Strength Properties of Single Dowel Joint Using Kelempayan Wood and Oil Palm Trunk

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Abstract

T-shape joints are widely used in furniture part installation, commonly applied in chair or desk for its rail and stretcher. Recently, detailing or dimension of joints was based on trial-and-error methods and was largely a matter of traditional. The strength structural of furniture depends on how strong that joint can hold the load for some period of time. It is necessary to identify the potential of joints with a specified strength to enhance the weakest joint system. This study was undertaken accordingly to obtain the strength of single dowel pin joint with different diameter sizes and length of straight dowels (6mm × 35mm, 8mm × 40mm, 10mm ×40mm) and Poly Vinyl Acetate (PVAc) as glue. The dowel pin joint will be tested on two different wood; kelempayan wood and oil palm trunk (OPT). This is to determine either the three sizes of dowel have significant effect on the two types of wood. If these sizes are significant, it will save the furniture production in terms of its cost. The testing result was analyzed using SPSS. The result analyzed using ANOVA through Least Significant Differential (LSD) with confident level 95%. The data shows for both species have significant value for three testing. It was determined when P-value is < 0.05. According to ANOVA, OPT recorded their P-value are P=0.025 for Maximum Load, P=0.030 for Tensile at Break and P=0.000 for Load at Break. For Kelempayan wood, it P-value are P=0.036 for Maximum Load, P=0.011 for Tensile at Break and P=0.000 for load at Break. Based on this result, all dowel sizes have a significant strength for all testing. The gradual increasing of dowel size will affect the joint strength by big contact between two adherents.

Keyword: Joint, dowel, OPT, Kelempayan, ANOVA, LSD

1. INTRODUCTION

1.1 General

Malaysian wood industry

Malaysian wood based industry will categories into four major sub-sectors. It stands from sawn timber industries, veneer and panel product industries, Builder's joinery and carpentry (BJC) industries and furniture industries. The Malaysia wood based industries predominantly owned by Malaysian and 80 to 90 percent of this company comprise from small and medium entrepreneurship (SME) establishment. Below is the table shows the Malaysia wood-based industry with their activity and production.

Table1: Shows the Malaysian wood-based industry with their activity or production.

No	Industries	Activity or production
1	Sawn Timber	Graded sawn timber
2	Veneer and panel product	Particle board, MDF and chipboard
3	Moulding and builders joinery and carpentry	Door, window, flooring board and parquet
4	Furniture	Furniture and furniture component

From this data, Malaysian sawmills and veneer industries located in East Malaysia (Sabah and Serawak). East Malaysia recorded 45 percent of the plywood mills and 60 percent for the moulding mills.

Furniture industry

Furniture plant consumes more than 50% of the wood-based mills. There are 2152 plants from 4162 wood-based mills in Malaysia. From the data recorded, furniture industry contributes 31% from RM 20.03 billion Malaysia's timber product export for the year 2011 (Hashim, 2012).

MTIB from National Timber Industry Policy (NATIP) targets 6.4% of annual growth of the Malaysia timber export by 2020. This export policy will achieve until RM 53 billion incomes with 60% is the value-added product and

40% from primary industry (Hashim, 2012). To achieve this goal, MTIB highlight 7 NATIP thrust;

I. Industry structure.
II. Supply raw materials.
III. Innovation and technology.
IV. Marketing and promotion.
V. Human capital development.
VI. Funding and incentives.
VII. Bumiputeraparticipation

1.2 Butt Joint

According to Cooper, butt-joint is the simplest technique or method by joint two or more members together (Cooper, 2006). It become simple because merely involve cutting the member into appropriate length and butting them together by adhesive. This joint is the weakest joint but it can be reinforce to increase their strength. In this study, dowel pin will be use to improve the butt-joint strength and it will widely use in furniture member joint.

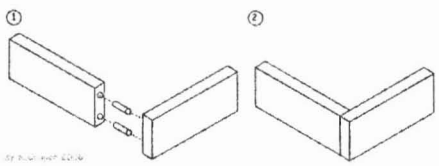

Figure 1: Existing of dowel will improve the wood joint. (Source by: Anon, 2011)

Materials

Oil Palm species

Oil palm (Elaeis guinnesis Jacq.) was firstly bought to Malaysia from Tropical African 1870 through the Singapore Botanical Gardens for ornamental purposes (Zin, Md, Zaidon, & Hamami, 1991). Palm oil industry is an important component of the national economy especially in agricultural sector (Basiron, 2002). Oil palm planted currently is the Tenera hybrid with yields about 4.0 tons of oil palm per hectare. The harvesting of the oil palm could begin 30 months after field planting.

