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Spruce timber bending strength for different loading modes

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Abstract: *Spruce timber bending strength for different loading modes.* Paper presents the tests of two loading methods: 4 *point and 3 point bending load.* Sawn timber was divided in two halves. First one was tested by 4-point bending according to STN EN 408 (f_{408}). Second half by 3-point bending, applying the setting parameters of Cook Bolinder device. Firstly, a critical part with minimal modulus of elasticity ($E_{CB,min}$) was determined. This part of sawn timber was subsequently loaded until the rupture and the strength in bending (f_{CB}) was calculated. Results of comparison between f_{408} and f_{CB} showed the significance of 3-point bending in strength grading of sawn timber.

Keywords: structure timber, 4 point bending load, 3 point bending load, bending strength, wood density,

INTRODUCTION

The variability of structural timber strength and stiffness properties is applied in a specification of strength classes according with STN EN 338. The quality parameters are set according with STN EN 408 and are representing a basis for prediction models. The database specifies physical and mechanical properties of wood, wood species, country of origin, purpose of use and it allows a reliable comparison between the individual countries and methods (PAZLAR *et al.* 2010, WEIDENHILLER - DENZLER 2009).

The aim of paper was to determine spruce sawn timber strength in bending for different loading modes. To compare bending strengths for methods and to verify a reliability of bending strength determination in the case of industrially used 3 point bending load.

RESEARCH OBJECTIVE

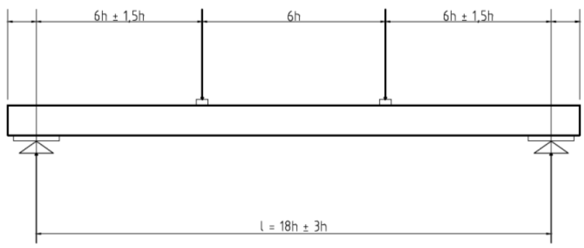
STN EN 408 is used to prove the compliance of quality parameters. It states the methods for a determination of selected physical and mechanical properties, which represent the basis for a determination of strenght classes and are used in non-destructive grading methods on different principles (ROHANOVA *et al.* 2010).

Bending characteristics (strength in bending, modulus of elasticity) are determined from stress – strain diagram.

4 point bending load (cross wise)

Loading scheme for a determination of strength in bending is illustrated in Fig. 1 (STN EN 408). In the case of 4 point bending load, the loading points (F/2) are for a span of 6h.

Fig. 1 Experimental scheme for a determination of modulus of rupture according to STN EN 408
(**l** - span, **h** - depth of cross section)



The bending strength is calculated from the following equation:

$$f_m = \frac{3Fa}{bh2} \qquad (1)$$

where:

F - is the loading for which the rupture occurs in N,
a - distance between the loading point and the closest support in mm,
b - width of cross section in mm,
h - depth of cross section in mm.

3 point bending load (flat wise)

The setting parameters of Cook Bolinder device were used in the design of loading scheme. Sawn timber is loaded flat wise by one force in the middle of span between the supports, which is 900 mm (Fig.2). The device works on the principle of constant deflection (a_n), calculated from a thickness of tested sawn timber. Application requirements for Cook Bolinders device are determined in STN EN 14 081-4, tab.1-2.

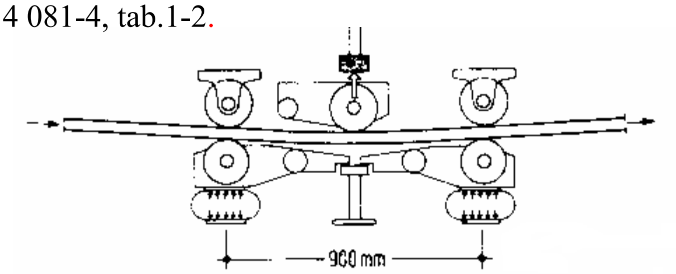


Fig. 2 Cook Bolinders SG-AF - scheme of 3-point bending load on sawn timber

For the simulation of bending strength determination by Cook Bolinder device in experimental conditions, the setting of wood species, dimensions of tested sawn timber and a calculation of constant deflection was necessary to perform. The strength in bending was determined in the part with a minimal modulus of elasticity.

Bending strength is calculated from the equation:

$$f_m = \frac{3F_{max} l_0}{2bh^2} \qquad (2)$$

where :

F_{max} - is the force for which the rupture occurs in N,
l_0 - distance between supports in mm,
b - width of sawn timber cross section in mm,
h - depth of cross section in mm.

