PROPOSAL FOR REDESIGN OF CHARACTERISTIC VALUES AND STRENGTH CLASSES FOR BEECH STRUCTURAL TIMBER

Alena Rohanová[1], Štefan Král[2]

[1]Faculty of Wood Sciences and Technology, Technical University in Zvolen, Slovakia

[2]Slovak Legal Metrology, Hviezdoslavova 31, 974 01 Banská Bystrica, Slovakia

Abstract

This paper presents a methodology for evaluation of the characteristic values and the strength classes of beech structural timber by using European standards. The characteristic values of the bending strength, the modulus of elasticity, and the density of wood experimentally reassessed according to EN 338. The bending strength appears to be underestimated and the beech structural timber assigns to a lower strength class in consequence of the characteristic values of the modulus of elasticity and the density of wood. Based on the experimental results, the modified characteristic values proposed. They predict a more objective strength grading of beech structural timber.

Keywords: *beech wood, structural timber, bending strength, modulus of elasticity, density of wood, characteristic value, strength class*

1. INTRODUCTION

Timber building structures fabricate mainly from the structural timber usually with rectangular cross section. The conformity assessment of the structural timber with rectangular cross section when placed on the EU market carries out according to Regulation (EU) No. 305/2011 [1] by using the harmonised standard EN 14081-1 [2].

The structural timber is strength graded either visually or by machine. A strength classes assign to the structural timber and characterise its quality. Spruce structural timber has the largest range of the strength classes - from C14 to C50 [3]. The design of the European system of strength classes is sophisticated and generally applicable to the structural timber of various wood species. The grading of the structural timber into strength classes is a subject of long-term research. The results of some studies may be found for instance in [4], [5], [6], [7], [8], [9], [10], [11]. The structural timber quality represents three essential parameters: the bending strength (MOR), the modulus of elasticity in bending (MOE) and the density of wood. The characteristic values of bending strength (MOR), modulus of elasticity in bending (MOE) and density for the timber apply in the structural calculations. The characteristic values are defined as 5-percentile for bending strength (MOR) and timber density and mean values for modulus of elasticity in bending (MOE). Procedures and calculations used for description of timber quality are very complex and extensive. General overview of regulations and their interrelationships is shown in Fig. 1.

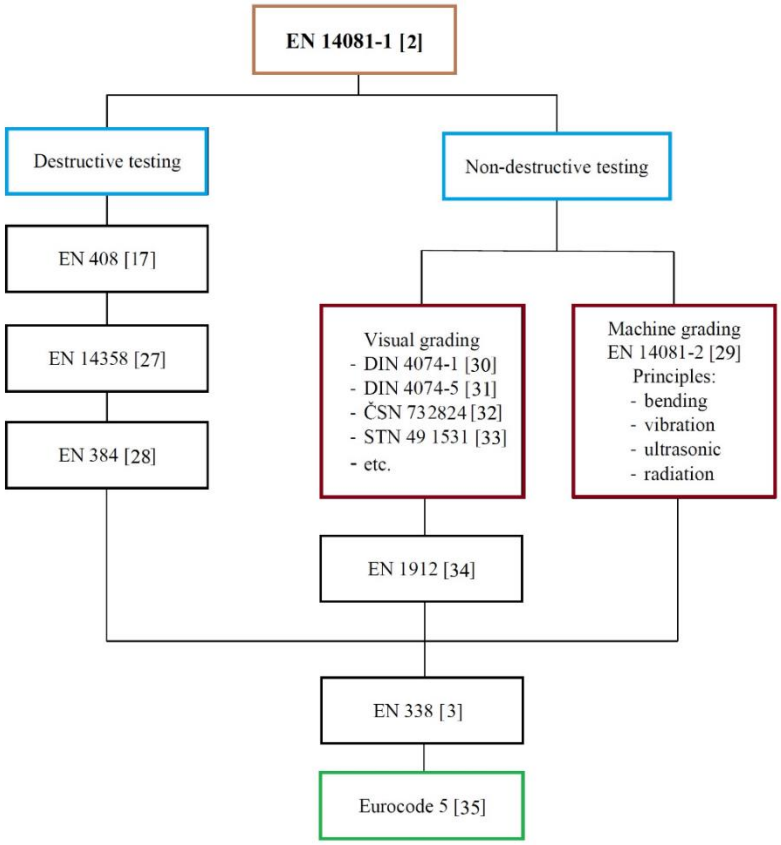


Fig. 1. Overview of important regulations and their levels in the field of structural timber

