

EXPERIMENTAL MECHANICAL CHARACTERISATION OF SELECTED SRI LANKAN HARDWOOD TIMBER SPECIES FOR LOCAL STRUCTURAL TIMBER DESIGN APPLICATIONS WITH REFERENCE TO EN 338

M.V.Y. De Silva¹, Kanishka Chandrathilaka^{1*}

¹ Department of Civil Engineering, University of Moratuwa, Sri Lanka

**Corresponding author: desilvamvy.21@uom.lk*

Abstract

Timber is a renewable structural material, but Sri Lankan design practice often relies on properties developed for foreign species and strength classes. This study established a preliminary local dataset for Hora, Jak, Mahogany and Teak and compared their behaviour with values commonly adopted from EN 338. Fifty-three small clear specimens were tested in four-point bending, tension parallel to grain, compression parallel to grain and compression perpendicular to grain. Moisture content and density were also measured. Clear differences occurred between species and loading directions. Teak had the highest density and bending stiffness, Hora the greatest bending strength, Mahogany the highest tensile strength, and Jak the highest moisture-normalised compression strength parallel to grain. Compression perpendicular to grain was far lower than longitudinal compression for all species tested in that mode, confirming the need for separate bearing and support zone checks. The measured mean properties showed different relationships with EN 338 benchmarks across the loading modes, indicating that a single reference class does not consistently represent all measured properties of these local hardwoods. The reported values are preliminary sample means rather than characteristic design values. The dataset supports the development of a nationally verified timber property database, although larger samples and full-size graded-member testing are required before formal strength classes can be proposed.

Keywords: Sustainable construction, Engineering materials, Eurocode 5, Anisotropic behaviour, Strength classification

1. Introduction

Timber is increasingly important in sustainable construction because it is renewable, relatively light and capable of storing carbon during service [1,2]. Sri Lankan hardwoods are widely used in roofs, floors, joinery, furniture and temporary works. However, structural calculations commonly depend on international handbooks and Eurocode-related values rather than on experimentally verified data for locally grown species.

Mechanical behaviour varies with species, density, moisture, grain direction and defects [1,2]. Direct use of European values may therefore underuse efficient local timber or overestimate a particular property. Because timber is orthotropic, bending, longitudinal tension and compression, and transverse bearing must be checked separately.

EN 408 defines mechanical test procedures and EN 338 provides strength classes used in Eurocode design [3,4]. Sri Lankan research has already highlighted the need for end-use-based classification [5]. This study characterises Hora, Jak, Mahogany and Teak, compares their measured behaviour with EN 338-related practice, and identifies local design implications. Formal class assignment is outside the scope because small clear specimens do not represent graded full-size populations.

2. Materials and Methods

Four commonly available hardwoods representing different density and strength ranges were tested. Small clear specimens were used to minimise large-defect effects. A total of 53 small clear specimens were tested: 20 in four-point bending, 12 in tension parallel to grain, 12 in compression parallel to grain, and 9 in compression perpendicular to grain, with direction defined relative to the grain. Table 1 summarises the arrangements and outputs, and Figure 1 shows the four test configurations.

Table 1: Experimental programme for mechanical characterisation.

Test	Specimen and loading arrangement	Coverage	Main output
Four-point bending	20 × 20 × 380 mm; 360 mm span	5 per species; 20 total	Strength and global modulus
Tension parallel to grain	10 × 20 mm critical section; along grain	3 per species; 12 tested	Tensile strength
Compression parallel to grain	20 × 20 × 120 mm; area 400 mm ²	3 per species; 12 total	Strength and elastic response
Compression perpendicular to grain	45 × 70 mm loaded area; height 90 mm	3 per species for Jak, Mahogany and Teak; 9 total; Hora not tested	Bearing strength and modulus
Moisture content and density	Masses and specimen volume	All four species	Moisture content and density

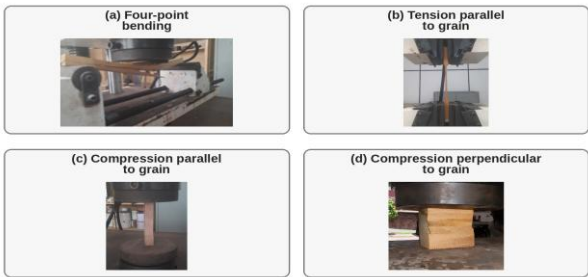


Figure 1: Experimental configurations used for the four mechanical loading modes.

Bending stiffness was obtained from the initial linear load-deflection region. Two tension specimens that failed at the grips were excluded from the strength analysis. No grip failures were present in the retained tension dataset. Compression parallel specimens used a 400 mm² area, while perpendicular specimens were loaded over 3150 mm² to represent support and contact-zone bearing.

