Determination of Correlation between Destructive and Nondestructive Test Methods Applied on Modified Wood Exposed to Natural Weathering

Eliška Oberhofnerová,[a,]* Karolina Arnetová,[a] Tomáš Holeček,[b] Vlastimil Borůvka,[b] and Jan Bomba [a]

The objective of this study was to determine a correlation between the dynamic modulus of elasticity (MOEd) and the static modulus of elasticity (MOEs), and to assess the potential of using nondestructive (NDT) methods as a grading tool for both treated and untreated wood exposed to weathering. In the experiment, test samples made from spruce and oak were exposed for four months to natural weathering. Half of the specimens were treated with a silicon-based nano-protection. The MOEd was determined using acoustic NDT methods–ultrasound transmission ($MOEd_u$) and the vibration methods ($MOEd_v$), while the MOEs was determined by a destructive three-point bending test. The results showed that there was no statistical significance for the influence of the time of exposure and the surface treatment on the modulus of elasticity. The ultrasound method, measured in the longest distance of the sample, had the most significant correlation with the MOEs. The vibration method also reached a similar correlation with the MOEs. The mean values of the $MOEd_u$ and $MOEd_v$ were higher than the MOEs. The influence of density on the acoustic wave velocity was not confirmed.

Keywords: Dynamic and static modulus of elasticity; Ultrasound transmission method; Longitudinal vibration method; Surface treatment; Weathering

Contact information: a: Department of Wood Products and Wood Constructions, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Kamýcká 1176, 165 21 Praha 6–Suchdol, Czech Republic; b: Department of Wood Processing, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Kamýcká 1176, 165 21 Praha 6–Suchdol, Czech Republic;
** Corresponding author: oberhofnerova@fld.czu.cz*

INTRODUCTION

Wood is an organic material that is characterized by a high natural durability, good mechanical and physical properties, and in favorable conditions it can last for centuries. When wood is exposed to the outdoors, it is subjected to weathering: a combination of chemical, mechanical, and light energy factors (Feist 1990). As a result the wood degrades and it slowly loses its original properties (Williams 2005).

Solar radiation, mainly UV light, and water from precipitation and air humidity are the factors with the most significant impact on the degradation of wood and other coatings in exterior conditions (Evans and Banks 1988; Dunningham *et al.* 1992; Evans *et al.* 1992; Feist 1992; Temiz *et al.* 2005; Williams 2005). Weathering is first manifested by a change in the color of the wood, which is followed by a loosening of wood fibers and then gradual erosion of the wood surface (Williams and Feist 1999). A loss in the mechanical properties during weathering is associated with a light-induced degradation of the lignin and cell wall constituents, as well as the subsequent breakdown of wood's microstructure (Yildiz *et al.*

2011). Using the proper finishing can inhibit the degradation process. The coatings and other treatments serve primarily as a protection of the wood against weathering. They create a protective barrier against the exterior influences (Williams 2005). Untreated wood shows more of an extensive degradation than the modified wood, which can be explained by the amount of massive, numerous cracks that occur during weathering (Dunningham *et al.* 1992). In the case that wood is exposed to the outdoor conditions, reliable tools for assessing the mechanical behavior of wooden members are needed (Machado *et al.* 2009).

Nowadays, nondestructive (NDT) testing is a powerful tool for evaluating the properties of wood. It is a class of scientific methods that is able to detect defects and evaluate the physical and mechanical properties of wood and wood-based materials, without altering the material (Ross and Pellerin 1994; Lin and Wu 2013). Acoustic NDT techniques appear to be relatively fast and affordable *in-situ* measuring methods, which have been already used to estimate wood properties in many cases (Sandoz *et al.* 2000). These techniques are based on sound wave propagation, which is directly related to the elastic properties of the material through which it propagates (Teder *et al.* 2011). The acoustic NDT methods have been shown to be reliable for accessing properties of wood in the form of timber (Hassan *et al.* 2013), logs (Zhou *et al.* 2013), and decayed wood (Yang *et al.* 2003). An important point for the continuous development of NDT methods is the testing in the field of chemically or mechanically treated wood materials (Loutridis *et al.* 2005). In the field of testing mechanical properties, Schubert *et al.* (2005) used an ultrasonic inspection to determine the change in the shear modulus of Norway spruce during 12 weeks of exposure to white-rot fungus. Baradit and Niemz (2012) determined the Young's modules and shear modules of elasticity of four native Chilean hardwoods using ultrasound techniques. In another study, Hassan *et al.* (2013) predicted the static bending using three NDT techniques–flexural and longitudinal vibration, and an indirect ultrasonic method. Machado *et al*. (2009) used an indirect ultrasound method for assessing the strength and stiffness of the wood. Other studies dealt with the estimation of strength properties of aged wood by means of ultrasonic devices (Kránitz *et al.* 2010, 2014; Kránitz 2015; Soederegger *et al*. 2015), where the elastic properties of aged wood showed no consistent trends.

