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Modulus of elasticity by flat wise bending method

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Abstract: *Modulus of elasticity by flat wise bending method.* Grading methods based on various principles are used for the quality assessment of structure timber. Flat wise bending method is used in practise. Cook Bolinder machine works on this principle. It determines the variability of moduli of elasticity along the sawn timber. It localizes the minimal values of moduli of elasticity, which are a basis for the assignment of resistance classes.

Flat wise bending method was verified on spruce sawn timber (boards). It took into account the setting parameters according with STN EN 14 081-4 (Cook-Bolinder). The results showed, that wood defects (knots – large, clustered) have major influence on the moduli of elasticity variability with these values significantly lower in the case of their presence. The influence of wood density on moduli of elasticity and determination of resistance class was also evaluated. Reliable determination of wood density predicts the assignment of final class of resistance. Fluctuating profile of moduli of elasticity is caused by knots. Their removal can significantly increase the quality of board.

Keywords: sawn timber, bending method, flat wise, modulus of elasticity, quality of board

INTRODUCTION

Wood is characterised by an important variability of its physical and mechanical properties. [POŽGAJ 1997]. The variability of density and wood moisture content, presence of different growth defects of wood, insect or fungi attack usually cause the reduction of strength and elasticity, which are important parameters in the grading of structure timber [WEIDENHILLER DENZLER, 2009].

Reliable assessment of wood quality for construction purposes is offered by machine grading based on different principles. The grading parameters (elasticity, strength, density) are determined and subsequently assigned to resistance class according with STN EN 338. These are non-destructive grading methods with negligible changes of wood properties important for its intended use. Determination of wood quality parameters for assignment of resistance class is effectuated on:

- *bending principle,*
- *different principles* (ultrasound, vibration, radiation etc.)

Equipments based on bending principles are the most widely used. They are simple and economically affordable. Modulus of elasticity E_{oh} is considered to be the most important grading parameter. Verified high correlation between wood bending strength (σ_{oh}) and the modulus of elasticity of wood E_{oh} represents the basis of this principle. It establishes the basics of sawn timber strength grading which is listed in STN EN 338.

Sawn timber during the grading process can be loaded by one force or by a pair of forces. The constant parameter for the determination of modulus of elasticity can be:

- preset deflection (magnitude of load is determined) or
- preset force, the deflection is measured.

Two basic types of timber grading machines working on bending principles are known: *off line* or *in line.*

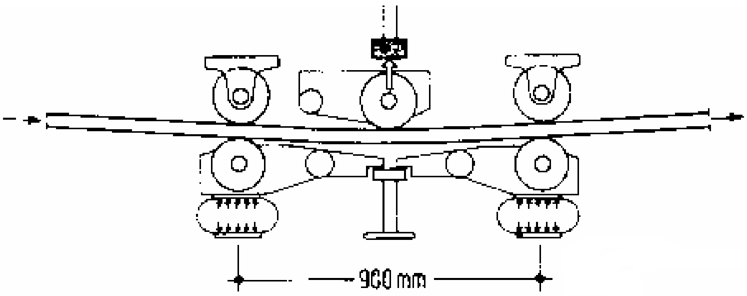

Fig. 1 Cook Bolinders SG-AF - scheme of three-point bending load on sawn timber

In foreign countries, timber grading machines intended for industrial use (producers or sawn timber importers) have been developped, e.g. Cook Bolinders SG-AF.

Sawn timber is loaded by one force in the middle of span between two supports (flat wise). The distance between the supports is 900 mm (fig.1). The deflection (a_n) is preset and it is calculated from the thickness of tested sawn timber.

