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***Research paper***

# Effect of Gluelines for Mengkulang Glulam Dowel-Bearing Strength

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**Abstract**

Malaysia is one of the tropical countries around the world which is the pioneer in timber harvesting. Mengkulang is known for its strength and durability. In timber construction, connection is the most important part. The strength of timber has huge impact of the connection strength and the whole structure. Furthermore, timber strength connections also depend on the factor affecting which is bolt diameters and end distances. The objectives of this research are to determine the dowel-bearing strength for 12mm, 16mm and 20mm bolt diameter thus to compare the dowel-bearing strength between glue line and without glue line. The dowel-bearing strength test was tested on Mengkulang timber species for different dowel diameters which are 12mm, 16mm and 20mm for with and without glue line parallel to the grain using half-hole test. The dowel-bearing strength, $F_y$ values of 5% diameter offset-load, $F_{5\%}$ are obtained from load versus displacement graph using ASTM D5764-97a. The dowel-bearing strength, $F_y$ for 20mm diameter with glue line showed 14.71 N/mm$^2$ higher than 16mm diameter and 12mm diameter with 14.44 N/mm$^2$ and 11.63 N/mm$^2$ accordingly. While, the dowel-bearing strength, $F_y$ for 20mm diameter without glue line showed 15.64 N/mm$^2$ higher than 16mm diameter and 12mm diameter with 14.71 N/mm$^2$ and 14.44 N/mm$^2$ respectively. In conclusion, the bigger diameter the higher dowel-bearing strength and the dowel-bearing strength for without glue line showed higher than dowel-bearing strength with glue line.

***Keywords***: *Mengkulang; connection; bolt diameters; dowel-bearing strength; half-hole test.*

## 1. Introduction

Malaysia is having many kind of wood. Malaysian wood can be categories into 4 categories as the follows, hardwoods and softwood which mentioned by Malaysian Timber Industry Board (MTIB), 2008. The importance of timbers is formed by this unique construction material which is applicable to several industries and in advanced projects related to engineering. Solid timber has been popularly used in construction worldwide however other materials such as concrete have replaced this valuable material in Malaysia. The materials of the structural Glulam have been quite utilized in many countries such as Japan, USA, European countries. These materials are involved in the process of construction including building skyscrapers as well as residential homes. Efficient utilization of Glulam for the purpose of construction requires comprehension of the basic behavior structure that involves various or different samples. In order for Glulam become more popular and widely used in Malaysia, further information is necessary, particularly on the issue regarding Glulam dowel-bearing strength and the use of Malaysian tropical timber species as well as purposes of design. Thus, the objectives of this research are to determine the dowel-bearing strength for 12mm, 16mm and 20mm bolt diameter thus to compare the dowel-bearing strength including of glue line known as with glue line and excluding of glue line known as without glue line for Mengkulang timber species.

## 2. Literature Review

Softwood and hardwood are the main classification group in timber. This classification is based on terms of botanical characteristics. Mengkulang is one of Malaysian wood which categorized under medium hardwood it has a density range of 625 to 894 kg/m$^3$ dry air. [1] noted that Mengkulang is considered as the standard name in Malaysia and also known as a Heritiera spp. According to [2] in his study, wood has been utilized as building material. Since the 20th century, in North America, the big diameter trees were readily harvested. With this being said; due to the abundance of the large diameter trees a large and clear cross section and lowered timber made available to utilize for associated construction purposes. This has encouraged the industry to develop new effective strategies for wood products as a way for the reduction of cost and increase of efficiency.
Figure 1 shows an example of Glulam from the one of Malaysian exotic wood created of Mengkulang varieties. According to [3] mentioned the Glulam's benefits is its smaller measures of from the commercial perspective available sawn wood can be structurally end jointed with glues to provide the needed complete laminations and almost endless versatility in style.

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**Fig. 1:** Glulam made of Mengkulang species

Bolt is one of the popular types of claws, also some other acquainted dowel securer like claws, timber rivet, leg attach, timber attach and raise. It can be used when the experience of flexing is required by [4].

As stated by [5] the ASTM D5764-97a [6] was used to determine dowel-bearing strength that will be the yield load acquired starting with those load-displacement bend of a dowel bearing test isolated as shown in Figure 2. The dowel-bearing quality could make decided utilizing full gap or the half-hole test.