One of the most important mechanical properties, which can be measured by NDT methods, is Young´s modulus, *i.e.* the modulus of elasticity, which describes the stiffness of the material. A high value of MOE indicates a high resistance of wood to deformation (Liang and Fu 2007). The modulus of elasticity and the density of the material strongly affect the acoustic properties of wood (Teder *et al.* 2011). The density of wood is one of the most important factors that affect the weathering characteristics (Williams 2005), but its effect on sound velocity is not clear. Bucur and Chivers (1991) stated that velocity decreases with an increased density. But in other investigations, the results have shown that velocity increases for larger density values (Haines *et al.* 1996). On the other hand, Mishiro (1996) found out in his research that velocity was not affected by density.

Several studies have already been conducted to estimate the exact correlation between the dynamic and static properties (Halabe *et al.* 1997). Certainly, the dynamic Young's modulus is greater than the static Young's modulus (Matsumoto and Tsutsumi 1968). The previous researches demonstrate that the value of the MOE obtained by the different acoustic NDT techniques is approximately 10% to 20% (even up to 40%) higher than the static MOE (De Oliveira *et al.* 2002; Kránitz *et al.* 2010; Niemz and Mannes 2012; Hassan *et al.* 2013; Kránitz 2015). The difference between a dynamic and static MOE can be explained by the high variability of wood properties (Kránitz *et al.* 2014) and considering wood as a highly damping and viscoelastic material. When force is applied for a very short duration, as with dynamic testing, the wood behaves like an elastic solid, while for longer duration that occurs with static testing, the behavior is like that of a viscous liquid (Halabe *et al.* 1997).

The aim of this study was to determine the correlation between dynamic and static MOE obtained from destructive and nondestructive tests applied on wood exposed to weathering. This research considered the reliability of acoustic NDT methods as a relatively fast and affordable tool for evaluating wood, both treated and untreated, exposed to initial stage of weathering. Effects of weathering cannot be avoided in the case of longer period of construction or storage of wood elements. Generally, this study will also help with an employment of NDT methods in the field for *in-situ* evaluation and inspection of wooden structures and in-service member testing.

EXPERIMENTAL

Materials

The wood material used in this study was harvested in the central region of the Czech Republic in Kostelec nad Černými lesy. Norway spruce (*Picea abies*) and English oak (*Quercus robur*) were chosen as the representatives of the most common used wood species in the Czech industry. The three radial planks from each wood species were processed into rectangular solids with dimensions of 50 mm x 25 mm x 650 mm (RxTxL) considering the minimum deflection of wood fibers in the level of bending (< 5 °). Two pieces, with dimensions 20 mm x 20 mm x 600 mm, were cut from this piece to obtain a pair of samples for proper comparison, both treated and untreated (Fig. 1, Table 1).

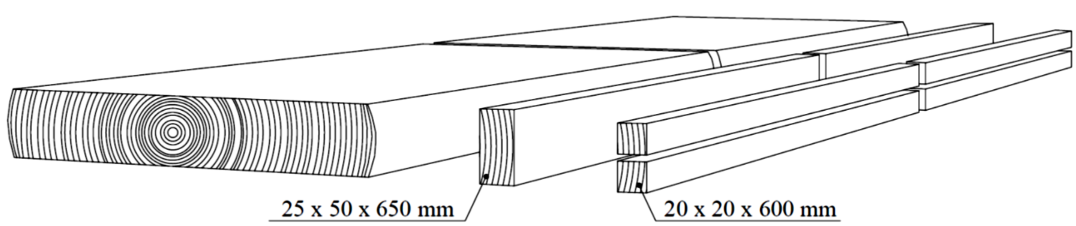

Fig. 1. Scheme of preparation of test samples

The samples were kept in a Climacell 707 conditioning chamber (BMT Medical Technology Ltd., Czech Republic) at 20 ± 2 °C and at a relative humidity of 65 ± 5% to achieve an equilibrium moisture content of 12%. The density ρ (at the moisture content of 12%) in kg/m^3 was determined according to ČSN 49 0108 (1993) using Eq. 1,

