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Escalation quality of wooden beams as building construction with densification technology

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Abstract. In this research has done the densification process of jabon wood and its measuring 5/7 cm into 5/5 cm by heat compression. The research objective determines the reliability of wood densification technology as improving the physical and mechanical wood properties. This research also used U steel as a tool press. The results showed that densification in jabon wood can improve its physical properties as indicated by the increase in specific gravity amounted to 28.95 percent; its density increased 26.83 percent; as well as water content declined of 32.68 percent. The mechanical properties of jabon wood shown by parameters like the strength perpendicular to fiber increased to 51.44 percent; MOE increased to 32.93 percent, and MOR increased to 36.14 percent. Treatment of densification on jabon wood has increased the strong class of jabon wood from strength class IV into a strength class III based on specific gravity and value of MOR rise to strength class II. Densified jabon wood is suitable for use as building construction materials and gives its aesthetic value because its color is more attractive. The architectural design of urban buildings can also use the densified wood material as it proves to be stronger, durable and natural.

1. Introduction

The declining potential of timber from Indonesia's tropical forest is a fact that cannot be denied anymore. The exploitation of natural forests in recent decades has resulted in a decline in log production, so that production was only 6.37 million m3 in 2011/2012; and in 2017/2018 log production was 5.47 million m^3 [2]. The decline occurred because the availability of wood from natural forests is decreasing. The government has anticipated a shortage of wood supply by establishing Industrial Plantation Forest as well as promoting the development of the folk forest. In the future, timber that comes from these plantations becomes a foundation for supplying Indonesia's timber needs. Wood from this plantation forest has the potential to be developed as a substitute for steel/metal substitution construction material, by seeking its improvement of physical, mechanical, and durable properties [5]. Jabon wood is one of the leading forestry commodities and has a fairly high economic value. The economic value of jabon, when compared to teak, is no less competitive. Jabon plants have white stems that tend to be yellowish with no visible fibers, causing the jabon wood plants to be needed by a processed wood industry and non-construction building materials. This is the advantage that makes marketing price does not experience problems, even the industry is willing to be ready to buy large amounts of jabon wood at any time.

The jabon tree is a high quality industrial raw material even when compared with sengon trees, which is still basic raw material commonly used in processed wood industries such as plywood, blockboard, particleboard, to containers [1]. This wood has a specific gravity (SG) is 0.29 to 0.56 with the durable class V, but the wood is not broken by insects, so it is possible to be utilized by wood industry and included in strong class III-IV [12]. Generally, wood is anisotropic material (easy to develop shrinkage). The shrinkage and development are not the same in their three axes (tangential, radial, and longitudinal) and greatly affect the strength of wood (mechanical properties); both in a direction parallel to fiber (longitudinal) or perpendicular to fiber (tangential and radial) [10].

Since the beginning of 1990 in some countries, especially Japan has been investigated a process to improve the quality of wood by densification [8, 11]. There are two ways of wood densification that have been carried out, namely in the form of densifying by impregnation and densifying by compression. Wood densification by pressing can modify its properties under plastic conditions without damaging the structure of wood cells. Also, wood densification by pressing is most environmentally friendly, because it does not use chemicals in the densification process [11]. The densification of wood by heat and using steel causes heat transfers [6]. The combination of wood moisture content, temperature, and duration of heating, as well as a rate and magnitude of press pressure, will affect the yield of compressed wood. Increasing temperature in water-saturated wood will soften the matrix so that hemicellulose and lignin as main components gradually from hard shapes such as glass change to close elastic shapes such as rubber. This phenomenon does not apply to microfibrils that remain in their harsh form and are hardly affected by water and temperature.

