

Physical and Mechanical Properties of Local *Styrax* Woods from North Tapanuli in Indonesia¹

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ABSTRACT

The objective of this research was to evaluate physical and mechanical properties of three species of *Styrax* woods from North Tapanuli in Indonesia. The woods were more than 15 years old. Physical properties such as specific gravity, green moisture content, and volume shrinkage were determined by the procedures based on BS-373 standard for small clear specimen. Furthermore, mechanical properties, including modulus of rupture, modulus of elasticity, compression parallel to grain and hardness were also tested according to the standard. Along the stem direction, the edge section had better properties compared with those near the pith section. And the base section had also better properties than upper section. Based on the specific gravity, all of the *Styrax* woods in this research were classified into III-IV strength classes. A good dimensional stability was demonstrated by the value of the tangential and radial ratio which reached one. With the consideration of the mechanical properties, *Styrax* woods were suitable use for raw materials of light construction, furniture and handy craft.

Keywords: *Styrax sumatrana*, *Styrax benzoin* Dryan, *Styrax benzoine* var. Hiliferum, *Styrax* sp, physical-mechanical properties

1. INTRODUCTION

Styrax is one of plant origin from North Sumatera, Indonesia. It is comprised of four species namely Toba (*Styrax sumatrana* J.J.Sm), Durame (*Styrax benzoin* Dryan), Bulu (*Styrax benzoine* var. Hiliferum) and Dairi (*Styrax* sp). The distribution area of *Styrax* woods in North Sumatera coverage of North

Tapanuli, South Tapanuli, Dairi, Humbang Hasundutan and Toba Samosir Regency. Productive *Styrax* plants resulted gum which can be further processed as raw material for medicine, parfume and cosmetic industry.

Besides gum production, *Styrax* plant also can result wood especially from non-productive plant. This wood can be used for energy wood, handy craft, furniture and light construction

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Fig. 1. The utilization of styrax wood for handy craft.

materials. To appropriate utilization of it, the information including the wood basic and its working properties is important to be investigated. Up to now, the limitation on proper information causes decrease on the value of styrax wood and the people utilize this wood for wood fuel purposes only. A good pattern and easy to be worked as described on Fig. 1 are advantages of this wood.

To the best of our knowledge, there is few study that reported on basic Styrax wood properties endemic from North Sumatra. These properties included of physical and mechanical properties as important parameter in utilization as furniture and construction material. Thus, this present research was intended to evaluate physical and mechanical properties of the three species of Styrax wood origin from North Tapanuli, Province of North Sumatra, Indonesia. Based on the observed study, it can be determined the appropriate utilization.

2. MATERIALS and METHODS

Three species of Styrax woods with more than 15 years old were used as raw material in this present study. They were styrax of Toba (*Styrax sumatrana*), Durame (*Styrax benzoin*)

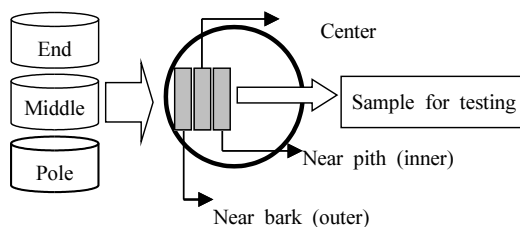


Fig. 2. The pattern of cutting stem for physical-mechanical properties.

and Bulu (*Styrax paralleloneurus*) collected from Adiankoting subdistrict, North Tapanuli, North Sumatra. The physical (i.e specific gravity-SG, green moisture content-MC, and volume shrinkage) and mechanical (i.e modulus of rupture, modulus of elasticity, compression parallel to grain and hardness) evaluation refers to BS-373. Air drying evaluation, samples were dried using fan at room temperature for 5 week. The data was collected every week.

Wood stem was cut in vertical direction into three sections namely pole, middle and end with the length of 1 meter, respectively. Furthermore, the stem was cut into three section in horizontal direction, namely outer (near bark), center, and inner (near pith). The illustration of cutting pattern is showed in the Fig. 2.