Table 1 Characteristic parameters for resistance classes and their combinations (Cook Bolinder)

Variations	***Resistance class***	***f** mod*	***a_n [mm]***	***I_n***	***F_n [kN]***	***P_n [bar]***
Basic classes	*C18*	*20,8*	*6,8924*	*5899,71*	*2,6480*	*1,2311*
	C24	*20,8*	*6,8924*	*5899,71*	*2,6480*	*1,2311*
	C27	*21,8*	*6,8924*	*6122,67*	*2,7480*	*1,2776*
	C30	*28,5*	*6,8924*	*7566,38*	*3,3960*	*1,5789*
Combination n°1	*C24*	*20*	*6,8924*	*5719,71*	*2,5672*	*1,1935*
	C30	*46,5*	*6,8924*	*11139,06*	*4,9996*	*2,3244*
Combination n°2	*C18*	*23,8*	*6,8924*	*6562,30*	*2,9454*	*1,3694*
	C30	*30,6*	*6,8924*	*8003,51*	*3,5922*	*1,6701*
	C40	*54,5*	*6,8924*	*12627,40*	*5,6676*	*2,6350*

MATERIALS AND METHODS

Settings parameters of Cook Bolinder machines are according with STN EN 14 081-4. Prior to the experimental testing we needed to verify relations on the specific sawn timber and in the testing conditions. **Combination n°2** is the most suitable model for experiments.

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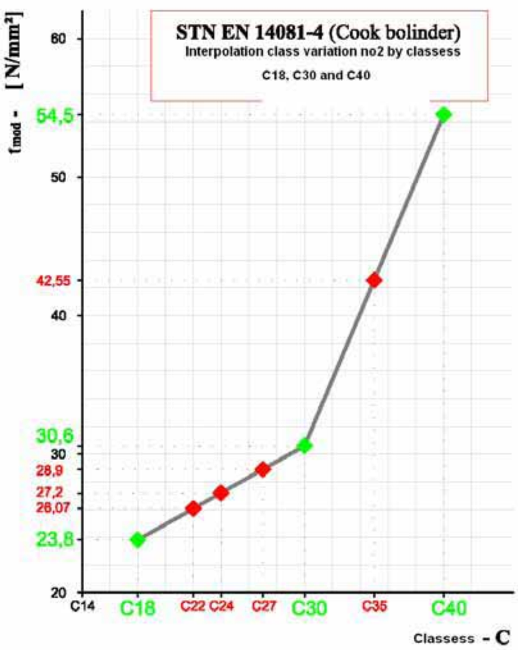

Fig. 2 Interpolation and extension of resistance class variation n°2 by classes C22, C24, C27 a C35.

Interpolated model values of characteristics for resistance classes C18 to C40 are listed in table two.

Table 2 Interpolated model values of grading characteristics (Cook Bolinder)

Proposed resistance classes	***Resistance class***	f_{mod}	a_n [mm]	I_n	F_n [kN]	E_{OH} [MPa]
Combination n°2 and interpolated classes	*C18*	*23,8*	*6,8924*	*6562,30*	*2945,4*	***6 700***
	C22	*26,07*	*6,8924*	*7051,28*	*3164,8*	*7 210*
	C24	*27,2*	*6,8924*	*7292,39*	*3273,1*	*7 460*
	C27	*28,9*	*6,8924*	*7650,15*	*3433,6*	*7 835*
	C30	*30,6*	*6,8924*	*8003,51*	*3592,2*	***8 205***
	C35	*42,55*	*6,8924*	*10384,63*	*4660,9*	*10 715*
	C40	*54,5*	*6,8924*	*12627,40*	*5667,6*	***13 115***

Determination of modulus of elasticity E – taking into consideration the effect of shear (G).

The experimental assessment of boards using bending method were based on theoretical knowledge in grading of structure timber and transformation of technical parameters of grading machine Cook Bolinder. STN EN 14 081-4 and STN EN 338 were used for the assessment. The acquisition of experimental results was difficult from the theoretical, material point of view and also it was time consuming.

Set of 52 boards was experimentaly tested. Bending load was applied to each board (side A + side B), moisture content, moduli of elasticity and desity of wood were determined. The moduli of elasticity and wood density was relatived to w = 12%. The resulted moduli of elasticity were used to determine a critical part of board with the minimal value of E_{min} and the resistance class ***C*** according with STN EN 338 was assigned to board.

RESULTS

The critical part was determined on each board (52 pcs.). The resistance class was assigned according with proposed model values.

Detailed description of moduli of elasticity distribution along the board is illustrated on selected boards with various quality (fig.3 and fig.4).

