Strength grading of Slovenian structural sawn timber

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Abstract

In the paper preliminary results of the research project dealing with introduction of grading methods into Slovenian sawmills and creating the database of Slovenian timber is presented. The aim of the project, partly financed by the Slovenian Research Agency and partly by the industry, is practical implementation of European standards into the production of sawn timber, finding the correlation between indicative properties of Slovenian timber and grading characteristics, and grading more than 1000 boards of *Picea Abies Mill*. The presented research is closely related with the work package WP3 “Experimental research” in the GRADEWOOD project.

1 Introduction

Although 60% of Slovenia is covered by forests, timber is relatively rarely used for construction. Whereas in the past the main products were wood-based panels recently the focus has been put on timber structures. However, the use of timber for roof and floor structures is still based on visual assessment of wood quality which is a combination of strength grading criteria (knots, annual rings) and visual appearance grading. Very few sawmills perform grading properly therefore the introduction of harmonized standard for strength grading of structural timber was quite a shock for Slovenian sawn timber companies.

To overcome this situation three Slovenian research organizations: Faculty for Civil and Geodetic Engineering, Department for Wood and Wood Technology of Biotechnical Faculty (both from University of Ljubljana), and Slovenian National Building and Civil Engineering Institute (ZAG, Ljubljana) started the second project aiming to inform producers about principles of grading of structural timber and to suggest the best grading method.

2 Current status of grading in Slovenia

As in Slovenia more than 25% of sawmills are small (production of sawn timber less then 10.000 m^3/year), and only 40% of sawmills have production exceeding 25.000 m^3/year (Kovac 2003). Some years ago an investigation into methods for visual grading used in several sawmills and wood suppliers was performed

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(Zorko 2005). The conclusion has been drawn that in smaller production sites no grading is performing whereas bigger producers use the internal methods which are the mixture of old Yugoslav standards (JUS) and the appearance grading standards. Even the producers who performed grading, did not mark structural timber.

In 2004 first national project aiming to introduce valid European grading rules into sawmills and inform the industry about the potentials of grading methods has been launched. In the framework of this project several seminars for producers have been performed but practically no interest for introducing grading methods into production has been shown. One of the reasons may be the fact, that at that time CE marking of structural timber has not been commonly accepted.

The continuation of this work is research project presented here where much more interest of producers is observed. Their representatives attended four workshops concerning the relevant topics, such as introduction of EN 14081-1 into sawmills, visual and machine grading, factory production control, certification principles, *etc*. They also participated in practical workshops where they visually graded timber and also attended the non-destructive and destructive tests. As sawmills produce on the average only approx. 10% of structural wood, the introduction of grading systems is according to their opinion complicated and quite costly. If the size of the sawmill and the share of structural timber in the production is taken into account, their decision that at least at the beginning they prefer visual grading is understandable.

3 Tests for determining properties

The cooperation in the GRADEWOOD project was among other the best opportunity to create the comprehensive database of Slovenian structural timber. We have carried out the non-destructive tests on more than 1000 boards of Slovenian *Picea Abies Mill.* sawn timber taken from several Slovenian forestry regions. The cross sections of the boards were adjusted to the proposed specimens in the GRADEWOOD project (40x100 mm^2, 50 x 150 mm^2, 44 x 210 mm^2), and at the end 74 boards of cross section 140x140 mm^2 were added. All boards were tested by 5 machine grading equipment from Sweden, Nederland, France, Belgium and Italy. They were also tested by simple non-destructive laboratory methods (using vibrations, ultrasound, static bending loading) to get relevant indicative properties. At the end all boards were loaded to the failure and before that MC and density were measured.

After obtaining properties (MOR, MOE, density) of Slovenian structural timber, the correlation between indicative properties obtained by non-destructive methods and strength has been found. The expected research outcome of the project is the initial database of Slovenian structural timber properties, and the practical one will be the machine settings for commercially available grading machines valid for Slovenia.

3.1 Specimens

In total 1074 boards of different cross sections which are in conformity with GRADEWOOD project, have been tested. They have been provided from four sawmills, cutting timber in the three Slovenian regions: Inner Carniola, Carinthia and Central Slovenia (the central part of Upper and Lower Carniola).

Figure 1: Slovenian Regions

Table 1: Description of specimens

Cross section (mm^2)	Source	Number of specimens	Total number for one dimension
40 x 100	Inner Carniola	119	251
	Carinthia	62	
	Central Slovenia*	70	
50 x 150	Inner Carniola	123	500
	Carinthia	126	
	Central Slovenia*	251	
44 x 210	Carinthia	61	249
	Central Slovenia*	188	
140 x 140	Carinthia	74	74
		Total	**1074**

* central part of Upper and Lower Carniola

3.2 Measurements of general characteristics

Before the tests measurements of dimensions, weights and moisture contents of all boards were performed. Density of wood was defined in two ways: by weighing and measuring the whole elements (global density) and the short pieces (ca 10 cm) cut near the point of failure from clear wood (clear wood density). The differences of both are shown in the next table where also density adjusted to 12% MC is included.