The purpose of wood densification is to improve the mechanical properties of wood such as Young's modulus, side hardness, shear strength, and improved dimensional stability of wood [7]. The use of densified wood is as diverse as spinning weavers, coils, wooden hammers, tool handles, propellers, cubes, and roof-mounted construction plates that require high friction strength. Besides, it can also be used for interior, furniture and wood construction. According to Forest Product Laboratory (FPL, 2010), the mechanical strength of densified wood will increase with thermo-hydromechanical; for example increasing specific gravity (SG) of wood, shear strength, surface hardness, and reduced water absorption in humid conditions [4]. Many researches results report, they can improve physical and mechanical properties [3, 14, 15, 16]. So far, wood is considered a construction material that is limited in use and is considered not as strong as construction materials from steel. This is understandable, because steel has dimensional stability (isotropic), whereas wood does not have the same strength in all three axes (tangential, longitudinal, and radial) or is anisotropic. However, based on the results of Rilatupa [15] densified wood planks as gusset plates can be relied upon as a connecting tool at various connection angles and have been semi-isotropic, so that the dimensional stability has improved.

This study aims to determine the reliability of wood densification technology as an effort to improve the physical and mechanical properties of wood as a building construction material. The physical and mechanical properties shown by the following parameters: 1) specific gravity, 2) moisture content, 3) stiffness or modulus of elasticity (MOE), 4) firmness patch or modulus of rupture (MOR), 5) firmness of the tap. This research also aims to find a reliable method in densifying wood and the best form of beams as a wooden construction material. Wood densification research is oriented towards the physical and mechanical properties of the wood. Densifying technology is expected to contribute many stakeholders, especially users who use wood as a construction material in order to increase the value or strength of medium and low-quality wood.

2. Method and materials

Material and Tools

This research was conducted in Bio Composite and Technology Laboratory of Quality Improvement of Wood - Faculty of Forestry, Bogor Institute of Agriculture. This research using jabon wood material (Anthocephalus cadamba) which is processed into a tangential beam with 7 cm thick and 5 cm wide. This beam is cut into a test sample with a size of 100 cm x 7 cm x 5 cm. The tool used for wood densification is a wooden densification machine (Cold and Hot Press) assembled by Indonesian Institute of Sciences Research Center for Applied Physics Research and Development with 40 x 40 cm^2 wide plate press, and a maximum of hydraulic pressure capability is 700 kg/cm^2 (1000 psi), and maximum temperature is 250ºC. The densification process also uses another machine that is Weili weavers. Other types of equipment used are Instron compressive wood test machine, saws, oven, slurry term, moisture meter, steel plate, and desiccator, drill, autoclave, and water bath.

Method

The jabon beam wood is sawed off to obtain a tangential beam with a thickness of 7 cm and a width of 5 cm, then the beam will be cut to obtain a flawless block that measures 100 cm x 7 cm. x 5 cm. This beam is immersed in water for seven days, then the wood is compressed with the first machine that is Weili weaved machine with provisions: wood placed in a radial direction; the temperature used is 150° - 175°C, for 1 - 1½ hours until the thickness reaches the size 5/5 cm from the original thickness (thickness 5/7 cm).

Testing of physical properties includes specific gravity (SG), density, and water content (WC) performed with three replications. This test aims to see changes in the physical properties of densified wooden rafters. This research is divided into two stages of activity, namely:

The first, consisting of an examination of the physical and mechanical properties of the densified wood rafters.

The second is research similar to the first, but the testing material is wood rafters without densification.

The mechanical properties tested for densified jabon beam are straightness of the fiber perpendicular press, the elastic modulus (MOE) and modulus of rupture (MOR). The mechanical properties test was performed with three replications using the Universal Testing Machine (UTM) Instron tool. Methods of measuring the formula for calculation of stronger currents, MOR and MOE following the British standard Methods [3]. The densified jabon wood that has size 100 cm x 5 cm x 5 cm is cut into a test sample that has a size of 15 cm x 5 cm x 5 cm. Meanwhile, wood with a size of 40 cm x 5 cm x 5 cm is also cut into test samples that have size 15 cm x 5 cm x 5 cm, but on the machine is installed U-steel. It aims to make the wood dimension more stable.