Board A 6/1 – fig. 3

12 points were measured in bending zone. Variation of moduli of elasticity has fluctuating course. The presence of wood defects – knots and their position was assessed. The lowest modulus of elasticity E_{min} = 12 563 MPa was measured in critical point n°10, the resistance class C30 was assessed to this point. We suppose that the wood density profile along full length of board has even influence and that the fluctuating course of moduli of elasticity is caused by knots. In the case of longer boards (more points) the results of grading can be even more explicit and objective.

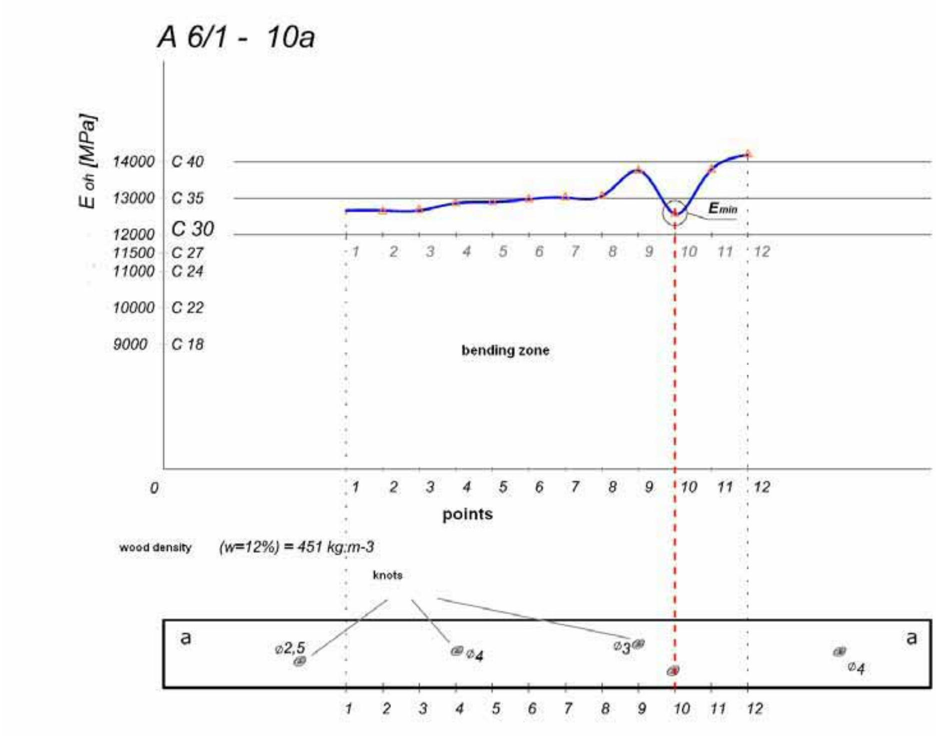

Fig. 3 The fluctuation of bending modulus of elasticity along board A 6/1

Doska B 5/2 – fig. 4

This board is characterised by an extreme presence of wood defects, it was assessed in 12 points. It is board containing pit and relatively hight presence of knots obtained from the central part of trunk. The value $\boldsymbol{E_{min}}$ = 7 394 MPa.

