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Short notes

EXPERIMENTAL TESTS OF RED MERANTI (*SHOREA SPP*.) DOWEL BEARING STRENGTH AT AN ANGLE TO THE GRAIN

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ABSTRACT

The angle to the grain has a significant influence on timber bearing strength. As the grain angle increases the bearing strength decreases. The aim of this research was to obtain the dowel bearing strength of the red meranti (*Shorea spp.*) timber at an angle to the grain. The scope of this research was as follows the specimens were made according to ASTM D143, the grain angle ranged from 0° to 12°, and the dowel bearing tests were displacement controlled in accordance with ASTM D5764. Results of this research was an empirical equation of dowel bearing strength (in MPa) in terms of an angle to grain θ (in degrees) namely $F_e = 32.74 - 4.701\theta + 0.2064\theta^2$. The importance of studying the influence of the grain angle to the dowel bearing strength for timber connection design is because the direction of the timber grain is not perfectly 0°.

KEYWORDS: Dowel bearing strength, grain angle, red meranti, orthotropic.

INTRODUCTION

The dowel bearing strength is the value that can be reached before a timber hole fails due to compression from dowel, when a timber connection is laterally loaded with axial tension internal load. Bearing strength is an important parameter used in timber design, for example in design of timber truss bridge and timber truss roof. The angle to the grain or the angle between the grain direction and the compressive bearing stress has a significant influence on timber bearing strength, since timber is an orthotropic material and have three main direction which are longitudinal, radial, and tangential. As the grain angle increases the bearing strength of the timber decreases.

The aim of this research was to determine the dowel bearing strength of the red meranti (*Shorea spp*.) timber at an angle to the grain experimentally. Red meranti is a species that is easily found in Indonesia and is commonly used as a construction material and as a nonstructural for example door and window. The importance of studying the influence of the grain angle to the dowel bearing strength is because the direction of the timber grain is frequently not perfectly 0°. The scope of this research was as follows the specimens were made according to ASTM D143, tests were provided on 169 specimens, the grain angle ranged from 0° to 12°, and the dowel bearing tests were displacement controlled in accordance with ASTM D5764.

Previous studies

Since the dowel bearing strength is an important parameter for design of wood connections, for example a tension member subjected to axial tension force, the past research were also carried out to tests the round timber bolted connections with slotted in steel plates subjected to axial tension (Lokaj and Klajmonova 2014).

Hankinson's formula (Bodig and Jayne 1993) is widely known as the analytical equation to predict the mechanical properties and the strengths of timber at an angle to the grain. In terms of experimental tests, there is no previous study for effect of grain angle to the timber dowel bearing strength. Experimental test, analytical research, and numerical analyses on the distortion energy criterion for timber that have been done previously were the compression at an angle and the tension at an angle.

The previous study on the effect of grain angle was the compression strength and the tension strength. The experimental tests and numerical analyses were done to study the compression strength of red meranti (*Shorea spp*.) timbers at an angle to the grain (Pranata and Suryoatmono 2012, Pranata and Suryoatmono 2013). Suryatmono and Pranata (2014) were also carried out to study the tensile strength of 8 species of timber at an angle to the grain. They used pete, red meranti, keruing, *Acacia mangium,* durian, mahoni, nangka, and sengon. Pranata and Surono (2015) were performed to study the tensile strength of yellow meranti timber at an angle to the grain. Agarana et.al. (2021) investigated the compressive strength of wood using Hankinson's criterion was also done for 5 species of wood.

The specimen dimension for dowel bearing test is 50 mm by 50 mm by 30 mm with a half of hole for placing the dowel. The applied load and the support of the specimen are on end-grain surfaces. The compression tool includes an adjustable crossbar to align the specimen and support the back surface at the base plate (ASTM D143-22 2022).

Calculation of the bearing load

The compression load for calculation of the bearing load is the 5% offset load that cause the failure of specimen in terms of bearing plane *t* mm (Fig. 2a) by bolt or dowel diameter in accordance with Munoz et.al. (2010). Proportional limit load is a load that is calculated as a yield point that shows the stress and strain in terms of plastic region. Method to determining the bearing load or proportional limit load used in this research is 5% offset diameter method. What is meant by diameter in this case is the diameter of the dowel. In this method, the first straight line that connects the origin and the point in the experimental curve with $0.4P_{max}$ is developed. The second straight line developed is the line that is parallel to the first line that starts from displacement of 5% diameter. The intersection of the second straight line with the experimental curve is the yield point P_y and Δ_y. Both lines and the yield point are shown in Fig. 1. In the following, the terms $P_{u5\%}$ is used as a replacement of the yield point.

