International Journal of Civil Engineering and Technology (IJCIET)
Volume 10, Issue 10, October 2019, pp. 313-322, Article ID: IJCIET_10_10_032
Available online at http://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=10
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

NON-DESTRUCTIVE TESTING OF THE EXISTING TIMBER COLUMNS OF MINAHASA TRADITIONAL HOUSE

Yosafat Aji Pranata
Associate Professor, Department of Civil Engineering,
Faculty of Engineering, Universitas Kristen Maranatha, Bandung, West Java, Indonesia

Muhammad Rusli
Researcher, Research Institute of Housing and Human Settlement,
Ministry of Public Works and Public Housing, Bandung, West Java, Indonesia

ABSTRACT

Non-destructive testing is a method used to predict the dynamic elastic moduli of timber, tree, pole, or log, both in the longitudinal or radial axis. The benefits of this test are to obtain the mechanical properties, to repair the damaged components, or to determining the type or the class of timber. These research aims are to conduct non-destructive testing of timber to obtain empirical data which is dynamic elastic moduli. The scope of the research is that the timber tested are the column components of the existing Minahasa Traditional House. The test results indicate that the dynamic elastic moduli is 23206.65 MPa and the static elastic moduli is 20653.91 MPa. This results indicated that the timber is categorized as an E20 Timber type.

Keywords: Timber, Column, Dynamic Elastic Moduli, Static Elastic Moduli, Non-Destructive Testing

Cite this Article: Yosafat Aji Pranata and Muhammad Rusli, Non-Destructive Testing of the Existing Timber Columns of Minahasa Traditional House. *International Journal of Civil Engineering and Technology* 10(10), 2019, pp. 313-322.

http://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=10

1. INTRODUCTION

The Minahasa traditional house of can be found in Manado City and several villages in North Sulawesi, Indonesia. The house is a building made of timber components, especially beam and column structural components, and non-structural components such are stair and floor slab. As the building grows older, there are several structural components, for example, beams and columns that need to be repaired due to damage. To prepare replacement structural components it is necessary to test the mechanical properties of timber so that substitute timber has the same strength and quality as or better than the original structural components.

Modern Minahasa Traditional Houses are changing form, that is, they are smaller and higher. With dimensions, for example, is 8 m x 16 m and height of the floor above 2 meters.

The house on stilts has changed shape under which the house was developed to function as the interior of the house so that the house is no longer a stilt house.

This research aims to conduct non-destructive testing of timber to obtain empirical data which is dynamic elastic moduli. The scope of the research is that the timber tested are the columns components of the existing Minahasa Traditional House located in Manado City, North Sulawesi, Indonesia. Figure 1 shows the 2-story traditional house located in Manado City, North Sulawesi, Indonesia, while Figure 2 shows the beam-column joint. The building uses a beam and column structure system (frame system), the floor-slab uses timber boards, the lower floor walls are made of brick walls, while the upper floor walls are made of timber boards.

Figure 1. Traditional house in Manado, North Sulawesi, Indonesia (source: authors)

Figure 2. A sample of beam-column joint of traditional house in Manado (source: authors).

Previous research to obtain empirical mechanical properties data which are elastic moduli of columns and beams members of traditional timber house was done by Pranata and Tobing (Pranata and Tobing, 2016) with the house tested is Traditional Minangkabau Wooden House and the results obtained were the average of the columns elastic modulus is 12670.08 MPa and the beams elastic modulus is 13119.00 MPa. These results indicate that the quality of the wood used in very good condition, there is no significant damage to the main structural components of the house. Figure 3 shows the traditional Minangkabau timber house.

Figure 3. The Minangkabau Traditional Wooden House in West Sumatera, Indonesia (Pranata and Tobing, 2016)

The non-destructive testing introduces by CBS-CBT as a nondestructive test using Sylvatest the first time in 2000, based on the experience of nondestructive technology for testing the quality of the wood on the ground. The concept of nondestructive testing is to provide convenience and savings about the cost of maintenance and reliability aspects of a wooden building structure (CBS-CBT, 2011). The advantages of non-destructive grading for new wooden poles are multiple which are objective evaluation, knowledge of the initial mechanical properties of structural components, the timber life time expectancies can be extended, and the maintenance costs are lower because fewer timbers need to be changed, which are only the damaged timbers need to be changed.