$$\rho = \frac{m}{V} \tag{1}$$

where m is the sample's mass at 12% moisture content, in kg, and V is the wood volume at 12% moisture content, in kg.

The samples were evaluated by NDT methods before and after the surface treatment and, therefore, before the exposure to weathering.

Surface treatment

A surface treatment was added using the transparent silicon-based nano protection PMO 62 (HF Servis Ltd., Czech Republic), which is hydrophobic and provides a reduction of the atmospheric degradation and aging of wood. A brush spread two layers of the coating, in the amount of 60 g/m^2.

Natural weathering test

The natural weathering of the samples was carried out according to EN 927-3 (2006) at Suchdol, Prague (50°07'49.68 "N, 14°22'13.87 "E, at an elevation above sea level 285 m), and lasted from June 4, 2015 to October 4, 2015. The samples were exposed outdoors, at a 45° inclination, facing south, and placed approximately 1 m above the ground.

Procedure

The test specimens were divided according to the time of exposure, the wood species, and the surface treatment, as can be seen from Table 1. Initially, all the specimens were tested by NDT methods. The first set of specimens, which were unexposed, was subjected to destructive tests and the rest of the test specimens were exposed outdoors. After two months of exposure, the samples were re-measured using NDT methods and the second set of test specimens was subjected to destructive tests. The last set of specimens was returned to the outdoor stands. After another two months of exposure, the third set of specimens was subjected to both nondestructive and destructive tests.

Table 1. Distribution of Test Specimens

Wood species	Modification	Time of exposure		
		Unexposed	2 months	4 months
Spruce	Treated	5	5	5
	Untreated	5	5	5
Oak	Treated	5	5	5
	Untreated	5	5	5
Number of test specimens in each set		20	20	20
Total number of test specimens				60

Methods

Ultrasound transmission method

Measurements were made using a Fakopp Ultrasonic Timer (Fakopp Enterprise, Hungary) with a frequency range of 15 kHz to 300 kHz. In this experiment, 45-kHz piezo-electric triangle shaped transducers for transmitting and receiving were used. An indirect method of measurement was performed.

The transducers were placed at the radial surface of the test specimens, as seen in Fig. 2, at distances of 60, 100, 140, 300, 500, and 565 mm, to estimate the exact wave velocity. Time correction was performed according to the manual of the ultrasonic device.

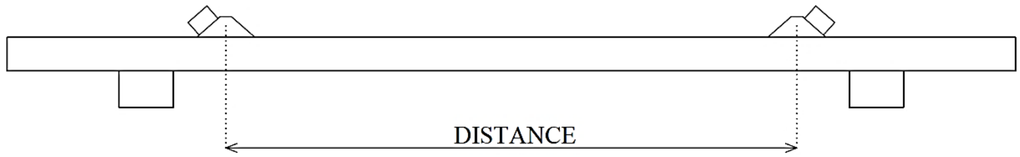

Fig. 2. Position of transducers during ultrasound NDT testing

The sound wave velocity v (m/s) was calculated according to Eq. 2,

$$v = L/t \quad (2)$$

where L represents the length of the test bar (m) and t is the time after time correction (s).

The dynamic modulus of elasticity (MPa) was calculated according to Eq. 3,

$$MOEd_u = v^2\rho \quad (3)$$

where ρ is the density of the specimen (kg/m^3).

Longitudinal vibration method

This test was performed using a Fast Fourier Transform (FFT) analyzer, which measures the frequency of sound waves. The waves were produced by an impact hammer and recorded with a microphone (ECM8000, Behringer GmbH, Germany), using an amplifier (UR 22, Steinberg GmbH, Germany), and rubber strips supported the test bar. Figure 3 shows how the test as was set up.

