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Perpendicular Dowel-bearing Strength Properties without Glue Line for Mengkulang Species

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ABSTRACT

The aim of this project is generate connection data that can employed in the design of connections for Malaysian timber species particularly for glulam products. This investigation focuses on evaluating dowel-bearing strength for timber based products. Thus far, limited studies on dowel-bearing strength were published and reported. Mengkulang, (Heritiera spp), was used to evaluate the dowel-bearing strength properties, Two bolt diameters 16 and 20mm consecutively were selected in this study. The project comprised experimental work that was based ASTM D5764, using half-hole testing setup. The dowel-bearing strength, F_e for 16mm and 20mm diameter were determined from 5% diameter offset yield load method. Through the experimental work and analysis, the percentage difference between 16mm and 20mm was found 15% increased from 16.24N/mm^2 to 19.21N/mm^2, respectively. The dowel-bearing strength increased when the dowel diameter increased. The comparison between dowel-bearing strength of 5% diameter offset load, Fe and maximum load, F_h of glulam without glue line has successfully analysed. The F_e and F_h was found 16.24 N/mm^2 and 18.50N/mm^2 for the 16 mm diameter while was 19.21N/mm^2 and 22.69 N/mm^2 for the 20mm diameter respectively.

Keywords: *timber; glulam; mengkulang; glue line; dowel-bearing strength*

Introduction

Dowel-bearing strength also referred to as embedment strength of timber. It is the one of the properties that is used to estimate the lateral connection of wood design strength performance to fastener bending strength. The embedment strength has relations to the glulam wood features such are wood species, thickness, moisture content, specific gravity, wood grain direction and presence of glue line. Glue line is a bonding between one or more thickness of wood surface to another using wood adhesive.

Dowel-bearing strength was additionally presence focus for the building timber materials, for example, laminated veneer timber, plastic wood composite and glue laminated. There are very limited studies on experimental work especially for structural size timber and connection system. According to Hassan et al., [1], dowel-bearing strength is one of an essential parameter in determination of European Yield Model (EYM) and it influences the design value capacity, Z of the bolts. Most available published data for dowel-bearing strength of the Malaysian tropical timber is for solid timber that has been investigated using Kempas species using Spring Theory method. This method tested for wood dowel compressed with steel block and wood block compressed by steel dowel [2]. Dowel-bearing strength of two species from Guatemalan hardwood in parallel to grain direction is found reported by Rammer [3].

In order to promote the application of glulam in Malaysia on the timber connection, this study is conducted to determine the dowel-bearing strength properties of glulam without glue line (lamination thickness) made of Mengkulang species on the effect of two (2) different bolt diameter sizes that are 16mm and 20mm.

Material and Method

In order to perform the dowel-bearing strength test, this study tested using half-hole test method according to ASTM-D5764-97a and BS EN 383:1993. This method allows full exposure of the specimens during testing. The details on the specimens during the test such as appearance of cracks or any failure patterns were observed. The important physical properties of Mengkulang specimen has been observed and recorded.

The specimen dimension for 16 mm bolt diameter is 64 mm × 64 mm × 38mm and 20 mm bolt diameter is 80 mm × 80 mm × 40 mm. Figure 1 shows the specimen hole free from glue line.

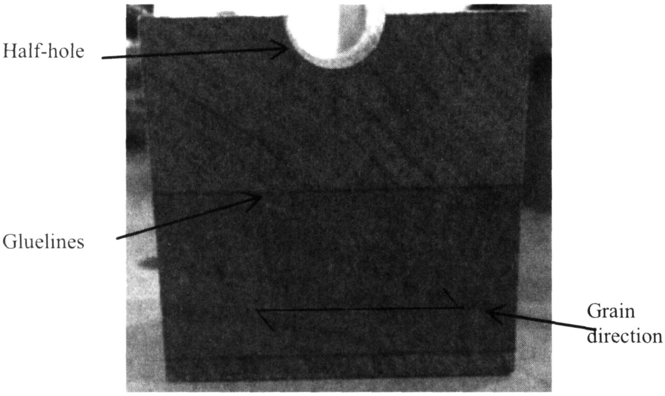

Figure 1: Specimen without glue line

Dowel-bearing strength set up comprised of a rectangular wooden block with half-hole set on the uniform base on UTM and a steel load head pushed to the dowel that placed in the half-hole on the specimen. The tests were run on a UTM with 97.8 kN limit load cell.