Dowel-bearing solidness might have been also constantly broke down to those mechanical transformation improvement timber materials for example, such that cement laminated, laminated polish wood furthermore plastic timber mix by [7]. Dowel-bearing quality may be an incredulous trademark about wood association plan. The association plan quality is dependent upon yield hypothesis that relates association [8] examined on the impacts of (3) sorts from claiming different dowel committed. From claiming steel, glass fiber fortified plastic (GFRP) and wood with Malaysian hardwood. Kempas known as Koompassia Malaccensis utilizing from TWO (2) different sizes of timber block and the dowel diameters used were 12.7mm and 19. 1mm. That determination from claiming dowel-bearing quality might have in understood on ASTM-D5764-97a, 2007 thus utilizing half-hole test.

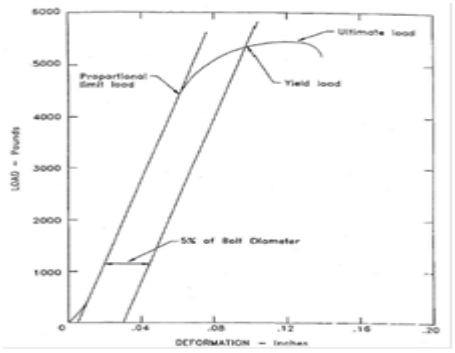


**Fig. 2:** Load definition obtained from load-deformation curve

## 3. Methodology

Figure 3 indicates the dimension for the timber specimen. Dimension for the thickness, T is the smaller of 1.5 In. or 38mm or 2 dowel diameters, 2d while for width, W is the larger of 2 in. or 50mm or 4 dowel diameters, 4d and for length, L; i) Loaded end more than the larger of 2 in. or 50mm or 4 dowel diameters, 4d. ii) Unloaded end more than the larger of 1 in. or 50 mm or 2 dowel diameters, 2d.

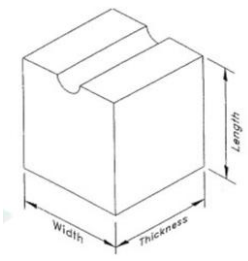


**Fig. 3:** Design for timber specimen dimension (ASTM D5764-97a)

The half-hole test was tested for parallel with glueline as shown in Figure 4 and parallel without glueline as shown in Figure 5, as referred to ASTM D5764-97. This test performed in the lab with total of 48 tests for Mengkulang Glulam timber, which are 16 samples for 12mm, 16mm and 20mm diameter each.

The major test prepared for all specimens is using the Universal Testing Machine (UTM), and all specimens should be fabricated to match the half-hole dowel-bearing strength test. Radial saw machine was used to cut the log according to the length, width and thickness as designed. Drilling machine is the machine used to drill the specimens with half-hole diameter, and that will be based on each specimen and its diameter. Then, UTM machine used to configure the half-hole test as shown in Figure 6. The following equations (1) are used to calculate the dowel-bearing strength according to ASTM-5764-97a (2013), from the experiment, using 5% offset-load diameter.

$$F_y = (F_{5\%})/(d.T) \quad (1)$$

**Fig. 4:** Specimen parallel with glue line

**Fig. 5:** Specimen parallel without glue line

**Fig. 6:** Half-hole test

## 4. Results and discussion

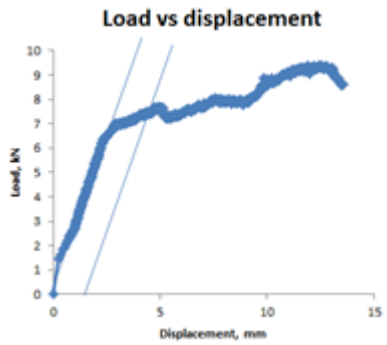


**Fig. 7:** Typical load versus displacement

Figure 7 shows the load deformation curve for 12mm diameter bolt which initially was in linear due to elastic behavior of materials and joints, and specimen has deformed with constant load that applied. The increasing in load and deformation occurred until it reached the maximum load and after that the load was decreased

due to deformation until the specimen cracked as shown in Figure 8.

