

Modified Osgood Equation for *Acacia Mangium*

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Abstract: The purpose of this study is to identify the Osgood's coefficient of species and the Modified Osgood Equation for *Acacia mangium*. *Acacia mangium* trees were cut to produce oven-dried Small Clear Specimens that were then tested until fracture. Results were gathered from static tensile tests in the direction parallel (0° angle), perpendicular (90° angle) and at 30° angle to the wood grain. All test results confirmed that the *Acacia mangium* wood is brittle as there was no obvious necking observed on the test specimens. From the static testing, the Osgood's coefficient of species for *Acacia mangium*, (a), is identified algebraically to be 0.49. *Acacia mangium*, by nature, has a significant difference in the strengths parallel and perpendicular to the grain line. The finalized results of the Ultimate Tensile Strength for 15-year old *Acacia mangium* demonstrated that the Ultimate Tensile Strength in parallel and perpendicular to the grain directions are 143.87 MPa and 6.32 MPa respectively, while the Ultimate Tensile Strength at 30° grain angle is 32.985 MPa. An extreme reduction of 95.6% of the Ultimate Tensile Strength was identified between 0° and 90° grain angles with a decreased value from 143.87 MPa to 6.32 MPa.

Keywords: Osgood, equation, *Acacia*, *Mangium*, coefficient.

INTRODUCTION

The Army Department of the United States of America developed the Hankinson's Equation/Criterion in 1921, which was intended for calculating the allowable compression stress of spruce wood at differing angles from the grain [1 and 3]. The finalized form of the equation was as **Equation 1**.

$$S_{\theta} = \frac{S_{\parallel} \cdot S_{\perp}}{S_{\parallel} \cdot \sin^2\theta + S_{\perp} \cdot \cos^2\theta} \quad (1)$$

With,

S_{θ} = Ultimate Compression Strength at angle, θ to the grain.

S_{\perp} = Ultimate Compression Strength perpendicular to the grain or at 0° grain angle, MPa.

S_{\parallel} = Ultimate Compression Strength parallel to the grain or at 90° grain angle, MPa.

θ = Angle to grain line.

The Hankinson's Equation has also been generally accepted as a base formula in the Australia's ANSI/AF&PA - National Design Specification for Wood Construction (NDS-2005) [4].

In 1928, Osgood, an Assistant Professor of Structural Engineering at Cornell University, publicized the Osgood Equation. It was a generalized version of the Hankinson Equation. The Osgood Equation is in the form of **Equation 2**.

$$S_{\theta} = \frac{S_{\parallel} \cdot S_{\perp}}{S_{\perp} + (S_{\parallel} - S_{\perp})(\sin^2\theta + a \cdot \cos^2\theta) \cdot \sin^2\theta} \quad (2)$$

With,

a = coefficient of species, by which Osgood finalized the value for the Southern Yellow Pine wood as 0.35. S_{θ} , S_{\perp} , S_{\parallel} and θ are of the same as in the Hankinson's Equation.

Once the Osgood's coefficient, (a) is increased to one (1), the Osgood Equation became the Hankinson's Equation. Hankinson's Equation is well-known for predicting the compression strength of wood at different angles to the grain line. Tests were conducted in order to review the application capability of the Hankinson's Equation for predicting the wood tensile strength according to the angles from the grain line. A tensile stress at a rate of 0.1 inches per minute was applied at varying angles from the grain of the Southern Yellow Pine board wood specimens. The study revealed that the

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Osgood Equation was a better fit compared to the Hankinson's Equation for tensile loading [3].

MATERIALS AND METHODS

The experiment was mainly related to the static tensile testing of oven-dried tensile specimens (dog-bone shaped) at 0°, 30° and 90° angles to the grain line. The test specimens were prepared according to the British Standard 373. **Figure 1** shows the actual processed dog bone shaped tensile test specimens. All tests commenced at relative humidity (RH) of (65 ± 2) %. The test specimens were produced from selected *Acacia mangium* trees that are 15 years of age. The static tensile test used a total of ninety (90) pieces of oven-dried Small Clear Specimen. As the specimens were tested at three (3) grain angle orientations, namely at 0°, 30° and 90° angles, each orientation used a total of thirty (30) pieces of specimens. Tensile forces were applied at both ends of the specimen at a constant speed until failure occurred at the smallest cross section (slender part) of the specimen. Failure occurred in the form of rupture after 1.5 to 2 minutes after loading started.

RESULTS AND DISCUSSION

All test results confirmed that the *Acacia mangium* wood is brittle as there was no obvious necking observed on the test specimens. Results also showed the values of the Ultimate Tensile Strength at 30° grain angle (S_{30°) and 90° grain angle (S_{\perp}) are 32.985 MPa and 6.32 MPa respectively. Meanwhile, the value of the Ultimate Tensile Strength parallel to the grain line (0° grain angle), S_{\parallel} , is identified as 143.87 MPa. These values were then inserted into the Osgood Equation in order to determine the value of species coefficient, (a), algebraically from the equation.