The bending load is the most common way of loading that occurs in timber building structures and it is usually the most critical [5]. The change of mechanical properties of the wood can be reached in a number of ways. Several significant scientific studies have been published on this topic. The modification of the wood at temperature of 160° C increased the impact bending strength of European oak (*Quercus robur L.*) and Norway spruce (*Picea abies (L.) H. Karst.*) about 30% while at temperatures of 180 °C and 210 °C the impact bending strength decreased compared to unmodified wood [12]. The thermal modification European oak (Quercus robur L.) and Norway spruce (*Picea abies (L.) H. Karst.*) at temperatures 160 °C and 210 °C decreases the modulus of elasticity, stress at the limit of proportionality and elastic potential compared to untreated timber [13]. The strengthening of the spruce wood (*Picea abies (L.) H. Karst.*) with reinforcement carbon lamella increased significantly the bending strength at thermo-mechanical loading. The bending deflection at the failure was about 10 % lower compared to unmodified wood [14]. The moisture content of spruce wood (*Picea abies (L.) H. Karst.*) has significant influence on the bending modulus of elasticity. The bending modulus of elasticity decreases with increasing the moisture content [15]. The thickness of the lamellae made of spruce wood (*Picea abies (L.) H. Karst.*) does not have a clear effect on the bending strength [16].

The actual bending strength for the structural timber determines according to EN 408 [17] by means of destructive bending tests. Subsequently, the obtain results use for prediction of the bending strength by non-destructive test methods. The studies concerning destructive and non-destructive tests of the structural timber may be found for instance in [18], [19], [20], [21], [22], [23].

On the present, there is lack of good quality spruce structural timber. Therefore, new species of wood (e.g. beech) investigate for use in timber building structures. European beech (*Fagus sylvatica* L.) is deciduous tree that occurs mainly in Central Europe [24]. The beech wood is considered a strategic material in timber building structures in the future. However, the use of beech wood is more difficult and complex than spruce wood. Wood defects like curvature, internal stresses and rot influence the

processing of beech raw material and eliminate the use of beech wood in load-bearing structures [25]. The significant wood defect of beech wood is the reaction wood that negatively affects its workability. Further, the yield of beech timber from beech logs is only approximately 18% [26].

There is insufficient knowledge currently available in the use of beech wood for timber structures. Moreover, only characteristic values are available for hardwood strength classes concerning the design of beech timber structures [3]. On the present, we have good knowledges about mechanical properties of spruce timber wood, not only among countries but also in their regions. Several studies were published in this area, for instance [26], [36], [37], [38]. On the other hand, the knowledges about mechanical properties of beech timber wood are still unsatisfactory. Every country that intends to use beech timber for building structures shall deal with extensive experimental research and determine the strength classes according to EN 338 [3]. Currently, only Germany has assigned strength classes for beech timber (D35 and D40). Therefore, extensive research in other European countries is expected. General overview of strength classes for European countries based on visual grading according to national specifications is given in Table 1. Only three strength classes use for spruce timber in practice. Beech timber is currently under verification.

Table 1. The characteristic values and strength classes-standards used in various countries

Properties			**Strength Classes - Characteristic Values**										
			softwood				**hardwood**						
			C16	**C18**	**C24**	**C30**	**D24**	**D30**	**D35**	**D40**	**D50**	**D60**	**D70**
EN 338	$f_{m,k}$	[N/mm^2]	16	18	24	30	24	30	35	40	50	60	70
	$E_{m,0,mean}$	[kN/mm^2]	8	9	11	12	10	11	12	13	14	17	20
	ρ_k	[kg/m^3]	310	320	350	380	485	530	540	550	740	840	960
Standards	STN 491531 [33] (Slovakia)		SII	-	SI	S0	-	-	-	-	-	-	-
	ČSN 73 2824 [32] (Czech Republic)		-	S7	S10	S13	-	-	-	-	-	-	-
	PN–D -94021 [41] (Poland)		-	KG	KS	KW	-	-	-	-	-	-	-
	DIN 4074-1 [30] (Germany)		-	S7	S10	S13	-	-	-	-	-	-	-
	ÖN DIN 4074-1 [42] (Austria)		-	S7K	S10K	S13K	-	-	-	-	-	-	-
	DIN 4074-5 [31] (Germany)		-	-	-	-	-	-	LS10 LS10K	LS13	-	-	-

Note: $f_{m,k}$ is the characteristic value of bending strength, $E_{m,0,mean}$ is the mean characteristic value of modulus of elasticity in bending parallel to grain, and ρ_k is the characteristic value of density.

The research and experiments suggest the possibility to use beech timber in both the classical and new construction types. These applications include glued laminated timber and glued solid timber with full cross-section, profiled truss elements and hybrid timber beams composed of wood elements and non-wood materials. Other use of beech timber is expected in prefabricated load-bearing materials as a laminated veneer lumber as is described in [39].