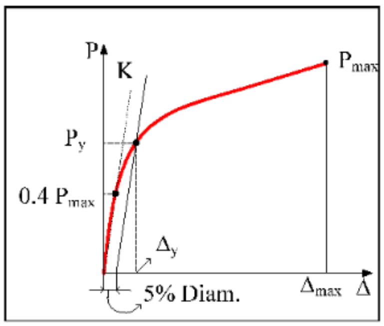


Fig. 1: The 5-% offset diameter method (Munoz et al. 2010).

In order to compute the dowel bearing strength $F_{e//}$, bearing are needs to be calculated according to Eq. 1, and the dowel bearing strength can be computed using Eq. 2, which is 5%-offset diameter load divided by the bearing area. The strain can also be calculated using Eqs. 3 and 4. Visualization of p, t, and L_o is shown in Fig. 2a.

$$A = t \times d \tag{1}$$

$$F_{e//} = \frac{P_{u5\%}}{A} \tag{2}$$

$$Lo = p - \frac{d}{2} \tag{3}$$

$$\varepsilon_{//} = \frac{D_{u5\%}}{L_o} \tag{4}$$

where: A is the bearing area of the specimen, t is the thickness of the specimen, d is dowel hole diameter, $F_{e//}$ is dowel bearing strength, $P_{u5\%}$ is 5% offset diameter load, L_o is the initial length of bearing line, p is total height of specimen, $\varepsilon_{//}$ is the dowel bearing strain, and $D_{U5\%}$ is the displacement at 5%-offset diameter load.

MATERIAL AND METHODS

Specimens for the dowel bearing tests were made from raw timber logs, which have been visually sorted to obtain defect-free parts. The number of test specimens in this study was

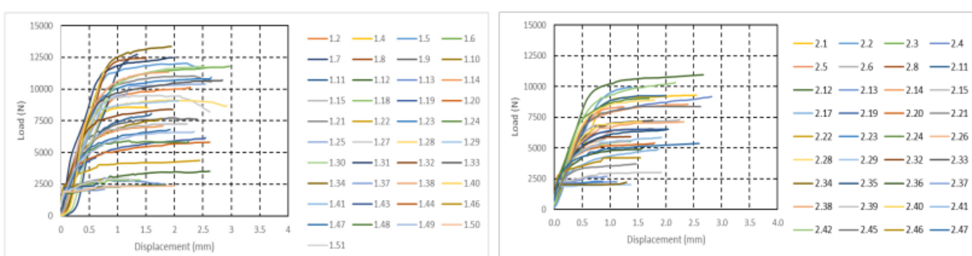
169 test specimens with grain angle variations ranging from 0° to 12° (Fig. 2b). The method of making the test specimens and the test methods are in accordance with ASTM D143-22 (2022). Fig. 2c shows setup of the experiment on the universal testing machine, set as bearing test mode with displacement controlled (crosshead speed) of 0.6 mm per minute according to ASTM D5764 (2018).

(a) (b) (c)

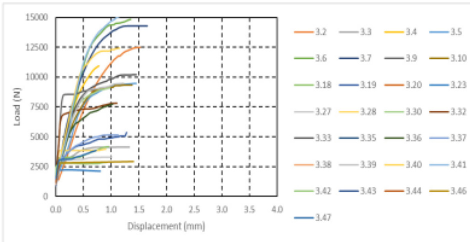
Fig. 2. a) The dowel bearing test specimen according to ASTM D143, b) samples, c) setup of the experiment on the universal testing machine.

RESULTS AND DISCUSSION

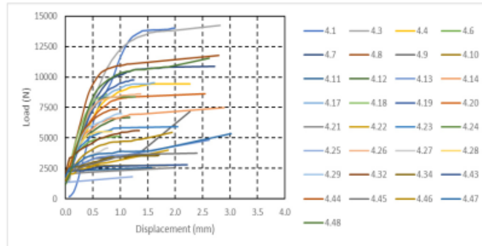
Five raw timber logs were used to make specimens for the dowel bearing tests in this research. 41 specimens using notation 1.xx were made from first timber log, 36 specimens using notation 2.xx were made from second timber log, 29 specimens using notation 3.xx were made from third timber log, 33 specimens using notation 4.xx were made from fourth timber log, and 30 specimens using notation 5.xx were made from the last fifth timber log. Fig. 3 shows the results of the experimental tests in terms of load versus displacement curves with various grain angle for all of 169 specimens. Fig. 4 shows an example of Specimen 1.23 on how proportional limit load P_y (= 5% offset diameter loads $P_{u5\%}$) is obtained.



