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Static and dynamic modulus of spruce structural timber

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Abstract: *Static and dynamic modulus of spruce structural timber.* A comparative study of static and dynamic modulus of spruce structural timber has been performed. 52 structural timber samples were cut from 13 different logs of the same forest stand. Static modulus of each board was obtained from bending test according to EN 408. Dynamic modulus was calculated from board density and measured wave propagation velocity in timber using Sylvatest Duo and MTG Timber Grader devices with build-in structural timber grading standards. Mean MOE from static test according to EN 384 and mean MOE given by Sylvates Duo and MTG Timber Grader were compared. Differences between MTG Timber Grader readings and static MOE were statistically non-significant. Results showed that Sylvatest Duo overestimates MOE and that a correction is required, which takes into account sample density and results of static bending tests.

Keywords: spruce wood, moisture wood , density, static modulus of elasticity, dynamic modulus of elasticity

INTRODUCTION

Wood is a strategic row material. In majority buildings, it is an inevitable part of constructions. Grading of wood is significant area of wood utilization. Two general methods are used for determination of strength and stiffness properties of wood: visual grading and machine grading. The visual method takes distribution of wood defects on the surface for determination of strength quality. Knots are the main sorting criterion. The method does not take into account wood density, which is significant parameter of wood quality. The machine grading is based on bending principle or other principles such as ultrasound, vibration, radiation, or combination of several indicating properties (Weidenhiller & Denzler 2009) related to stiffness or strength. The most reliable is bending method however, it requires sophisticated technologies.

The recent trend in machine grading focuses on acoustic principles (ultrasound, vibration).
The important feature of acoustic method is sound velocity „c“. It can be related to grading characteristics:

$$c = \sqrt{\frac{E}{\rho}} \quad [m \cdot s^{-1}] \qquad (1)$$

where $\boldsymbol{E}$ is dynamic modulus [MPa] and $\boldsymbol{\rho}$ is wood density [kg.m^{-3}].

Grading device MTG Timber Grader uses vibration principles, Sylvatest Duo device uses ultrasound. Reliability of devices can be found while comparing their results with a static bending test according to EN 408.

MTG Timber Grader

MTG Timber Grader is hand-operated device for grading structural timber. It grades based on measured natural frequency of wooden board. Besides that it requires wood species, moisture content (MC), board dimensions and weight. This device provides ***MOE*** at 12% of MC, strength classes according to EN 338 at levels of C18, C24 and C30.

Sylvatest Duo

This portable device can sort boards, trunks or in situ construction elements. Based on time of ultrasound wave propagation between probes and distance between probes it is able to give ***MOE***, ***MOR*** and ***C*** class. Sylvatest Duo also allows calculating the dynamic modulus $E_{S,dyn}$ using the equation (1). This can be a useful tool for recalibration of given species from a different location or unknown species when compared with static bending test results.

Bending method

It is performed according to EN 408 and two other standards are taken into account EN 384, EN 338. Results of the method are modulus of elasticity ***MOE*** and bending strength ***MOR*** at 12% of MC.

MATERIAL AND METHODS

For testing we used construction size samples (boards) of spruce wood (*Picea abies*). Dimension of these boars are 40x120x2200 mm^3. 52 dried boards were placed into conditioned chamber for reaching equilibrium moisture content w = 12% (RH = 65 %, t =20°C) according to EN 384. MC and clear sample density were determined for each board. ***MOE*** was evaluated using three mentioned methods: bending, ultrasound (Sylvatest Duo), vibration (MTG Timber Grader).

RESULTS AND THEIR ANALYSIS

The basic statistic is shown in the Table 1. From the results one can see the final.

Table 1: Descriptive statistic of clear specimen density and basic outputs of bending, ultrasound and vibration methods. MOE_B - static bending test, MOE_S - Sylvatest Duo (dynamic modulus -eq.1), $MOE_{S,corr}$ - Sylvatest Duo corrected, MOE_M - MTG Timber Grader

Basic mathematic-statistical characteristics	*Density*	*Bending*	*Ultrasound*		*Vibration*
	ρ_{12} [kg.m^{-3}]	MOE_B	MOE_S	$MOE_{S,corr.}$	MOE_M
Number of samples	52	52	52	52	52
Arithmetic mean	413	11 518	13842	11518	11303
Maximum value	494	17318	16703	15532	15584
Minimum value	347	7107	10833	8405	8047
Coefficient of variation [%]	8	18	11	15	16

Paired t test showed that there were big differences between MOE_S and MOE_B from bending test. Differences between other were non significant on significance level of α = 0,01 (Table 2, Figure 1). It is obvious that the $MOE_{S,corr}$ and MOE_B are absolutely equal due to direct derivation of $MOE_{S,corr}$. MTG device very well matched the static bending test.