The present research focuses on high variability of deciduous tree and wood properties (beech, oak, ash) and on their characteristic values. It was found that beech timber has unbalanced characteristic values and interrelationship between MOR, MOE and the density [22], [23], [40]. According to research results, the correlations between MOR, MOE and the density of beech wood are significantly lower in

comparison with the spruce wood. Following nowadays knowledge it seems that value MOR is undervalued for beech wood and there is almost no correlation between MOR and the density of beech wood in terms of characteristic values [19], [20]. These findings predict the revision of characteristic values of deciduous wood according to EN 338 [3].

2. MATERIAL AND METHODS

2.1. Sampling

European beech (*Fagus sylvatica L.*) from the Horehronie region in Slovakia was used for the preparation of the specimens. Individual trees were selected from the area of approximately 200 × 200 m. The number of trees was N = 15 and the number of logs was 30 (20.8 m^3). The length of the logs was 3300 ÷ 3500 mm and their cross sections were treated against cracking using punched metal plate fasteners. The quality of the logs was determined according to STN 48 0056 [43]. The logs were assigned to class III A or class II and cut into boards by means of Wainscot sawing pattern. The dimensions of boards were 50 × 150 × 3 100 mm, N = 247 (7.4 m^3). The boards were visually graded according to STN 49 1531 [33]. 118 boards - planks (3.5 m^3) were suitable for structural purposes and for testing. The dimensions of specimens for the destructive bending test were 50 × 150 × 2 700 mm, N = 52. The average moisture content of specimens was 12% determined at laboratory conditions. Moisture content was monitored and controlled by Hydromette HT 85T.

2.2. Method of determination of characteristics values in strength classes

Following method was used for determination of characteristics values in strength classes:

- performance of destructive bending test according to EN 408 [17] and determination of values: modulus of rupture (MOR_{408}; $f_{m,408}$), modulus of elasticity (MOE_{408}; $E_{m,g}$) and density of wood (ρ_{408});
- verification of normal distribution for the values MOR_{408}, MOE_{408}, and ρ_{408};
- calculation of characteristic values according to EN 384 [28] - modulus of rupture (MOR_{384}) and density of wood (ρ_{384}) as a 5-percentile, modulus of elasticity (MOE_{384}) as a mean value and $k_s(n)$ factor;
- design of 3-step model of linear dependencies MOR/MOE, MOR/ρ, and ρ/MOE;
- classification of the test specimens into strength classes according to standard line for the hardwood of EN 338 [3] and proposed (redesigned) line;
- redesign of characteristic values and determination of MOE_{modif} ($E_{m,0,mean}$) and ρ_{modif} (ρ_k) for strength classes in the range D24 ÷ D70.

3. RESULTS AND DISCUSSION

3.1. Destructive bending test

The results from the destructive bending test are shown in Table 2.

Table 2. The statistical summary of results from destructive bending tests for beech wood, moisture content 12% (Slovakia)

Characteristics		**Density of wood** ρ_{408} **(kg/m^3)**	**Bending characteristics**	
			MOR$_{408}$ ($f_{m,408}$, N/mm^2)	**MOE$_{408}$ ($E_{m,g,408}$, N/mm^2)**
mean	$\bar{x}$	**694**	**76,5**	**13844**
max	x_{max}	745	94,4	16679
min	x_{min}	613	51,6	11465
SD	s_y	33	9,7	1228
V_x	**[%]**	5	12,7	9

N = number of specimens, MOR = modulus of rupture, MOE = modulus of elasticity, SD = standard deviation, V_x = coefficient of variation.

3.2. Distribution parameters and correlations

The normal distribution of the bending characteristic (MOR$_{408}$, MOE$_{408}$ and ρ_{408}) was tested and confirmed by three statistical tests: Kolmogorov–Smirnov, Lilliefors and Shapiro–Wilkov (Fig. 2, Fig. 3 and Fig. 4). The presumption of normal distribution applied for the calculation of characteristic values [27]. The correlation analysis shown weak linear dependence MOR$_{408}$ on ρ_{408} as well as MOR$_{408}$ on MOE$_{408}$. On the other hand, the moderate linear dependence MOE$_{408}$ on ρ_{408} (r = 0.60) was found (Fig. 5).