3. RESULTS and DISCUSSION

3.1. Specific gravity (SG)

3.1.1. SG in green, air and oven dry stated SG value in green, air and oven dry stated was showed that in Fig. 3.

As displayed at the Fig. 3, the average value of SG in green, air and oven dry stated for all



Fig. 3. Specific gravity of StyraX wood.

of styraX woods ranged between of 0.43 to 0.62. Toba StyraX wood had a higher value than Bulu and Durame. The result had slightly higher than that of Pasaribu *et al.* (2012) with SG value of Bulu and Toba StyraX wood of 0.55. Changes of wood moisture content result in a change of its SG. Accordance with the Forest Product Laboratory (1999), SG and moisture content have a negative correlation whereas a higher of wood moisture content result in a lower of SG. Furthermore, SG distribution in both directions of stem was presented in Fig. 4.

Fig. 4 shows that, the trend of SG slightly decreased from the pole towards the end of stem based on the vertical direction. A similar trend was also occurred in horizontal direction, from outer towards to inner (pith). According to the stem orientation for the green, air and oven dry, the SG had almost the similar trend on spread patterns. Bowyer *et al.* (2003) stated the pole wood tends to have higher SG than upper part in the main stem. Furthermore, wood SG variation is caused by the amount of cell wall constituent and extractive substances per unit volume (Brown *et al.*, 1952). And cell wall

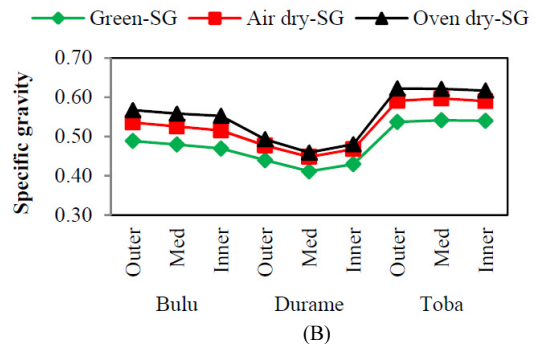
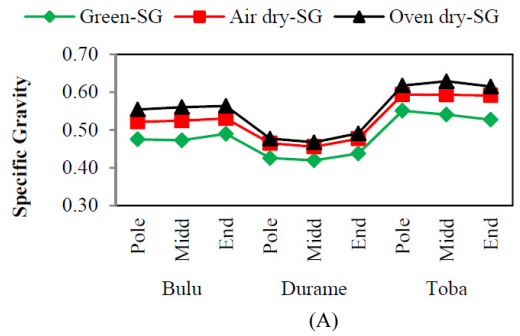


Fig. 4. Specific gravity of green, air dry and oven dry condition for (A) vertical and (B) horizontal direction of stem.

thickness greatly affected to wood SG.

According to Zobel & Buijtenen (1989), normally the wood density of pole part is higher than middle and end, this is due to higher heartwood poportion at the pole than that of end of stem. The last has a high juvenile section with a low density related to small proportion of the heartwood and dominated by thin cell walls (Haygreen and Bowyer, 1996).

Its density varies horizontally from the pith to the bark and vertically from the pole to the end of the stem (Haygreen and Bowyer, 1996). The variation from the pith to the bark is caused by the existence of early wood and late

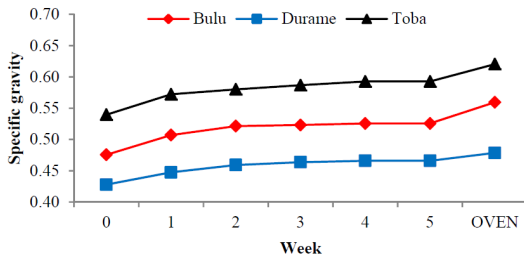


Fig. 5. Specific gravity every week.

wood in tissue of the trunk. While of Larson (1969) stated that the increasing of density from pith to the bark is due to the juvenile wood to mature wood transition. This condition also indicated the thinness of the cell wall near the pith and it has thicker at the outer of the stem.

