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Short Communication: The clay nanoparticle impregnation for increasing the strength and quality of sengon (*Paraserianthes falcataria*) and white meranti (*Shorea bracteolata*) timber

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Abstract. *Alex T, Winarni B, Kusuma IW, Arung ET, Budiarso E. 2017. Short Communication: The clay nanoparticle impregnation for increasing the strength and quality of sengon (*Paraserianthes falcataria*) and white meranti (*Shorea bracteolata*) timber. Nusantara Bioscience 9: 107-110.* The clay nanoparticle impregnation for increasing the strength and quality of sengon (Paraserianthes falcataria) and white meranti (Shorea bracteolata) timber. The clay nanoparticles as a fine particle material dissolved in water was impregnated into the sengon and white meranti timber in order to improve its strength properties. Impregnation is the process of inserting the material dissolved in specific water or liquid in the timber using vacuum tube and air pressure. Materials used in this study were clay nanoparticles and the sample test of sengon (P. falcataria) and white meranti (S.bracteolata) timbers with a size of 2 cm x 2 cm x 40 cm. A total of 30 samples for each type of dried timber were impregnated using clay nanoparticles with a pressure of 60 psi for 2 hours. The results showed that impregnation with clay nanoparticles at concentrations of 5% gave the retention value of sengon and white meranti timber of 22.73 kg.m^3 and 24.89 kg.m^3, respectively. Wood strength is indicated by the voltage value at the boundary proportion (SPL), modulus of rupture (MOR) and modulus of elasticity (MOE). sengon timber shows the value of SPL, MOR, MOE by 296.57 kg.cm^2, 376.36 kg.cm^2, and 38027.663 kg.cm^2, while the white meranti timber had the value of SPL, MOR, MOE as follows: 623, 32 kg.cm^2, 729.69 kg.cm^2 and 160.187 kg.cm^2. The strength of sengon timber was increased from class V (very low) to class IV (low), whereas white meranti was increased from class IV (low) into class II (strong).

Key words: Impregnation, strength, nanoparticle

INTRODUCTION

Timber is an important material for building construction. In order to use as building material, timber should have mechanical and the high strength characteristics. According to The Indonesian Standardization Institute (SNI 2013) 7973-2013, the strength of timber in Indonesia was classified into 4 classes i.e; class I, II, III, and IV with the category of very high/very strong, high/strong, medium, low and very low. Based on the fissure level or the value of Modulus of Rupture (MOR), timber was clustered from the highest class to the lowest class with the range of value as follows; > 1100 kg.cm^2, 1100 – 725 kg.cm^2, 725 – 500 kg.cm^2, 500 – 300 kg.cm^2 and < 300 kg.cm^2. Supriati et al. 2011. Timber with the high qualification especially ranked in class I and II naturally is very rare timber. Of the reasons, the timber management or timber engineering is of importance to increase the strength and the quality of timber. The impregnation is an engineering process of timber by inserting the chemical material or particle into timber prior to increasing the strength and the good preservation of timber (Febrianto et al. 2014).

Clay nanoparticle is one of material used in the impregnation process, which was obtained from the clay soil. The clay soil is a type of soil with a poor micro and macro nutrition for plant living; therefore, it also known as marginal soil or acrisol. The size of clay particle is mostly from 50 to 2 micron, containing the ferric, aluminum and silicate clay (with a lot of iron, aluminum and silicate argillaceous) (Paoli et al. 2008; Kamp et al. 2009; Kajiura et al. 2012; Tashakor et al. 2014). According to Anda and Subardja (2013), this soil is categoryzed as a marginal soil because it can inhibit the agricultural growth. The small particle size of clay soil will have a high value and benefit by further processing the soil into nanoparticle so that it would be easily absorbed into the timber structure. The clay nanoparticle consist of metal elements especially iron, which could be easily impregnated into the timber and will be optimally absorbed into the whole timber structure leading to the increase level of its strong characteristics.

Sengon (*Paraserianthes falcataria*) is known as a woody plant belonging to the Fabaceae family. Generally, sengon grows very fast, which is mostly planted as favourable woody plant in the industrial forest plantation (HTI) and community forest in Indonesia. This wood was further processed and used as material for light construction or non-structural material. sengon timber has a density index of 0,33, which was categoryzed as the strong class V. white meranti (*Shorea bracteolata)* is a commercial woody plant belonging from Dipterocarpaceae family. white meranti grows in the natural forest, which was mostly used as building materials. white meranti has a density index of 0,54, which is categorized in the strong class IV (Prihatmaji et al. 2012). According to Alex (2014), another type of timber such as Anggrung *(Trema orientalis)* showed the increase level of its strength from the strong class V to the class IV after it was impregnated using intrusion material. Fitriasri et al. (2011) has reported that several type of timber impregnated with polysterene material resulted in the significant increase of its strength. Priyono et al. (2012) also stated that the treatment using the different connector materials such as adhesives type had an impact on the strong characteristics of timber. According to Supriati et al. (2011), the indicator value of timber strength is correlated with the density index. It means that the higher density index will result in the higher and stronger value of the timber. The objective of this study was to know the effect of impregnation process using clay nanoparticle to the strong capacity of sengon and white meranti timber as well as its correlation to the strong characteristic of timber.