3. Results and Discussion

3.1. *The physical appearance of densified jabon wood*

White jabon wood and sapwood cannot be distinguished from the wooden terrace, texture is smooth until rough, and the direction of the fiber are straight, while a surface impression of wood is slippery.
This wood has a kind of pseudo-white color, light yellow, light yellow and pseudo-amber yellow color. Good wood texture (mild to slightly coarse), straight fiber direction and produce smooth wood surface. Wood has no odor. Pores on wood jabon join two to three in a radial direction, rarely solitary [12].

The densification of a 5/7 cm wood rafters into a 5/5 cm wood rafters gives a different color to its original color, the color becomes slightly darker as a result of the influence of drying temperature during the wood process. Wood densification with heat-forging treatment produces a slightly different color to the original, in some parts color becomes slightly darker. This occurs due to high-temperature influence at the time of forging or densification process. Densified jabon wood has a finer and glossier touch feel that is clearer than non-densified jabon wood. Densified wood gives an attractive color display. The densification process can produce colors that are different from the original color.

3.2. *The physical properties of densified jabon rafters wood*

The results showed that the average densification treatment of specific gravity (SG) of jabon wooden rafters increased from 0.38 to 0.62. The density () of jabon wood rafters also increased from 0.41 g/cm^3 to 0.62 g/cm^3. Meanwhile, another consequence of the treatment of wood densification is a decrease in water content (WC) of jabon wood rafters from 17.44 percent to 8.74 percent as shown in Table 1.

According to Inoue (1996) high-temperature densification can increase the specific gravity of wood [8]. The increased due to densification occurs because lumen and cell cavity become denser and contain very little cellulose in the primary wall and middle lamella. Meanwhile, the increase of wood density is expected due to heating that leads to the degradation of chemical components of wood [15]. Wood density has a linear correlation with the wood strength, a higher of wood density, strength properties will higher also [9].

Table 1. Physical properties of control/non-densified and densified jabon wood

Physical properties	Control	Densified	Percentage (%)
Spesific Gravity	0.38	0.49	+ 28.95
Density (g/cm^3)	0.41	0.52	+ 26.83
Water Content (%)	17.44	11.74	- 32.68

The improvement of specific gravity and density of densified jabon wood rafters compared to non-densified jabon wood rafters (control) is quite high; the percentage of each is 28.95 percent (specific gravity) and 26.83 percent (density). Meanwhile, the percentage of water content decrease from jabon wood rafters is 32.68 percent. This result shows that the water content of densified jabon wood rafters is 0.02 percent for each cm^3, thereby the physical properties of densified jabon wood rafters better than the physical properties of non-densified jabon wood rafters.

Table 2. Strength class of wood based on spesific gravity (PKKI, 1961)

Strength Class	Spesific Gravity
I	> 0.9
II	0.6 – 0.9
III	0.4 – 0.6
IV	0.3 – 0.4
V	< 0.3

In addition to the above results, the densification treatment which is conducted on jabon wood rafters also shows improvement in terms of solid grade. In this case, non-densified wood rafters still belong to strength grade class IV and after densification, wood rafters belong to the strength class III [13] as shown in Table 2. The improvement of densified jabon wood rafters specific gravity happened due to reduced wood volume (reaches 28.57 percent), while the mass of wood is not reduced. Besides of specific gravity factor, water content water also influences the strength difference [5]. According to Haygreen (2003), more cell wall substances that are indicated by a large specific gravity, the greater dimensional changes that might occur at the same water content changes [5]. The statement does not apply to densified jabon wood rafters, where wood rafters are more stable than without densification. This happens because the drying of water molecules causes damage to H bonds between molecules that can reach the crystallite region. Damage to H bonding also results in densified wood tuber not easily expand or shrink, so it becomes more stable than jabon wood without densification.