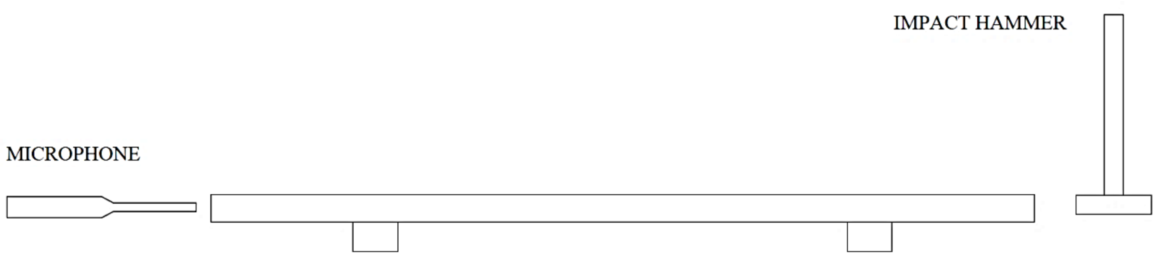

Fig. 3. The principle of longitudinal vibration method

The sound wave velocity (m/s) was calculated according to Eq. 4,

$$v = 2Lf \quad (4)$$

where f is represents the longitudinal frequency (Hz).

The dynamic modulus of elasticity (MPa) was calculated according to Eq. 5:

$$MOEd_v = v^2\rho \quad (5)$$

Static bending test

The destructive test was carried out according to valid standards ČSN 49 0116 (1982). The three-point bending test, using a universal testing machine, TIRA 50 kN (TIRA GmbH, Germany), was performed. The samples were tested in the tangential direction, with a distance between supports of 240 mm, *i.e.*, 12-fold greater than the sample height. The static modulus of elasticity (MPa) was calculated according to Eq. 6,

$$MOEs = \frac{\Delta F \cdot l_0^3}{4 \cdot b \cdot h^3 \cdot \Delta y} \quad (6)$$

where ΔF is the difference between the forces at maximum and minimum load limits (N), l_0 is the distance between the supports (mm), b and h are the width and height dimensions, respectively (mm), and Δy is the test sample deflection in the area of pure bending, which is equal to the difference between the bending values corresponding to maximum and minimum load limits (mm).

Data analysis

For statistical evaluation, analysis of variance (ANOVA, three-factors) was performed using the software Statistica 12 (Statsoft Ltd., USA). A linear regression model was used to set the degree of correlation of the selected factors. For all analyses, the 99% significance level ($\alpha = 0.01$) was employed.

RESULTS AND DISCUSSION

The density of the spruce wood specimens used in this study was 449 kg/m^3 (coefficient of variation CV = 5.2%), and the oak wood had a density of 677 kg/m^3 (CV = 4.9%) at a moisture content of 12%. All the mean values of the MOE obtained from the nondestructive and destructive measurements can be seen in Table 2. The influence of the wood species factor showed as statistically significant for both the dynamic and static MOE, where $p < 0.01$. On the contrary, the factors of the time of exposure and the surface modification were not demonstrated as being statistically significant, where $p > 0.01$ as can be seen in Tables 3 through 5. It was a predictable fact in this case of initial stage of weathering that these factors are becoming more significant with an increasing duration of outdoor exposure. In spite of this, the effect of weathering and wood aging is not clear even in the case of aged wood. According to some studies there is no obvious trend in the dynamic and static MOE of recent and aged wood (Kránitz 2015; Sonderegger *et al*. 2015). However, in this study a decreasing trend for the values of dynamic MOE, both for the treated and untreated samples, was observed with increasing outdoor exposure time, but the results were not statistically significant.

