Density of Densified *Paraserianthes falcataria* Wood Pre-treated with Alkali

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Density of Densified *Paraserianthes falcataria* Wood Pre-treated with Alkali

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Abstract. Wood densification is done to improve its mechanical and physical properties, by compressing the porous structure under steam, heat and pressure called Viscoelastic-Thermal Compression (VTC). This study had been done to evaluate the effect of alkaline pre-treatment using different concentrations of Sodium hydroxide (NaOH) on *Paraserianthes falcataria* (local name: Batai) and its density. Alkaline pre-treatment was done before the densification process, using three different concentrations of NaOH (3%, 6% and 9%) with 0% NaOH as the control. There were 30 replicates used for the study. The lamina was prepared by trimming the lamina sawn timber into specific size. Then, laminas cooking process in different NaOH concentrations for 30 minutes, followed by hot water extraction with acetic acid for 20 minutes and 24 hours of oven dried under temperature 103 ± 5°C. The laminas were then pressed using hot press machine under 105°C temperature and 6 MPa pressure for 30 minutes before cooling phase were conducted for 10 minutes. The density was evaluated continuously for 7 days and the results showed that densified *P. falcataria* without alkaline pre-treatment (0% NaOH) has the highest density compared to treated densified *P. falcataria* with different alkaline pre-treatments (3%, 6% and 9%); meanwhile the highest concentration of NaOH (9%) has the lowest density value compared to 3% and 6%, as 3% has the higher value than 6% NaOH.

1. Introduction

The concept of wood densification was first invented in 1900s. There are many studies had been done on wood densification using different wood species and produce many results. Wood densification is a process where wood compression, impregnation of cell lumens with liquid or both was done as to increase the wood density. Viscoelastic-Thermal Compression (VTC) of wood is a process to increase the density of the material properties [1]. Wood compression against the wood grain under extreme heat and pressure condition are included in VTC process. Densification can be achieved when the wood is softened by heat and compressed with pressure.

It is hard to compress a natural wood into compact and compress wood without eliminating lignin. The void in cell wall after the lignin removal after alkali pre-treatment lead to porous cell wall and can be easily compacted during pressing [2]. There were several wood compressions had been reported over years ago. Previous study shows that high value of wood produced from wood densification process is suitable for construction material, strong as metal and alloy materials. Densification allowed low-density wood to be substitute for harder species as the species can be modified from low-density into high performance and high value product [3]. Wood species that already with high density can be

further modified through densification [4]. However, this study is to shows the effects of lignin removal on wood densification.

2. Materials and Methods

For this study, *Paraserianthes falcataria* (Local name: Batai) were obtained from Sapulut Forest Development Sdn. Bhd. *P. falcataria* is a fast-growing large tree and can grow up to 40m tall. This species widely planted in tropics country such as Indonesia and Malaysia.

For sample preparation, wood laminas of *P. falcataria* were collected random (sapwood and heartwood) as to avoid biasness in results. The woods were trimmed to 300 mm (length) x 50 mm (width) x 20 mm (thickness).

For the alkaline pre-treatment, Soda Pulping method for Pulp & Paper Technology (2016), was used, where Sodium hydroxide, NaOH was used at different concentrations (3%, 6%, & 9%) with 0% NaOH as control. Wood laminas had been treated in closed chamber in the fume hood for safety precautions. Then hot water extraction was done for 20 minutes, after a fixed amount of acetic acid (GAA) were added to neutralize the NaOH, to wash out the remaining NaOH (until the water turned clear). The laminas were then oven-dried under temperature 103 ± 3 °C for 24 hours and undergone conditioning phase. After that, the treated laminas were compressed using hot press at 6 MPa and 100°C for 30 minutes with 8 mm stopper as targeted final thickness. Cooling phase had been done for 10 minutes before the compressed wood being taken out from the machine. There are 30 replicates for each parameter. First reading had been measured 15 minutes after the cooling phase. The densities of the compressed woods were studied for 7 days continuously and plotted.