Table 2. Results of paired t-test, probability that compared paired groups are equal

	MOE_S	$MOE_{S,corr.}$	MOE_M
MOE_B	0.0000	1.0000	0.0645
MOE_S	x	0.0000	0.0000
$MOE_{S,corr.}$	x	x	0.0137

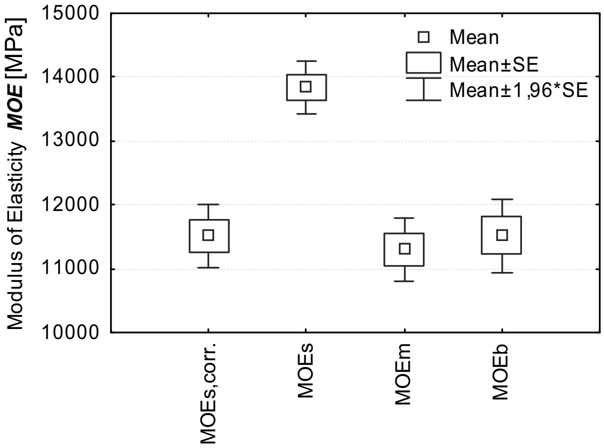

Figure 1. Comparison of ***MOE'***s between the methods

These ***MOE***'s results compared to the density according to standard EN 338 tell us something about reliability of measurements. One can see that ***MOE*** from Sylvatest Duo device without taking into account a sample density is off the real result. Similar result was obtained on different set of samples (Rohanova et al. 2010). Readjustment of this device based on a static bending result is required (see ***MOE***$_{S,corr}$).
Some boards of lower density cross over the standard line according to EN 338 and therefore should be degraded to lower strength classes because of the density (Figure 3).

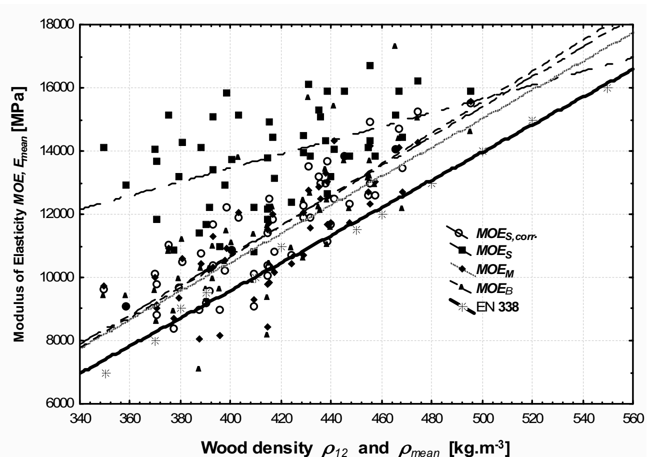

Figure 3 Density - ***MOE*** relations between methods and comparison to EN 338.

CONCLUSION

Mean ***MOE*** from static test according to EN 384 and mean ***MOE*** given by Sylvates Duo and MTG Timber Grader were compared. Differences between MTG Timber Grader readings and static bending ***MOE*** were statistically non-significant. Therefore, MTG is more reliable device for measuring ***MOE*** when comparing to static bending test results. Sylvatest–Duo device overestimates ***MOE*** and a correction is required, which takes into account sample density and results of static tests according to EN 408.

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Streszczenie: *Statyczny i dynamiczny moduł sprężystości świerkowej tarcicy konstrukcyjnej.* Przeprowadzono studium porównawcze statycznego i dynamicznego modułu sprężystości tarcicy świerkowej. Wycięto 52 próbki z 13 różnych kłód z tego samego środowiska. Statyczny moduł wyznaczono poprzez zginanie zgodnie z normą EN 408. Dynamiczny moduł sprężystości był wyznaczony z gęstości tarcicy i prędkości rozchodzenia się fal przy użyciu urządzeń Sylvatest Duo oraz MTG Timber Grader. Średnie wartości statycznego modułu wyznaczonego z normy EN 384 oraz dynamicznego modułu otrzymanego z Sylvatest Duo i MTG Timber Grader zostały porównane. Różnice pomiędzy wynikami z MTG Timber Grader oraz otrzymanymi statycznie nie były istotne statystycznie. Wyniki wskazują że Sylvatest Duo zawyża wartości modułu sprężystości i wymaga korekcji.

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