Screw Withdrawal Properties of Kelampayan and Sesendok Glue-Laminated Timber

Wan Mohd Nazri Wan Abdul Rahman, Nur Aisah Sajali, Nor Yuziah Mohd Yunus

Abstract**: *Glue-laminated timbers were produced using two species, Kelampayan and Sesendok. Polyvinyl Acetate (PVAc) was used as binder for the glue-laminated timber manufacturing. Screws with same diameter (3.5mm) and length (50mm), but with different angle and distance of pitch were used. The screw-withdrawal test position was selected for 3 direction designated as the surface, front and side. The test result found that both of pitches of screws are suitable for Kelampayan species. In side position, Kelampayan species showed the best screw holding strength and this result is followed by Sesendok species. In surface position, Pitch 2 has highest withdrawal strength for the Kelampayan species. In all position, Pitch 1 is suitable for Sesendok species and Pitch 2 is suitable for Kelampayan species. In both of pitches, Kelampayan attained higher withdrawal strength when compared to Sesendok.***

Keywords : Distance of pitch, Glue-laminated timber, Kelampayan, Screw withdrawal, Sesendok.

I. INTRODUCTION

The strength and stability of any structure depend heavily on the fastening that holds its parts together. One prime advantage of wood as a structural material is the ease with which wood structural parts can be joined together with a wide variety of fastenings such as nails, spikes, screw, bolt, staples and metal connector of various types [1]. Screws provide an excellent method of fastening [2]. Screws are of considerable importance when they are required to resist forces which tend to cause direction separation of members joined; for example when the screws are in withdrawal loading. This is because the strength in withdrawal loading for screws is much higher than that for nails of the same diameter. Thus screw fasteners are difficult to dislodge and perform well when vibration is a factor [3]. Therefore, knowledge of the withdrawal of screw will provide useful information about the durability and stability of the whole jointed system. In this study, screw withdrawal testing on glued-laminated timbers was investigated. Glue-laminated timber refers to two or more layers of wood glued together with the grain of all layers or laminates approximately parallel [3].

Kelampayan or Neolamarckia cadamba has been selected for planted forest development in Malaysia. It has been planted in Sabah and Sarawak and mainly planted in Perak and Pahang, Malaysia [4], [5]. This species is a fast growing plantation tree species that confers various advantages for timber industry and it is also planted as a strategy for reducing the logging pressure on natural forest for wood production to an acceptable level [6]. The species came from the Rubiaceae family and can grow in lowlands to mountain forest of about 1000 m. Its character of heartwood is white to yellow in color and similar in color to sapwood. This species texture is moderately fine and is categorized as light hardwood timber [7]. Its density is around 290 to 560 kg/m3 at 15% moisture content, It is easy to handle and can be machine tooled with smooth finishing and easily nailed [8], [9]. This wood is suitable for making veneer, fiber and others [10]. Sesendok or Endospermum diadenumis is widely distributed in lowland secondary forest up to 1000m elevation in Peninsular Malaysia and usually grows in the logged over forest [11]. Sesendok is suitable for fabrication of wood furniture or wood-based product such as particleboard, plywood, wood lamination and veneer. This timber is classified as light hardwood with density ranges from 270-500 kg/m^3 [12]. Kelampayan and Sesendok are one of the best candidates for raw materials for the wood or furniture industry in Malaysia. This is due to their multipurpose function and utility as well as having short rotation period.

The rate of growth of world population is currently is around 1.07% per year estimated via early data of 2019. This is showing a slight down trend when compared to 1.09% in 2018, 1.12% in 2017 and 1.14% in 2016. At this rate the current average population increase is estimated at 82 million people per year [13]. Growth in population and limitation of floor space in modern living environment for the normal working class spurs the demand in knock down (KD) furniture. Knock down furniture is a form of furniture that required customer assembly or do it yourself (DIY). Usually, screws and dowels are used as fastener to assemble the KD furniture. The joints assembly of KD furniture has tendency to get loosen or even breakdown overtime. For these KD's, the holding strength of fasteners used for the joint is important. Withdrawal strength testing, to ensure good holding power of the fastener onto substrate is important.

Popular material used for KD furniture includes engineered substrates such as particleboard, oriented strand board, and medium density fiberboard. Glue-laminated timber is a substrate that could easily be used for supports such as legs and bracing of chairs and tables in knock down furniture. Unfortunately, glue-laminated timber has not been thoroughly explored for such purpose. Data on the holding strength of screws in

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***** Correspondence Author

Wan Mohd Nazri Wan Abdul Rahman, Faculty of Applied Sciences, Universiti Teknologi MARA, Pahang, Malaysia. wmdnazri@uitm.edu.my

Nur Aishah Sajali, Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Malaysia. aisah_sajali@yahoo.com

Nor Yuziah Mohd Yunus*, Faculty of Applied Sciences, Universiti Teknologi MARA, Pahang, Malaysia. noryuziah@uitm.edu.my

glue-laminated timbers has not been widely reported. As such it would be good to know the ability of this material to hold on to fasteners like screws which will allow usage of the glulam in the future.

