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Investigation of some modulus properties of rubberwood by means of bending test

Benjama MEETHAWORN[1], Harutaya SUKMATTA[1], Pattra BILLAH[1], Suthon SRIVARO[1,*] and Zoltan PASZTORY[2]

[1]*Materials Science and Engineering Program, School of Engineering and Resources, Walailak University, Nakhon Si Thammarat 80161, Thailand*
[2] *Innovation Center, University of Sopron, Sopron 9400, Hungary*

([*]Corresponding author's e-mail: ssuthon@wu.ac.th)

Abstract

The aim of this study was to investigate some modulus properties (Shear modulus (G), modulus of elasticity (MOE) and true modulus of elasticity in longitudinal direction (E_L)) of rubberwood by means of bending test. The comparison of the obtained result with ones obtained by using different testing methods reported elsewhere was also made. The bending test was conducted in accordance with ASTM D198 and ASTM D 143 standards. Effect of annual ring orientation on the examined properties was considered. In addition, effect of span length to thickness ratio (L/t) on MOE value was also examined. The result showed that annual ring orientation did not affect MOE values but slightly affected G value. Shear modulus in radial-longitudinal plane (G_{RL}) was about 1.34 times higher than shear modulus in tangential-longitudinal plane (G_{TL}). However, it was found that the shear modulus obtained from this study was lower in comparison with ones determined by using different testing methods reported in literature. Notably, MOE value was decreased with decreasing L/t ratio. Finally, the relationship between MOE/E_L and span length to thickness ratio was finally achieved.

Keywords: Rubberwood, modulus properties, bending test

Introduction

Rubber trees (*Hevea brasiliensis*) are generally planted for the production of latex and they can be widely found in Southeast Asia. The total plantation area of rubber trees around the world is about 8.81 million hectares (Shigematsu et al. 2011). Indonesia has the largest plantation area followed by Thailand and Malaysia, respectively. Generally, rubber trees are cut down for replanting at an age of about 25-30 years because the yield of latex is relatively low. The trunks of rubber tree are then converted into lumber. These lumbers are typically used for furniture production. Since, mechanical properties of rubberwood are comparable with that of typical structural timber (Nadir et al. 2014; Kretschmann 2010), the use of rubberwood for structural application is now considered (Nadir & Nagarajan 2014; Meethaworn & Srivaro 2017).

Modulus properties of wood are generally required for the design of wooden structure. According to the literature, these properties of wood could be determined from various testing methods such as compression test (Nadir et al. 2014), Iosipescu shear test (Nadir et al. 2014), off-axis shear test (Xavier et al. 2004), torsion test (Yoshihara et al. 2001) and bending test (Kretschmann 2010; Nadir et al. 2014). It has been reported that some values obtained from using different testing methods were different (Yoshihara et al. 2001; Xavier et al. 2004; Nadir et al. 2014). For rubberwood, most of modulus properties have been investigated by using the first two methods mentioned above (Nadir et al. 2014). In this study, some modulus properties of rubberwood were investigated by using bending testing method and the obtained results were then compared with ones obtained by using different testing methods reported in literature. Effect of annual ring orientation on the examined modulus properties was also considered.

Materials and methods

Rubberwood lumbers with the dimensions of 10 cm (radial) ×2.5 cm (tangential) ×100 cm (longitudinal) were taken from a local sawmill in Nakhon Si Thammarat province, Thailand. The moisture content of lumber was approximately 12%. These lumbers were cut into the test specimens with some modification to ASTM D 198 and 143 standards to determine modulus properties (shear modulus in radial-longitudinal and tangential-longitudinal planes, modulus of elasticity and true modulus of elasticity in longitudinal direction) of rubberwood.

Determination method of modulus properties by means of bending test

According to ASTM D 198, shear modulus (G) could be determined from the relationship between apparent modulus of elasticity (E_P) (or modulus of elasticity, MOE) and thickness to span length ratio (h/L) as the following equation

$$\frac{1}{E_P} = \frac{1}{E_L} + \frac{1.20}{G}(h/L)^2 \tag{1}$$

The specimens with the dimensions of 2 cm (radial) ×2 cm (tangential) ×42 cm (longitudinal) were prepared for the test. Each specimen was loaded in radial and tangential directions at mid-span of various test span lengths of 11, 13, 28 and 40 cm to a required load (P_{elas}) so that the beam still deformed within elastic range using a 150 kN universal testing machine (Lloyd) (see **Figure 1**). The corresponding deflection (δ_{elas}) at mid span length was then taken to determine apparent modulus of elasticity (E_P) using the following equation.

$$E_P = \frac{L}{4bh^3}\frac{P_{elas}}{\delta_{elas}} \tag{2}$$

where *b* is the width of the specimen. *h* is the height of specimen and *L* is the span length.