Kelempayan species

In India, Noelamarckia cadamba or Kelempayan wood known as Kadam. This tropical tree widely growth in South and South-East Asia. Kelempayan is the light hardwood and poor durability. Kelempayan came from Rubiacea family and the density range around 440kg/m3 in an oven dry weight (2(Faeza, 2008).

1.3 Dowel

Dowel pin is a solid cylindrical rod usually made from wood, plastic and metal. The original manufactured dowel called dowel rod. Dowel rod was cut into short length called dowel pins. Dowel is employed in numerous, diverse applications, including axles in toys, structural reinforcements in cabinet making and supports for tiered wedding cakes. Other uses of dowel are;

I. Furniture shelf supports
II. Moveable game pieces
III. Support for hanging items such as clothing, key rings and tool

In modern manufacturing volumes, wood dowels are typically manufactured in industrial dowel machines. High- volume dowel manufacturing is done in a wood shaper which simultaneously forms in multiple dowels from a single piece from a single piece of rectangular stock

Wooden dowel in woodworking commonly cut into dowel pins, and it was used to reinforce the joint and support shelves and other components. Dowel based joinery typically used fluted dowel pins. Fluted dowel pin has a series of parallel grooves cut along its length. The fluting design will provide channels through which excess glue that used to secure the dowel pin in its holes. There are three types of dowels body;

I. Plain
II. Straight
III. Annular

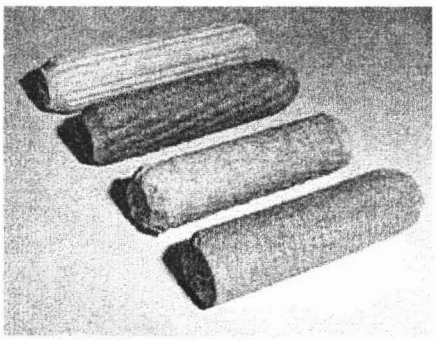

Plate 1: Type of dowel body arrangement

1.4 Adhesive

Adhesives are substances, which are capable of joining materials (Adherent) together by surface attachment or boding (Anonymous, 1991). To enhance and improve the T-shape butt joint with assistant with dowel, adhesive was used in this jointing system. Adhesive that use in this study is Polyvinyl Acetate (PVAc).

Polyvinyl Acetate (PVAc) is a thermoplastic resin, and this type of resin can return into the original formed. Polyvinyl Acetate adhesives are aqueous emulsions used primarily for furniture industry and other non-structure joint. Poly Vinyl Acetate emulsion is the most common adhesive well known as "white glues." Either used in woodworking industry, Poly Vinyl Acetate adhesive was used with paper, plastics, metal foil, leather and cloth.

Polyvinyl Acetate adhesives develop the bonding strength from loss of water into a wood joint (Anonymous, 1991). This adhesive has excellent high dry adhesion strength and good gap-filling properties. The characteristic of this adhesive is high bond strength, fast setting, and colourless glue lines. The disadvantages of this adhesive is low resistance to weather and moisture. Cured adhesive film is light stable but tend to soften at high temperature.

PVAc adhesive available as spray-dried powders which can be dry mixed with other resins, pigments and fillers and dispersed in water as important. PVAc adhesive is normally applied at 16-30°c working temperature and this adhesive curing time depending on the formulation (Anonymous, 1991). The curing ranges of this adhesive from 10 minutes to a few hours. The clamp pressure is 1 MPa is normally recommended (Anonymous, 1991).

2. MATERIALS AND METHODS

2.1 Material preparation

This study used the Oil Palm Trunk (OPT) and Kelempayan wood. Sample was cut using live sawing pattern technique because only Layer 1 (peripheral) area and this technique were applied for kelempayan wood to achieve high recovery. It happened when this area compact with Vascular bundle. The sample thickness must over than 2 inches to avoid lacking in diameter after sanding process. The sample dimension is 2" × 2" × 4'. Before making specimen, oil palm sample was dried in a kiln dryer around one week to achieve 12% moisture content (MC). Special treatment using ethanol must be done on the oil palm sample. Sample was soaked in the ethanol to make it adsorb in the wood cell and make the sample uniform in drying. It is important to eliminate oil palm sample defect like twisting.

2.2 Specimen

Specimen was being prepared in 120 replicate for both two testing (Tensile and Bending) and three sizes of dowel (6mm, 8mm and 10mm). Testing was run using In-house method and followed the tensile and bending testing method.