This study focused on two glue laminated species. Kelampayan and Sesendok will be used to produce the glue-laminated timbers, which in turn will be tested for the withdrawal strength of screw. The screws used were of two different pitches and the withdrawal was tested for three different attachment positions.

II. MATERIALS AND METHODS

A. Preparation of gluelam from Kelampayan and Sesendok and test pieces preparation

The two local species, Kelampayan (Neolamarckia cadamba) and Sesendok (Endospermum diadenumis), were harvested from Universiti Teknologi MARA, (UiTM) Jengka, Pahang, Malaysia Educational Forest Reserves. The trees were cut into billets and transported to the UiTM workshop. The billets from Kelampayan and Sesendok were debarked and cut into planks by using Band-ripsaw. The planks size was of 20 mm thickness, 55 mm width and 780 mm length. The planks were then kiln dried to 15% maximum, as this is the required moisture content prior to adhesive application. Polyvinyl Acetate adhesive was applied to the kiln dried planks. For lamination the plank were pressed together using clamps with approximate glue-line pressure from 0.4 to 1.2 N/mm2, with the final cross-section lying on its side. Four layered planks were pressed together. The glue-line was kept under pressure in controlled climate at room temperature with relative humidity of ~85% for at least 6 hours before the clamps were removed. The glued-laminated timbers were then cut into required test samples for screw withdrawal testing process using radial arm saw. The size of the sample was 51 mm x 51 mm x 152 mm for its thickness, width and length respectively in accordance with ASTM D1761: 2012 [14] requirement. Flow chart of the glulam manufacturing process is given in Fig. 1.

Two different screws were tested. Both screws have the same outer diameter (3.5 mm) and shaft length with pitch (50 mm). They differ at the distance of pitch which was 1mm and 2mm. Pitch angle was determined according to (1).

$$\text{Tan } \alpha = (\text{Pitch length})/\text{Diameter} \quad (1)$$

Where;

α signify the angle in degree

The calculated angle of pitch was Pitch 1: $\alpha = 15.95^\circ$ and Pitch 2: $\alpha = 29.74^\circ$. The screws were driven into the glue-laminated timber at different position namely, surface, front and side, by using electronic screwdriver to a depth of 50 mm. The positions were measure accordingly using a ruler. The screws were attached at the glue-line of the glue-laminated timber for the surface and front position. The side position penetrates through two glueline.

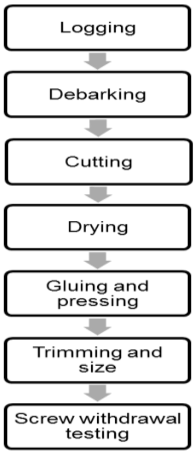

Fig.1: Flow chart of glue-laminated timber manufacturing process

The test piece was mounted onto a test machine that was capable of applying increasing load to the underside of the screw head. An even withdrawal force was applied at a fixed rate of 6mm/min until a maximum load was achieved..

III. RESULTS AND DISCUSSION

The average of the maximum load for the screw withdrawal strength test results and comparison of 2 species, 2 different pitch of screw and 3 different positions of screws is shown in Table I.

Table I: The average of the maximum load for the screw withdrawal strength in Newton (N)

Species	Pitch	Side	Surface	Front
Sesenduk	1	3,121.71	3,279.73	2,353.10
Sesenduk	2	3,328.05	3,322.17	1,924.40
Kelampayan	1	3,259.49	3,284.90	2,087.41
Kelampayan	2	3,475.23	3,407.70	2,663.58

A. Overall performance of screw withdrawal

Fig. 2 shows the value of maximum load for the screw withdrawal strength on different species and position. Result from ANOVA shows that the difference between species and positions are highly significant at $p \leq 0.05$. Based on the graph, Kelampayan with surface position have highest value. Then, Sesendok at front position have the lowest value. In terms of performance, overall Kelampayan gave better strength in all direction compared to Sesendok. The structure of kelempayan differs from Sesenduk. The combined resistance of the two pitches showed the surface and side having similar performance for both species. When the pitch is attached to the front position both species showed significantly lower performance then the other directions. At this position combined performance of Sesenduk versus Kelampayan is also significantly different.