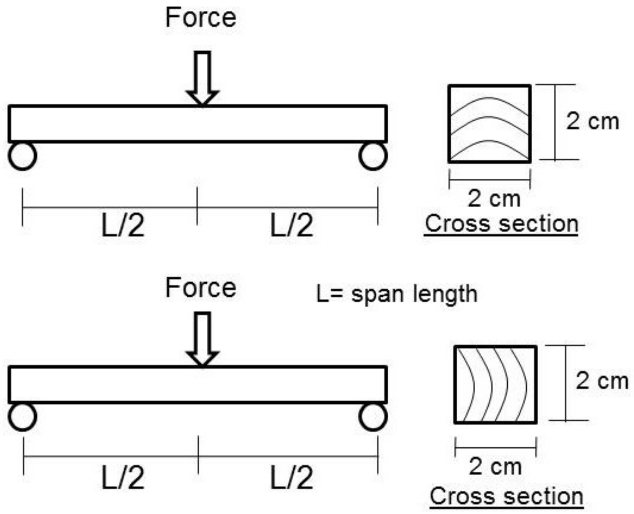

Figure 1 Center point bending test of rubberwood specimen. Load was applied in radial and tangential directions.

The relationship between $1/E_P$ and $(h/L)^2$ was then plotted. G_{RL} and G_{TL} were then determined from the slope of the obtained curve. E_L was determined from intersection point on vertical axis. A total of 20 specimens (ten specimens for each loading direction) were used for this test.

Results and discussion

Shear modulus (G) and true modulus of elasticity in longitudinal direction (E_L)

The result showed that the obtained shear modulus in radial-longitudinal (G_{RL}) plane was slightly higher than shear modulus in tangential-longitudinal (G_{TL}) plane. They were approximately 213±35 MPa and 159±11 MPa, respectively (**Figure 2**). The trend of this result corresponds to that of other wood species which has been reported that G_{RL} was greater compared with G_{TL}. Moreover, it is noticed that the ratio between G_{RL} and G_{TL} (~1.34) of rubberwood obtained from this study is similar and slightly higher than that of typical hardwood (G_{RL}/G_{TL}~1.36) and softwood (G_{RL}/G_{TL}~1.07), respectively (Kretschmann 2010).

However, it was found that the obtained G_{RL} and G_{TL} of rubberwood were lower compared with ones obtained by using different testing method (Nadir et al. 2014). Nadir et al. (2014) reported that G_{RL} and G_{TL} of rubberwood determined by Iosipescu tests were approximately 1,073 MPa and 1,008 MPa, respectively and the G_{RL} to G_{TL} ratio was about 1.06. Xavier et al. (2004) also found that the different values of shear modulus could be obtained if the different testing methods were used. It should be noted that, in case of Iosipescu test, the specimen was subjected only to shear stresses (it was in pure shear stresses) while in case of bending test (this study) the specimen was subjected to a combination of shear and normal stresses. The different states of stresses in the specimen might lead to the different shear modulus between the two test methods. Variation of wood properties among different locations of planted area might also contribute to these different values.

The true modulus of elasticity in longitudinal direction (E_L) obtained from this study was about 14,623 ±3,553 MPa. This value was higher than ones obtained by compression test (E_L = 8,175 MPa) (Nadir et al. 2014) about 1.8 times. Generally, the tensile modulus of elasticity of wood is greater compared with the compressive modulus about 2 times (Kim and Shim 2010).

