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BONDING ABILITY OF SENGON WOOD TREATED WITH NATURAL EXTRACTS

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ABSTRACT

Wood preservation technology has been using a lot of synthetic preservatives for a long time. However, some disadvantages have been recorded such as environment quality degradation and killing more untargeted wood destroying organism than targeted one. Recently environment quality maintenance has been required causing a significant change in general wood processing technology and wood preservation paradigm. In terms of wood preservatives has changed from synthetic to natural wood preservatives application. Sengon is the fast growing wood species chosen in Indonesia to fulfill national and international wood demand. Unfortunately this wood species is class V of wood durability and has to be treated with preservatives. Glued wood products such as plywood, lamination, particleboard and fiberboard use low durability wood such as sengon. The objective of this research is to know the adhesion strength of sengon wood after treatment with the natural preservatives.

This research was conducted by wood adhesion block method. The fast growing sengon plantation wood was chosen since this type of sengon wood was classified as low grade of wood quality (Class V). This type of wood had high portion of sapwood which was susceptible to wood destroying organism and absence of natural preservatives. The sources of natural wood preservative chosen were gadung tubers, pulai bark and kumis kucing leaves, while the extraction methods were hot water and alcohol toluene. The wood adhesive used was bio-industrial PVAc. Extraction procedure of natural wood preservatives followed ASTM D1110-1984 and D-1107-1996-2013. The procured naturally extracts was processed to obtain extract concentration 1 gram per liter. Wood preservative application used padding method on the wood surface by 0; 1; 2 and 3 application times. Each padding method was processed was applied after the former one was air dried. Wood adhesion test followed block type with with $196 \cdot gm^{-2}$ glue spread and cold press system. Compression shear test of block samples followed British Standard (1957).

The research results showed that adhesion strength was highly significantly affected by single factor of padding application. Padding application exerted a negative correlation to adhesion strength. Increased natural preservatives treatment (padding application) on the wood surface resulted lower adhesion strength. The average sengon wood adhesion strength of control, 1; 2 and 3 padding application were 5.10; 3.00; 2.22 and 1.05 MPa respectively. The average wood failure were 69.20; 66.71; 62.12 and 45.83% respectively.

KEYWORDS: Natural wood preservatives, padding method, extraction method, adhesion properties.

INTRODUCTION

Background

Sengon wood has been planted in a large area in Java island of Indonesia. This sengon wood is fast growing species, has 0.3 $g\cdot cm^{-3}$ wood density and not durable as prime wood such as teak. This type of wood is expected to fulfill the national wood demand and give time to grow for other higher durable wood. In order to substitute the commercial wood therefore this sengon wood shall be treated with preservatives.

Wood preservation technology has been using synthetic wood preservatives for long time. Synthetic wood preservatives have several advantages and disadvantages. The significant disadvantages observed were environment quality degradation and killing so many organisms other than wood destroying organism that reducing the diversity of organism. New paradigm of wood preservation in Indonesia is using natural bio chemical come from herbal. This bioactive chemical is expected producing better effect compared to synthetic one. One advantage of using synthetic chemical is fast response, efficient and effective preservation system, while herbal one is slower response but acceptable and preferred by the people due to less toxic to the environment. Wood preservation history shows that a lot of wood preservatives have been banned due to the significant disadvantages such as PCP (Penta-chloro-phenol), CCA (Chrome copper arsenic), cresosote and others.

The most important of wood preservation objectives is to make service life of wood products longer. The wood products are exposed to many destroying factors in the end utilization. Furniture can face interior condition as chairs, bed, wall panel and others. On the other hand, garden furniture is exposed to exterior condition which is very severe condition to wood. Similar condition observed when construction wood products such as beam and truss to support roof (subject to interior condition) or as exterior fence (subject to exterior condition). Only a small number of wood species can withstand to the exterior condition. Most commercially wood can be used only for interior condition (Martawidjaya et al. 2005). For that reason wood preservation is a must to improve wood capability to face exterior condition. The same technology employed to improve the wood based product span life when they are exposed to destroying insects and other organism. Consequently when wood products can serve longer then fresh wood demand will decrease significantly (Anonym 2012).