Table 2: Measured density

Density	mean value (kg/m^3)	5th percentile (kg/m^3)
global	458.6	390.8
clear wood	443.7	373.4
adjusted to 12% MC	444.1	373.8

Distribution of clear wood density is presented in Figure 1.

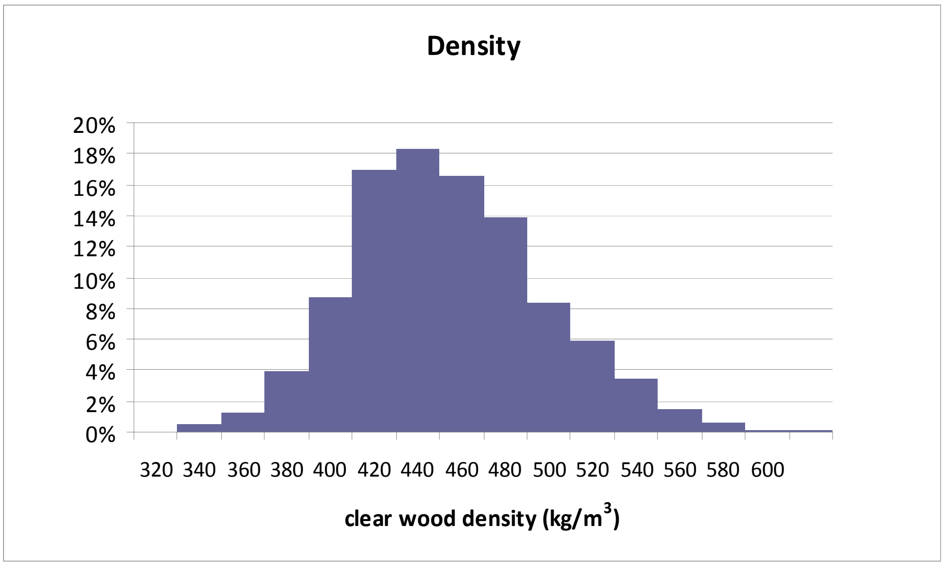


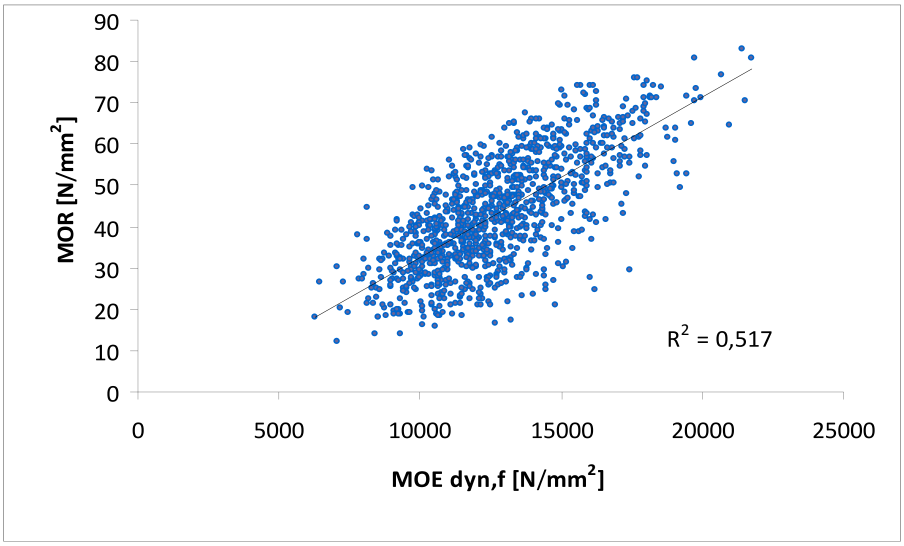
Figure 2: Clear wood density distribution

Moisture content of boards were measured with resistance type moisture meter before non-destructive tests. The measured values were in the range between 10.1 and 15.8%, while the average moisture content was 12.5%.

3.3 Non-destructive tests

As mentioned, tests were performed as a part of GRADEWOOD project in which different producers of grading equipment used their machine to grade the timber. Results of these measurements and correlation to measured strengths are, at the present time, not analysed and are not a subject of this paper.

Here, two simple non-destructive tests performed before failure tests are presented: measurement of natural frequency at impact load and measurement of ultrasound velocity (running time). Correlation between calculated dynamic modulus of elasticity based on both measurements, and the strength was established (Figure 3), as well as the correlation with other grade determining properties - density, static modulus of elasticity (Table 3). Strength is adjusted according to EN 384:2010 with factor k_h to the height of 150 mm.