Table 2. Mean Values of MOE Obtained by NDT and DT Methods*

Months of exposure	Modulus of elasticity	Spruce		Oak	
		Untreated	Treated	Untreated	Treated
0	Ultrasound	15069 (13.7)	14898 (12.9)	13616 (8.3)	13316 (6.7)
	Longitudinal vibration	14484 (10.8)	14444 (11.3)	12763 (5)	12629 (4)
	Static bending	9396 (12.3)	9262 (14)	9866 (5.6)	9729 (5.3)
2	Ultrasound	14716 (12.2)	14700 (10.3)	13418 (8.2)	13006 (7.3)
	Longitudinal vibration	14045 (10.7)	14246 (10.1)	12542 (4)	12522 (4.3)
	Static bending	8458 (12.4)	8499 (12.3)	9552 (6.6)	9678 (4.3)
4	Ultrasound	14420 (11.7)	14399 (10.6)	13524 (6.3)	13247 (9.4)
	Longitudinal vibration	14066 (8.8)	14168 (9.8)	12747 (4.1)	12521 (4.2)
	Static bending	9679 (11.6)	8561 (6.2)	9578 (6.1)	9838 (3.4)

*Note: Mean values of MOE in MPa and coefficient of variation are in parenthesis in %

Table 3. Impact of Factors on Dynamic MOE Obtained by Ultrasound Method

Monitored Factor	Sum of Squares	Degree of Freedom	Variance	Fisher´s F-test	Significance Level p
Intercept	1.13E+10	1	1.13E+10	7164.13	P < 0.01
Wood Species	2.96E+07	1	2.96E+07	18.75	P < 0.01
Treatment	5.38E+04	1	5.38E+04	0.03	P = 0.85
Time	2.52E+06	2	1.26E+06	0.78	P = 0.46
Wood Sp.*Treatment	2.73E+05	1	2.73E+05	0.17	P = 0.68
Wood Sp.*Time	1.77E+06	2	8.84E+05	0.56	P = 0.58
Treatment *Time	2.56E+05	2	1.28E+05	0.08	P = 0.92
Wood Sp.*Treatment*Time	2.09E+05	2	1.04E+05	0.07	P = 0.94
Error	7.59E+07	48	1.58E+06		

Table 4. Impact of Factors on Dynamic MOE Obtained by Vibration Method

Monitored Factor	Sum of Squares	Degree of Freedom	Variance	Fisher´s F-test	Significance Level p
Intercept	1.09E+10	1	1.09E+10	6905.32	P < 0.01
Wood Species	5.30E+07	1	5.30E+07	33.56	P < 0.01
Treatment	1.71E+04	1	1.71E+04	0.01	P = 0.92
Time	2.91E+06	2	1.46E+06	0.92	P = 0.40
Wood Sp.*Treatment	1.39E+05	1	1.39E+05	0.09	P = 0.77
Wood Sp.*Time	1.84E+06	2	9.19E+05	0.58	P = 0.56
Treatment*Time	5.49E+05	2	2.75E+05	0.17	P = 0.84
Wood Sp.*Treatment*Time	5.67E+04	2	2.83E+04	0.02	P = 0.98
Error	7.58E+07	48	1.58E+06		

Table 5. Impact of Factors on Static MOE Obtained by Static Bending Test

Monitored Factor	Sum of Squares	Degree of Freedom	Variance	Fisher´s F-test	Significance Level p
Intercept	5.24E+09	1	5.24E+09	7546.69	P < 0.01
Wood Species	8.01E+06	1	8.01E+06	11.54	P < 0.01
Treatment	3.86E+05	1	3.86E+05	0.56	P = 0.46
Time	2.83E+06	2	1.41E+06	2.04	P = 0.14
Wood Sp.*Treatment	8.89E+05	1	8.89E+05	1.28	P = 0.26
Wood Sp.*Time	1.27E+06	2	6.33E+05	0.91	P = 0.41
Treatment*Time	6.62E+05	2	3.31E+05	0.48	P = 0.62
Wood Sp.*Treatment*Time	1.49E+06	2	7.47E+05	1.08	P = 0.35
Error	3.33E+07	48	6.94E+05		

The results from the ultrasound transmission measurements are given in Table 2. It can be demonstrated that the values of the dynamic MOE for both the treated and untreated wood samples of spruce and oak decreased after 4 months of weathering. There was no obvious difference in behavior of the treated and untreated samples. The values of the MOE obtained from this method were the highest compared to other methods used in this experiment. The correlation with the MOEs for different distances of measurement was determined, as can be seen in Table 6. The results showed that the correlation increased with the increasing distance of the transducers. This indicated that the wave propagates in the material differently. For the shorter distances, the surface propagation of a wave can affect the longitudinal propagation. With increasing distances, the effect of the surface transmission of a sound wave decreases (Machado *et al.* 2009). Teder *et al.* (2011) demonstrated in their study that the shorter distances serve only for the local evaluation of a wooden member.