In this study, lengths, widths, and thicknesses of all the woods were measured using Vernier caliper and the mean values were recorded as to calculate the volume (V) of the laminas. On other hand, the weight (W) of the laminas were also measured using weigh balance. Then, the density of the laminas was calculated according to Equation 1:

$$\text{Density (kg/m}^3\text{)} = W/V \qquad (1)$$

Where,

W = weight of lamina (kg)
V = volume of lamina (m^3)

3. Results and Discussion

Generally, density is simple to decide and very much associated to numerous other physical and mechanical properties of wood, such as strength and stiffness. Density is also utilized as a wood quality value indicator, where related to various purposes. For example, wood with high density and strength is used for construction; meanwhile low-density wood is suitable for pulp and paper [5]. Wood density can be affected by many factors, such as wood species, chemical composition in the wood naturally, age of the tree, part of tree used and the wood processing pattern.

The results for this study had been showed as a graph where, Figure 1 shows that the higher concentration of NaOH usage in alkaline pre-treatments lead to lower wood density, where densified wood with 9% NaOH has the lower density compared to untreated densified wood with 0% NaOH.

According to previous study, Alkaline pre-treatment leads to removal of lignin and hemicellulose content in natural wood, whereas the wood will become more porous and less rigid [2]. The spring-back occurs in the wood after compression might influenced by the absence of the lignin [6] as lignin act as the binder that bind the cellulose and hemicellulose together [7]. Alkaline treatment degrades certain amount of hemicellulose, lignin, wax, and oils of fiber cell wall. Reduction of lignin could weaken the particle strength as the lignin acts as binder of cellulose fibers [8].

Wood compression resulting in reduced of thickness to about 40% as the wood lumen and porous wood cell had collapsed [2]. High density wood will be used for structural application where resistance is important. From the graph in Figure 1, the density of untreated wood before densification shows very low in density, as not more than 400 kg/cm^3, however after the densification process, the

density of the untreated wood shows drastic increases in density from344.6 kg/cm^3 to 909.2 kg/cm^3 on day 7th. The density of treated wood after compression also had showed major changes in density, as the highest concentration, 9% NaOH has the lowest density compared to 3% and 6% NaOH. From my study, lignin played the major role in wood modification especially wood densification. Alkaline pre-treatment diminished hemicellulose, lignin, wax and oils of fibre cell wall. Removal of lignin might weaken the properties as the lignin used as the binder [8].