MATERIALS AND METHODS

Sengon and white meranti timber with the size of 2 cm x 2 cm x 40 cm was dried until the water level in the hygrometer shown in the level of 18%. Before entering into the impregnated vacuum, the timber was measured its total volume and weight. Timber was then impregnated with the clay nanoparticle solution at the concentration of 2,5% and 5%. The number of sample timber in each type of timber was 10 cutting samples treated in different solution concentrations and control. The total number of cutting samples was 60 samples in all treatments. The pressure of impregnation was set in 60 psi for 2 hours, with the initial vacuum at 10 cm.Hg for 30 minutes and the final vacuum was 10 cm Hg for 15 minutes. Afterward, the timber was taken from the impregnated vacuum and then weighted again for determining the retention value. The measurement of the retention value was done using Febrianto et al. (2014) equation. All the timber samples were subsequently dried in the oven at the temperature of 80^{o}C until the level of the water was 10% shown in the hygrometer.

All the timber samples were then tested the strength of the timber using Universal Testing Machine for measuring stress on proportion limit (SPL), modulus of rupture (MOR), and modulus of elasticity (MOE) using the ASTM D143-94.2007 pattern (ASTM 2007). The detail measurements of SPL, MOR and MOE were presented in the Table 1.

RESULTS AND DISCUSSION

The effect of clay nanoparticles impregnation to the timber retention value

Table 2 presents the retention value of two-plant timber, sengon and white meranti, impregnated with clay nanoparticles in the different concentrations. Results show that clay nanoparticles could be easily absorbed into sengon timber shown in the lower retention value of sengon compared to that in white meranti. This result was in accordance with Tascioglu and Tsunoda (2011) who stated that, the main retention prerequisite for timber preservation purposes was from 8 to 12 kg.m^3 with the concentration ranging from 2 to 5%. Based on the retention value of timber type, it shows that the white meranti timber had the higher retention value compared to that in sengon timber in the same concentration dosage. It means that the selected white meranti timber was the timber type, which could be easily impregnated by the material of clay nanoparticles, although its timber density value (0.47) was larger than that in sengon timber (0.30). The retention value was the main factors for determining the successful process of timber preservation. It was also an indicator for timber treatability, which means the timber type could be preserved easily or not with the certain chemical material or particles (Alex 2014). The higher retention value, the easier possibility for timber could be preserved. According to Hidayat et al. (2013), the solution concentration and the characters of timber structure was the main factors for determining the permeability and the absorption of chemical solution into the timber for preservation purposes. Furthermore, the timber permeability will have an impact on the retention value.

Table 1. The dimension of the timber samples and the parameter analysis

The tested mechanical properties	The size of cutting timber		The observed parameter analysis
	The cutting dimension (cm)	The long size	
Retention	2x2	40	$R=\{(W_2 - W_1)x\ C\}/V$
Strength	2x2	40	$MOR=(3xPmaxL)/(2bh^2)$ $MOE=(P_{PL}xL^3)/(4fbh^3)$ $SPL=(3xP_{PL}xL)/(2bh^2)$

Note: R= The retention; W_1= the weight before the impregnation treatment; W_2= the weight after the impregnation treatment; C=concentration; V=volume ; SPL= stress at proportional limit; MOR= modulus of rupture; MOE= modulus of elasticity; P_{max}= the maximum burden weigth; P_{PL}= the load limit in the proportion ; b & h= the width and thickness of the sample; f= the deflexion; L=the span distance.