Wood based products need adhesives for their manufacture. Up to now a lot of conventional wood adhesives are already classified commercial one. However, due to some environment pollution several formaldehyde based adhesives have been reduced their utilization. For that reason, new type of adhesive such as natural adhesive (glue) and other carboxylic acid has been tried to replace them. A research has been conducted for citric acid utilization (Widyorini et al. 2015). Polyvinylacetat glue has been commercially used in wood processing in Indonesia. This type of glue has produced high quality of wood adhesion in furniture processing.

Several glued wood products such as plywood, lamination, particleboard, fiberboard and other wood composite used any adhesives to joint and combine them. The ideal condition of wood gluing is the availability of high attachment capacity of wood surface. Unfortunately this ideal condition is difficult to obtain due to many factors such as dirt, wood extractives, wood preservatives and other foreign materials that are deposited on wood surface (Haygreen and Bowyer 1996). This results in a reduction of adhesion strength of the wood. For that reason, a research on this adhesion reduction of wood adhesion strength is needed.

Research objectives

The objective of the research is to know the bonding ability of the fast grown sengon wood adhesion treated with natural extracts as wood preservatives.

Research benefit

The research results would be very useful and beneficial for wood processing mill and other wood composite producers using fast grown species such as sengon wood. They would be provided data of adhesion strength reduction when the wood is processed for glued wood products. They would have some scientific reason for making a right decision in wood gluing and preservation.

MATERIALS AND METHODS

Materials

Fast growing sengon wood used as raw material for glued wood products testing. They were supplied by community forest in Central Java Indonesia. Wood adhesive used was commercial bio-industry PVAc which was a new type of PVAc adhesive family. The natural wood preservatives were obtained by two extraction methods namely hot and alcohol toluene extraction of three different type plant sources namely, gadung tubers (*Dioscorea* spp), pulai bark (*Alstonia* spp) and kumis kucing leaves (*Orthosiphon* spp).

The research was conducted in the Laboratory of Biomaterial Engineering, Faculty of Forestry, University of Gadjah Mada Yogyakarta Indonesia. The adhesion block test was conducted in Forest Product Technology Laboratory by using UTM machine.

Methods

The research entitled the bonding ability of sengon wood treated with natural preservatives was executed by following several standards. First standard used was ASTM D1110-84 for extracting the three kinds of natural biochemical sources, namely gadung tubers, pulai bark and kumis kucing leaves. Second standard used was adhesion block testing followed British standard. The procedure for completing the research was described below:

1. Procuring the fast growing sengon wood from community forest in Temanggung Central Java and brought to Saw-mill laboratory of Forest Product Technology Department, Faculty of Forestry. The sengon logs were sawn into radial sawn timbers and then air dried to reach air dry moisture content of the lumber. The lumber were then re-saw and cut to produce the adhesion block sample following British standard 2 x 2 x 15cm The sengon wood strips were then sanded in such a way to produce completely pair assembly for adhesion test.
2. Collecting the natural biochemical sources namely gadung tubers, pulai bark and kumis kucing leaves from the rural herbal plantation in Kulon Progo Yogyakarta and Temanggung. The natural preservatives sources were grinded to produce powder passing 40mesh sieve.
3. Hot water extraction (HWE) and alcohol toluene extraction (ATE) were chosen. The ratio herbal extract to hot water and alcohol toluene was 1:10 w/w to produce natural hot water

and alcohol toluene extracts following the standard ASTM D 1110-84 (2013) and ASTM D-1107-96 (2013) respectively. The collected extracts were then evaporated to produce 1:1 ratio of w/v.