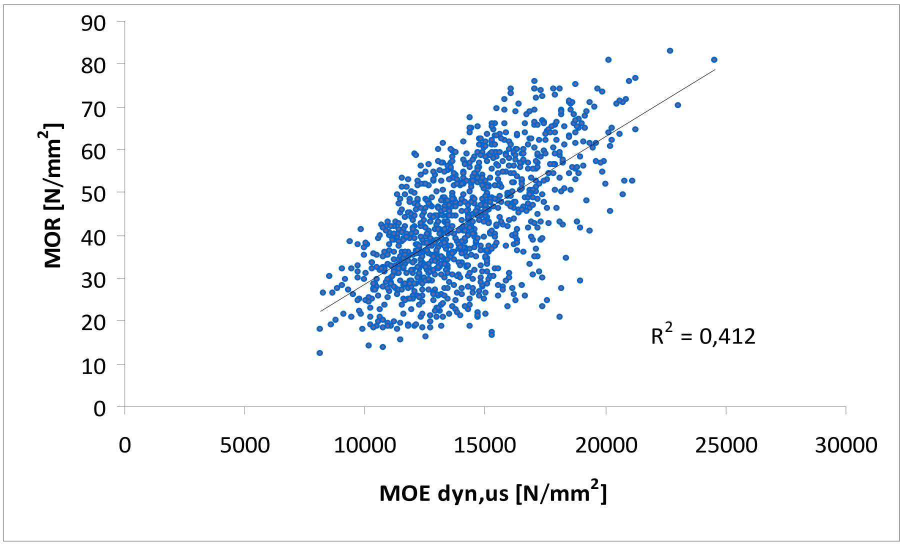


Figure 3: Relation between frequency and ultrasound dynamic MOE and adjusted MOR

Table 3: Correlation matrix between indicative properties*

	$MOE_{dyn,f}$	$MOE_{dyn,us}$	$MOE_{stat,gl}$	$\rho_{clear\ wood}$	MOR
$MOE_{dyn,f}$	1	0.963	0.904	0.806	0.719
$MOE_{dyn,us}$	0.963	1	0.868	0.834	0.642
$MOE_{stat,gl}$	0.904	0.868	1	0.739	0.816
$\rho_{clear\ wood}$	0.806	0.834	0.739	1	0.553
MOR	0.719	0.642	0.816	0.553	1

*all MOE for the actual MC measured by gravimetric method (not adjusted to 12%)

3.4 Destructive tests

On four types of boards the local and global modulus in bending and bending strength were tested according to EN 408:2003. Boards were tested edgewise with the four point load on the span 18xh as presented in Figure 4. Whereas boards of heights up to 150 mm were loaded without lateral restraints, boards of 210 mm height needed to be firmly restrained otherwise they buckled.

Figure 4: Destructive tests of boards 44 x 210 mm with lateral restraints

In Table 4 measured values (local and global MOE, adjusted strength) are presented, and in Figure 5 the distribution of adjusted strength.

Table 4: Measured values of tested boards

Property	mean value (N/mm^2)	5^{th} percentile (N/mm^2)
Local MOE in static bending	12173	7532
Global MOE in static bending	11158*	7618
Bending strength	43.28	23.74

* According to EN 384 the sample mean MOE was adjusted to the pure bending using the formula $E_{pure} = 1.3\ E_{global} – 2860$ equals 11645 N/mm^2

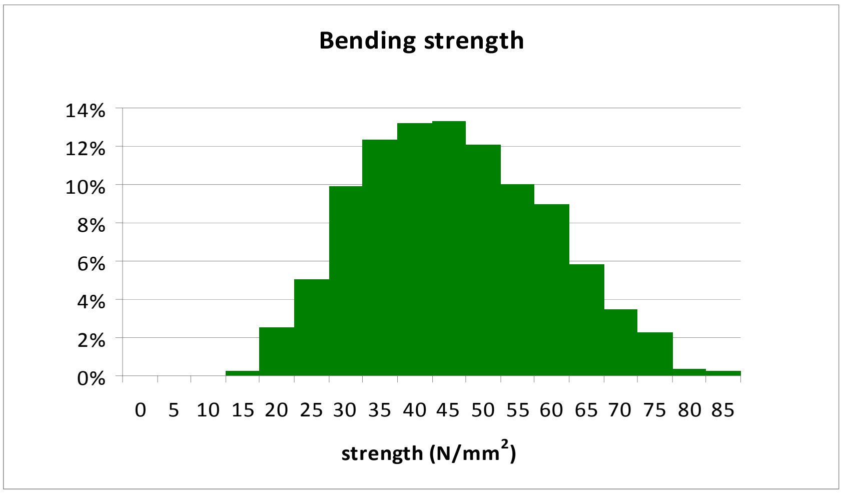


Figure 5: Strength distribution adjusted to 150 mm height

In Figure 6 strength distribution of boards with different dimensions can be seen. Because groups consist of different number of boards, distribution of the smallest group (74 boards 140x140 mm^2) is quite irregular, whereas distribution of the largest one (500 boards 50x150 mm^2) is similar to the distribution of the whole sample.