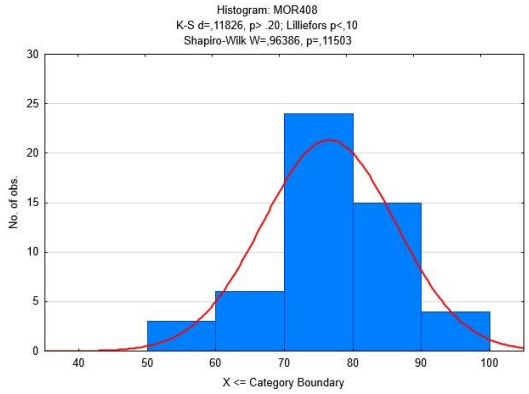


Fig. 2. The normal distribution tests for the MOR$_{408}$

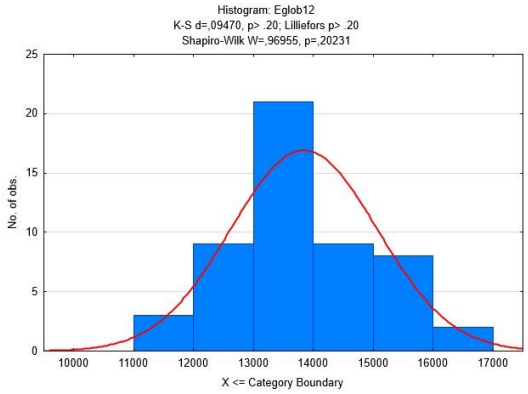


Fig. 3. The normal distribution tests for the MOE$_{408}$

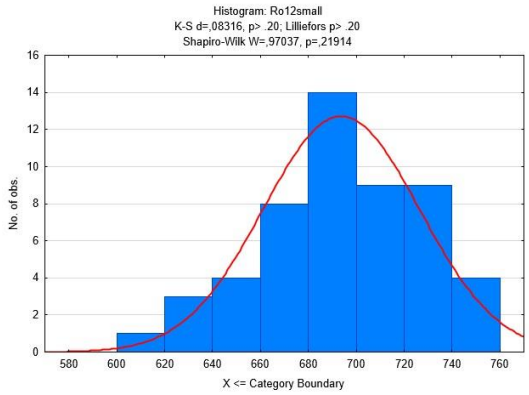


Fig. 4. The normal distribution tests for the ρ_{408}

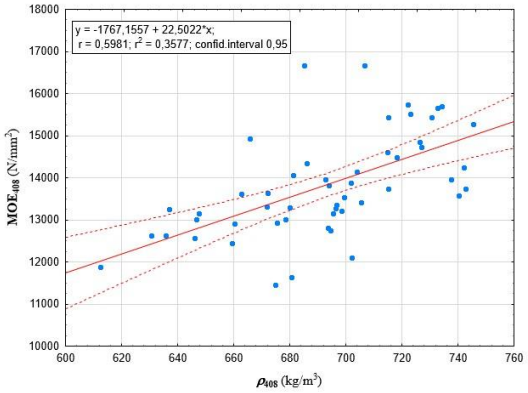


Fig. 5. Linear dependence between MOE_{408} and ρ_{408}

3.3. Characteristic values of mechanical properties and density

Calculated characteristic values of mechanical properties and density of beech wood according to EN 384 [28] at reference conditions (moisture content 12%, depth of 150 mm) are summarised in Tab 3.

Table 3. The characteristic values of MOR_{384}, MOE_{384} and ρ_{384} (beech structural timber)

Characteristics		**Density of wood ρ_{384} (ρ_k, kg/m³)**	**Modulus of rupture MOR_{384} ($f_{m,k}$, N/mm²)**	**Modulus of elasticity MOE_{384} ($E_{0,mean}$, N/mm²)**
EN 14358	$\bar{y}$	694	76,5	13844
	s_y	33	9,7	1228
	k_s (n) (m_k)	1,816		-
	k_s (n) (m_{mean})	-	-	0,0949
	m_k (5%)	**631**	**58,9**	-
	m_{mean}	-	-	**13727**

ρ_k = 5-percentile, $f_{m,k}$ = 5-percentile, $E_{0,mean}$ = mean value of the modulus of elasticity parallel to grain, $\bar{y}$ = mean value, s_y = standard deviation, $k_s(n)$ = factor used to calculate characteristic properties, m_k (5%) = 5-percentile value, m_{mean} = mean value.

3.4. Strength classes

The strength classes were determined and evaluated by means of two methods. First method is based on the determination of strength class using characteristic values. Second method is based on the determination of strength class using 3-step models of linear dependencies.

3.4.1. Determination of strength class using characteristic values

The characteristic values of the beech wood from the experiments and their comparison with characteristic values for the strength class D40 are shown in Table 4.