Figure 4. New-wooden-poles quality evaluation using non-destructive testing (Benoit and Sandoz, 2011)

Figure 5 presents the ultrasonic measurement concept for a timber. The correlation between the measured ultrasonic velocity and the mechanical properties has been obtained befofe by destructive tests which is the coefficient of determination is $R^2 = 0.60$ (Benoit and Sandoz, 2011). The measurements can be made before or after timber's impregnation.

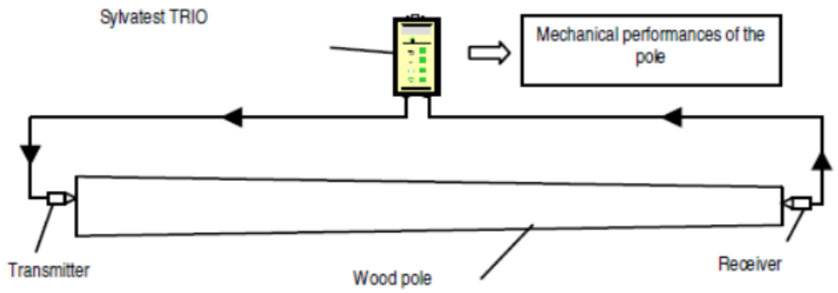
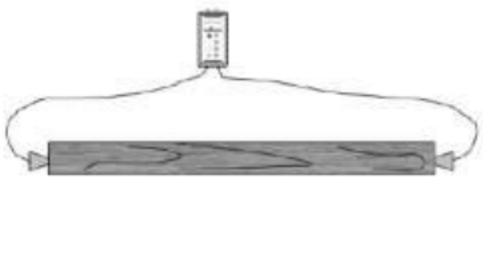


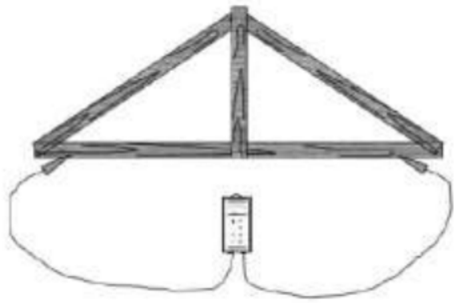
Figure 5. Concept of the ultrasonic measurement for a timber with one emitter and one receiver (Benoit and Sandoz, 2011)

2. METHODS

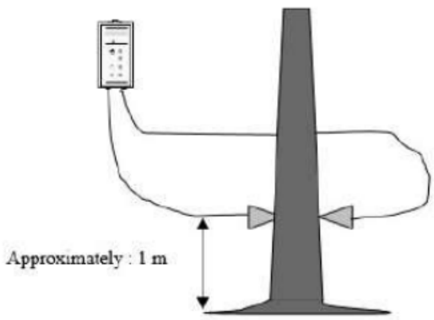
Non-destructive test equipment named Sylvatest TRIO was introduced by CBS-CBT, based on the experience of nondestructive technology for testing the quality of timber (CBS-CBT, 2011). The concept is to provide convenience and savings about the cost of maintenance and reliability aspects of a timber building structure, a beam member, a column member, a pole, a log, or other wooden components. To evaluate the mechanical properties of timber, which is the elastic moduli, the nondestructive techniques using ultrasonic wave parameter may be used, uses 2 (two) pieces of transducers, one as a transmitter and one as a receiver ultrasonic velocity signal, and then measured and translated into data (Pranata et.al., 2015).



(a). Direct measurements



(b) Indirect measurements



(c). Radial measurements

Figure 6. Methods for determining dynamic elastic moduli (CBS-CBT, 2011)

The advantages of this testing can be used for quality grading of the new timber building, the existing timber building, the heritage buildings, or the timber components that will be used to build a new building. This testing also can be used to determine the damage of timber component, predicting the residual strength of timber members in an existing building, and lower maintenance costs. Methods can be used are a direct measurement method in the direction parallel to the grain or longitudinal axis as shown in Figure 6.a, while the indirect measurement method which forms an the angle of 30º in the direction parallel to the grain shows in Figure 6.b. there is another measurement method especially to predict %-damage that occurs inside the member named radial measurement as shown in Figure 6.c (CBS-CBT, 2011).