3.1.2. Trend of changing on every week of SG

Specific gravity change during the five-week measurements using air dry and followed by oven dry after fifth week presented in Fig. 5.

Based on Fig. 5, SG increases after air and oven dry drying treatment. It is due to the release of water as a consequence of drying activity resulted in the wood cell shrinkage thus the wood cells become denser. The changes pattern from that Fig. 5 are almost the same for the third of wood species. According to the changing pattern of SG from air to oven drying, the StyraX wood of Bulu and Toba had steeper of SG pattern than styraX Durame.

3.2. Moisture content (MC)

3.2.1. Green and air dry of wood moisture content

The green and air dry MC of the three StyraX wood species ranged between of 57.69 to 69.93% and 13.74 to 14.60%, respectively (Fig.

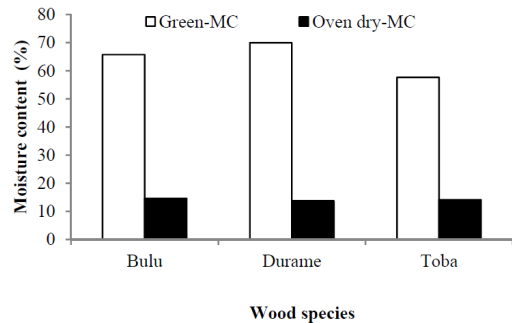


Fig. 6. Moisture content of StyraX wood in green and oven dry stated.

6). The lowest green MC was resulted by Toba wood while for the highest ones on the Durame wood, a higher SG of Toba wood compared to the others might caused it. A low density wood has many vessels that possible are filled by free water to result high MC (Skaar, 1972).

The lowest and the highest of air dry MC were found Durame and Bulu StyraX wood, respectively. The MC variation of the trees is influenced by several factors such as stem positions (longitudinal or transverse, heartwood or sapwood), variations in density, climate and location of growth (Yakub *et al.*, 1978; Bowyer *et al.*, 2003).

In the vertical direction, the pole had a lower MC compared to the end stem. While for the horizontal direction, the inner part had lowest ones (Fig. 7).

3.2.2. The changes behavior of MC every week

Fig. 8 showed that air dry MC for StyraX wood can be achieved in fourth to fifth week (13-15%) which indicated there is no MC changes which called by equilibrium MC Based on the figure, in the first week, the curve tends

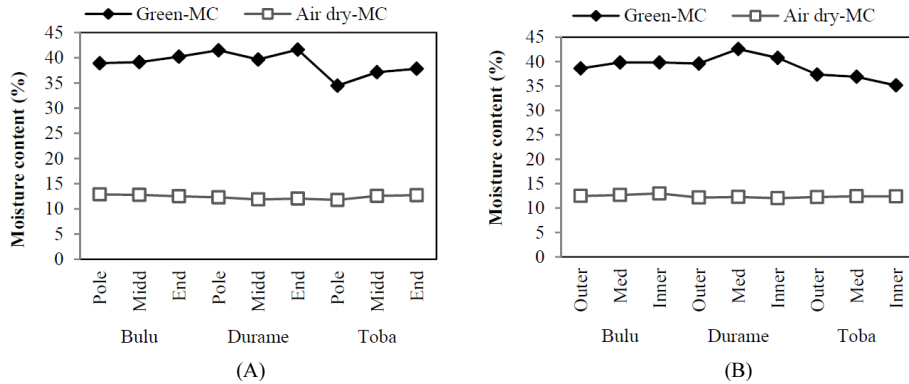


Fig. 7. Moisture content of green and air dry condition for (A) vertical and (B) horizontal direction of stem.