4. The extract was then applied to wood surface by padding system. The number of application of 1, 2, 3 in order to know the effect of number application on the adhesion capability of the wood samples. The new padding application was conducted after the wood surface was air dried after the first padding.
5. The air dried wood strips after natural preservatives treatment was then spread with the glue amount to to 196 g.m-2. The type of wood adhesive used was bio-industry PVAc which was claimed to be much better than the white, commercial one.
6. The glued wood strips were then assembled to become adhesion block test following British standard (BS 373, 1957).
7. The adhesion block tests were then conditioned for a week. The adhesion sample tests were then cut for compression adhesion test and then subjected to test machine.
8. The adhesion strength and wood failure data were analyzed by SPSS employing CRD ANOVA test following Steel and Torrie (1981).

RESULTS AND DISCUSSION

The average adhesion shear strength and wood failure for three different extract sources, four different padding application, and two different extraction method of extract source on sengon wood glued by PVAc bio-industry were presented in Tab. 1. The mean values and standard deviation are calculated from the 3 replication samples for each padding application. In addition to data bonding shear strength, percent wood failure on the fracture surface was also measured (Tab. 2). The premise of measuring percent wood failure is that adhesives are generally assumed to be stronger than the substrate, therefore the failure plane should be in the wood and not in the glue line (Xiao 2007).

The result of ANOVA (Tab. 3) proved that padding application was significant to the bonding shear strength and wood failure. The padding application number was meant to give more layers of natural extract preservative to the wood surface before adhesion. Padding application chosen as a method of preservation on sengon wood because it is conventional and economical for the furniture producers. The more layer of natural preservative on the wood surface, the more organic materials attached to cellulose molecules of wood surface, and the less OH site of wood available to the adhesive attachment. Consequently, this condition would produce less attachment site for adhesive molecules that using OH site, and give no effect to those non OH attaching one. In the case of OH adhesive attachment, lower adhesion strength would be the result. In this research this padding application exerted a high significant effect. This means that low bonding strength and wood failure resulted by sengon wood samples treated with more layer of natural extracts.

Tab. 1: Average bonding strength of sengon wood affected by natural preservative application(MPa).

Extract source	Extraction method	Padding application 0	1	2	3	Sub Average	Avg of EM
Gadung tubers	ATE	4.95	3.16	2.17	1.30	2.90	2.85
	HWE	4.82	2.54	1.39	0.94	2.42	2.83
SubAverage		4.89	2.85	1.78	1.12	2.66	
Pulai bark	ATE	4.94	3.13	2.67	0.70	2.86	
	HWE	4.81	2.86	2.23	0.75	2.66	
SubAverage		4.87	3.00	2.45	0.73	2.76	
Kumis kucing leaves	ATE	5.02	2.91	2.14	1.12	2.80	
	HWE	6.09	3.39	2.73	1.47	3.42	
SubAverage		5.55	3.15	2.43	1.29	3.11	
Grand average		5.10	3.00	2.22	1.05		
Standard deviation		0.45	0.27	0.44	0.28		

Tab. 2: Average percentage wood failure of sengon wood affected by natural preservative application(%).

Extract source	Extraction method	Padding application 0	1	2	3	Sub average	Avg of EM
Gadung tubers	ATE	69.25	60.36	47.29	45.79	55.67	58.95
	HWE	81.42	76.50	64.25	47.92	67.52	62.99
SubAverage		75.33	68.43	55.77	46.85	61.60	
Pulai bark	ATE	52.38	67.71	66.83	44.67	57.90	
	HWE	57.33	71.67	71.17	54.67	63.71	
SubAverage		54.85	69.69	69.00	49.67	60.80	
Kumis kucing leaves	ATE	79.50	66.46	63.21	43.96	63.28	
	HWE	75.33	57.58	60.00	38.00	57.73	
SubAverage		77.42	62.02	61.60	40.98	60.51	
Average		69.20	66.71	62.12	45.83		
Standard deviation		10.93	6.39	7.46	4.98		

Tab. 3: ANOVA of bonding strength and wood failure of sengon wood.

