THE EFFECT OF SODIUM HYDROXIDE PRE-TREATMENT ON THE DENSIFICATION PROPERTIES OF LOW-DENSITY *Paraserianthes falcataria* PLANTATION TIMBERS

VINODINI A/P RAMAN

FACULTY OF TROPICAL FORESTRY
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Disahkan Oleh,

VinodiniRaman

VINODINI A/P RAMAN
MS1821049T

(Tandatangan Pustakawan)

Tarikh : 12 Mei 2022

(Assoc. Prof. Ts. Dr. Liew Kang Chiang)
Penyelia Utama

DECLARATION

I hereby declare that the material in this thesis is my own except for citations, equations, summaries, and references, which have been duly acknowledged.

16 February 2022

VinodiniRaman

Vinodini A/P Raman
MS1821049T

CERTIFICATION

NAME	:	**VINODINI A/P RAMAN**
MATRIC NO.	:	**MS1821049T**
TITLE	:	**THE EFFECT OF SODIUM HYDROXIDE PRE-TREATMENT ON THE DENSIFICATION PROPERTIES OF LOW-DENSITY *Paraserianthes falcataria* PLANTATION TIMBERS**
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As a conclusion, I hope this study can be used as a reference for future study.

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16 February 2022

ABSTRACT

Wood densification was done by compressing the wood using hot-press machine, with temperature and pressure. By densification, low-density wood can reach higher density after the cell walls were collapsed under condition. Densification can be done by chemical treatment and compression to achieve the maximum density by fully compacting the microstructures. Low-density timber species can be used as an alternative to hardwood species. The higher mechanical properties of densified wood products allow their use in diverse and advanced applications. This study was designed to evaluate the morphological, physical, mechanical, and dimension stability properties of untreated (D0) and treated (D3, D6, D9) densified *Paraserianthes falcataria* glulam. Besides that, this study was aimed to investigate the effects of different alkaline concentrations and the relationship between cell lumen areas with morphological, physical, mechanical, and dimension stability properties of untreated (D0) and treated (D3, D6, D9) densified *P. falcataria* glulam. Three different concentrations of NaOH (3%, D3; 6%, D6; 9%, D9) were used for alkaline pre-treatment with 0% NaOH as control and prepared according to soda pulping method. The untreated and treated laminas were compressed at 105°C temperature and 6 MPa pressure for 30 minutes with 8 mm metal stopper, followed by cooling phase for 10 minutes without releasing the plate. After conditioning, laminas were planned and laminated into 3 layers using Polyvinyl acetate (PVAc) as adhesive, before trimmed into desirable sizes. ASTM, JAS, BS and TAPPI were used generally for lignin content determination, static bending, compressive strength, hardness, compressive strength, contact angles, delamination, block shear, moisture content, thickness swelling and water absorption, while Scanning Electron Microscopy and Chromaticity Reader 10 were used to determine cell lumen areas and chromaticity values. Some results obtained shows improvement after alkaline pre-treatment and densification, such as in total differences of chromaticity values (35.7%), Modulus of Elasticity and Modulus of Rupture of edgewise (31% and 20%), Modulus of Elasticity of flatwise (4.5%), compression perpendicular to the grain (10%), hardness of tangential and radial (21.3% and 18.1%), delamination (7.2%), thickness swelling and water absorption (2.1% and 3%), moisture content for lamina and glulam (1.3% and 8.8%), respectively, density profile for lamina and glulam (24.6% and 9.1%), contact angles using water and PVAc (43.3% and 5.3%), compared to the control. While, other tests show declining results after alkaline pre-treatment and densification, such as reduction of lignin content (55%), Modulus of Rupture of flatwise (25.4%), compression parallel to the grain (22.2%), hardness of longitudinal (13.4%), block shear (10.6%) and density (27.6). In general, the range of Pearson's coefficient correlations for these studies were in the level of correlation of moderate positive linear and moderate negative linear. In conclusion, this study can be sum up that some properties showed up to 35% improvements after being treated and densified, while a few shows decline and no improvement. This result would be influenced by the natural characteristics of *P. falcataria*, NaOH or densification. As there were many studies had been done to overcome the disadvantageous characters in woods as to improve its quality, value adding and maximize the utilization of the materials, probably more research should have been done for low-density plantation timber.

ABSTRAK

RAWATAN ALKALI PADA SIFAT PEMADATAN KAYU PELADANGAN *Paraserianthes falcataria* BERKETUMPATAN RENDAH