Table 6. The Values of Coefficient of Correlation *r*

		Dynamic Modulus of Elasticity (Ultrasound Method)					
		60 mm	100 mm	140 mm	300 mm	500 mm	565 mm
Static Modulus of Elasticity (Static bending test)	Spruce	0.57	0.72	0.64	0.68	0.69	0.70
	Oak	0.26	0.47	0.61	0.65	0.67	0.70

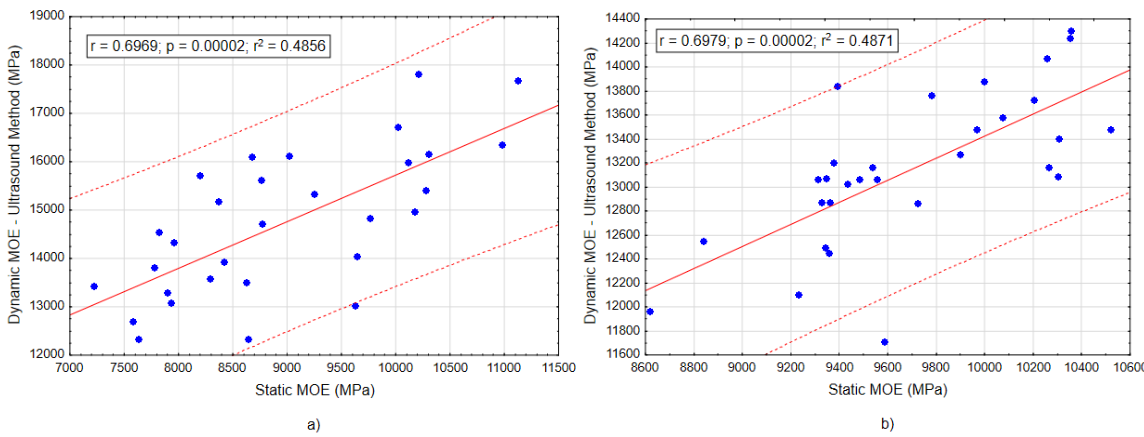

Fig. 4. Correlation between $MOEd_u$, measured in 565 mm, and MOEs for spruce (a) and oak wood (b)

The highest correlation between the $MOEd_u$ and the MOEs for both wood species (r = 0.70) was found for the distance of transducers of 565 mm, as can be seen in Table 6 and Fig. 4. This result is in agreement with the previous study, which noted that with increasing distance between transducers the influence of deeper wood layers on the wave velocity propagation increases (Machado *et al.* 2009). Teder *et al.* (2011) presented a study where the distance of 600 mm turned out to be the best, in regards to the prediction of mechanical properties.

The results from the longitudinal vibration method are given in Table 2. As in the case of an ultrasound method, it was observed that the values of the dynamic MOE for both the treated and untreated wood samples of spruce and oak decreased after 4 months of weathering with no statistical significance. There was no obvious difference shown between the treated and untreated samples in this period of weathering. The correlation with the MOEs was determined for both spruce (r = 0.71) and oak wood (r = 0.69) specimens, as shown in Fig. 5. The results showed a relatively good correlation with the static MOE. It was in agreement with other studies that also found a good correlation between the dynamic MOE obtained from longitudinal vibration method and the MOEs (Hassan *et al.* 2013; Baar *et al.* 2015).