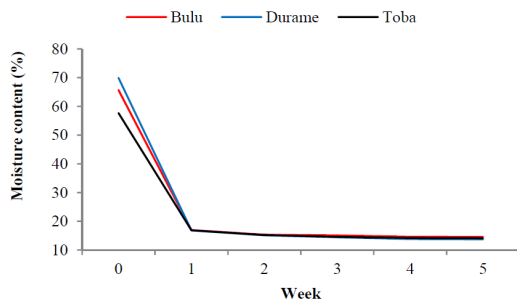


Fig. 8. Air dry moisture content every week.

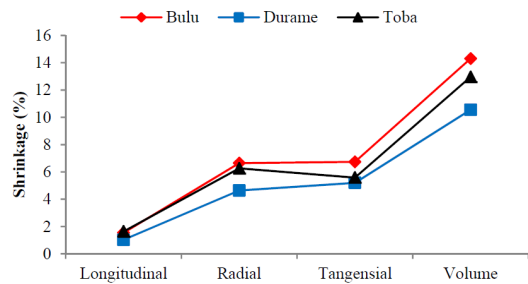


Fig. 9. Shrinkage of *Styrax* wood in oven dry stated.

to decline sharply, and after that it will be decrease slightly. MC decline drastically at first week during the air-drying process and after that MC changes ramps until fifth week to reach stabilized level. Removing of amount water from cell cavity can be caused it.

3.3. Shrinkage

3.3.1. Wood dimension and volume shrinkage

Fig. 9 showed that shrinkage for the longitudinal, radial and tangential directions ranged of 1.03 to 1.64%, 4.63 to 6.65%, and 5.20 to 6.73%, respectively. Meanwhile the volume shrinkage was around 10.55 to 14.30%. In

general, tangential shrinkage had slightly greater value than radial and longitudinal. This statement also supported by Forest Product Laboratory (1999). It was caused by arrangement of rays extend towards in radial, consequently restrained shrinkage in radial section. The larger number of pith in radial section and thin cell walls are another factors can also influenced of shrinkage (Brown *et al.*, 1952). Overall the smallest and highest wood shrinkage in this research were achieved on Durame and Bulu wood, respectively. Similar research conducted by Pasaribu *et al.* (2012) who reported that Toba had smaller shrinkage compared to Bulu ones. A high shrinkage value

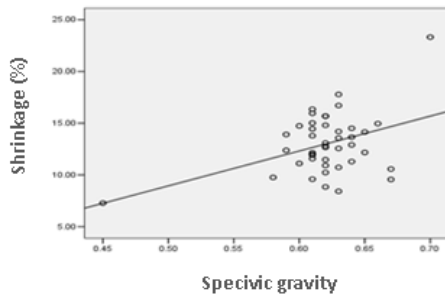


Fig. 10. The relation between specific gravity and volume shrinkage.

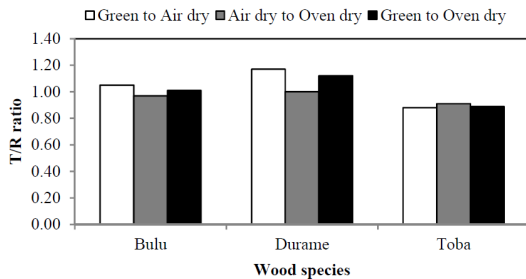


Fig. 11. Tangential/Radial ratio of styrax wood.

indicated a greater internal stress and has potency to resulted in defect during wood processing.

As shown in Fig. 10 that the shrinkage positively correlated with SG. Pearson correlation of 0.41 indicates the significance correlation between SG and shrinkage. This relationship shows that greater SG result in greater wood shrinkage. It is similar with Glass & Zelinka (2010) stated that the shrinkage is affected by wood SG, the increasing of wood SG can cause greater of shrinkage. The wood shrinkage is affected by many variables, and the most important variable is wood density (Lima *et al.*, 2014).