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Osgood Equation (**Equation 2**) is in the form of:

$$S_{\theta} = \frac{S_{\parallel} \cdot S_{\perp}}{S_{\perp} + (S_{\parallel} - S_{\perp})(\sin^2\theta + a \cdot \cos^2\theta) \cdot \sin^2\theta}$$

By inserting the values of S_{30° , S_{\perp} and S_{\parallel} the Osgood Equation becomes:

$$32.947 = \frac{143.87 \times 6.32}{6.32 + (143.87 - 6.32)(\sin^2 30^\circ + a \cdot \cos^2 30^\circ) \cdot \sin^2 30^\circ}$$

Using the algebraic method, it was found that the coefficient of species, a , is equal to 0.49.

As the final step, the finalized form of the Modified Osgood Equation for the *Acacia Mangium* was generated. This was done by substituting the values of S_{30° , S_{\perp} , S_{\parallel} , and a , into the Osgood Equation:

$$S_{\theta} = \frac{S_{\parallel} \cdot S_{\perp}}{S_{\perp} + (S_{\parallel} - S_{\perp})(\sin^2\theta + 0.49 \cdot \cos^2\theta) \cdot \sin^2\theta}$$

$$S_{\theta} = \frac{143.87 \times 6.32}{6.32 + (143.87 - 6.32)(\sin^2\theta + 0.49 \cdot \cos^2\theta) \cdot \sin^2\theta}$$

$$S_{\theta} = \frac{909.258}{6.32 + (137.55)(\sin^2\theta + 0.49 \cdot \cos^2\theta) \cdot \sin^2\theta}$$

Hence, the Modified Osgood Equation for *Acacia Mangium* that is 15 year of age is shown as **Equation 3** below.

$$S_{\theta} = \frac{909.258}{6.32 + (137.55)(\sin^4\theta + 0.49 \cdot \sin^2\theta \cdot \cos^2\theta)} \quad (3)$$

The simulated result of the Modified Osgood Equation for *Acacia Mangium* generates a curve that explains the relationship between tensile strengths and grain angles. This relationship is shown in **Figure 2**.



Figure 1: Dog bone shaped tensile test specimens

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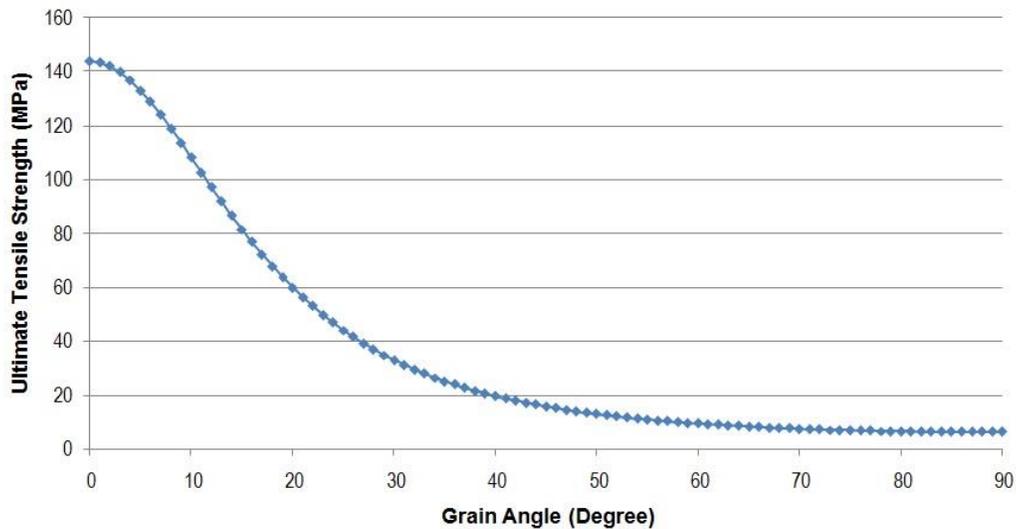


Figure 2: Ultimate Tensile Strengths based on Grain Angles (Simulation of the Osgood Equation)

CONCLUSION

All test results confirmed that the *Acacia mangium* wood is brittle, as no obvious necking was observed on all test specimens. From the static testing, the Osgood's coefficient of species for *Acacia mangium*, (a), was derived algebraically to be 0.49. By nature, the *Acacia mangium* has significant difference in the strengths parallel and perpendicular to the grain line. The finalized results of the Ultimate Tensile Strength for a 15-year old *Acacia mangium* demonstrated that the Ultimate Tensile Strength in parallel and perpendicular to the grain directions as 143.87 MPa and 6.32 MPa respectively. Meanwhile, at 30° grain angle, the Ultimate Tensile Strength is 32.985 MPa. An extreme reduction of 95.6% of the Ultimate Tensile Strength was identified between the 0° and the 90° grain angles where the value reduced from 143.87 MPa to 6.32 MPa. The Osgood Equation may be used to derive the *Acacia mangium* ultimate tensile strengths for grain angle domain of:

$$0^\circ \leq \text{Grain angle} \leq 90^\circ$$

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