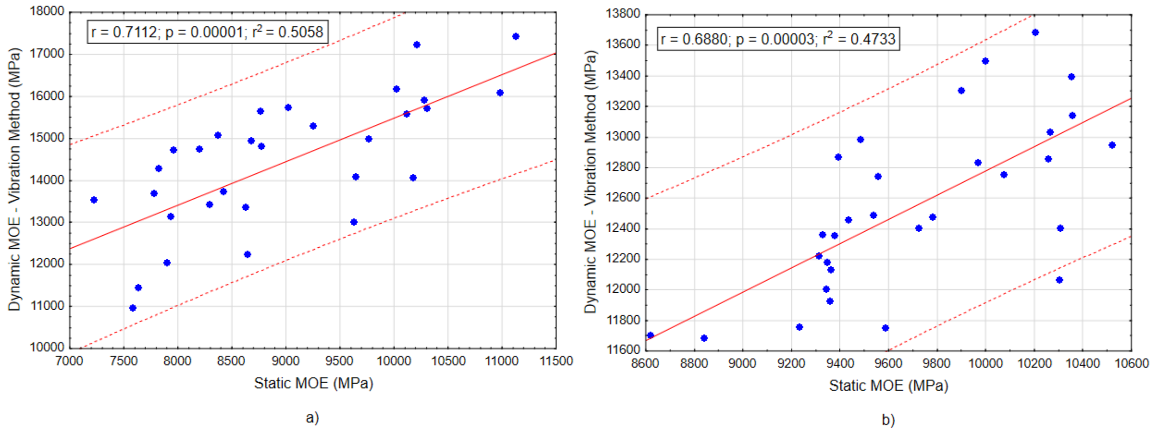

Fig. 5. Correlation between static and dynamic vibration MOE for spruce (a) and oak wood (b)

The ultrasound transmission method and longitudinal vibration method correlate well among themselves, as can be seen in Table 7, which indicates that the material response to NDT measurements was very good (Halabe *et al.* 1997). From the results, it was observed that the correlation was increasing with the increasing distance between transducers used in the ultrasound technique. The highest values were recorded for the MOEd_u measured in 300, 500, and 565 mm (Table 7, Fig. 6).

Table 7. Values of Correlation Coefficient r between Dynamic MOE

		Dynamic modulus of elasticity (ultrasound method)					
		60 mm	100 mm	140 mm	300 mm	500 mm	565 mm
Dynamic modulus of elasticity (vibration method)	Spruce	0.71	0.89	0.93	0.98	0.95	0.95
	Oak	0.36	0.59	0.66	0.80	0.83	0.81

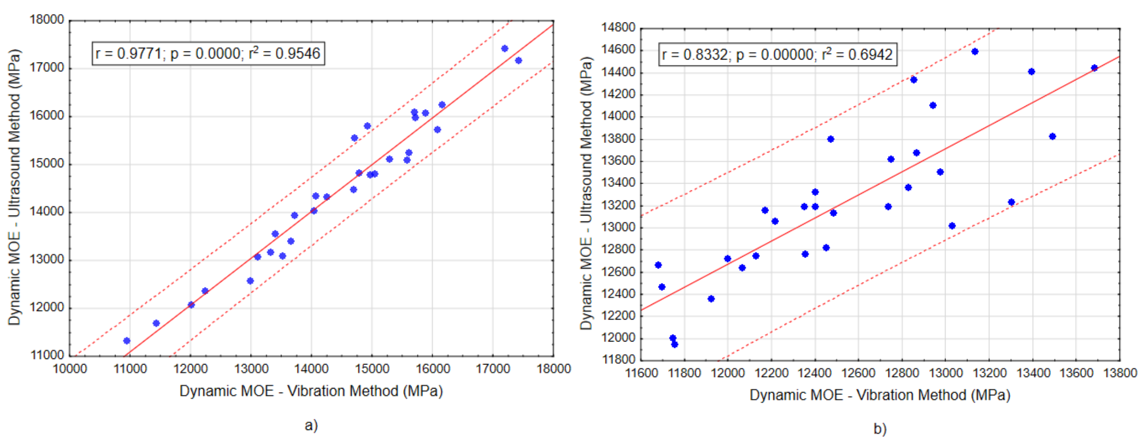

Fig. 6. Correlation between dynamic modulus of elasticity for spruce (a) and oak wood (b)