Fig. 11 showed the ratio of tangential and radial shrinkage (T/R) for air dry and oven dry

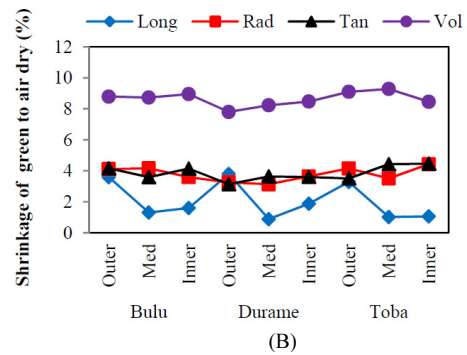
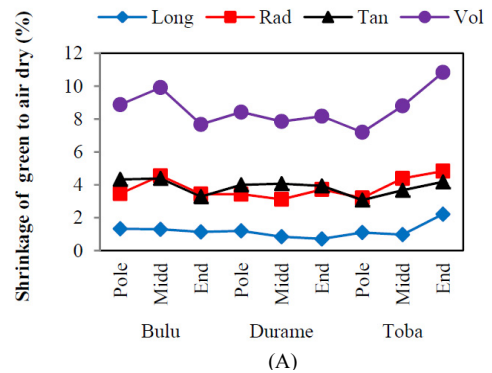


Fig. 12. Wood shrinkage on green toward air dry condition for (A) vertical and (B) horizontal direction of stem.

conditions ranged between of 0.97 to 1.05 and 0.88 to 0.91, respectively. It described that styra x wood had a good dimensional stability. Wood had good dimensional stability if the T/R ratio value reached of 1.00 (Phansin & de Zeeuw, 1980). The small shrinkage differences in tangential and radial direction showed in this study. Generally, shrinkage of wood in the tangential direction is greater than the radial ones, in some species tangential and radial shrinkage ratio is achieved 2 : 1 (Tsoumis, 1991).

Fig. 12 to 14 showed that the distribution of Styra x wood shrinkage of according to vertical and horizontal of stem orientation. The drying

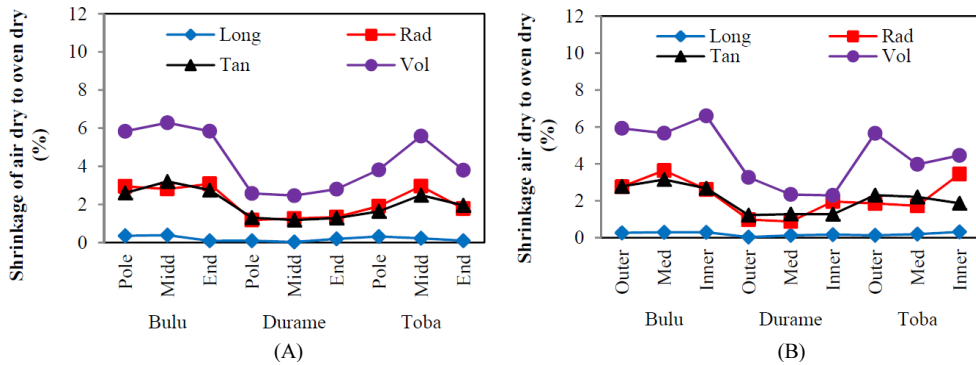


Fig. 13. Wood shrinkage on air dry toward oven dry for (A) vertical and (B) horizontal direction of stem.

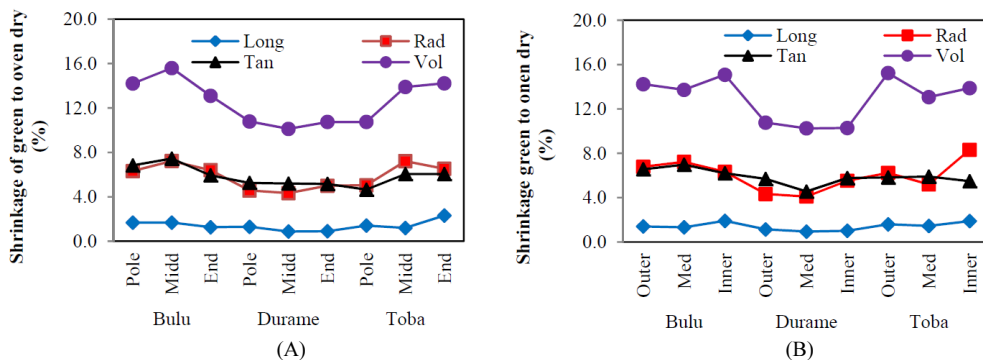


Fig. 14. Wood shrinkage of green and oven dry condition for (A) vertical and (B) horizontal direction of stem.