2.2.1 Specimen preparation

Testing specimen was being prepared in 35mm × 35mm × 100mm. The opening diameter must less than the dowel diameter to make it perform in their service. The opening depth is 35mm for 6mm dowel size, 40mm for dowel 8mm size and 40mm for 10mm dowel size. The glue (PVAc) was used to improve the joint strength and the amount must be put better. Amount of the glue determine after the opening volume minus dowel volume. The equation is:

Glue amount= $\pi r^2 h$ (opening) - $\pi r^2 h$ (dowel)

Teflon paper was used when assemble the specimen to avoid the excessive glue gift mechanical support on the joint. When it happens, the study doesn't determine the pure or true strength of specimen.

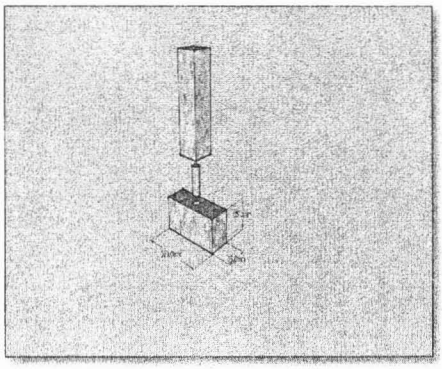

Figure 2: T-shape butt-joint improve by dowel.

2.2.2 Testing process

Specimen was being prepared in 60 replicate for both two testing (Tensile and Bending) and three sizes of dowel (6mm, 8mm and 10mm). Testing was run using In-house method and followed the tensile and bending testing method.

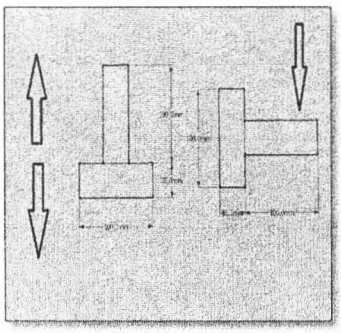

Figure 3: T-shape butt-joint improve by dowel.

3. RESULTS AND DISCUSSIONS

3.1 General

The objective of this study was analyzed from the result obtain. Statistical Package for the Social Sciences (SPSS) was used to analyze the data obtains. The main objective of this study is to determine the strength properties of T-shape joint using three sizes of dowel (6mm, 8mm and 10mm). Others of objective of this study are to evaluate the efficiency of dowel pin with both species Oil Palm Trunk (monocot) and Kelempayan wood.

Table 2: The mean ultimate moment capacities of the dowel in T-shape joint

Species	Dowel size	Tensile Test (N)	Bending Test (N)
Oil Palm Trunk (OPT)	6 mm	348.478	48.100
	8 mm	444.408	85.707
	10 mm	327.323	129.193
Kelempayan Wood (KW)	6 mm	916.783	169.100
	8 mm	1212.643	272.375
	10 mm	1369.305	325.778

According to Table 2, Kelempayan wood has recorded the greater result compared with OPT for both testing (Tensile and Bending). It is happened because the water based adhesive (PVAc) cure before the cell adsorb the glue into the cell (lumen). This situation support by the OPT tensile specimen for 10mm size showed the lesser result compared with 6mm specimen. For this size, the density of the specimen is lower than 100kg/m3 compare with other than around 200-500kg/m3. The lesser result for 10mm OPT tensile specimen might be a sample that produce specimen was taken from L2 or L3 part. This part contains more parenchyma (starch) compare with L1 part. The larger difference in content probably due to presence of a higher amount of parenchyma tissues in the core region (&(Halimahton & Rashid, 1991). Polyvinyl Acetate adhesives develop the bond strength from loss of water into the wood (Anonymous, 1991).

For dowel size comparison, 10mm was dominated for all species and test but in tensile test for OPT, 10mm show the lesser result. The wider area of adhesion force will affect the joint strength. This factor influenced the 10mm dowel are more strengths compare with 6mm.

3.2 Comparison between species toward the tensile test

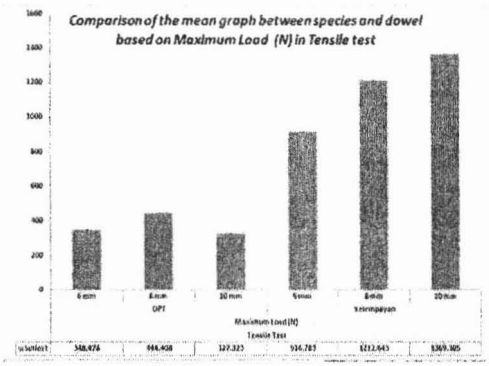

Figure 4: Comparison of the mean graph between species and dowel sizes based on Maximum Load (N) in tensile test

Tensile test was run to evaluate the joint strength toward the different force. Tensile is one of the destructive tests by breaking the two jointing member. The span length of this test is 80mm. In this testing, two values were taken to evaluate the T-shape jointing system. This is Maximum Load (N) to evaluate maximum force to break the specimen and Tensile at Break (MPa) to determine the maximum force of pressure to break the joint.