The dynamic elastic moduli (MoE_{dyn}) can be calculated using Equation 1 (CBS-CBT, 2011), which are based on parameters such as the wave velocity (m/s) and the specific gravity of the timber following the measurement of the time history,

$$MoE_{dyn} = \rho V^2 10^{-6} \quad (1)$$

where MoE_{dyn} is dynamic elastic moduli (MPa), ρ is specific gravity (kg/m^3), and V is ultrasonic wave velocity.

Oliveira et.al. (Oliveira et.al., 2002) through his research concluded importantly literature related to nondestructive testing that dynamic elastic moduli and the result of the conversion of static elastic moduli. Several parameters that affect the propagation of ultrasonic waves in timber mechanical properties, the geometric characteristics of wood (both for macro and micro), temperature, humidity, the procedures used for the measurement which are frequency and the sensitivity of the transducer, size, position, and dynamic characteristics of the equipment (Bucur and Bonhke, 1994).

The relationship between dynamic elastic moduli and static elastic moduli (Modulus of Elasticity or *MoE*) has been widely studied before, including Raymond et.al. (Raymond et.al., 2007), Nowak (Nowak, 2015), Poggi (Poggi, 2017), Divos and Tanaka Divos et.al. 2005). Previous studies have shown that static elastic moduli (MoE) is 11% lower than dynamic elastic moduli (Raymond et.al., 2007), or it's can be calculated using Equation 2, with percentage of variance accounted for R^2 is 93% and standard error of prediction (SEP) is 0.73.

$$MoE = 0.899\, MoE_{dyn} \quad (2)$$

3. RESULTS AND DISCUSSION

3.1. Non-destructive Testing of the Existing Building

(a). Test of exterior column (b) Test of interior column

Figure 7. The non-destructive testing process of Merbau timber (Source: authors)

Non-destructive testing was done with the Sylvatest TRIO instrument. The test is carried out at the location of the existing building, with the specimen being the raw material of Merbau

(*Intsia spp.*) timber to be used as all of the column components. Figure 7.a shows the non-destructive testing process of one of the exterior columns located at 2^{nd} story of building, Figure 7.b shows the non-destructive testing process of one of the interior columns located at 2^{nd} story of building, while Figure 8 shows the process of reading the test data in the Sylvatest TRIO instrument. The data that recorded is ultrasonic wave velocity.

Figure 8. The process of reading the test data in the Sylvatest TRIO instrument (Source: authors)

Tests were carried out on timber specimens/logs, which are all of the columns located both at 1^{st} and 2^{nd} floors. The full test results are shown in Table 1. The Velocity (V) is the empirical data that obtained from the test, while the specific gravity (ρ) of Merbau Timber is taken from Atlas Kayu Indonesia (PPPTHH, 2004), and then dynamic elastic moduli (MoE_{dyn}) can be done calculated using Equation 1.

The length parameter is the distance between transducers, while Temperature parameter shows the air temperature at the location of the building during testing, although there is no relationship between temperature and velocity. Figure 9 shows the column's ID that used during the test. The sylvatest distance varies because it adjusts to the measurement conditions of the exciting columns in the building.

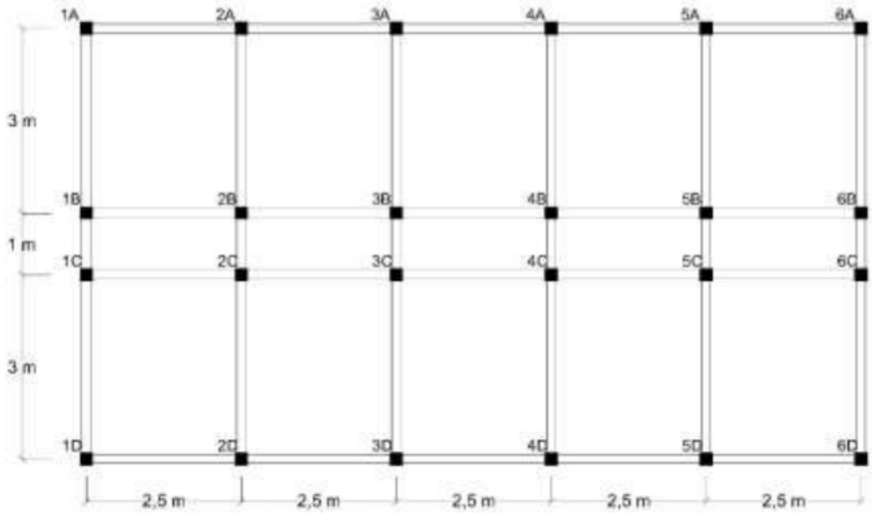


Figure 9. The column's ID that used during the test

Table 1. Results obtained from tests: velocity, dynamic and static elastic moduli