A steady displacement rate of 1mm/min or 0.02 mm/s was utilized and the tests were run until the load head touches the sample or when the displacements load remain consistent [4]. Figure 2 shows the dowel-bearing strength test set up.

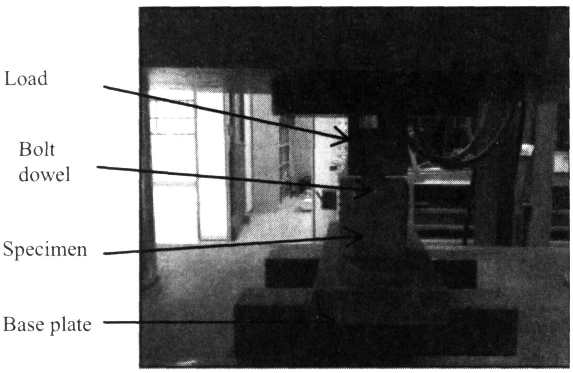

Figure 2: Dowel bearing strength test set up

Dowel-bearing strength properties are resolved from 5% offset load as shown in Figure 3. The methodology was started with the dowel has been placed into the dowel hole. Then, the specimen has allocated in the testing machine where its easier for compressive load uniformly applied along dowel length. The dowel and moveable crosshead were used to prevent bending of dowel during loading. The failure specimen was configured by dowel-bearing strength test perpendicularly. Next, the load has been selected at which the offset line meets the load displacement curve. The greatest intersect load should be utilized as the 5% offset load if the offset line does not meet the load-displacement curve.

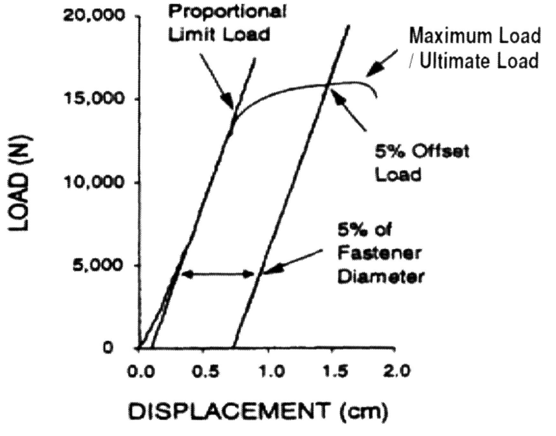

Figure 3: Load definition obtained from load-displacement curve (ASTM-5764-97a, 2013)

As indicated by ASTM-D5764-97a:2013, the Equation 1 shows calculation for dowel-bearing strength, F_e which comprised 5% diameter offset load, $F_{5\%}$.

$$Fe = \frac{F5\%}{d.T} \tag{1}$$

If the offset line does not meet the load displacement curve, Equation 2 is used to compute the dowel-bearing strength, F_e which consisted of maximum load, F_{max}.

$$Fe = \frac{Fmax}{d.T} \tag{2}$$

Where F5% is 5% diameter offset load obtained from the test, Fmax is the maximum load collected from the test, d is a bolt/dowel diameter and T is the thickness of dowel-bearing samples. Equation 3 shall be computed for determination of the dowel-bearing strength (Fh), according to BS EN 383:1993 [5].

$$Fh = \frac{Fmax}{d.T} \tag{3}$$

Result and Discussion

Dowel-bearing Strength, F_e Properties For Without Glue Line of Mengkulang Species using 16 mm Dowel Diameter.