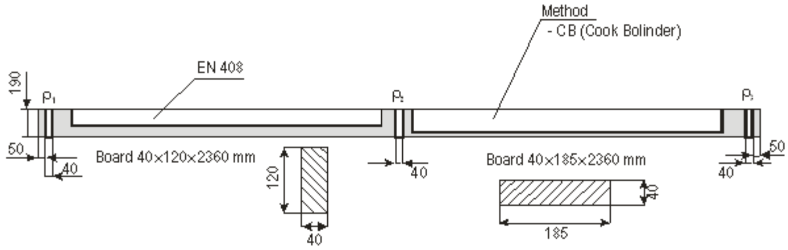
MATERIAL AND METHODS

Spruce sawn timber (*Picea abies,* L. Karst.) grown in Slovakia was experimentally tested. From the sawn timber of dimensions 40 × 190 × 5000 mm, following specimens were prepared:

- *4 point bending load* (40 × 120 × 2360 mm), 52 pcs., left part of sawn timber,
- *3 point bending load* (40 × 185 × 2360 mm), 52 pcs., right part of sawn timber.

The selection of specimens and specimens for density determination of sawn timber is illustrated in Fig.3.

Fig. 3 Specimens selection



Bending strength determined by methods:

4 point bending load – bending strength (f_m) and wood density ($\rho_{1,2,3}$) were corrected to reference moisture content w = 12%.

3 point bending load - 100 mm interval of loading lengthwise the specimen, deflection a_n = 6,89 mm. The minimal modulus of elasticity ($E_{CB,min}$) was determined on specimen and in this point the specimen was loaded until the rupture occurred. Bending strength was corrected to w = 12%.

RESEARCH RESULTS

Bending strength were graphically determined and calculated for methods as follows:

4 point bending load – stress – strain diagram in bending was elaborated for each specimen,
- calculation of bending strength f_m (equation 1),

3 point bending load - localization of rupture point on each specimen (F_{min} ~ $E_{CB,min}$),
- calculation of $f_{CB,min}$ according with equation 2.

Statistical characteristics of observed parameters are listed in table 2.

Tab. 2 Statistic characteristics of wood density and modulus of rupture (f_{408}~ 4-point bending load, f_{CB} ~ 3-point bending load) of structural timber

	Statistic characteristics	**Wood density**	**Bending strength** (4-point bending load - f_{408}) (3-point bending load - f_{CB})	
		ρ_{12} [kg.m^{-3}]	f_{408} [MPa]	f_{CB} [MPa]
Structural timber	*n*	**52**	**52**	
	ϕ	417	42	49
	min	350	16	20
	max	496	63	79
	V%	8	28	13

- Student´s pair t-test for dependent values showed, that method 408 gives significantly ***higher values*** of strength in bending (f_{408}) than method CB (f_{CB}), which means that method CB systematically undervalues the strength in bending. Level of significance is P = 0,0000.
- Graph of 95% intervals of reliability proved a significance of differences between methods (f_{408} a f_{CB}).

CONCLUSION

Method CB (3-point bending) has an experimental output, it applies the setting parameters of Cook Bolinder device according with EN 14 081-4, tab.1-2, it interpolates new strength classes and their characteristics. Average bending strength f_{CB} = 49 MPa is compairing to value of f_{408} = 42 MPa higher values by 17 %. Average wood densities ρ_{408} and ρ_{CB} are in conformity.

Results of *4 point bending load* and *3 point bending load* comparison proved that the method CB is suitable for an application use. It is simple, objectively and reliably defines the quality parameters along the whole length of sawn timber. It allows localizing the critical parts, which can be excluded. Higher quality of timber products can be obtain by following V-joining, e.g. in the case of glulam production.

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Streszczenie: *Wytrzymałość na zginanie tarcicy świerkowej przy różnych sposobach obciążenia*. Praca prezentuje badania tarcicy świerkowej przy dwóch typach zginania, trzypunktowym I czteropunktowym. Tarcicę świerkową podzielono na dwie grupy. Pierwszą zginano czteropunktowo zgodnie z normą STN EN 408 (f_{408}). Druga grupa była zginana trzypunktowo, przy parametrach z urządzenia Cook Bolinder. Wyznaczono minimalny moduł sprężystości ($E_{CB,min}$) . Tarcica była obciążana aż do złamania, wyznaczono wytrzymałość na zginanie (f_{CB}). Porównanie wytrzymałości f_{408} oraz f_{CB} wykazało znaczenie zginania trzypunktowego przy sortowaniu wytrzymałościowym tarcicy świerkowej.

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