Variation source	Bonding strength F	Bonding strength Prob	Wood failure F	Wood failure Prob
Extraction method (EM)	NS	0.519	NS	0.590
Extract source (ES)	NS	0.970	NS	0.862
Padding application (PA)	HS	0.000	HS	0.003
EM x ES	NS	0.074	NS	0.064
EM x PA	NS	0.619	NS	0.780
ES x PA	NS	1.000	NS	0.337
EM x ES x PA	NS	0.985	NS	0.762

Remarks: NS=not significant, HS= highly significant

Some research on wood preservation using several methods such as soaking, diffusion, impreg and/or compregnation etc. The result of preservative treatment on wood by impregnation were shrinking, swelling, and unwanted cracking of the wood or adhesive bond lines. The impregnation process with tanalith- C, creosote, and Protim negatively affected the adhesive bonding strength, the highest shear strength was obtained in not impregnated and PVAc gluing oak were 5.33 $N \cdot mm^{-2}$ (Uysal 2006). Long preservation process of laminated veneer lumbers with impregnation in sea water have negative effect on adhesion srength (Kurt 2006). This research showed that the highest bonding strength was obtained by kumis kucing treated sengon (3.39MPa).

The experiments of merging two phases material of both binding agent and preservatives on Norway spruce were conducted by added boron to the adhesive (Lesar et al. 2011). The shear strength showed a reduced slightly bonding strength in test sample that were bonded with melamine-urea formaldehyde adhesive containing boron compound, but this reduction was not significant. The research using other adhesive reported that the inclusion of boron in the polyurethane adhesive increased both the shear strength and the percentage of wood failure, but the difference was not significant (Lesar et al. 2011).

The result of ANOVA (Tab. 3) showed that other source of variation such as extract source and extract method was not significant to the adhesion strength and wood failure. This result emphasized that interaction effect of herbal source, extraction method of HWE and ATE and padding application did not exert any effect on the adhesion strength of sengon wood. The three combinations of 2-factors interaction of extraction method combined with natural preservatives source, the extraction method combined with padding application while the last is factor natural preservatives source combined with padding application did not affect significantly to the adhesion strength of sengon wood. The interaction of EM and ES however showed significant effect at 7% level.

A similar research using cold water extract (CWE) for newly fast grown teak wood adhesion test showed that this CWE exerted high significant effect (Prayitno and Widyorini 2016). Hot water extracts contains more chemicals that cold water extracts with almost similar chemicals, i.e. carbohydrate, sugars, starch, coloring materials and it was expected to influence the adhesion of sengon wood similar to teak wood. This result might be due to different wood density of sengon (0.3 $g \cdot cm^{-3}$) and young teak wood (0.6 $g \cdot cm^{-3}$).

The two methods of extraction resulted in different chemical constituents in their extracts, but they did not differ in the adhesion influence. Santos et al (2011) conducted a research on the chemical constituents of eucalyptus by different extraction of ethanol, toluene and water. Their result showed that more quantity of extractives with different polarized were quantified. This supports that the extraction methods might influenced the adhesion strength reduction. When the cold water research data was combined with the hot water and ethanol toluene, the ANOVA produced the highly significant effect of extraction method. This emphasized the chemical constituents would affect significantly to the adhesion strength of sengon wood.

As stated above that the research showed single factor of padding system exerted its significant effect on adhesion strength. The factor extract source did not exert significant effect on the bonding ability of sengon wood. The average adhesion strength of sengon wood influenced by gadung tubers extract of both hot water and alcohol toluene applied 1; 2 and 3 padding were 2.85; 1.78 and 1.12MPa consecutively. The pulai bark extracts padding application of 1; 2 and 3 layer decreased the adhesion strength of 3.00; 2.45 and 0.73MPa. The third preservative namely kumis kucing leaves extract also reducing the sengon wood adhesion strength of3.15; 2.43 and 1.29 MPa. Generally higher number of extract layer resulted in lower adhesion strength. Fig. 1 shows the average adhesion strength of sengon wood affected by natural preservatives application. Fig. 1 also shows that padding application number exerted similar effect on adhesion strength produced by all combination factors. This means that no other factor than padding application number affected the adhesion strength.