Figure 4 shows load versus displacement in determining 5% offset load for 16 mm dowel diameter. Figure 5 shows of 5% diameter offset load for the minimum, mean and maximum of the load.

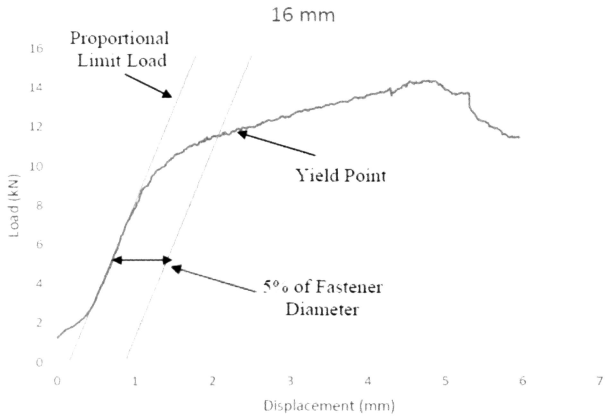

Figure 4: Load versus displacement for 16 mm dowel diameter

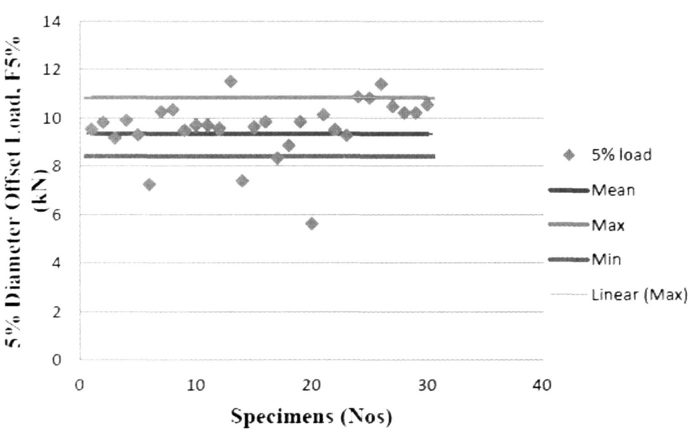

Figure 5: $F_{5\%}$ diameter offset load test result for dowel-bearing strength without glue line specimens using 16mm dowel diameter

Figure 5 shows one result of the 5% diameter offset load is outliers and disposed of with 23 remaining samples. The mean value for 5% diameter offset load was 9.83 kN and standard deviation and the coefficient of variance were 0.56 and 13%, accordingly.

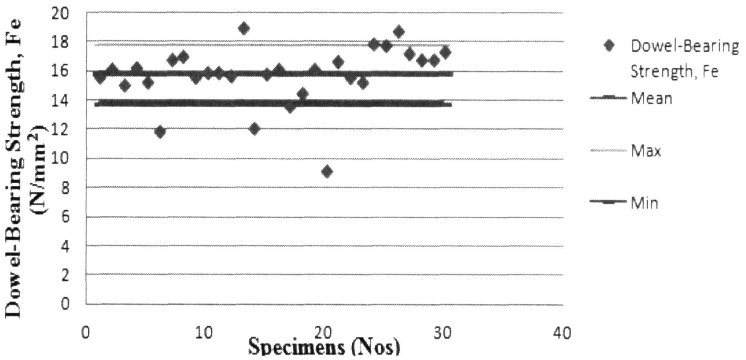

Figure 6: The dowel-bearing strength result for without glue line specimens using 16mm dowel diameter

Figure 6 shows the distribution of dowel-bearing strength values. The F_e was 16.24 N/mm^2 and standard deviation was 0.80 and the coefficient of variance was 4.93%.

For computation of moisture content and density, the mean estimation of moisture content and density for samples was 13.75% and 650.06 kg/m^3, individually. Figure 7 demonstrates the regular state of samples after an optimum load was applied to samples without glue line using 16 mm dowel diameter.