Table 4. The characteristic values of the beech wood - experimental characteristic values and comparison with D40

Characteristic value	**Experimental values**		**Reference values for strength class D40**		**Difference (%)**
MOR ($f_{m,k,}$ N/mm^2)	MOR_{exp}	59	MOR_{D40}	40	+ 47,5
MOE ($E_{0,mean}$, N/mm^2)	MOE_{exp}	13727	MOE_{D40}	13 000	+ 5,6
ρ_k (kg.m^{-3})	$\rho_{k,exp}$	631	$\rho_{k,D40}$	550	+ 14,7

MOR_{exp} = modulus of rupture from experiments, MOR_{D40} = modulus of rupture for D40, $f_{m,k}$ = characteristic values of bending strength, MOE_{exp} = modulus of elasticity from experiments, MOE_{D40} = modulus of elasticity for D40, $E_{0,mean}$ = mean value of the modulus of elasticity parallel to grain, $\rho_{k,exp}$ = characteristic value of density from experiments, $\rho_{k,D40}$ = characteristic value of density for D40, ρ_k = characteristic value of density.

According to obtained results all experimental characteristic values (MOR_{exp}, MOE_{exp}, and $\rho_{k,exp}$) are higher than reference values for strength class D40. The similar results were obtained from the study stated in [23]. Based on the experimental characteristic values MOR_{exp} and $\rho_{k,exp}$, the beech wood could be assigned to the strength class higher than D40. On the other hand, the experimental characteristic value MOR_{exp} is suitable for the strength class D40.

3.4.2. 3-step models of linear dependencies

Proposed 3-step models of linear dependencies determine the strength classes based on standard lines for characteristic values according to EN 384 [28] and on modified (redesigned) lines. Assignation of values to the strength class was determined from the experimental values as follows:

Using standard line according to EN 338 [3]:

The experimental values of characteristic values were allocated to the corresponding strength classes. Subsequently, the number of experimental values and their percentage in the corresponding strength class were determine for dependencies MOR_{338}/MOE_{338} (Fig. 6), MOR_{338}/ρ_{338} (Fig. 7) and ρ_{338}/MOE_{338} (Fig. 8).

Using modified line based on redesign of characteristic values:

The experimental values of characteristic values were allocated to the new proposed strength classes. Subsequently, the number of experimental values and their percentage in the corresponding strength class were determine for dependencies MOR_{338}/MOE_{modif} (Fig. 9), MOR_{338}/ρ_{modif} (Fig. 10) and ρ_{modif}/MOE_{modif} (Fig. 11). MOE_{modif} and ρ_{modif} were approximated with regard to MOR_{338}.

The obtained results in relation to the standard line are summarized in the Table 5. The obtained results in relation to the modified line are summarized in the Table 6.

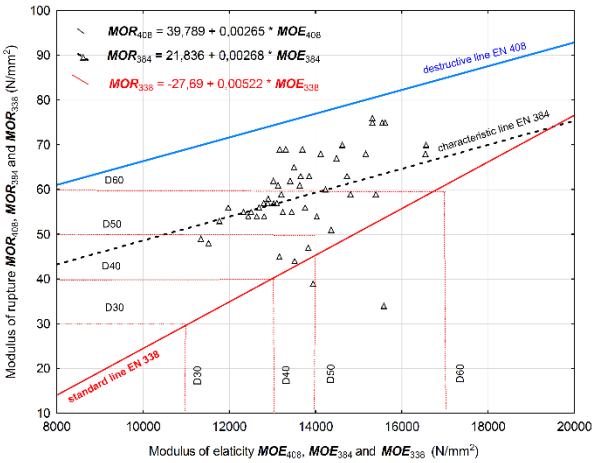


Fig. 6. Strength classes-standard line EN 338 ($MOR_{338} - MOE_{338}$)

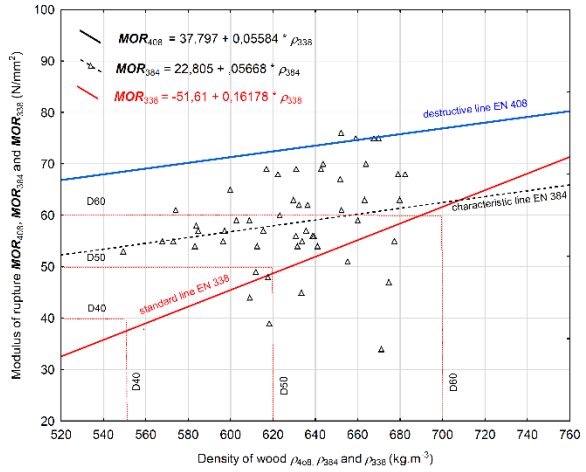


Fig. 7. Strength classes-standard line EN 338 (MOR_{338}–ρ_{338})