process from green to oven dry resulted longitudinal direction had higher shrinkage, it was predicted by the presence of juvenile wood. Fast growing wood species tend produce higher juvenil portion that would contribute on reducing strength and high longitudinal shrinkage (Bowyer *et al.*, 2003).

Durame species provided the lowest volume shrinkage compared to Bulu and Toba for all moisture content condition (Fig. 14). Based on vertical stem direction, there is decrease shrinkage from pole to end of stem the *styrax* wood. This similar trend also was presented in horizontal direction from outer to inner part.

According to Josue (2004) stated that the wood shrinkage increased from the inner to outer and from end to pole.

3.4. Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)

Refers to the Fig. 15, Bulu species resulted the highest value of MOE and MOR. The average value of MOE and MOR ranged between of 77,685 to 85,900 kgfcm⁻² and 637 to 770 kgfcm⁻², respectively. Compared to Pasaribu *et al.* (2012), the bending (MOE and MOR) value was higher than that of them. Furthermore, den-

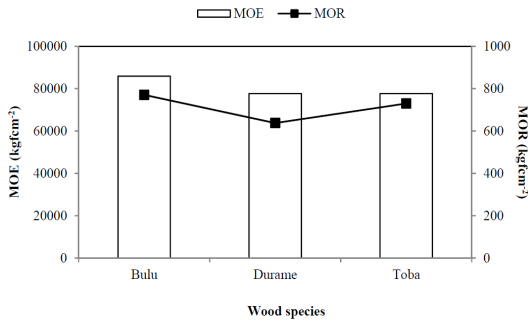


Fig. 15. MOE and MOR of Styrax wood.

sity, microfibril angle, knots, fiber length, fiber spiral, moisture content and temperature of environment include as factors that also affect the MOE values (Huang *et al.*, 2003).

Overall in vertical and horizontal direction, the highest MOE and MOR were resulted from pole and outer part (Fig. 16). It was due to the pole and the outer part have higher SG than the other parts. Furthermore, major proportion of heartwood and mature wood structures dominated in pole and outer part. In addition, basic mechanical properties and density varied along with the height of tree (Schneider *et al.*, 1991). Getahun *et al.* (2014) reported that the highest MOE and MOR value are located in the pole of stem and will decrease to the end part. It indicates that a high proportion of juvenile wood in the end of stem results a low MOR. This part had lower density than that of mature ones (Ishengoma and Gillah, 1992).

The bending properties had positive linier correlation with SG (Haygreen and Bowyer, 1989., Forest Product Laboratory, 1999). The results showed that correlation of SG and MOR value described by Pearson correlation was

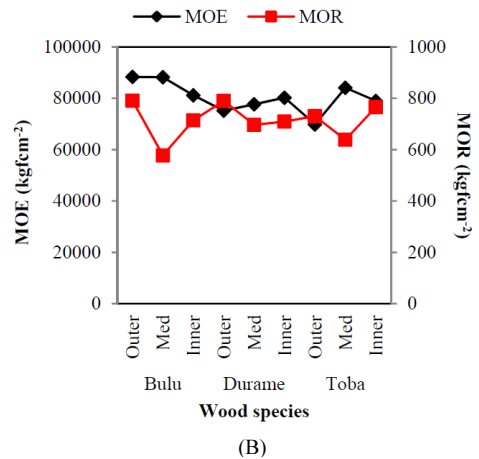
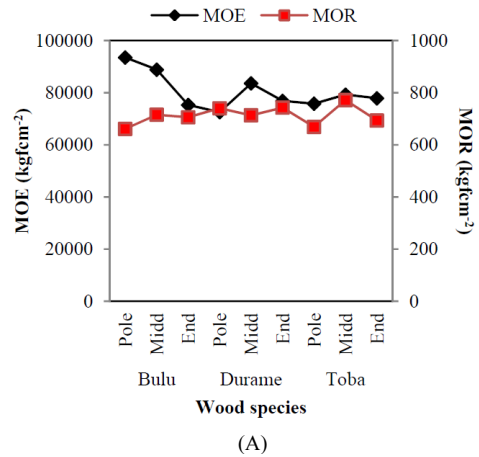