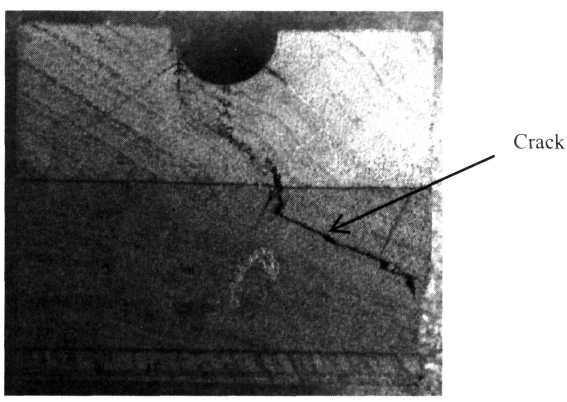

Figure 7: Typical crack of 16mm diameter without glue line samples

As a summary, the 16 mm dowel diameter without glue line given value for mean 5% diameter offset load, $F_{5\%}$ was 9.83 kN while for the mean dowel-bearing strength, F_e was 16.24kN and the value for coefficient of variance was 4.93%.

Dowel-Bearing Strength, F_e Properties for Without Glue Line of Mengkulang Species using 20 mm Dowel Diameter

Figure 8 shows load versus displacement in determining 5% offset load for 20 mm dowel diameter. Figure 9 shows of 5% diameter offset load for the minimum, mean and maximum of the load.

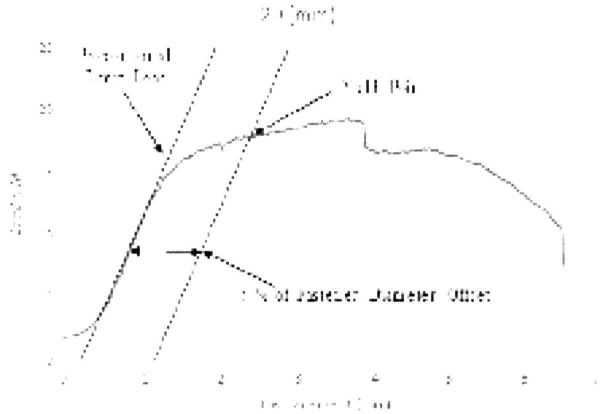

Figure 8: Load versus displacement for 20 mm dowel diameter

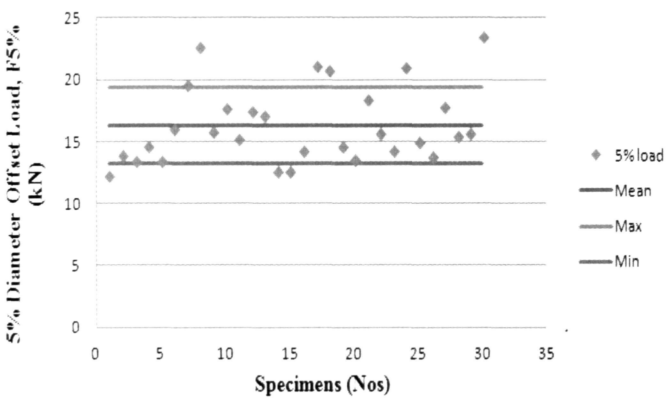

Figure 9: $F_{5\%}$ diameter offset load test result for dowel-bearing strength without

glue line samples using 20 mm dowel diameter

Figure 9 shows $F_{5\%}$ diameter offset load remaining 21 samples with few outliers disposed. The mean value for 5% diameter offset load was 15.36 kN and standard deviation was 1.56 while the coefficient of variance was 19%. Figure 10 similarly shows the distribution of dowel-bearing strength for the minimum, mean and maximum value.