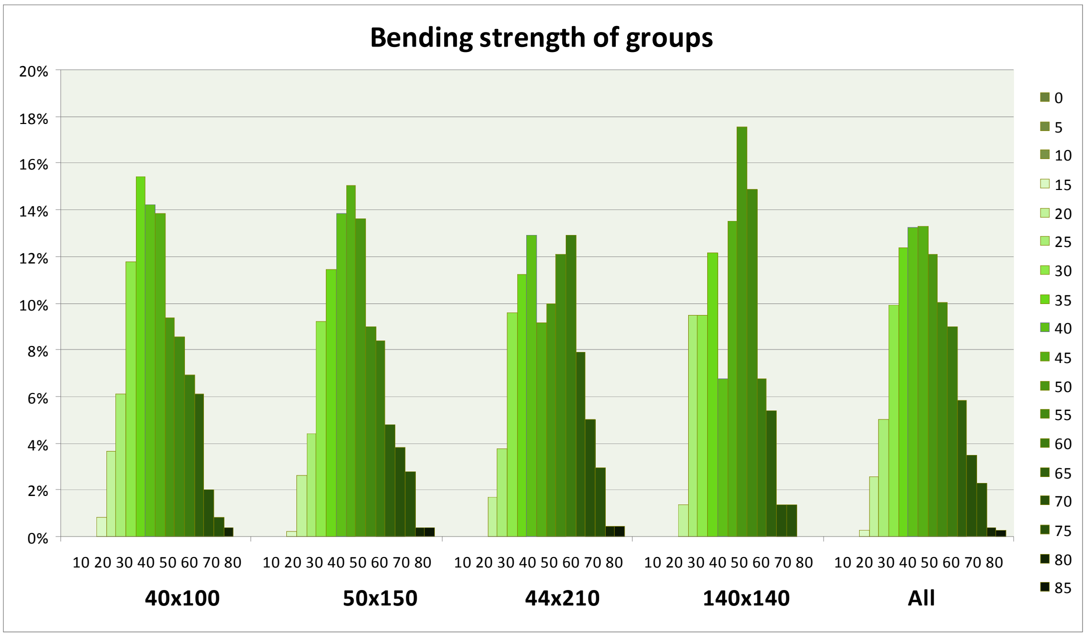


Figure 6: Strength distribution for different dimensions

4 Grading

4.1 General assumptions

Grading of structural timber has been done according to EN 338: to define C classes of the boards three criteria: strength, MOE and density are used. As foreseen in EN 384, strength has to be adjusted to the height 150 mm whereas density and MOE have to be adjusted to 12% MC. According to EN 338 the MOE for the required class has been reduced by 95%.

4.2 Optimum grading

Optimum grading provides the optimum assignment of strength class to the tested boards. This calculation is not so trivial task because all three properties (density, strength and MOE) should be optimized simultaneously according to algorithms from EN 14081-2 (Turk, Ranta Maunus 2003). Different combination of grades can be chosen – in our cases we chose five of them: C24 only, C30-C18, C30-C24-C18 (combination used in old JUS standards), C35-C24-C18 and C40-C24-C18.

As seen from the table 5, representative boards of Slovenian timber are in 98% in class C24 or higher. If we grade them in classes C30-C24-C18 as continuation of traditional grading classes, 86% of boards are in class C30.

Even when we grade boards in the classes C40-C24-C18, 52% of boards are in the highest class – the yields of Slovenian spruce are obviously quite high.

Table 5: Optimum grading – share of boards assigned to classes

	Grade combination				
	C24	**C30-C18**	**C30-C24-C18**	**C35-C24-C18**	**C40-C24-C18**
C40					52%
C35				71%	
C30		86%	86%		
C24	98%		3%	12%	34%
C18		12%	8%	10%	3%
reject	2%	2%	3%	7%	10%

5 Conclusion

The presented results show that all correlations are in the expected boundaries. Simple non-destructive tests *e.g.* measuring dynamic MOE are the strength indicators, but for reliable grading process measurement of additional quantities (*e.g.* density, knots) are needed. We expect that on the basis of the further investigations inclusion of Slovenian timber into wider region “Central Europe” can be confirmed.

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