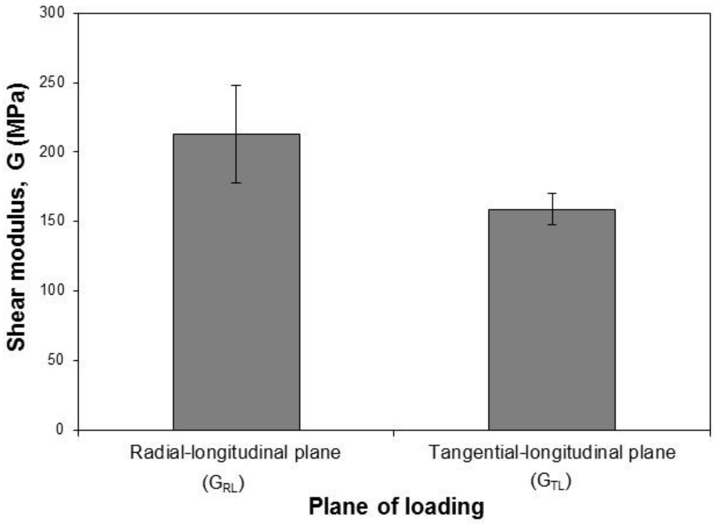

Figure 2 Shear modulus in radial-longitudinal (G_{RL}) and tangential-longitudinal (G_{TL}) planes.

Modulus of elasticity (MOE)

Figure 3 shows the MOE of rubberwood specimens which were loaded in radial and tangential directions at various span length to thickness ratios (L/h). It was found that annual ring orientation had no effect on MOE value. As can be seen from **Figure 3**, specimens loaded in radial and tangential directions had similar MOE values for all examined L/h ratios. However, the values appeared to decrease with decreasing L/h ratio. Notably, only bending deflection is generally taken into account for the calculation of MOE value because it is always assumed that shear deflection is relatively small compared with bending deflection. However, this is only true for a relatively long span beam (Bodig and Jayne 1982). Thus, the decreasing of MOE value at a relatively short span length should be due to shear effect (Bodig and Jayne 1982).

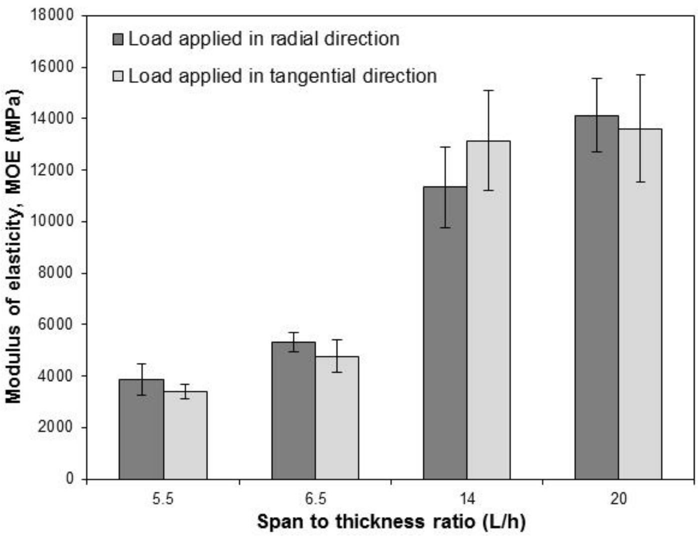

Figure 3 Modulus of elasticity of rubberwood obtained by center point bending test at various span lengths.

In order to avoid shear effect, the L/h ratio of 14 for three point bending test of clear wood specimen is generally recommended for determination of bending properties of wood (ASTM D 143). Generally, the MOE values of typical wood species provided in Wood Handbook were test based on the recommended L/h ratio. The obtained values are approximately 90% of E_L value (Kretschmann 2010). Thus, it is worth to plot the relationship between modulus of elasticity to true modulus of elasticity ratio (MOE/E_L) and span length to thickness (L/h) ratio for rubberwood, the result obtained is shown in **Figure 4**. It was found that MOE were about 25, 34, 84 and 95% of E_L value at L/h ratios of 5.5, 6.5, 14 and 20, respectively. In order to achieve MOE of 90% of E_L for rubberwood, it was found that the L/h ratio of 17.6 is required for three point bending test of clear wood specimen.