Variation of percentage of wood failure has been shown in Fig. 2. Factor of padding application number affect significantly to the percentage of wood failure. This effect is the same as adhesion strength wherein more layers of natural extract on wood surface will produce lower percentage of wood failure. The similar pattern effect is observed on gadung tubers and kumis kucing leaves, and slightly different on pulai bark effect. However general reduction pattern was observed wherein more layer extracts produce lower wood failure.

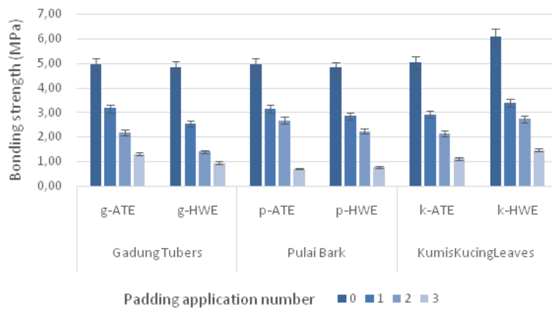

Fig. 1. Adhesion strength of sengon wood affected by natural preservatives.

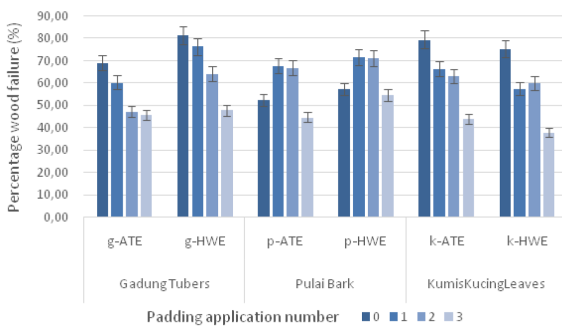

Fig.2. Percentage wood failure of sengon wood affected by natural preservatives

In terms of adhesion strength reduction, the highest adhesion strength was found to be exerted by the third natural preservatives application, i.e. kumis kucing leaves extract. Adhesion strength reduction due to gadung tubers extract application of 1; 2 and 3 application were 36.41; 56.25 and 73.78 % consecutively. Pulai bark extracts produced adhesion reduction of 36.49, 45.81 and 85.75 %, while kumis kucing leaves extract application resulted in 41.94, 57.35 and 77.67% adhesion strength reduction. These results showed that higher number of natural preservatives application then higher adhesion strength reduction percentage.

Comparison to the similar research on cold water extraction of three natural preservatives source which was conducted earlier showed that the number of padding application exerted highly significant to adhesion strength of fast growing teak wood. That same effect was proven i.e. the padding number factor showed high significant effect to adhesion strength of sengon wood. The preservative source factor, however, gave a different effect. In the research of cold water extract, it influenced the teak wood adhesion strength (Prayitno and Widyorini 2016), while in this research of hot water and alcohol toluene, this extract source factor did not affect the sengon adhesion strength. This result needed some data comparison between fast growing teak and sengon wood. Fast growing teak wood has higher density (0.6 g·cm^{-3}) compared to fast growing sengon wood (0.3 g·cm^{-3}). This produced different porosity and behaved differently in preservative penetration (Martawijaya et al. 2005). This physical factor might contribute to the non significant effect of extract source of natural preservatives.

The extraction method namely hot water extraction and ethanol toluene extraction did not give a significant effect to the adhesion strength reduction as well. The two methods of extraction resulted in different chemical constituents in their extracts, but they did not differ in the adhesion influence. Santos et al (2011) conducted a research on the chemical constituents of eucalyptus by different extraction of ethanol, toluene and water. Their result showed that more quantity of extractives with different polarized were quantified. This supports that the extraction methods might influence the adhesion strength reduction. When the cold water research data was combined with the hot water and ethanol toluene, the ANOVA produced the highly significant effect of extraction method. This emphasized the chemical constituents would affect significantly to the adhesion strength of sengon wood.