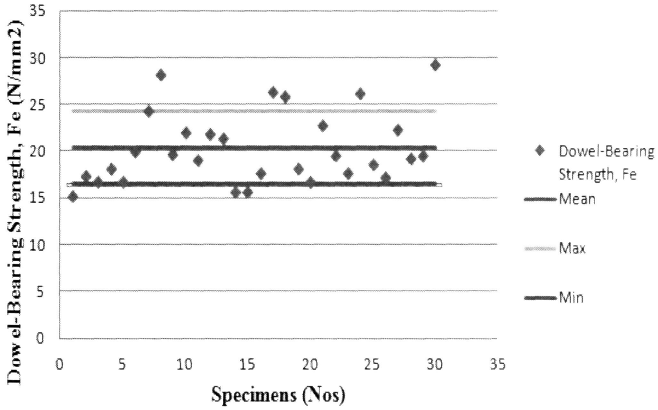

Figure 10: Dowel-bearing strength result for dowel-bearing strength without glue line samples using 20 mm dowel diameter

Figure 10 shows the dowel-bearing strength for the remaining 21 samples F_e with few disposed outliers. The mean value for dowel-bearing strength, F_e was 19.21 N/mm^2 although the standard deviation and coefficient of variance were 1.95 and 10.15%, accordingly. For computation of moisture content and density, the mean estimation of moisture content and density for samples were 9.56% and 772.50 kg/m^3, respectively. Figure 11 demonstrates the regular state of typical crack after an optimum load was applied using 20 mm dowel diameter.

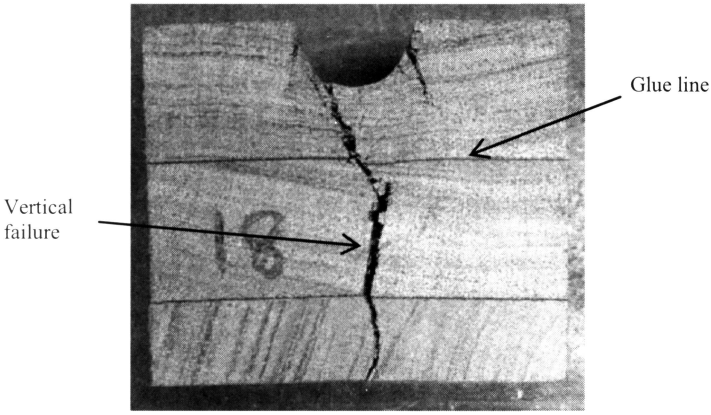

Figure 11: Typical crack for 20 mm dowel diameter

As a summary, the 20 mm dowel diameter without glue line given value for mean 5% diameter offset load, $F_{5\%}$ was 15.36 kN while for the mean dowel-bearing strength, F_e was 19.21 kN and the value for coefficient of variance was 10.15%.

Dowel-bearing Strength, (F_e and F_h) of Glulam to the Different Dowel Diameter for Without Glue Line

Table 1 demonstrated the percentage differences of dowel-bearing strength between 5% diameter offset load, F_e and maximum load, F_h of glulam for without glue line samples. Figure 12 demonstrates the dowel-bearing strength of 16 mm dowel diameter for without glue line specimens was increased 15% from 16.24 N/mm^2 to 9.21 N/mm^2 while 20 mm dowel diameter was increased 18% from 18.50 N/mm^2 to 22.69 N/mm^2.

Table 1: The percentage differences for dowel-bearing strength between (Fe and Fh)

Dowel diameter (mm)	Mean dowel-bearing strength, F^e (N/mm^2)	Mean dowel-bearing strength, F^h (N/mm^2)	Percentage difference (%)
16	16.24	18.50	15
20	19.21	22.69	18

It is shown that 16 mm for F_e and F_h produced lower dowel-bearing strength value compared to 20 mm. This outcome demonstrates that the higher the bolt diameter, the higher the dowel-bearing strength of glulam made of Mengkulang species. The percentage difference for dowel-bearing strength in terms of pattern is discovered where all mean estimation of dowel-bearing strength increased when the dowel diameter is increased. It demonstrates that this findings support the statement reported by Jumaat *et al.* claimed the dowel-bearing strength of timber was influenced by the dowel diameter [6].