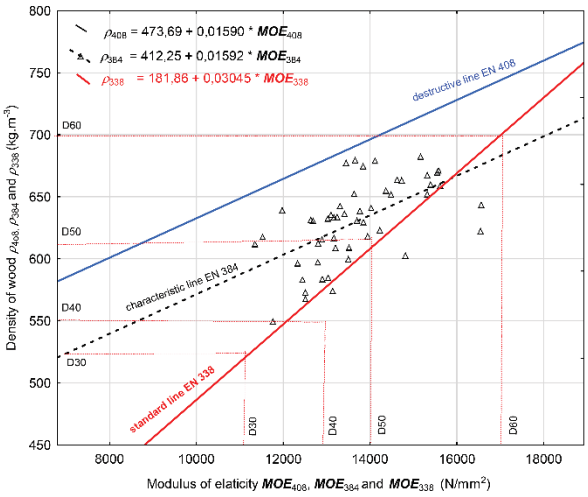


Fig. 8. Strength classes-standard line EN 338 (ρ_{338}–MOE_{338})

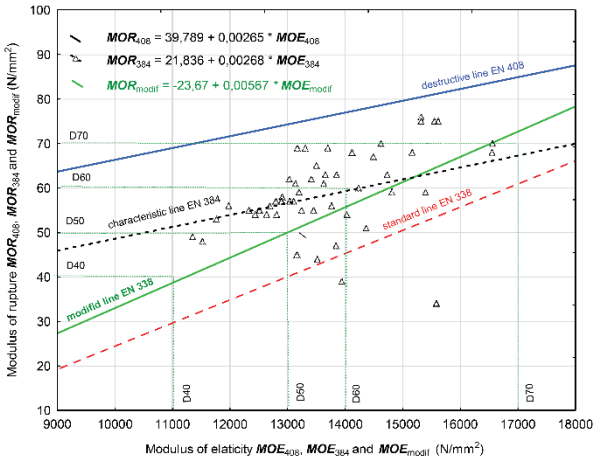


Fig. 9. Strength classes-modified line ($MOR_{338} - MOE_{modif}$)

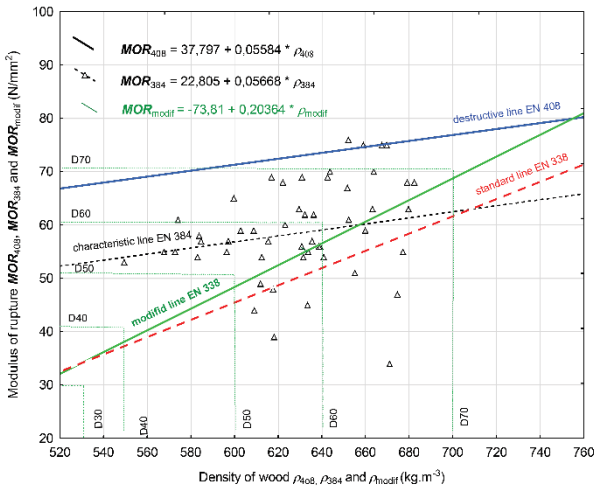


Fig. 10. Strength classes-modified line ($MOR_{338} - \rho_{modif}$)

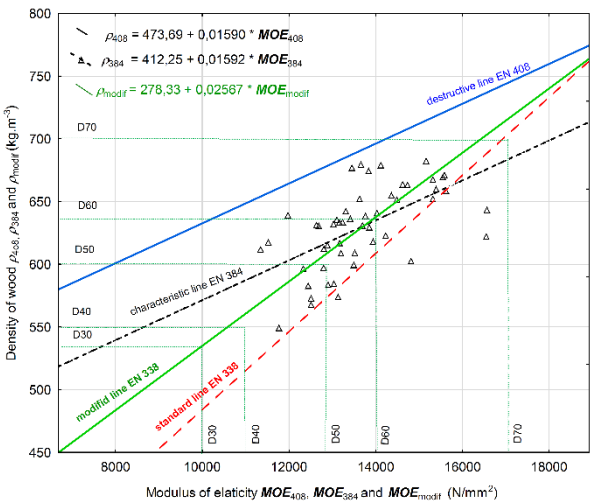


Fig. 11. Strength classes-modified line ($\rho_{modif} - MOE_{modif}$)

The values listed in Table 5 and Table 6 are categorized into following levels:

Identical: the values that are assigned to the strength classes as are specified by the using line (specified by the MOR, MOE and ρ);

Higher: the values that are assigned to the higher strength class than the strength class specified by the using line on the basic of the screening parameters MOE or ρ;

Lower: the values that are assigned to the lower strength class than the strength class specified by the using line on the basic of the screening parameters MOE or ρ.