Pemadatan kayu dilakukan dengan memampatkan kayu menggunakan mesin tekan panas, dengan suhu dan tekanan. Dengan pemadatan, kayu berketumpatan rendah dapat mencapai kepadatan yang lebih tinggi setelah dinding sel dimampatkan semaksimumnya. Pemadatan dapat dilakukan dengan rawatan kimia dan pemampatan untuk mencapai ketumpatan maksimum dengan memadatkan struktur mikro sepenuhnya. Kajian ini dirancang untuk menilai sifat morpologi, fizikal, mekanikal dan kestabilan dimensi Paraserianthes falcataria berlapis yang dirawat (D3, D6, D9) dan tidak dirawat (D0). Selain itu, kajian ini bertujuan untuk mengetahui kesan kepekatan alkali yang berbeza dan untuk mengkaji hubungan antara kawasan lumen sel dengan sifat morpologi, fizikal, mekanikal dan kestabilan dimensi P. falcataria berlapis yang tidak dirawat (D0) dan dirawat (D3, D6, D9). Tiga kepekatan NaOH yang berbeza (3%, D3; 6%, D6; 9%, D9) digunakan untuk pra-rawatan alkali dengan 0% NaOH sebagai panduan. Kepekatan pra-rawatan alkali disediakan menggunakan kaedah pulpa soda. Kayu yang dirawat dimampatkan menggunakan mesin pemampat pada suhu 105°C dan tekanan 6 MPa selama 30 minit dengan penyekat logam 8 mm sebagai ketebalan akhir yang disasarkan, diikuti dengan fasa penyejukan selama 10 minit tanpa melepaskan plat. Selepas pengkondisian, permukaan kayu dihaluskan sebelum proses laminasi. Lapisan P. falcataria dilakukan menggunakan Polyvinyl acetate (PVAc) sebagai pelekat dan dibiarkan selama 24 jam. Kayu dipotong mengikut dimensi yang ditetapkan pada piawaian setiap ujian. Piawaian ASTM, JAS, BS dan TAPPI digunakan untuk menentukan kandungan lignin, lenturan statik, kekuatan mampatan, kekerasan, sudut sentuhan, ricih blok, kandungan lembapan, pembengkakan ketebalan dan penyerapan air. Beberapa hasil yang diperoleh menunjukkan peningkatan selepas pra-rawatan dan pemadatan alkali, seperti jumlah perbezaan nilai kromatik (35.7%), MOE dan MOR edgewise (31% dan 20%), MOE flatwise (4.5%), mampatan tegak lurus terhadap butir (10%), kekerasan tangen dan radial (21.3% dan 18.1%), pencabutan (7.2%), pembengkakan ketebalan dan penyerapan air (2.1% dan 3%), kandungan lembapan untuk kayu lamina dan berlapis (1.3% dan 8.8%), masing-masing, profil ketumpatan untuk kayu lamina dan berlapis (24.6% dan 9.1%), sudut hubungan menggunakan air dan PVAc (43.3% dan 5.3%), dibandingkan dengan panduan (D0). Sementara, ujian lain menunjukkan hasil yang merosot setelah pra-rawatan dan pemadatan alkali, seperti pengurangan kandungan lignin (55%), MOR flatwise (25.4%), pemampatan selari (22.2%), kekerasan membujur (13.4%), ricih blok (10.6%) dan ketumpatan (27.6%). Secara umum, julat korelasi pekali Pearson untuk kajian ini berada pada tahap korelasi linear positif dan negatif sederhana. Kesimpulannya, kajian ini telah merumuskan bahawa beberapa data menunjukkan peningkatan sehingga 35% setelah dirawat dan dimampatkan. Manakala beberapa data yang lain menunjukkan penurunan dan tiada perubahan. Hasil ini akan dipengaruhi oleh ciri semula jadi P. falcataria, NaOH atau pemadatan. Oleh kerana terdapat banyak kajian yang dilakukan untuk mengatasi karakter buruk di dalam hutan untuk meningkatkan kualitinya, menambah nilai dan memaksimalkan penggunaan bahan, mungkin lebih banyak penelitian harus dilakukan untuk kayu perladangan berkepadatan rendah.

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LIST OF ABBREVIATIONS

NaOH	-	Sodium hydroxide
GAA	-	Acetic acid
ASTM	-	American Society for Testing and Materials
JAS	-	Japanese Agricultural Standard
BS	-	British Standard
EN	-	European Standard
D0	-	0% NaOH
D3	-	3% NaOH
D6	-	6% NaOH
D9	-	9% NaOH
MOE	-	Edgewise Modulus of Elasticity
MOR	-	Edgewise Modulus of Rupture
TS	-	Thickness swelling
WA	-	Water absorption
MC	-	Moisture content
SEM	-	Scanning electron microscopy
FTIR	-	Fourier transform infrared spectroscopy
PVAc	-	Polyvinyl acetate
UTM	-	Universal testing machine
LSD	-	Least Significant Difference
Sec	-	Second

LIST OF SYMBOLS

N/mm^2	-	Newtons per millimetre squared
N	-	Newtons
%	-	Percentage
kg/m^3	-	Kilogram per meter cubic
°	-	Degree
°C	-	Degree celcius
cm^{-1}	-	Reciprocal centimeter
mm^3	-	Cubic millimeter
MPa	-	MegaPascal
g/m^2	-	Grams per square metre
P	-	Load
L	-	Length of specimen or span between 2 supports
d	-	Deflection
I	-	Moment of Inertia
T_1	-	Thickness after soaked in water
T_0	-	Thickness before soaked in water
W_1	-	Weight of glulam after soaked in water
W_0	-	Weight of glulam before soaked in water
W_{AD}	-	Width of glulam on air-dry
W_{OD}	-	Width of glulam after oven-dried

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Wood densification is one of the effective methods in enhancing the mechanical properties of wood, as wood is viable constructional material. In addition, wood with high porosity has a pyramid arrangement, which causes density and strength to deteriorate. After the cell walls have crumbled under condition, low-density wood can be densified to achieve a greater density. In order to maximize the value of density of woods, it was possible to undergone both chemical treatment, such as alkaline pre-treatment or klason pre-treatment, and wood densification.

As stated by Gindl *et al.* (2004) and Pelit *et al.* (2014), improvement of wood properties had obtained, for instance, hardness, by filling or by the combination of filling and compression of solid woods. On the authority of Lin *et al.* (2017), woods refer to imperishable and perishable composites based on cellulose fibre. Woods are made of cellulose, hemicellulose, and lignin. During wood densification, the woods' porous composition will be pressured and influence the characteristics of wood includes mechanical, and physical properties.