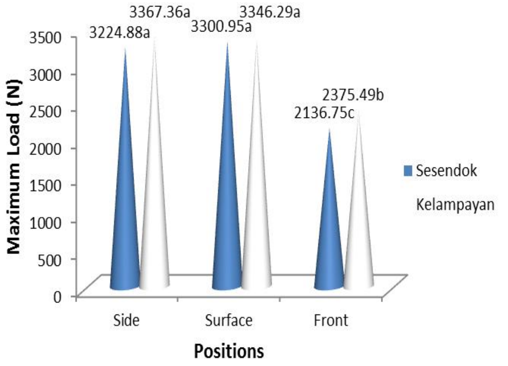

Fig. 2: Maximum load for the screw withdrawal strength for different species and positions. Letters a, b and c indicate values in cluster to be significantly different at p < 0.05

With reference to Fig. 3, the average of maximum load for the screw withdrawal strength based on differences pitches and species for combination of all position is shown. Result from ANOVA shows that the different between pitches and species are not significant different at p>0.01. Pitch 2 with Kelampayan get highest value at average value of 3080.65 N. Pitch 2 also has lowest value with Sesendok and its performance is significantly different form Kelampayan with pitch 2. Sesendok and Kelampayan with Pitch 1 is not significantly different from either Sesendok and Kelampayan with Pitch 2. However, the higher value of for Kelampayan at 3080.65N for pitch 2 compared to Pitch 1 with 2969.53 N indicated potential suitability of pitch2 for this specie. Pitch 1 with the lower angle (α = 15.95°) seems to be suitable for Sesendok. For Kelampayan Pitch 2 with α = 29.74° gave better overall performance. In term of performance, Kelampayan still gave better results for both pitches compared to Sesendok. This gave an indication on the wood specie suitability with the fastener used.

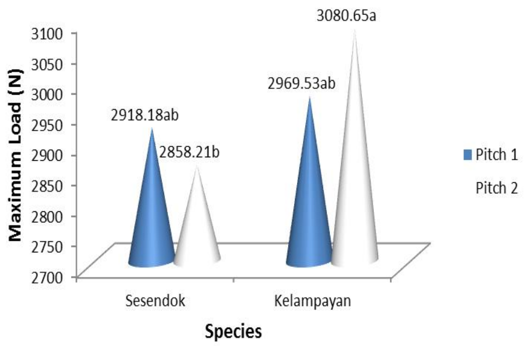

Fig. 3: The maximum load for the screw withdrawal strength based on differences pitches and species for all positions. Letters a indicate values in cluster not to be significantly different at p < 0.05

B. Effects of attachment position on screw withdrawal

Fig. 4 shows the value for the average of maximum load for the two species, Sesendok and Kelampayan. The pitches of screw are marked as Pitch 1 and Pitch 2. Based on the graph, Kelampayan get highest value of the maximum load at both of Pitch 1 and Pitch 2 which are 3259.49 N and 3475.23 N. While the Sesendok exhibit the lowest value. Screw attachment on the side does not have a glueline. Similar trend is seen for the surface direction, in which the screw was driven in at the glue line (Fig. 5). The presence of glue line does not seem to impact performance of screw withdrawal. This is a plus factor for glulam as non-disturbance of performance with presence of glueline allows easy usage of glulam. This is opposed to the study on the effect of layering, which showed lower values when the screw needs to penetrate through more glueline due to fiber alignment disruption [15].

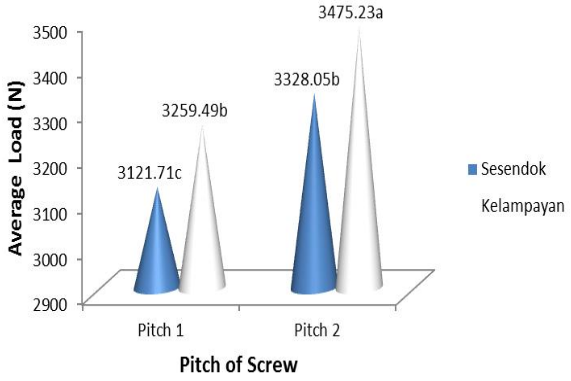

Fig. 4: The average of maximum load for the screw withdrawal strength based on different species and pitch of screw on side. Letters a, b and c indicate values in cluster to be significantly different at p < 0.05

The graph in Fig. 5 shows the average of maximum load for screw withdrawal at surface position. Both species showed the same trend in strength where Pitch 1 has lower value than Pitch 2. The reason for this was that screws are drawn perpendicular to the grain configuration of tested materials. The distance of pitch at Pitch 2 is larger than Pitch 1. Therefore, Pitch 2 did not split the grain of wood. The closer interval of Pitch 1 cuts the fibers in the wood giving rise to lower strength. The finding has similarity to work by [16] where less wood splitting give way to better withdrawal strength. The highest strength was attained by Kelampayan species for Pitch 2 at 3407.70 N. The result is highly significant when compared to the other three settings. For pitch 1, Kelampayan performance only equals Sesenduk.