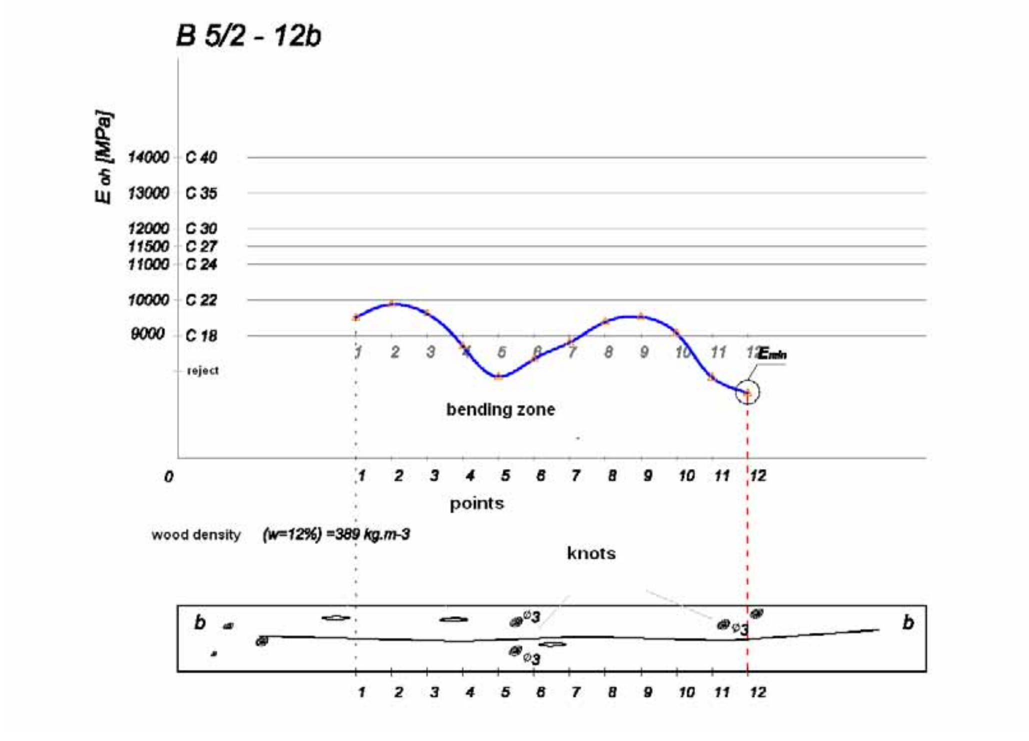

Fig. 4 Fluctuation of bending modulus of elasticity along the board B5/2 – 12p.

Althought it was clearly graded as reject, the values of moduli of elasticity of certain portions of board meet requirements for resistance class C18. It is important to underline here very variable fluctuation of moduli of elasticity (C18 ~ C16 ~ reject), which actually disallow to reliably assign the lowest resistance class C16 ~ SII specified in STN EN 1912. For this reason, the use of wood C16 in timber structures should be restricted to the minimum.

CONCLUSIONS

Contribution is dedicated to the spruce board testing using bending method, which takes into consideration the quality parameters of wood according with Cook Bolinder machine setting (STN EN 14 081-4). The principle of this equipment resides in sawn timber loading in linear (elastic) part of stress – strain diagram to the proportional limit ($\boldsymbol{\sigma_{ú}}$). The bending method determines the real moduli of elasticity in bending $\boldsymbol{E_{CB,ohyb}}$.

The proposal of testing methodology flat-wise – Cook Bolinder in experimental conditions is considered to be the orginal result. We determined model values of calculations, new interpolated classes and material characteristics. Detailed analysis of modulus of elasticity variation along the board determines the critical portion – minimal modulus $\boldsymbol{E_{CB,ohybmin}}$, which can be characterised by the presence of wood defects (knots). In the case of its elimination, it is possible to assign higher resistance class with positive economic effect.

Bending method is the most objective and it determines the resistance classes to structure timber with the sufficient reliability according with STN and EN.

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Streszczenie: *Moduł spręźstości przy zginaniu płaskim*. W użyciu sąróżnorodne metody sortowania jakościowego tarcicy. Metoda zginania płaskiego jest używana w praktyce, na tej metodzie bazuje maszyna Cook Bolinder . Znajduje najniższą wartość modułu na całej długości tarcicy i na tej podstawie klasyfikuje surowiec.

Metoda zginania płaskiego zostałą zweryfikowana na tarcicy świerkowej. Wzięto pod uwagę parametry ustalowe w normie STN EN 14 081-4 (Cook-Bolinder). Badanie wykazało że wady drewna (duże sęki i i grupy sęków) mają znaczący wpływ na moduł sprężystości, który obniża się w ich obecności. Badano także wpływ gęstości drewna na moduł sprężystości oraz klasę wytrzymałościową. Określenie gęstości ma znaczenie przy kasyfikacji wytrzymałościowej, zmienny moduł sprężystości jest rezultatem występowania sęków. Ich usunięcie wyraźnie oprawia jakość tarcicy.

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