Table 5. The percentage of experimental values assigned to the strength classes according to the standard line based on the relationships MOR_{338}/MOE_{338}, MOR_{338}/ρ_{338} and ρ_{338}/MOE_{338}.

Strength classes allocated to the experimental values (assigned on the basic of MOR_{exp} and $\rho_{k,exp}$, as relevant)		**Strength classes according to the standard line (EN 338)**												Total		
		D30			**D40**			**D50**			**D60**					
		MOR_{338}/MOE_{338}	MOR_{338}/ρ_{338}	ρ_{338}/MOE_{338}	MOR_{338}/MOE_{338}	MOR_{338}/ρ_{338}	ρ_{338}/MOE_{338}	MOR_{338}/MOE_{338}	MOR_{338}/ρ_{338}	ρ_{338}/MOE_{338}	MOR_{338}/MOE_{338}	MOR_{338}/ρ_{338}	ρ_{338}/MOE_{338}	MOR_{338}/MOE_{338}	MOR_{338}/ρ_{338}	ρ_{338}/MOE_{338}
D30		0	0	2	2	2	19	4	4	6	0	0	0	6	6	27
D40		4	0	0	6	6	13	0	4	25	0	0	0	10	10	38
D50		23	2	0	11	21	2	10	21	33	0	0	0	44	44	35
D60		0	0	0	19	6	0	13	26	0	0	0	0	32	32	0
D70		0	0	0	0	0	0	8	8	0	0	0	0	8	8	0
Total	MOR_{338}/MOE_{338}	27			38			35			0			100%		
	MOR_{338}/ρ_{338}		2			35			63			0				
	ρ_{338}/MOE_{338}			2			34			64			0			

Note: - identical level - higher level - lower level

Table 6. Percentage of experimental values assigned to the strength classes according to the modified line based on the relationships MOR_{338}/MOE_{modif}, MOR_{338}/ρ_{modif} and ρ_{modif}/MOE_{modif}.

Strength classes allocated to the experimental values (assigned on the basic of MOR_{exp} and $\rho_{k,exp}$, as relevant)		**Strength classes according to the modified line**												Total		
		D30			**D40**			**D50**			**D60**					
		MOR_{338}/MOE_{modif}	MOR_{338}/ρ_{modif}	ρ_{modif}/MOE_{modif}	MOR_{338}/MOE_{modif}	MOR_{338}/ρ_{modif}	ρ_{modif}/MOE_{modif}	MOR_{338}/MOE_{modif}	MOR_{338}/ρ_{modif}	ρ_{modif}/MOE_{modif}	MOR_{338}/MOE_{modif}	MOR_{338}/ρ_{modif}	ρ_{modif}/MOE_{modif}	MOR_{338}/MOE_{modif}	MOR_{338}/ρ_{modif}	ρ_{modif}/MOE_{modif}
D30		0	0	0	0	0	0	2	2	0	4	4	0	6	6	0
D40		0	0	2	4	0	12	6	8	13	0	2	0	10	10	27
D50		0	2	0	23	14	6	12	21	23	10	7	9	44	44	38
D60		0	0	0	0	4	0	19	11	6	13	17	29	32	32	35
D70		0	0	0	0	0	0	0	0	0	8	8	0	8	8	0
Total	MOR_{338}/MOE_{modif}	0	0	0	27	0	0	39	0	0	35	0	0	100 %		
	MOR_{338}/ρ_{modif}	0	2	0	0	18	0	0	42	0	0	38	0			
	ρ_{modif}/MOE_{modif}	0	0	2	0	0	18	0	0	42	0	0	38			

Note: - identical level - higher level - lower level

3.5. Analysis of the results

Identical level: From the obtained results (Fig. 12 and Fig. 13) follows that more values comply with the strength classes predicted by the modified line than by the standard line according to EN 338 [3] for all three dependencies (MOR/MOE, MOR/ρ and ρ/MOE). It indicates that modified characteristic values provide a more objective allocation to the strength class.