Fig. 16. MOE and MOR for (A) vertical direction and (B) horizontal direction of wood stem.

around 0.425 (Fig. 17). It indicated the significant correlation between SG with MOR at 95% confidence interval.

MOE is one important parameter, especially for wood construction. Refers to the MOE value, Styrax wood was classified into strength class of III to IV. It means that this wood can be used for light construction, furniture and handicrafts and other purposes which not require of strength.

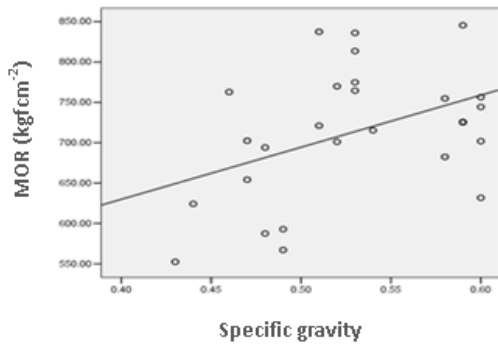


Fig. 17. The relation between specific gravity and Modulus of rupture.

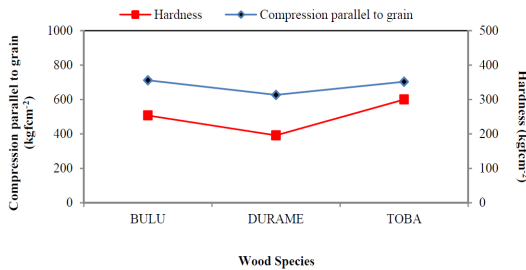
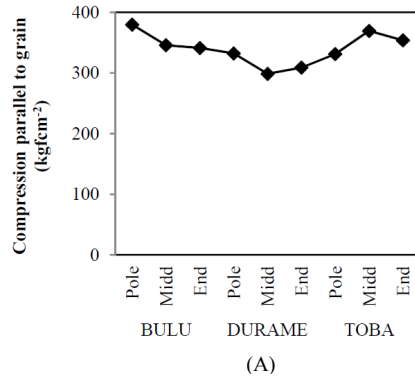


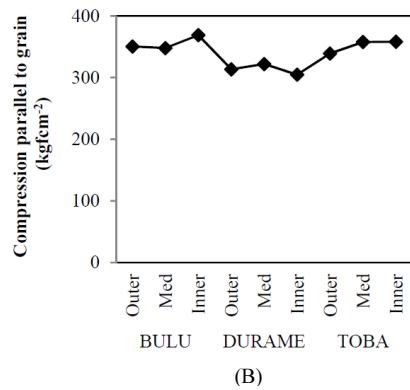
Fig. 18. Compression parallel to grain and hardness of *Styrax* wood.