Figure 4 showed the strength properties of T-shape jointing system by using different dowel sizes 6mm, 8mm, and 10mm for Oil Palm Trunk and Kelempayan wood based on a tensile test. For small size dowel (6mm) show the value is 348.4 N for OPT and 916.7 N for kelempayan wood. For the 8mm size dowels show the value is 444.4 N for OPT and 1212.6 N for kelempayan wood. For 10mm diameter dowels recorded 1369.3 N for OPT and 1369.3 N for kelempayan wood.

Followed to the graph pattern, 6mm and 8mm dowel for both species are followed the trend which the bigger sizes are more strength compared with 10mm size, OPT strength is lesser the small once. It might be happened when the Layer 2 with high content with parenchyma compared with Layer 1 was adsorbing the adhesive (PVAc) before it cured. This condition support by Halimahton with presence of the higher amount of parenchyma tissues in the core region (Halimahton & Rashid, 1991) and Polyvinyl Acetate adhesives develop the bonding strength from loss of water into wood joint (Anonymous, 1991).

Kelempayan wood suitable for applying in furniture industry with three sizes of dowel and adhesive (PVAc) but when apply in furniture from OPT; layer will affect the joint strength except manufacturers used the fast curing adhesive.

3.3 Comparison between species toward bending test

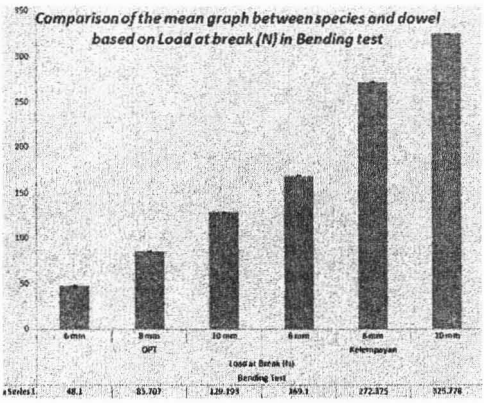

Figure 5: Comparison of the mean graph between species and dowel sizes based on Load at Break (N) in bending test

Bending test was run to determine the strength from single direction. Same like tensile, bending test is one of the destructive tests by breaking the two jointing member. The span length of this test is 90mm. In this testing, one value was taken to evaluate the T-shape jointing system. The value taken is Load at Break (N) to evaluate maximum load to break the specimen joint.

Figure 5 above showed the strength properties of T-shape butt-joint by using different dowel sizes 6mm, 8mm and 10mm for Oil Palm Trunk and Kelempayan wood based on bending test. For small size dowel (6mm) recorded value is 48.1 N for OPT and 169.1 N for kelempayan wood. For size 8mm size dowels show the value is 85.7 N for OPT and 272.3 for kelempayan wood. For 10mm diameter dowels recorded 129.1 N for OPT and 325.7 N for kelempayan wood.

Different with tensile test, bending test follow the graph pattern which valued increasing followed the size increasing and species differences. This situation followed the hypothesis by widen an adhesion surface will give more strength to the joint strength. The better graph pattern performed when the parts are taken to do a specimen was uniform that mean all samples taken to produce specimen taken from Layer 1.

According to bending test analysis, kelempayan wood suitable to make furniture that used this type of jointing system with the adhesive (PVAc). OPT still to show the lesser result when used this jointing system and the bigger size dowel for OPT (10mm) is recorded lesser result compared with small size dowels (6mm) for kelempayan wood. That mean when applied this jointing system to OPT furniture product, fast curing adhesive or other method curing adhesive is important to give better strength performance.