The velocity of sound wave, which directly affects the dynamic MOE, obtained from the ultrasound method was higher for spruce samples (v = 5689 m/s; CV = 4.6%) than for oak samples (4396 m/s; CV = 2.8%). In the case of the vibration method, the velocities reached similar values, for spruce (v = 5626 m/s; CV = 5.1%) and oak (v = 4294 m/s; CV = 3.0%). A lower velocity of sound characterized the oak samples. It can be explained by several reasons. The acoustic wave velocity can be affected by the moisture content, temperature, grain orientation, density, decay, and also geometry (Beall 2002) and by the length of fibers and ray dimensions (Baar *et al.* 2013). The difference in velocity can be caused by a different anatomical structure of spruce and oak (Saadat-Nia *et al.* 2011). The presence of vessels in oak can decrease the velocity of wave, due to the fact that the wave tries to avoid these elements and go through the solid material. The velocity of sound in air is estimated as 340 m/s (Bucur 2006). In another study, the velocity of longitudinal waves in the fiber direction was found to increase with increasing fiber length (Hasegawa *et al.* 2011). The impact of fiber characteristics on the elastic properties of wood was demonstrated in other studies; the elastic modulus increases with increasing fiber length and also the location of the sample within a trunk influences the elastic modulus as well (Kránitz 2015). Vobolis and Albrektas (2007) report variation in the elastic modulus along the height of the trunk and state that the center part shows lower values in spruce, but higher values in oak. In the study of Soederegger *et al.* (2015), the similar results, as in this study, were reached. The values of dynamic MOE obtained by ultrasound for spruce were higher than for oak, both for aged and recent wood. The explanation is due to the high variability of wood density more than effect of aging. In this study, the decreasing character of wave velocity was observed for the increasing density of wood for both species. However the exact influence of the density on wave velocity was not concluded, as in previous studies (Mishiro 1996; Ilic 2003; Baar *et al.* 2012; Kránitz 2015).

The values of the dynamic MOE were higher than those obtained from static testing, as expected. This confirmed the results from previous studies (De Oliveira *et al.* 2002; Niemz and Mannes 2012; Hassan *et al.* 2013). The values were significantly higher than the expected percentage, ranging from approximately 10% to 20%. The mean values of the MOEd obtained from the indirect ultrasound ($MOEd_u$) and longitudinal vibration method ($MOEd_v$) were 65.2% and 61.5% for spruce wood, and 35.6% and 29.4% for oak wood, higher than the MOEs, respectively. These findings are in agreement with previous studies where the values of MOEd obtained by the ultrasound and longitudinal vibration method were 37% to 48.5% and 20.6% higher than the MOEs, respectively (Baar *et al.* 2015). Smulski (1991) reported in his study that the value of MOEd of oak was 32% higher than MOEs, which was approved by presented results. The significant difference between MOEd and MOEs was observed for spruce wood. It follows the increased values of wave velocity. The individual methods for the determination of the MOE provided different values of that parameter; in the order from low to high it was MOEs < $MOEd_v$ < $MOEd_u$, which corresponds with the results of previous studies (Haines *et al*. 1996; Baar *et al.* 2015).

It can be concluded that the vibration and ultrasound nondestructive methods presented good potential for evaluation of the properties of wood exposed to the outdoors. But further testing, especially with longer times of outdoor exposure and different surface treatments, will be needed for the nondestructive evaluation of the wood exposed to weathering.

CONCLUSIONS

1. A very high correlation was determined for the modulus of elasticity obtained by the longitudinal vibration and ultrasound method (measured in distances of 300 mm, 500 mm, and 565 mm of the sample) both for spruce (r = 0.95 to 0.98) and oak (r = 0.80 to 0.83).
2. The best correlation with static modulus of elasticity (MOE) for both spruce and oak wood (r = 0.70) was observed for the dynamic MOE measured with ultrasound in the longest distance of the wooden sample (565 mm). The dynamic MOE measured with the longitudinal vibration method reached a high correlation with the static MOE, both for spruce (r = 0.71) and oak wood (r = 0.69).
3. The mean values of the dynamic MOE obtained by the ultrasound and longitudinal vibration method were 65.2% and 61.5% (spruce) and 35.6% and 29.4% (oak) higher than the static MOE, respectively.
4. During four months of weathering, application of the surface treatment did not cause any significant changes in the dynamic and static MOE.
5. Due to the obtained correlation with MOEs, the acoustic nondestructive methods can be used for evaluation of wood exposed to weathering, both in the case of treated and untreated wood.
6. The influence of density on acoustic wave velocity was not statistically confirmed.

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