Test Points / Spots	Specimens/ Column's ID	*V* (m/s)	Temp. (Celcius)	Length (cm)	*ρ* (kg/m^3)	MoE_{dyn} (MPa)	*MoE* (MPa)
1	Column 1A	1845	28	60	620	20703.96	18426.53
2	Column 1A	1628	28	60	620	16120.17	14346.95
3	Column 1A	1836	28	60	620	20502.46	18247.19
4	Column 1A	1883	28	22	620	21565.59	19193.37
5	Column 1B	1969	28	90	620	23580.45	20986.60
6	Column 1B	1609	28	90	620	15746.09	14014.02
7	Column 1B	1664	28	30	620	16840.98	14988.47
8	Column 1C	2174	28	30	620	28746.16	25584.08
9	Column 1B	1489	28	30	620	13484.97	12001.63
10	Column 1B	2124	28	30	620	27439.09	24420.79
11	Column 1B	2076	28	30	620	26212.92	23329.50
12	Column 1A	2124	28	30	620	27439.09	24420.79
13	Column 1C	2076	28	30	620	26212.92	23329.50
14	Column 1C	1443	28	30	620	12664.65	11271.54
15	Column 2C	2200	28	30	620	29437.85	26199.68
16	Column 2C	2031	28	30	620	25088.84	22329.07
17	Column 2B	2100	28	30	620	26822.50	23872.03
18	Column 2B	2124	28	30	620	27439.09	24420.79
19	Column 3C	2129	28	30	620	27568.43	24535.90
20	Column 3C	2031	28	30	620	25088.84	22329.07
21	Column 3C	2100	28	30	620	26822.50	23872.03
22	Column 3B	1776	28	30	620	19184.33	17074.05
23	Column 3B	1776	28	30	620	19184.33	17074.05
24	Column 3B	1776	28	30	620	19184.33	17074.05
25	Column 3B	2031	28	30	620	25088.84	22329.07
26	Column 5C	2009	28	30	620	24548.25	21847.94
27	Column 5B	2053	28	30	620	25635.31	22815.43
28	Column 5B	1431	28	30	620	12454.89	11084.85
29	Column 5B	2031	28	30	620	25088.84	22329.07
30	Column 5A	2174	28	30	620	28746.16	25584.08

Table 1. Results obtained from tests: velocity, dynamic and static elastic moduli (continued).

Test Points / Spots	Specimens/ Column's ID	*V* (m/s)	Temp. (Celcius)	Length (cm)	*ρ* (kg/m^3)	MoE_{dyn} (MPa)	*MoE* (MPa)
31	Column 5A	2076	28	30	620	26212.92	23329.50
32	Column 4C	1966	28	30	620	23508.65	20922.70
33	Column 4C	2053	28	30	620	25635.31	22815.43
34	Column 4C	1466	28	30	620	13071.60	11633.72
35	Column 4C	1848	28	30	620	20771.35	18486.50
36	Column 4B	2009	28	30	620	24548.25	21847.94
37	Column 4B	2053	28	30	620	25635.31	22815.43
38	Column 4B	2149	28	30	620	28088.82	24999.05
39	Column 4B	2124	28	30	620	27439.09	24420.79
40	Column 1"A	2154	28	22	620	28219.68	25115.52
41	Column 1"C	2087	28	22	620	26491.44	23577.38
42	Column 1"C	2154	28	22	620	28219.68	25115.52
43	Column 1"C	2188	28	22	620	29117.58	25914.65
44	Column 1"C	2154	28	22	620	28219.68	25115.52
45	Column 1'D	1966	28	22	620	23508.65	20922.70