3.4 Comparison strength for both species toward different dowel sizes

Table 3: Show the significant value between species based on T-test analysis

Comparison	Test type	T-Test	Significant	Equation
μOPT 6mm = μKW 6mm	Tensile at Break (MPa)	0.000	Yes	**μ KW*6mm* > μ OPT *6mm***
	Maximum Load (N)	0.000	Yes	**μ KW*6mm* > μ OPT *6mm***
	Load at Break (N)	0.000	Yes	**μ KW*6mm* > μ OPT *6mm***
μOPT 8mm = μKW 8mm	Tensile at Break (MPa)	0.000	Yes	**μ KW8mm > μ OPT 8mm**
	Maximum Load (N)	0.000	Yes	**μ KW8mm > μ OPT 8mm**
	Load at Break (N)	0.000	Yes	**μ KW8mm > μ OPT 8mm**
μOPT 10mm = μKW 10mm	Tensile at Break (MPa)	0.000	Yes	**μ KW 10mm > μ OPT 10mm**
	Maximum Load (N)	0.000	Yes	**μ KW 10mm > μ OPT 10mm**
	Load at Break (N)	0.000	Yes	**μ KW 10mm > μ OPT 10mm**

According to the table 3 recorded for overall sizes and test, kelempayan joint has greater strength compared with OPT joint. Refer to the graph height with shown the strength value, kelempayan joint with small size dowels (6mm) have more strength joints compared with OPT joint in both testing with three (Maximum Load, Tensile at Break and Load at Break) parameters. For 6mm dowel joint in tensile test, the result recorded 916.7 N load and 0.258 MPa force achieved for kelempayan wood compared with OPT joint with 348.4 N load and 0.095 MPa force recorded. This trend followed until bending test with value 169.1 N compared with OPT with value 48.1 N. These values recorded shows there has a significant strength for the size (6mm) of dowel.

For the middle size of dowel (8mm), the trend show in a graph has a same pattern with 6mm dowel size. In tensile test, 1212.6 N loads with 0.32 MPa force for 8mm size kelempayan joint compared with 444.4 N loads and 0.116 MPa force for OPT joint. Bending test graph followed the pattern with 272.3 N loads for kelempayan wood and 85.7 N loads for OPT. The far strength values show the significant strength for this dowel size between two species. Same like 6mm, kelempayan wood more dominant in strength compared with OPT.

The pick issue in this study is in the 10mm dowel size. It happens when the tensile value for this bigger size of dowel is lesser than small once (6mm). It is happened for OPT species, and it not followed the graph trend. In tensile test, the result recorded 1369.3 N load and 0.368 MPa force for kelempayan wood, but the very different value recorded for OPT with 327.3 N load in maximum loading and 0.086 MPa force in tensile at break. This result makes the strength is very significant. In bending test, with followed graph pattern, kelempayan wood record 325.7 N load and OPT recorded 129.1 N load values. These differences still show the significant dowel strength for both species. The difference value might be happened when the layer taken to make the specimen not uniform and the result produce in vice versa condition.

4. CONCLUSIONS AND RECOMMENDATION

After analyze the data obtain from tensile and bending test, that shown the wider adhesion area will give greater mechanical strength to a furniture joint. The 10mm diameter dowels size was the best performance properties and gives strong jointing strength compared with 6mm and 8mm diameter. That fact can be proved by the result on a tensile and bending test for both species.

In four categories (tensile OPT, tensile kelempayan wood, bending OPT and bending kelempayan wood), three categories shows the bigger diameter sizes will give the strong wood joint. Based on this study, the result can approve the requirement for strength properties of T-shape jointing system for general uses, especially in furniture manufacturing are very significant for every dowel sizes. When it has significant strength, the proper sizes that will use in furniture joint assemble will save the manufacturing cost.

The effect of the strength properties for T-shape jointing system can be influent by many factors. Understanding the cause and characteristic of fracture in adhesion bonding and material is very important to improve the joint strength performance, developing new product and material, predicting the performance for new product and developing new design method for structural joints (Asnawi, 2011).

Besides that, choosing wood species that have good properties is an important element to produce good performance as a furniture component. Species in medium category to light hardwood species with density approximately 500 kg/m3 and above could give the standard requirement for furniture industry (Asnawi, 2011). Some of lightwood species also can be utilized as raw material similar to kelempayan wood especially for indoor or light weight duty. In case of kelempayan wood, the texture and appearance of this species are very good and has high ecstatic value. These elements will give advantage to kelempayan wood to make it as raw material especially for exporting to countries like Japan because their citizen like light colour furniture.

Adhesive choosing is another important element to improve the T-shape jointing strength. For kelempayan wood, they have no problem to use any synthetic resin (adhesive). For Oil palm trunk furniture, the adhesive selection is very important to make the joint perform in it service. The high parenchyma part will absorb the resin form water based adhesive before it cured (&(Halimahton & Rashid, 1991). This issue will affect the joint by the PVAc curing method by loss of water (Anonymous, 1991). Thus, it recommended that the joint from Oil palm trunk furniture must use the fast curing adhesive like epoxy and non-conventional wood adhesive (Anonymous, 1991)

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