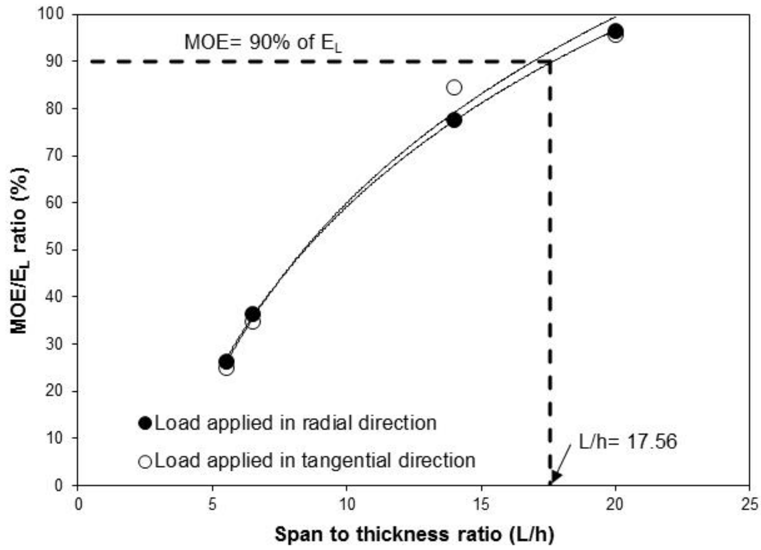

Figure 4 Relationship between modulus of elasticity to true modulus of elasticity ratio (MOE/E_L) and span length to thickness (L/h) ratio.

Conclusions

1. Annual ring orientation had slightly effect on shear modulus; G_{RL} was slightly greater than G_{TL}.
2. Annual ring orientation had no effect on modulus of elasticity of rubberwood (MOE); MOE was mainly affected by span length to thickness ratio used in bending test.
3. Shear modulus obtained by bending test from this study were different from ones obtained by Iosipescu shear test reported elsewhere.

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References

American Society for Testing and Materials. (2012). *ASTM D 143-12: Standard test methods for small clear specimens of timber.* In: ASTM annual book of standards. West Conshohocken: ASTM International.

American Society for Testing and Materials. (2012). *ASTM D 198-12: Standard test methods of static tests of lumber in structural sizes.* In: ASTM annual book of standards. West Conshohocken: ASTM International.

Bodig, J., & Jayne, B.A. (1982). *Mechanics of wood and wood composites*. New York: Van Nostrand Reinhold Company Inc.

Hibberler, R.C. (1997). *Mechanics of materials.* (3rd ed.), New York: Prentice-Hall.

Junior, H.J.E., Ohto, J.M., Silva, L.L., Palma, H.A.L., & Ballarin, A.W. (2015). Potential of rubberwood (Hevea brasiliensis) for structural use after the period of latex extraction: A case study in Brazil. *Journal of Wood Science 61*, 384-390.

Kin, K.M., & Shim, K.B. (2010). *Comparison between tensile and compressive Young's modulus of structural size lumber*. In: Proceedings of the World Conference on Timber Engineering. Italy: Riva del Garda.

Kretschmann, D.E. (2010). *Mechanical properties of wood.* Madison: U. S. Department of Agriculture, Forest Products Laboratory.

Meethaworn, B., & Srivaro, S. (2017). Structural performance evaluation of finger jointed rubberwood manufactured by factories in Thailand. *BioResources 12*(4), 9420-9426.

Nadir, Y., & Nagarajan, P. (2014). The behavior of horizontally glued laminated beams using rubber wood. *Construction and Building Materials 55*, 398-405.

Nadir, Y., Nagarajan, P., & Midhun, A.J. (2014). Measuring elastic constants of Hevea brasiliensis using compression and Iosipescu shear test. *European Journal of Wood and Wood Products 72*, 749-758.

Shigematsu, A., Mizoue, N., Kajisa, T., & Yoshida, S. (2011). Importance of rubberwood in wood export of Malaysia and Thailand. *New Forests 41*, 179-189.

Teoh, Y.P., Don, M.M., & Ujang, S. (2011). Assessment of the properties, utilization, and preservation of rubberwood (Hevea brasiliensis): A case study in Malaysia. *Journal of Wood Science 57*, 255-266.

Wongprot, T., Matan, N., Matan, N., Preechatiwong, W., & Kyokong, B. (2013). Response Surface Modeling of Hydrothermal Treatment Conditions on Color Changes, Strength, and Durability Properties of Rubberwood. *Bioresources 8*(1), 302-312.

Xavier, J.C., Garrido, N.M., Oliveira, M., Morais, J.L., Camanho, P.P., & Pierron, F. (2004). A comparison between the Iosipescu and off-axis shear test method for the characterization of Pinus Pinaster Ait. *Composites Part A 35*, 827-840.

Yoshihara, H., Ohsaki, H., Kubojima, Y., Ohta, M. (2001). Comparisons of shear stress/shear strain relations of wood obtained by Iosipescu and torsion tests. *Wood Fiber Science 33*(2), 275-283.