3.5. Compression parallel to grain and hardness

Fig. 18 showed that Bulu species resulted the highest value of compression parallel to grain and hardness. The value of compression parallel to grain and hardness perpendicular to grain ranged 313 to 355 kgfcm⁻² and 391 to 599 kgfcm⁻², respectively. The lowest specific gravity of Durame species was caused by the lowest compression parallel to grain and hardness of it. According to the Fig. 19, Durame and Toba wood had clearly pattern of compression parallel to grain distribution in vertical direction. The highest compression parallel to



(A)



(B)

Fig. 19. Compression parallel to grain (A) vertical and (B) horizontal direction of stem.

grain value is located in the pole section and then decreased to the end part. However this trend does not occur in horizontal direction. In addition, compression parallel to grain for horizontal direction was varied depend on wood specific gravity (Shanavas and Kumar, 2006). A high SG resulted in a high compression parallel to grain. According to Fig. 20, Toba and Durame species had clearly trend both vertical and horizontal direction. In the former, hardness value decreased from pole to end part, while in horizontal direction, it decreased from outer to its inner. Pearson correlation value to describe

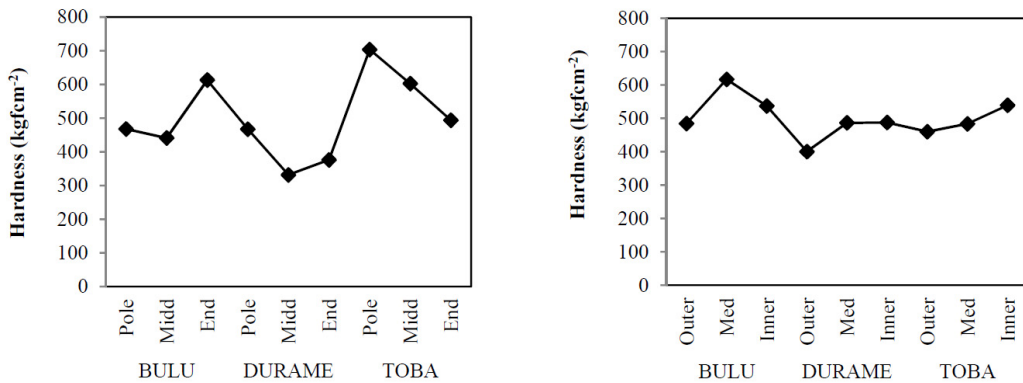


Fig. 20. Hardness for (A) vertical and (B) horizontal direction of stem.

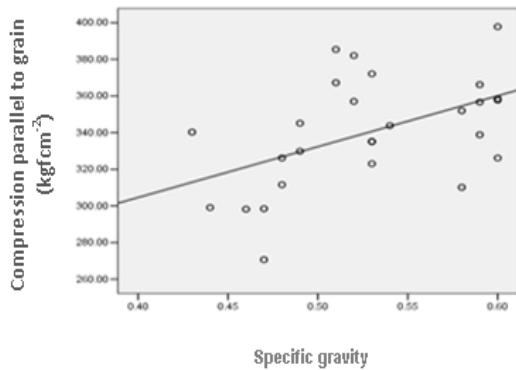


Fig. 21. The Relation between specific gravity and compression parallel to grain.

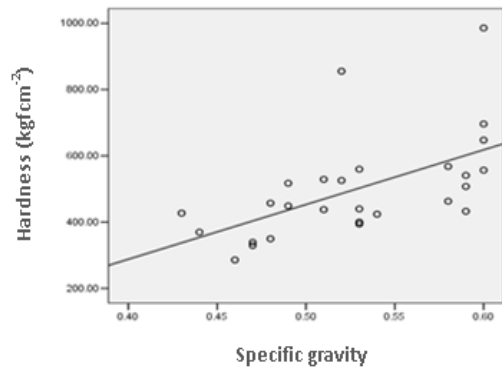


Fig. 22. The relation between specific gravity and hardness.

of correlation between of specific gravity and compression parallel to grain was around 0.495 (Fig. 21). It the positive value means there is significant correlation between them. The similar trend also occurred in hardness parameter (Fig. 22).

4. CONCLUSION

In general, the pole and outer part of stem showed better properties compared to other position. Considering its specific gravity the

Styrax woods are classified into III-IV strength classes. In this class, they are suitable for light construction, furniture and handy craft materials. Based on T/R ratio value, the Styrax wood had good dimensional stability.

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