3.3. Mechanical properties of densified jabon rafters wood

The research results showed that densification treatment can improve the mechanical properties of jabon wood rafters (Table 3). The firmness of perpendicular force of fiber increases from 82.55 kg/cm^2 to 122.95 kg/cm^2 by densification treatment without being clamped with U-steel; And 123.61 kg/cm^2 with U-steel clamping for one hour and 125.01 kg/cm^2 with U-steel clamping for two hours. Meanwhile, the densification treatment also increased modulus of elasticity (MOE) from 47428.65 kg/cm^2 to 61925.72 kg/cm^2 each (without being clamped with U steel); 62476.85 kg/cm^2 (U-steel clamping for one hour) and 63045.94 kg/cm^2 (U-steel clamping for two hours). Similarly, there was an increase in fracture modulus (MOR) occurring as a result of densification treatment from 564.22 kg/cm^2 to 749.62 kg/cm^2 (without being clamped with U-steel); 765.82 kg/cm^2 (U-steel clamping for one hour) and 768.11 kg/cm^2 (U-steel clamping for two hours). These results indicate that densified jabon wood rafters are more rigid (flexible) and can withstand greater loads than jabon wood rafters without densification.

Table 3. Mechanical properties of jabon wood rafters (control/non-densified and densified)

Mechanical Properties	Control (kg/cm^2)	Densified (kg/cm^2)		
		Without U-steel (1 hour)	With U-steel	
			1 hour	2 hour
Firmness press ⊥ fiber	82.55	122.95	123.61	125.01
MOE	47428.65	61925.72	62476.85	63045.94
MOR	564.22	749.62	756.82	768.11

The range of mechanical properties of densified jabon wood rafters is higher than non-densified jabon wood rafters, explaining that the densification treatment affects the mechanical properties of the wood. The obvious difference due to the densification treatment is also due to the modification of the properties of densified jabon wood cotton by reducing its water content so that a cell structure becomes denser. Strength class of non-densified jabon wood rafters with MOR value 564.22 kg/cm2; belonging to strength class III (Table 4). The result of MOR calculation from this research is grouped by strength class based on Indonesian Wood Construction Regulations (PKKI NI 5-1961) [13]. Based on these criteria, the MOR of densified jabon wood a range is 749.62 kg/cm^2 to 768.11 kg/cm^2 (725 - 1100 kg/cm^2) belonging to the strength class II [13].

Table 4. Class of wood (according to PKKI NI 5-1961)

Strength Class	Modulus of Rupture (kg/cm^2)	Absolute Press Tension (kg/cm^2)
I	*A. > 1100*	*B.* > 650
II	725 - 1100	425 – 650
III	500 – 725	300 – 425
IV	360 – 500	215 – 300
V	< 360	< 215

3.4. The benefit of densified wood in architecture

Utilization of wood materials on the architecture of tropical buildings can support the mindset of preserving vernacular archipelago architecture in Indonesia. This is related to the preservation of culture in terms of traditional buildings by considering the availability of natural building materials such as wood. The densified wood is an appropriate method for the availability of building materials without damaging the natural environment in the countryside and forests.

The requirement of densified wood is designated only on young wood (<20 years old) planted in industrial plantation areas (not natural forests old). Thus, the availability of this young wood (<20 years old) in the future will not suffer from a deficiency or remain with its availability. The densified wood method can be carried out on a variety of wood sizes for building structural components. Furthermore, the design of urban architecture can also use the densified wood because it proved stronger, durable and still memorable natural. In addition, wood color is part of a design in architecture. Densified jabon wood gives its own aesthetic value because its color is more attractive (giving it a more aesthetic look) compared to non-densified jabon wood.

4. Conclusions

The densified wood rafters have a smoother impression touch and lighter polish compared to non-densified wood rafters. The densification process of jabon wood rafters gives a different color to its original color, the color becomes slightly darker. This occurs due to high-temperature influence at the time of the densification process. The improved physical properties of the densified jabon wood are quite high. This is indicated by the increase in the percentage of specific gravity (28.95 percent) and density (26.83 percent) of jabon wood rafters. Meanwhile, densification treatment resulted in a water content decrease (0.02 percent for each cm^3). Based on its physical properties, densification treatment on jabon wood rafters also shows a strength class increase, from strength class IV to strength class III.