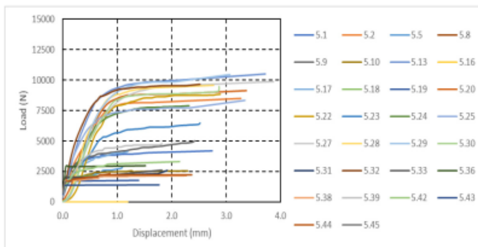
(a) (b)



(c)



(d)



(e)

Fig. 3: Bearing load versus deflection curves obtained from experimental tests. a) specimens 1.xx, b) specimens 2.xx, c) specimens 3.xx, d) specimens 4.xx, e) specimens 5.xx

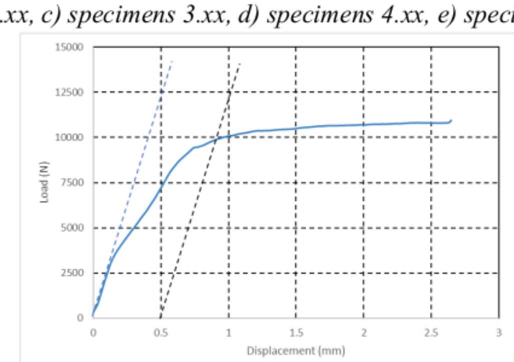


Fig. 4: Calculation of 5-% offset diameter or proportional limit load of specimen 1.23.

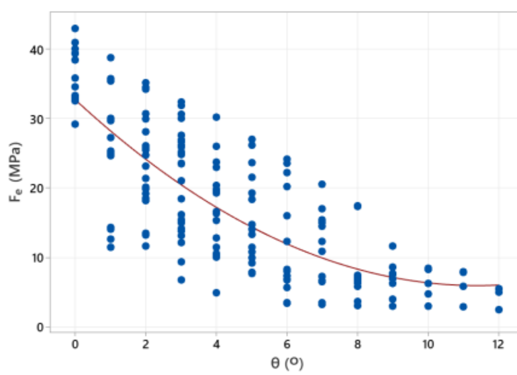


Fig. 5: Results obtained from polynomial regression analysis.

Fig. 5 shows the data points obtained experimentally and the curve obtained from the polynomial regression analysis that shows the relationship between the dowel bearing strength F_e (in MPa) and the grain angle θ (in degrees). The regression equation for the curve in Fig. 5 is shown in Eq. 5:

$$F_e = 32.74 - 4.701\theta + 0.2064\theta^2 \quad (5)$$

With the coefficient of determination of $R^2 = 60.3\%$. Although the coefficient is generally not convincing because it is relatively far from 100%, for wood this is considered normal because wood is a material that comes from nature and far from homogeneity. Using the regression equation (Eq. 5) it can easily be seen that grain angle of just 4^o reduces the dowel bearing strength by approximately 50%, while grain angle of 10^o reduces dowel bearing strength by 80%. It is, therefore, important to design and construct connection in timber structure using zero or as small as possible grain angle.

CONCLUSIONS

An empirical regression equation to predict the dowel bearing strength of red meranti (*Shorea spp*.) The dowel bearing strength (in MPa) as a function of the grain angle (in degrees), namely $F_e = 32.74 - 4.701\text{x}\theta + 0.2064\text{x}\theta^2$ with coefficient of determination R^2 of 60.3%. This result shows that the dowel bearing strength decreases significantly with the increasing grain angle. Therefore, it is important to consider the grain angle (the angle between the grain and the direction of the bearing stress), if any, in the design and construction of timber connection using dowel fastener. The equation of F_e (at an angle to the grain) can be alternative solving to calculate the dowel bearing strength, one of main parameter in analysis or design of axial tension timber connection, that widely used for design of timber truss bridge or timber truss roof, especially for famous structural timber in Indonesia such as red meranti (*Shorea spp*.).

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