**Fig. 8:** Typical cracks for specimen with glue line

**Fig. 9:** Typical cracks for specimen without glue line

Figure 9 shows the typical cracks for specimen without glue line. The specimen has failed parallel to the grain which the major bearing failure was in wood surface area. Figure 10 shows the total average graph for 12mm, 16mm and 20 mm diameter parallel without glue line. The lowest dowel-bearing shows the average for 12mm diameter, which has the lowest value of dowel-bearing strength, comparing to the other two diameters which can sustained the $F_y$ was 14.44N/mm$^2$. Next, for 16mm diameter specimen with glueline, can bear the dowel-bearing strength until $F_y$ was 14.70N/mm$^2$ and for 20mm diameter it is the strongest diameter comparing to the others, which can bear dowel-bearing strength until $F_y$ was 15.63N/mm$^2$.

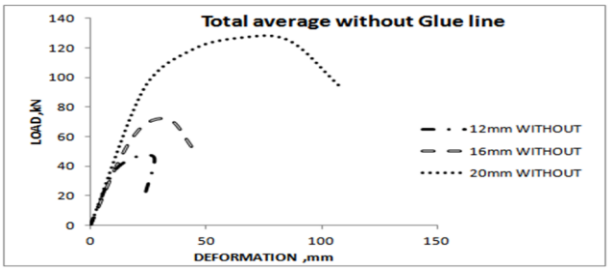


**Fig. 10:** Comparison average for three different bolt diameters 12mm, 16mm and 20mm for without glue line

Table 1 shows the mean strength comparison for 12mm dowel diameter specimen with glue line was 11.63 N/mm$^2$ and without glue line was 14.44 N/mm$^2$. Table 2 shows the mean strength comparison for 16mm dowel diameter specimen with glue line was 14.44 N/mm$^2$ and without glue line was 14.70 N/mm$^2$. Table 3 shows the mean strength comparison for 20mm dowel diameter specimen with glue line was 14.71 N/mm$^2$ and without glue line was 15.63 N/mm$^2$.

**Table 1:** Comparison of 12mm with glue line and without glue line

| 12mm diameter | Mean strength (N/mm$^2$) | |
|---|---|---|
| | $F_{5\%}$ | $F_y$ |
| With Glue line | 5.35 | 11.63 |
| Without Glue line | 8.81 | 14.44 |

**Table 2:** Comparison of 16mm with glue line and without glue line

| 16mm diameter | Mean strength (N/mm$^2$) | |
|---|---|---|
| | $F_{5\%}$ | $F_y$ |
| With Glue line | 8.8125 | 14.44 |
| Without Glue line | 8.975 | 14.70 |

**Table 3:** Comparison of 20mm with glue line and without glue line

| 20mm diameter | Mean strength (N/mm$^2$) | |
|---|---|---|
| | $F_{5\%}$ | $F_y$ |
| With Glue line | 8.975 | 14.71 |
| Without Glue line | 12.575 | 15.63 |

## 5. Conclusion

The comparison of dowel-bearing strength for the different dowel diameters parallel with glue line and without glue line is can be discussed as, the dowel-bearing strength $F_y$ for specimen with glue line, shows 20mm diameter bolt is higher with value of 14.71 N/mm$^2$ and 15.63 N/mm$^2$ with glue line and without glue line respectively, then the 16mm diameter bolt of 14.43 N/mm$^2$ and 14.71 N/mm$^2$ with glue line and without glue line respectively and for 12mm diameter bolt dowel-bearing strength of 11.63 N/mm$^2$ and 14.44 N/mm$^2$ with glue line and without glue line respectively. The specimen failed because of the larger bolt diameter can bear more loads compared to the smaller bolt diameter. The wood grain direction of specimen also influenced the cracks failure. The dowel-bearing strength, $F_y$ for parallel with glue line and without glue line using 5% diameter offset load can be discussed as, the dowel-bearing strength, $F_y$ for 12mm diameter bolt for without glue line is higher than with glue line as 19.46%. While for 16mm diameter bolt, the dowel-bearing strength $F_y$ for without glue line is higher than with glue line as 1.77% and for 20mm diameter bolt was 5.89%.

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