Properties were calculated using EN 408-compatible expressions [3]. The oven-dry method provided moisture content, and density was estimated at 12 % moisture. Bending modulus and compression parallel strength were normalised to the same reference condition. EN 338 served only as a benchmark and was not used to assign classes [4]. The retained tension specimens showed comparatively brittle failure, while compression parallel to grain exhibited progressive fibre crushing and post-peak softening, and compression perpendicular to grain showed local crushing across the grain.

3. Results and Discussion

Mean moisture content during testing ranged from 15.1 % for Teak to 18.2 % for Hora. Estimated density at 12 % moisture ranged from 494 kg per cubic metre for Mahogany to 778 kg per cubic metre for Teak. The principal strength results are presented in Table 2. The data show that the four species cannot be treated as one uniform hardwood group.

Table 2: Experimental mean $\pm$ SD properties and EN 338 characteristic benchmarks.

Species / bending benchmark	Density at 12% (kg/m ³)	Bending strength (MPa)	Tension parallel (MPa)	Compression parallel at 12% (MPa)	Compression perpendicular (MPa)
Hora / D50	534	47.8 $\pm$ 10.0 / 50	18.6 $\pm$ 0.884 / 30	17.1 $\pm$ 0.742 / 30	Not tested / 6.2
Jak / D40	685	38.7 $\pm$ 4.88 / 40	32.6 $\pm$ 12.6 / 24	37.7 $\pm$ 7.75 / 27	12.8 $\pm$ 1.63 / 5.5
Mahogany / D30	494	30.4 $\pm$ 2.91 / 30	46.4 $\pm$ 0.884 / 18	26.0 $\pm$ 1.61 / 24	5.88 $\pm$ 0.601 / 5.3
Teak / D45	778	46.5 $\pm$ 10.3 / 45	41.8 $\pm$ 14.6 / 27	34.2 $\pm$ 11.9 / 29	14.7 $\pm$ 1.60 / 5.8

Values are experimental mean $\pm$ SD / EN 338 characteristic benchmark. Valid n: bending = 5/species; compression-parallel = 3/species; compression-perpendicular = 3 for Jak, Mahogany and Teak; tension = 2, 3, 2 and 3 for Hora, Jak, Mahogany and Teak after two grip-failure exclusions. D-classes are nearest bending-strength benchmarks only; no formal class assignment is implied.

Hora and Teak gave the highest bending strengths, 47.8 MPa and 46.5 MPa. Teak also had the greatest global bending modulus at 7.07 GPa. Rankings changed with loading mode: low-density Mahogany produced the highest tensile strength at 46.4 MPa, whereas Jak achieved the highest moisture-normalised compression-parallel strength at 37.7 MPa. Density alone therefore did not predict the full mechanical response.

Directionality was clearest in compression. Jak, Mahogany and Teak recorded perpendicular strengths of 12.8 MPa, 5.88 MPa and 14.7 MPa, respectively, compared with parallel strengths of 37.7 MPa, 26.0 MPa and 34.2 MPa. Supports and concentrated contact zones therefore require separate across-grain checks. Hora was not tested in compression perpendicular to grain because suitable material meeting the required specimen dimensions was not available within the experimental programme.

Comparison with the EN 338 benchmarks in Table 2 shows that similarity in bending strength does not imply corresponding agreement in tension or compression. The comparison is indicative only because the experimental results are sample means from small clear specimens, whereas EN 338 values are characteristic properties of structural timber; therefore, no formal strength-class assignment is proposed.

4. Design Implications and Conclusions

The results demonstrate strong species- and direction-dependent behaviour and support the need for locally verified timber properties rather than direct substitution of a single foreign strength class. The reported values are preliminary sample means and should not be treated as characteristic design values. Larger datasets using multiple source trees and full-size graded members, together with further investigation of perpendicular compression, shear, connections, load duration and moisture effects, are required before formal Sri Lankan strength classes can be proposed.

References

- [1] C. Wiedenhoef, "Structure and function of wood," in Wood Handbook: Wood as an Engineering Material, USDA Forest Products Laboratory, 2010.
- [2] D. W. Green, J. E. Winandy, and D. E. Kretschmann, "Mechanical properties of wood," in Wood Handbook: Wood as an Engineering Material, USDA Forest Products Laboratory, 2010.
- [3] BS EN 408:2010, Timber structures - Structural timber and glued laminated timber - Determination of some physical and mechanical properties, British Standards Institution, 2010.
- [4] SIST EN 338:2016, Structural timber - Strength classes, Slovenian Institute for Standardization, 2016.
- [5] N. D. Ruwanpathirana, "Development of a timber property classification based on the end-use with reference to twenty Sri Lankan timber species," Journal of Tropical Forestry and Environment, vol. 4, no. 1, pp. 1-13, 2014.