46	Column 1'D	1995	28	22	620	24207.31	21544.50
47	Column 1'D	1540	28	30	620	14424.55	12837.85
48	Column 1'D	2124	28	30	620	27439.09	24420.79
49	Column 1'D	2053	28	30	620	25635.31	22815.43
50	Column 1'D	2076	28	30	620	26212.92	23329.50
51	Column 1'D	2031	28	30	620	25088.84	22329.07
52	Column 1D	1443	28	30	620	12664.65	11271.54
53	Column 1D	1945	28	30	620	23009.11	20478.11
54	Column 2D	1829	28	30	620	20346.42	18108.32
55	Column 2D	1794	28	30	620	19575.17	17421.90
56	Column 2D	2053	28	30	620	25635.31	22815.43
57	Column 2D	2149	28	30	620	28088.82	24999.05
58	Column 2D	2124	28	30	620	27439.09	24420.79
59	Column 3D	1811	28	30	620	19947.92	17753.65
60	Column 3D	1811	28	30	620	19947.92	17753.65
61	Column 3D	1811	28	30	620	19947.92	17753.65
62	Column 5B	1776	28	30	620	19184.33	17074.05
63	Column 1A	1945	28	30	620	23009.11	20478.11
64	Column 2A	1966	28	30	620	23508.65	20922.70
65	Column 3A	1794	28	30	620	19575.17	17421.90
66	Column 3A	2031	28	30	620	25088.84	22329.07
67	Column 3A	2031	28	30	620	25088.84	22329.07
68	Column 4A	1987	28	30	620	24013.55	21372.06
69	Column 4A	1987	28	30	620	24013.55	21372.06
70	Column 4A	1885	28	30	620	21611.43	19234.17
71	Column 4A	1905	28	30	620	22072.46	19644.49
72	Column 5A	1848	28	30	620	20771.35	18486.50
					Average	23206.65	20653.91
					Std. Deviation	4503.83	4008.41
					C.o.V.	19.41%	19.41%

The test results indicate that the dynamic elastic moduli (MoE_{dyn}) are ranged from 12454.89 MPa to 29437.85, the average value of MoE is 23206.65 MPa, the standard deviation is 4503.83 MPa, and Coefficient of Variation (C.o.V.) is 19.41%. while the static elastic moduli (MoE) are ranged from 11084.85 MPa to 26199.68, the average value of MoE is 20653.91 MPa, the standard deviation is 4008.41 MPa. According to the Wood Handbook, the value of Elastic Moduli of Merbau (*Intsia spp.*) timber is 15400 MPa (FPL, 2010), this value is in the range of modulus of elasticity obtained from the test results.

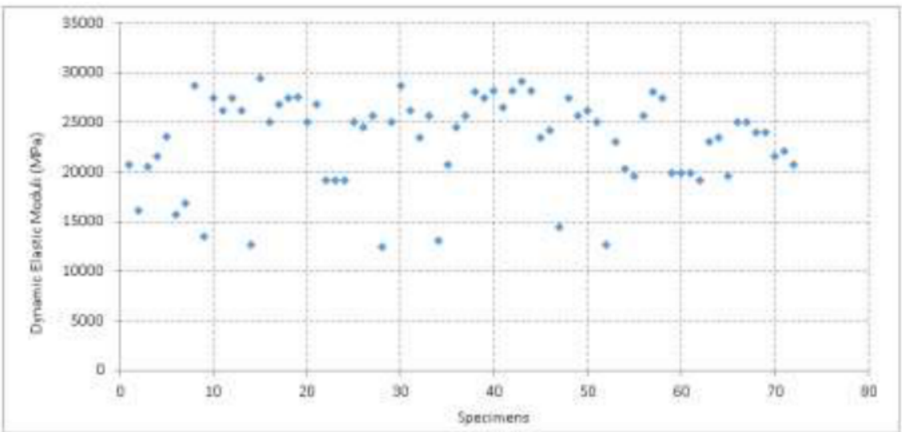


Figure 10. Results of dynamic elastic moduli obtained from tests.

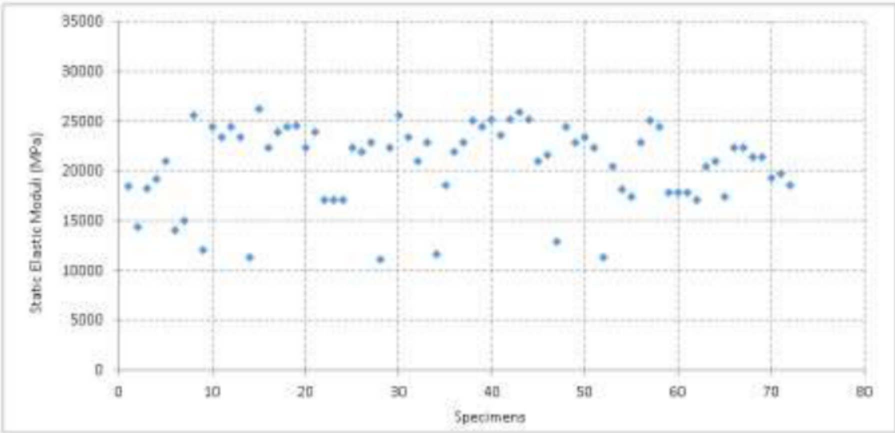


Figure 11. The conversion of static elastic moduli from dynamic elastic moduli obtained from tests.

