPa**, respectively.
- Compressive properties appear to correlate with stem height, with **bottom sections** displaying the **lowest compressive strength** and **modulus of elasticity** at **17.04 MPa** and **0.876 GPa**.
- Global failure primarily occurred in nodal sections due to the diaphragm redistributing vertical forces laterally, whereas internodal sections often failed by localised kinking.

Further comparative analysis revealed that knotweed had strength properties similar to those of balsa wood, suggesting it could be utilised in similar low-weight composite applications

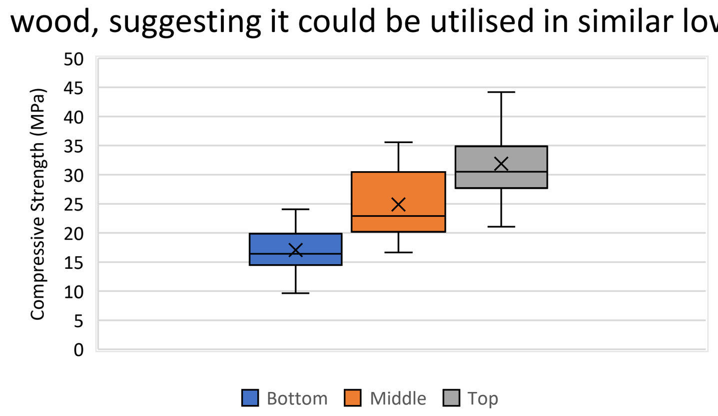



*Figure 3: Compression Strength of Bottom, Middle and Top Sections.*

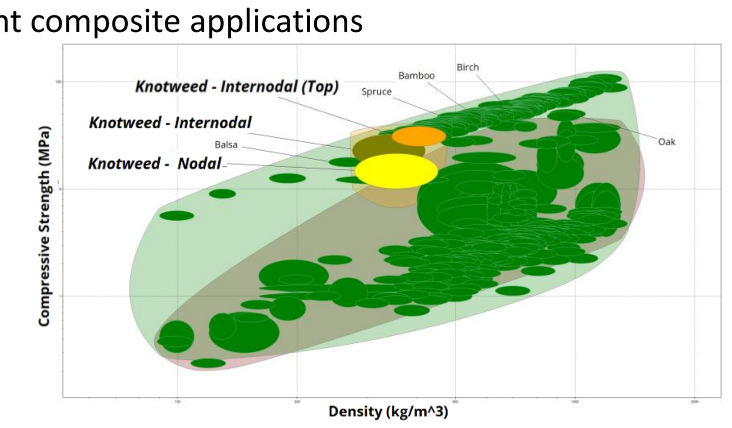



*Figure 4: Ashby Chart of Compression Strength vs Density.*

## Tension Test Results

Tensile testing was performed on 31 Japanese Knotweed specimens, with multiple samples taken from the top, middle, and bottom sections of each stem. Tests were conducted using a modified "dog-bone" geometry to ensure central failure and improve result accuracy.

- **Top section specimens** displayed the highest performance, with a **mean tensile strength of 20.97 MPa** and **modulus of elasticity of 5.03 GPa.**

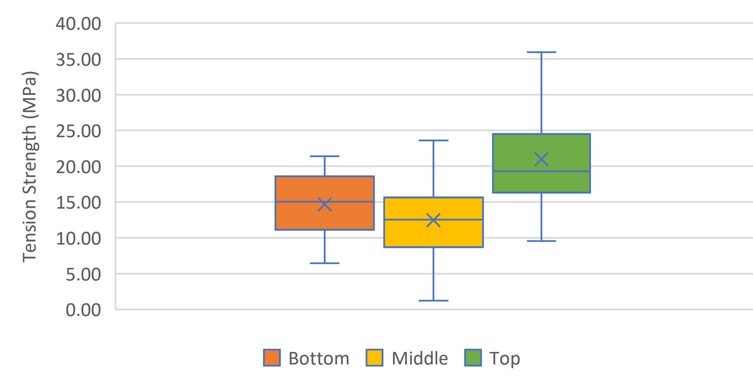



*Figure 5: Box and Whisker Plot Showing the Tension Test Results.*

- **Middle and bottom sections** showed reduced tensile strength, averaging **17.86 MPa** and **15.34 MPa**, respectively, with corresponding decreases in modulus of elasticity.
- Failure consistently occurred within the central gauge region, confirming the effectiveness of the specimen geometry.

Moisture content had **no statistically significant effect** on tensile strength or stiffness within the tested range, reinforcing findings from the shear test.

## Shear Test Results

Shear strength testing was conducted on 90 Japanese Knotweed specimens across the top, middle, and bottom stem sections. All tests followed ISO22157 guidelines, adapted for the smaller culm size of knotweed.

- **Top sections** showed the highest shear strength, with a **mean value of 1.56 MPa**, indicating greater resistance to parallel shear forces in smaller diameter, upper culm areas.
- **Middle and bottom sections** exhibited lower average strengths of **1.25 MPa** and **1.10 MPa**, respectively.
- The majority of failures were clean shear fractures; specimens exhibiting crushing or slippage were excluded.

Moisture content varied across samples but showed **negligible correlation with shear strength**, suggesting that Japanese Knotweed's internal structure dominates performance more than water content. Comparative analysis places Japanese Knotweed below bamboo and hemp in shear strength, yet within a usable range for **low-strength, non-structural bio-composite applications.**

*Figure 6: failure modes of shear tests*

## Conclusions & Discussions

This study demonstrates that the mechanical behaviour of Japanese Knotweed (JKW) varies significantly with stem height and the presence of nodes. Mechanical testing revealed that the upper internodal sections consistently outperformed the middle and bottom regions, with average values of 31.87 MPa in compression, 20.97 MPa in tension, and 1.56 MPa in shear strength. These findings suggest superior fibre alignment and quality in the top segments, making them more suitable for composite reinforcement. Bending sample B23 further reinforced this trend, highlighting the upper stem's dominance in load-bearing performance. The modulus of elasticity followed a similar pattern, indicating greater rigidity in the upper culm.

Moisture content was anticipated to influence mechanical performance but showed no statistically significant correlation with strength or stiffness in any of the tests. This suggests that the short-term moisture variability has minimal impact on the structural integrity of JKW, simplifying its handling, storage, and processing for material applications.

Ashby chart analysis highlighted the following:

- **Low density and moderate strength** of JKW make it a potential low-cost, biodegradable alternative to glass fibres in fibre-reinforced polymers.
- While mechanically inferior to bamboo, **upper stem segments of JKW may outperform balsa** in specific parameters, supporting their use as sandwich panel cores.
- Despite lower strength values overall, JKW remains promising for **non-structural, cost-sensitive applications**, including insulation panels, interior cladding, and biodegradable consumer products.

In summary, while Japanese Knotweed does not match the mechanical capabilities of conventional bio-fibres, its ecological abundance, ease of cultivation, and minimal processing demands support its application in low-strength, sustainable composite materials.

## References


1. ISO22157 - Bamboo structures - Determination of physical and mechanical properties of bamboo culms - Test methods. (2019). International Organisation for Standardisation.
2. ISO178 - Plastics - Determination of flexural properties - Sixth edition. (2019). International Organisation for Standardisation.



**Emyr Jenkins & Philip Lloyd**

School of Engineering
Newcastle University

**Supervisor: Dr Sigong Zhang**