Table 2. The retention value of sengon timber and white meranti timber impregnated with clay particles in different concentration

Wood species	Concentration of impregnated treatment (%)	Retention value (kg.m^3)
Sengon	2.5	11.20
	5	22.73
White meranti	2.5	13.09
	5	24.89

Table 3. The average of the strength timber parameters in both sengon and meranti putih impregnanted using clay particles in different percentage of concentration

Type of timber	Concentration of impregnanted treatment (%)	Mechanical properties		
		SPL (kg.m^2)	MOR (Kg.cm^2)	MOE (Kg.cm^2)
Sengon	2,5	276,87	320,46	32411,893
	5	298,57	372,46	38027,663
	Non impregnated treatment (control)	194,46	234,46	19903,973
White meranti	2.5	614,29	711,01	156147,025
	5	623,32	729,69	160187,667
	Non impregnated treatment (control)	324,36	368,19	30615,397

Note: SPL: stress at proportional limit; MOR: modulus of rupture; MOE: modulus of elasticity

The impregnation of clay particles toward the strength of timber

The strength of sengon and white meranti timber impregnanted by clay particles in different treated concentration was presented in Table 3. Results show that white meranti timber had a higher value of timber strength parameters i.e stress at proportional limit (SPL), modulus of rupture (MOR), and modulus of elasticity (MOE) compared to those obtained in sengon timber in all concentration of impregnated treatments and control (non-impregnated treatment). The impregnation of sengon timber using clay particles had the increase value of SPL from 194,46 kg/cm2 to 276,87 kg.cm (for the concentration of 2,5%) and 296,57 kg.cm2 (for the concentration of 5%). It means that the impregnation treatments in both concentration of 2,5% and 5% had increase the stress at proportional limit of sengon timber around 42% and 53%, respectively.

Based on the value of MOR, it shows that the MOR value of sengon timber increase significantly around 37% and 61% after the impregnation treatments in both concentration of 2,5% and 5%, respectively. Of these results, the clustering class of sengon timber increased from the strength class V to the strength class IV. The increase trend of sengon timber was also shown in the MOE value which increases 63% and 91% after impregnated treatments in both concentration of 2,5% and 91%. However, that increase value did not change the position of sengon timber in the class of strength based on the category of the elastic modulus. According to the Supriati et al. (2011) the value of MOE and MOR was in line with the relationship between density values and MOE and MOR. It means that the higher value of MOR will result in the higher value of MOE. The same positive correlation also happened in the density value of timber with another strength timber parameters in both MOR and MOE. It might happen due to the strength of timber depended on the type of timber, which also stated in the study conducted by (Hariono and Firmanti 2014).

White meranti, the other type of timber used in this study, mostly showed the same increased value of timber strength parameters including SPL, MOR and MOE as those obtained in sengon timber (Table 3). Of the SPL value, it show that white meranti showed in increase trend of SPL value from 324,36 kg.cm^2 to 614,29 kg.cm^2 and 623 kg.cm2 after the treatments of impregnation in both concentration of 2,5 and 5%. It means in both impregnation concentrations, there was a high increase of SPL value around 89% and 92%, respectively. The same result also happened in the MOR value of white meranti timber, which showed the increase trend from 368, 19 kg.cm^2 to 711,01 19 kg.cm^2 and 729,69 kg.cm^2 after the impregnation treatments in both concentration of 2,5 and 5%. Interestingly, the results of both different concentration treatments resulted in different strength class category. Of the impregnation treatment in the concentration of 2,5%, it showed that white meranti timber has increased the strength class level from IV to III. While in the concentration of 5%, it showed that, white meranti changed from the strong class level of IV to II, respectively.

Based on the MOE value of white meranti, it shows that after the impregnation treatment using clay particles, the increase value of MOE in white meranti increased from 30615,397 kg/cm^2 to 156147,025 kg/cm^2 in the concentration of 2,5% and 160187,667 kg/cm^2 in the concentration of 5%. According to Yap (1984), the classification of the timber strength based on the elastic modulus value could be clustered into 4 classes i.e, class I with the MOE value more than 125.000 kg/cm^2, class II with the range between 125.000 and 100.000 kg/cm^2, class III with the MOE value from 100.000 to 80.000 kg/cm^2, and the class IV with the MOE value less than 80.000 kg/cm^2. Of those results, white meranti impregnated using clay nanoparticles in both concentration of 2,5 and 5% could be grouped in the class I based on the MOE value category. It means that this timber was very elastic. Compared to sengon timber, white meranti mostly gave a high value of SPL, MOR and MOE. According to the Supriati et al. (2011), those parameters had a positive correlation which means the high value of one parameter, for example, MOE will be linear with the high value of MOR and vice versa.

In conclusions, based on the retention value obtained in this study, it could be concluded that sengon (*P. falcataria*) and white meranti (*S. bracteolata*) were two species of woody plant, which could be easily impregnated with clay nanoparticles. Clay nanoparticles can increase the strength of the timber, for example, sengon from the strong class V to the strong class IV and white meranti from the strong class IV to strong class II, respectively.

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