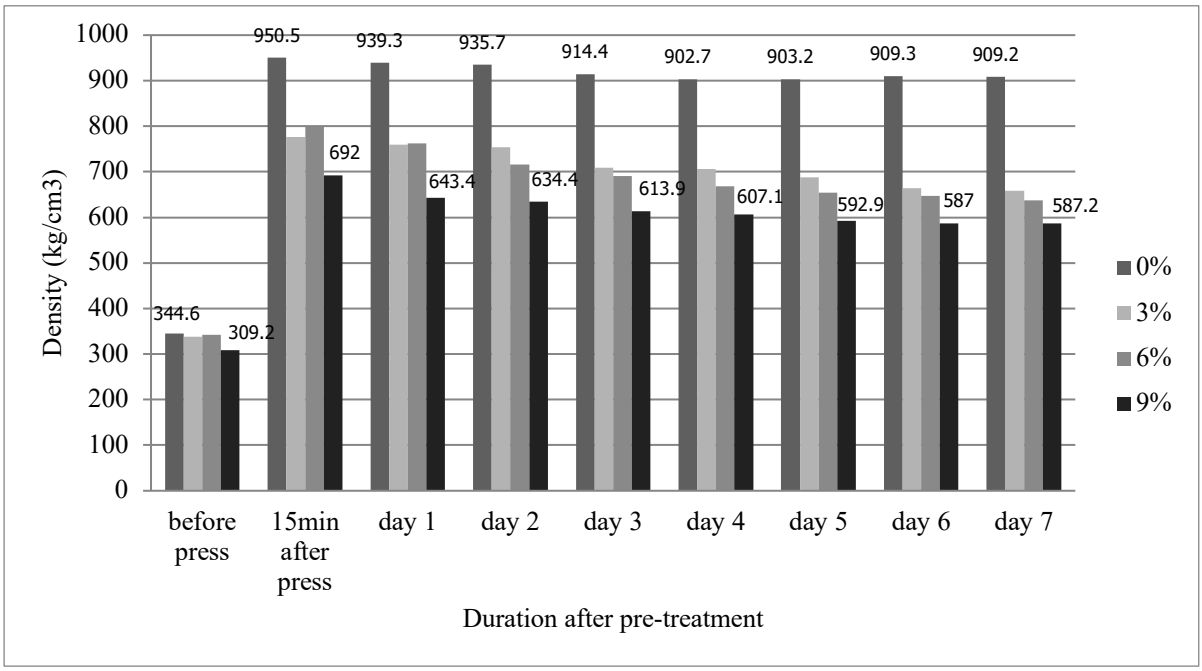

Figure 1. The density of *P. falcataria* after treated with different concentrations (0%, 3%, 6% and 9%) of NaOH.

Figure 2 shows the densified *P. falcataria* with and without alkaline pre-treatment after 7 days observation. From the Figure 2, the densified woods show slightly differences in thickness as all the woods were compressed using 8 mm stopper. Elastic deformation recovered after load was removed from the densified wood. Continuous deformation can be recovered when the densified woods were exposed to humidity when there's so external force applied [6]. This is called spring-back. Wood is well-known as viscoelastic material and the mechanical properties depend on time, heat and environment humidity. Alkaline pre-treatment was done to eliminate lignin from the cell wall of the wood. Chemical pre-treatment, such as alkaline pre-treatment, leads to lignin and hemicelluloses content elimination from cell wall. The wood becomes more porous and less rigid when lignin and hemicelluloses partially removed from the cell wall [2]. When the hot-pressing to opposite to the wood growth direction, the cell wall without lignin breakdown altogether. This process caused the densified wood to reduce in thickness for about 40% (Figure 3) and increased in density.

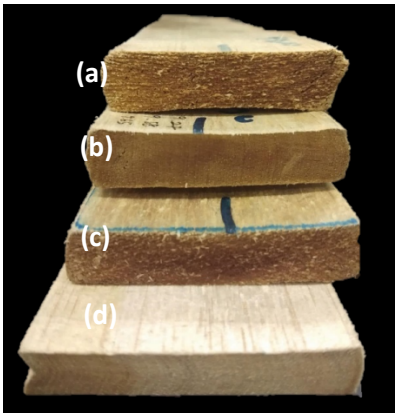

Figure 2. Thickness comparison after 7 days of observation on densified wood: (a) 9% NaOH, (b) 6% NaOH, (c) 3% NaOH, (d) 0% NaOH (control).

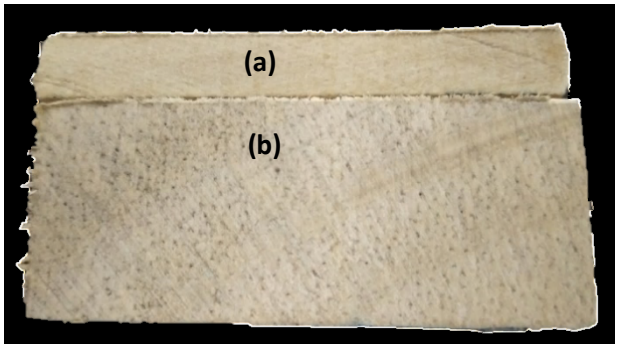

Figure 3. The thickness comparison before and after densification. (a) the densified wood lamina(untreated), (b) the undensified wood lamina.

It is hard to compress a natural wood without lignification into a compact densified wood [2]. However, the same studies showed that after the removal of lignin from the natural wood, the wood become brittle and easily crushed during pressing, probably because of the delignification process, as lignin is used as a binder in the cell wall [7]. Wood density is one of the wood qualities which corelated to other properties, such as toughness, stiffness and performance in use [5].

4. Conclusion

The densification procedure, where plasticizing of the wood, is considered as VTC densification process. In this preliminary study, the density of the densified *P. falcataria* with and without alkaline pre-treatment had been studied for 7 days, where high amount of NaOH used to delignify the wood laminas lead to lower in wood density.

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