4. CONCLUSION

The test results indicate that the average dynamic elastic moduli (MoEdyn) is 23206.65 MPa with Deviation Standard is 4503.83 MPa and Coefficient of Variation is 19.41%. in term of static elastic moduli, the test result is 20653.91 MPa. This results indicated that the timber is categorized as an E20 Timber type following SNI 7973:2013 (BSN, 2013) and categorized as a Class 1 Timber. The E20 timber type has good durability and high resistance to termite attack.

ACKNOWLEDGEMENT

The authors acknowledge the financial support from the Research Institute of Housing and Human Settlement, Ministry of Public Works and Public Housing. The authors also gratefully acknowledge the Sylvatest TRIO support from the Laboratory of Structure, Department of Civil Engineering, Faculty of Engineering, Universitas Kristen Maranatha.

REFERENCES

[1] CBS-CBT, 2011. Sylvatest TRIO User Manual, CBS-CBT.

[2] Badan Standardisasi Nasional, 2013. *Spesifikasi Desain untuk Kontruksi Kayu SNI 7973:2013* (in Indonesian), Badan Standardisasi Nasional.

[3] Benoit, Y., Sandoz, J.L.,2011. New Wooden Poles Grading Using Non-Destructive Technology, *21st International Conference on Electricity Distribution*, Frankfurt, June 6th-9th, 2011.

[4] Bucur, V.; Böhnke, I.,1994. Factors affecting ultrasonic measurements in solid wood, *Ultrasonics*, Volume 32 Issue 5, pp. 385-390.

[5] Divos, F., Tanaka, T., 2005. Relation Between Static and Dynamic Modulus of Elasticity of Wood*, Acta Silv. Lign. Hung.,* Vol. 1, pp. 105-110.

[6] Forest Product Laboratory, 2010. *Wood Handbook*, United States Department of Agriculture Forest Service.

[7] Nowak, T.P., 2015. Experimental Testing Of Glued Laminated Timber Members Using Ultrasonic And Stress Wave Techniques, *3rd International Conference on Structural Health Assessment of Timber Structures SHATIS 2015.*

[8] Oliveira, F.G.R., de Campos, J.A.O., Pletz, E., Sales, A., 2002. Nondestructive Evaluation of Wood Using Ultrasonic Technique, *Maderas, Cienc. Tecnol.* Volume 4 No. 2, pp. 133-139, 2002.

[9] Poggi, F., 2017. *Bending properties of commercial wood-based panels by NDT methods*, Master thesis in Forestry and Wood Technology, Linnaeus University.

[10] Pranata, Y.A., Kristianto, K., Pattipawaej, O., 2015. Pengujian Non-destruktif Modulus Elastisitas (MoE) Kayu Penyusun Sambungan Join Balok-Kolom (in Indonesian), *National Conference on ReTII 2015*, STTNas Yogyakarta, Desember 19th, 2015.

[11] Pranata, Y.A., Tobing, H.L., 2016. Non-destructive Testing to Obtain the Dynamic Elastic Modulus of the Existing Minangkabau Wooden House, *ITP Open Conference Systems, The First International Conference on Technology, Innovation, and Society* (ICTIS) 2016.

[12] Pusat Penelitian dan Pengembangan Teknologi Hasil Hutan, 2004. *Atlas Kayu Indonesia*, (in Indonesian) Departemen Kehutanan, Badan Penelitian dan Pengembangan Kehutanan, Pusat Penelitian dan Pengembangan Teknologi Hasil Hutan.

[13] Raymond, C.A., Joe, B., Evans, R., Dickson, R.L., 2007. Relationship between timber grade, static and dynamic modulus of elasticity, and SilviScan properties for Pinus radiata in New South Wales, *New Zealand Journal of Forestry Science* 37(2): pp. 186–196.