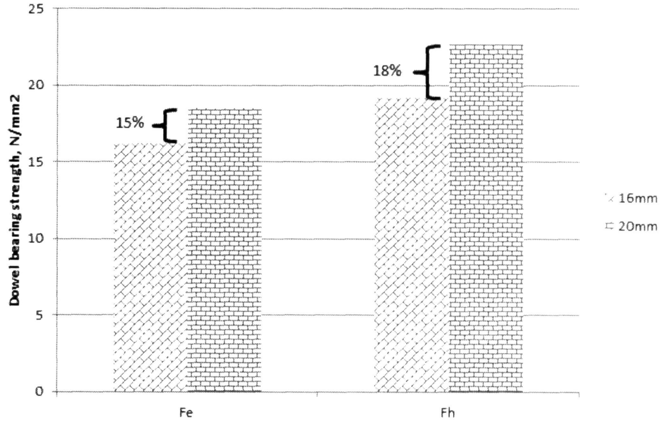

Figure 12: The percentage differences of dowel-bearing strength, F_e and F_h without glue line specimens

Comparison Between Dowel-bearing Strength (F_e and F_h) of Glulam without Glue Line Using 5% Diameter Offset Load and Maximum Load

The comparison between dowel-bearing strength, Fe and Fh without glue line specimens using 16 mm and 20 mm dowel diameter shown in Figure 13.

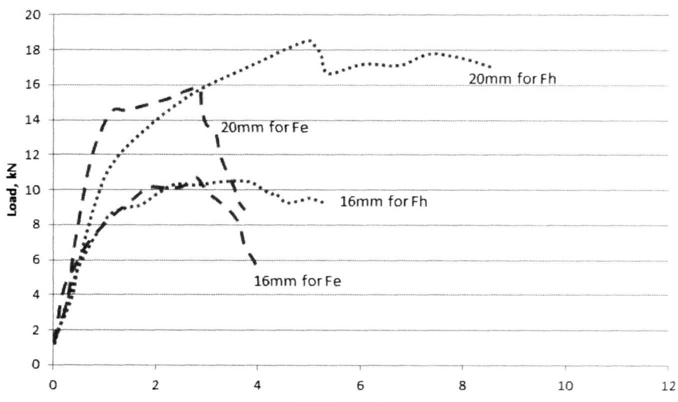

Figure 13: Comparison between F_e and F_h without glue line specimens using 16mm and 20 mm dowel diameter

In this study, no significant different were found between the dowel-bearing strength without glue line of Mengkulang samples to the results of solid timber samples that was studied with utilizing three (3) different dowel diameter which were 8, 10 and 12 mm [6]. All measurements of the sample test method were referring to BS EN 383:1993 and utilizing full-hole test technique. For conclusion, it was found that the dowel-bearing strength (F_e) utilizing 5% diameter offset load by ASTM-5764-97a (2013) is lower than determination of the dowel-bearing strength (F_h) by BS EN 383:1993.

Conclusion

The dowel-bearing strength, F_e (ASTM) was determined from 5% diameter offset load method, $F_{5\%}$ while F_h (BS EN) was determined from maximum load, F_{max}. The dowel bearing strength, F_e of glulam for two different dowel diameters were compared. The percentage of F_e and F_h between 16 mm and 20 mm diameter was increased by 15% and 18% respectively. The value of 16 mm diameter was 16.24 N/mm^2 to 19.21 N/mm^2 and for 20 mm diameter was from 18.50 N/mm^2 to 22.69 N/mm^2, respectively. It was found that the dowel-bearing strength increased when the dowel diameter increased. The comparison for dowel-bearing strength of glulam without glue line which is 5% diameter offset load, F_e and maximum load, F_h have been analysed. The mean value for dowel-bearing strength, F_h of 16 mm dowel diameter was 18.50 N/mm^2 while the standard deviation and coefficient of variance were 1.29 and 7%, accordingly. The mean value of dowel-bearing strength, F_h for without glue line using 20 mm dowel diameter was 22.69 N/mm^2 while the standard deviation and the coefficient of variance were 1.63 and 7%, respectively.

Acknowledgement

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