Gadungtubers extract contains cyanide compound such as hydrogen cyanide. Hydrogen cyanide is a poison form and capable to conduct a strong reaction with or without catalyst. This chemical can react to keton and aldehyde to form cyanohydrin (Nikita 2012).Several references mentioned that gadung containing cyanide which is powerful toxic to the wood destroying organism and in the cold water research did not reduce the adhesion strength significantly.

On the other hand pulai bark containing alkaloid and kumis kucing containing flavonoid were also high potency for wood preservatives (Ngasifudin and Sukosrono 2006) Gadung extract had been tested for wood preservatives (Wulandari 2012) and also applied as bamboo preservatives (Hirmawan et al. 2010).Pulai bark extract contains alkaloid compound. They are ditamin ($C_{16}H_{19}NO_2$), echitamin ($C_{22}H_{29}N_2O_4$) danechitenin ($C_{20}H_{27}NO_4$). Other alkaloid compound detected by Yamauchi et al. (1990)is 17-0-Acetylechytamin. Wood preservation research employing pulai bark extract was conducted by Khanifatun (2003), Fadhli et al. (2012) and showed a good result. It was reported that pulai bark extract contained saponin and flavonoid. The research focus in finding the effect of natural preservatives on adhesion strength has not been conducted yet. This research result has shown that natural preservatives applied on the wood surface reduced the adhesion strength. As stated above that the number of attachment site of the wood surface could be reduced significantly by natural preservatives or other chemicals. For that reason the number attachment site available for adhesives is reduced and resulting lower adhesion strength. Wood cellulose could react to alkaloid compound. Alkaloid compound shows base behavior (alkali-oid) and this contain nitrogen compound. The reaction of alkaloid to cellulose was likely hydrogen reaction and electron substitution.

On the other hand, kumis kucing extract contains flavonoid (tannin), oil (essential) and saponin (Anonym 2008). Tannin has monomer of flavonoid and used for drug, while essential oil could give a specific smell to repel the wood destroying organism. Flavonoid has back bone of C6-C3-C6 atom carbon. When tannin reacts to the wood cellulose, possible site attachments are hydrogen and methyl linkage.

Essential oil is a very complex chemical compound and very easy to evaporate. This oil contains lower than 10 carbon atom skeleton with variety of bonding types. This chemical might be grouped to hydrophobic compound which inhibit adhesion between wood and adhesives.

Research on kumis kucing extracts as wood preservatives had been conducted by Sutjipto et al. (2009), Azis (2011) and Mariana et al. (2013) with good result as well. The adhesion strength affected by kumis kucing extract significantly. For that reason an advanced research on kumis kucing is needed to find out the cause of significant reduction of adhesion strength.

CONCLUSIONS

This research entitled the adhesion strength reduction of sengon wood treated with natural preservatives has several conclusions as followed:

1. Padding application number on the sengon wood surface affected highly significant the adhesion strength and wood failure. Higher number of application, lower adhesion strength and wood failure. The average of bonding strength of sengon wood is reduced from 5.10 MPa (control) to 3.00 MPa (1 application), 2.22 MPa (2 application) and 1.05 MPa (3 application). The average wood failure affected by padding application number were 69.20, 66.71, 62.12 and 45.83 % respectively.
2. The other single factor such as extraction source and extraction method did not affected the bonding strength and percentage of wood failure of sengon wood.
3. All combination factors in the research did not affect significantly adhesion strength and wood failure of sengon wood. Interaction 3-factor of extraction method combined with natural preservative source and padding application number did not affect significantly to adhesion strength and wood failure of sengon wood block test. The interaction of 2 factors such as extraction method combined with extract source; extraction method combined with padding application and extract source combined with padding application showed the same effect, even though the last was significant at 7 % level.

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