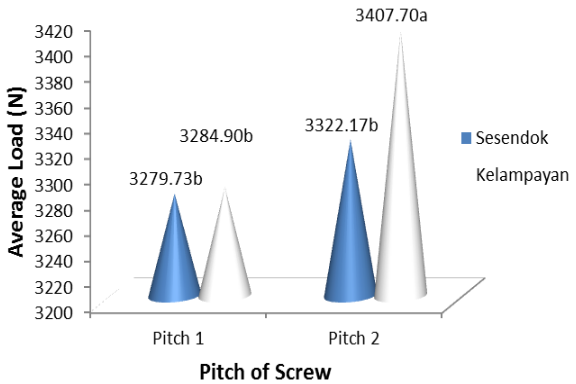

Fig. 5: The average of maximum load for the screw withdrawal strength based on different species and pitch of screw on surface. Letters a and b indicate values in cluster to be significantly different at p < 0.05

For the behavior of screw withdrawal front direction, the values are much lowered for both species (Fig. 6). The front direction is the cross-cut section of the wood sample. There is presence of voids created by xylem and phloem, the vessels for nutrients transport. The arrangement of the voids and fibers could prevent the screw from having proper hold on the material. Tangential and cross-section behaviour variation was also seen by [17] in their screw withdrawal study. Screw withdrawal values for cross-section tend to be lower. For Sesenduk, pitch 2 with angle of 29.74^o gave a much lower reading then Pitch 1 ($\alpha = 15.95^\circ$). Kelampayan on the other hand, gave better value of 2663 N with pitch 2 compared to 2087 N for pitch 1. All screw withdrawal test in the front position gave significantly different results. This is related to how the fibers in the wood behave as the pitch cuts into the wood. In this study, it clearly demonstrated that small pitch screw is not a suitable fastener for Sesenduk. The low results were shown for all position of screw attachment.

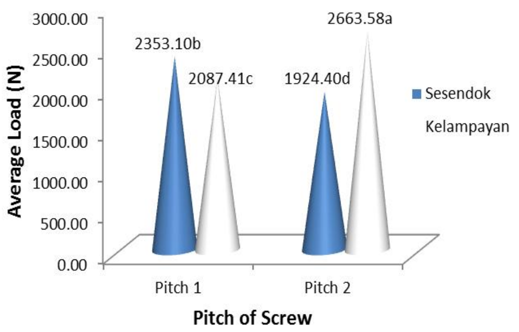

Fig. 6: The average of maximum load for the screw withdrawal strength based on different species and pitch of screw on front. Letters a and b indicate values in cluster to be significantly different at $p < 0.05$.

Generally both of pitches used seem to be more suitable for Kelampayan species. This indicates the fibers of the Kelampayan and the pitch of screw can be held together to get higher strength when the screw was pulled.

IV. CONCLUSION

The Completely Randomized (2 x 3) factorial design method on screw withdrawal for Kelempayan and Sesenduk showed differing strength behaviour. In term of species effect for both pitches, Kelampayan performed better than Sesendok. At side or tangential position, Kelampayan specie showed the best screw holding strength and this result is emulated by Sesendok specie but at a lower scale. At surface position, Pitch 2 has highest withdrawal strength on the Kelampayan species because the distance of pitch is larger than Pitch 1 and it did not split the wood grain. In all position, Pitch 1 seems to be suitable for Sesendok specie, while both pitches are suitable for Kelampayan specie even though Pitch 2 gave better performance.

For future work, the effect of other pitch sizes, screw diameters or screw length as well as depth of penetration could be looked at. This will give better variations in choice of screw to be used on glue-lam made from Kelampayan and Sesendok.

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AUTHORS PROFILE

Wan Mohd Nazri Wan Abdul Rahman is an associate professor at the Department of Wood Industry, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Jengka Campus, Pahang, Malaysia. He started teaching at UiTM since 2000. He obtained his Bachelor of Science (Forestry) Degree in 1998 and Master Degree of Science (Wood Utilization) in 2000 at Universiti Putra Malaysia (UPM). He holds a Philosophy Degree in 2009 from UiTM. His research fields in forest plantation, biomass and wood composite.

Nur Aisah Sajali obtained her Degree in Science (Furniture Technology) in 2015 from Universiti Teknologi MARA (UiTM). Her thesis involved evaluation on screw withdrawal properties of gluelam from Kelampayan and Sesendok.

Nor Yuziah Mohd Yunus is an associate professor at Department of Wood Industry, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Jengka Campus, Pahang. She started at UiTM since 2014. Before joining academic profession, she was R&D manager and Director for Malayan Adhesives & Chemicals Sdn. Bhd. for 26 years. She is a chemist by profession and her research fields in adhesive and wood composite and also holds an MBA. Her Philosophy Degree in 2005 from Universiti Putra Malaysia is in the field of wood plastic composite – conventional versus radiation treatment.