RE-EVALUATING TIMBER STRUCTURES IN SRI LANKA: EXPERIMENTAL CHARACTERISATION OF SELECTED HARDWOODS

A corrected research flow for local structural timber design

1 RESEARCH GAP & OBJECTIVE

CURRENT PRACTICE (SRI LANKA)

Design based on European softwoods and EN 338 assumptions



European softwood (e.g., Spruce)

Generic EN 338 values not representative of local hardwoods

NEED FOR LOCAL SPECIES-SPECIFIC DATA



Sri Lankan hardwoods show wide variation in density and strength.

Local data required for safe, efficient design.

OBJECTIVE

- Experimentally characterise selected Sri Lankan hardwoods.
- Compare behaviour across loading modes, using EN 338 as a benchmark only.

Problem: Sri Lankan timber design often relies on foreign EN 338-related values rather than experimentally verified local hardwood data.

2 TIMBER MATERIAL SELECTION (SRI LANKA)

Hora

Dipterocarpus zeylanicus



Jak

Artocarpus heterophyllus



Mahogany

Swietenia macrophylla

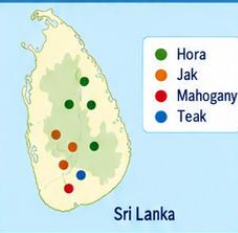


Teak

Tectona grandis



STUDY CONTEXT



DENSITY AT 12% MOISTURE

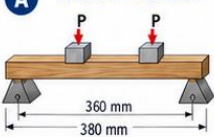
Species	Density (kg/m ³)
Hora	534
Jak	685
Mahogany	494
Teak	778

53 small clear specimens total

Mean moisture content during testing: 15.1% – 18.2%

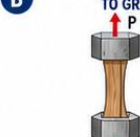
3 MULTI-MODE MECHANICAL TESTING PROGRAM

A FOUR-POINT BENDING



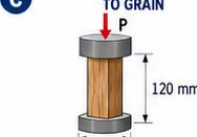
- Specimen: 20 × 20 × 380 mm
- Span: 360 mm
- Output: bending strength and global modulus ($f_{m,g}$, $E_{m,g}$)

B TENSION PARALLEL TO GRAIN



- Critical section: 10 × 20 mm
- Corrected critical area: 200 mm²
- Output: tensile strength ($f_{t,0}$)

C COMPRESSION PARALLEL TO GRAIN



- Specimen: 20 × 20 × 120 mm
- Area: 400 mm²
- Output: compression strength and elastic response ($f_{c,0}$)

D COMPRESSION PERPENDICULAR TO GRAIN



- Loaded area: 45 × 70 mm
- Height: 90 mm
- Loaded area = 3150 mm²
- Output: bearing/compression perpendicular strength and modulus ($f_{c,90}$)

EN 408-compatible expressions used for property calculation.

4 KEY RESULTS: MEAN LOAD-DISPLACEMENT RESPONSES & REPRESENTATIVE MEAN VALUES

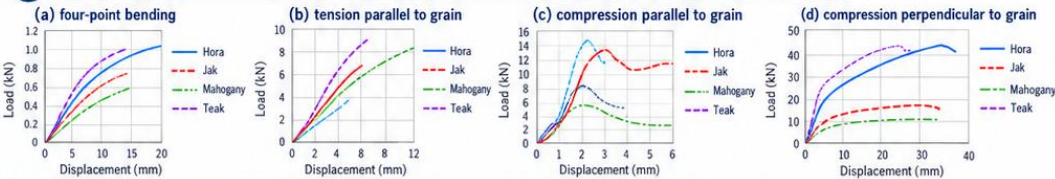


Figure 5 Mean load-displacement responses of selected Sri Lankan hardwood species under different loading modes: (a) four-point bending, (b) tension parallel to grain, (c) compression parallel to grain, and (d) compression perpendicular to grain.

Representative mean species-specific values (MPa)

Species	Bending strength f_m (MPa)	Global bending modulus $E_{m,g}$ (MPa)	Tension parallel $f_{t,0}$ (MPa)	Compression parallel at 12% $f_{c,0,12}$ (MPa)	Compression perpendicular $f_{c,90}$ (MPa)
Hora (H)	47.8	6289	18.6	17.1	Not tested
Jak (J)	38.7	5353	32.6	37.7	12.8
Mahogany (M)	30.4	4611	46.4	26.0	5.88
Teak (T)	46.5	7066	41.8	34.2	14.7

H – Hora J – Jak M – Mahogany T – Teak NT – Not tested

SYNTHESIS FINDINGS

- Hora:** strongest in bending.
- Mahogany:** highest tensile strength despite low density.
- Jak:** highest moisture-normalised compression parallel strength.
- Teak:** highest density and bending stiffness.
- Compression perpendicular to grain is much lower than compression parallel to grain for all species tested.
- EN 338 is a benchmark only; species-specific local data are recommended.