The increased of a perpendicular force of fiber, MOE, and MOR of densified jabon wood rafters because it is suspected that there has been destruction of wood cells so that wood cell becomes more compact and evenly distributed on each part of densified wood. Based on results of research on the mechanical properties of jabon wooden rafters, densification treatment increases the strength class of jabon wood from strength class IV (before densification) into strength class II (after densification). Meanwhile, an application of U-steel in the UTM Instron tool for densified jabon wood rafters proved the increase of the perpendicular strength of fiber, modulus of elasticity (MOE) and modulus of rupture (MOR) that suppressed for one hour and two hours compared with densification without using U-steel.

References

[1] Anonymous. (2017). HKTI. Accessed on January 29, 2019, from Kualitas dan Karakteristik Kayu Jabon: http://hkti.org/kualitas-dan-karakteristik-kayu-jabon.html
[2] BPS, B. S. (2020). Biro Pusat Statistik (BPS). Retrieved February 2, 2017, from Produksi Kayu Bulat Perusahaan Hak Pengusahaan Hutan (HPH) Menurut Provinsi (m3), 2003-2017: https://www.bps.go.id/dynamictable/2015/09/08/863/produksi-kayu-bulat-perusahaan-hak-pengusahaan-hutan-hph-menurut-provinsi-m3-2003-2017.html
[3] Darwis, A. (2008). Fiksasi Kayu Agathis dan Gmelina Terpadatkan Pada Arah Radial Serta Observasi Struktur Anatominya (Thesis). Bogor: Institut Pertanian Bogor.
[4] FPL, F. P. (2010). Wood Handbook: Wood as an Engineering Material. Washington: USDA Department of Agriculture.
[5] Haygreen, J. &. (2003). Hasil Hutan dan Ilmu Kayu. Yogyakarta: Gadjah Mada University Press.
[6] Holman, J. (2010). Heat Transfer. New York: McGraw-Hill.
[7] Hwang, G. (1997). Effect of Heat Treatment on the Properties of Compressed Wood. Taiwan Journal Forestry of Science Vol. 12 No. 10, pp.198-203.
[8] Inoue, M. N. (1996). Dimensional Stabilization of Wood Composites by Steaming I. Fixation of Compressed Wood by Pre-Steaming. The Third Pacific Rim Bio-Based Composites Symposium, (pp. 240-248). Kyoto, Japan.
[9] John R. Barnett and George Jeronimidis. (2003). Wood Quality and Its Biological Basis. London: CRC Press.
[10] Kasmudjo. (2010). Teknologi Hasil Hutan. Yogyakarta: Cakrawala Media.
[11] M. Inoue, N. S. (2008). Fixation of Compressive Deformation in Wood by Pre-Steaming. Journal of Tropical Forest Science 20 (4), pp. 273-281.
[12] Martawidjaya, A. I. (2005). Atlas Kayu Jilid II. Bogor: Badan Penelitian dan Pengembangan Kehutanan, Departemen Kehutanan.
[13] PKKI. (1961). Peraturan Konstruksi Kayu Indonesia NI-5. Bandung: Yayasan Lembaga Penyelidikan Masalah Bangunan.
[14] Ramdhania, D. (2010). Perbaikan Sifat Mekanis Kayu Randu (Ceiba pentandra L.) Dengan Teknik Kompregnasi Menggunakan Tanin Limbah Kulit Kayu Akasia (Acacia mangium). Bogor: Institut Pertanian Bogor.
[15] Rilatupa, J. (2001). Scientific Repository. Retrieved February 2, 2017, dari Keandalan Papan Lapis dari Kayu Damar (Agathis loranthifolia Salisb.) Terpadatkan sebagai Pelat Buhul pada Konstruksi Atap Bangunan Bentang Lebar: http://repository.ipb.ac.id/handle/123456789/22150
[16] T.R. Mardikanto, L. Karlinasari dan E.T. Bahtiar. (2011). Sifat Mekanis kayu. Bogor: IPB Press.