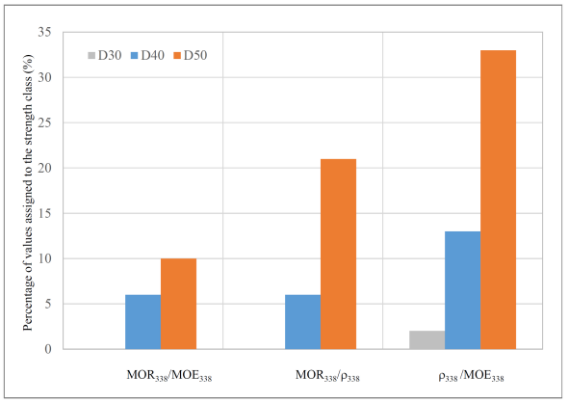


Fig. 12. Percentage of values assigned to the strength classes as are specify by the standard line EN 338

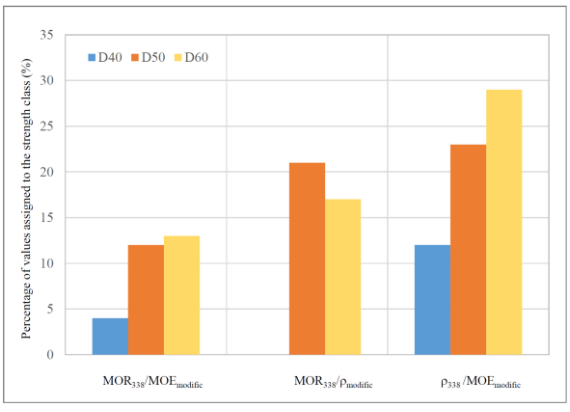


Fig. 13. Percentage of values assigned to the strength classes as are specify by the modified line

Higher level: From the obtained results (Fig. 14 and Fig. 15) follows that more values were assigned to a higher strength classes at the standard line according to EN 338 [3] than at the modified line. It indicates that modified characteristic values provide a more objective allocation to the strength class. The beech structural timber with a higher MOR as is prescribed by the standard line at the screening parameter MOE and ρ are undervalued and their real strength is not utilized. Very high values of MOE and ρ were not obtained which corresponds to the results of the study stated in [40].

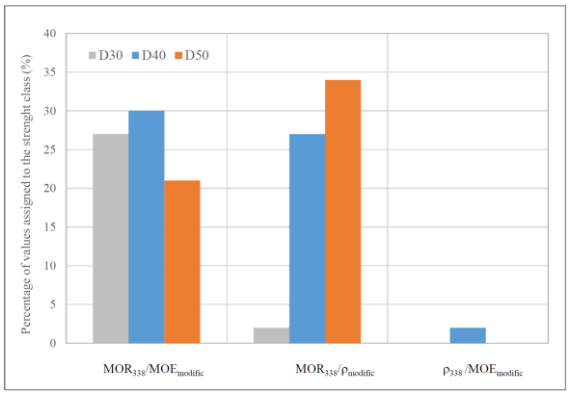


Fig. 14. Percentage of values assigned to a higher strength classes than are specify by the standard line EN 338

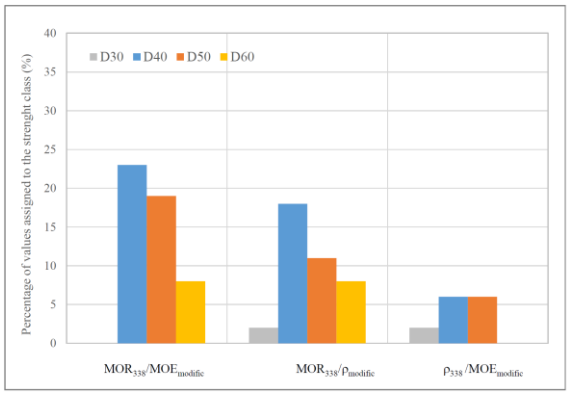


Fig. 15. Percentage of values assigned to a higher strength classes than are specify by the modified line

Lower level: From the obtained results (Fig. 16 and Fig. 17) follows that globally the same number of values was assigned to a lower strength classes at the standard line according to EN 338 [3] and at the modified line.

The summary results of the strength grading according to the strength classes of EN 338 [3] and modified strength classes, on the basic of dependencies MOR/MOE, MOR/ρ and ρ/MOE, are shown in Table 7.

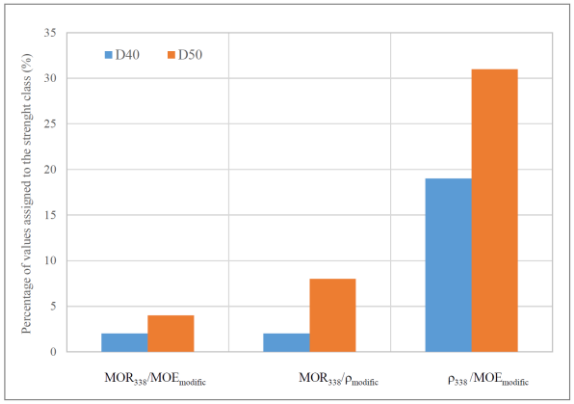


Fig. 16. Percentage of values assigned to a lower strength classes than are specify by the standard line EN 338

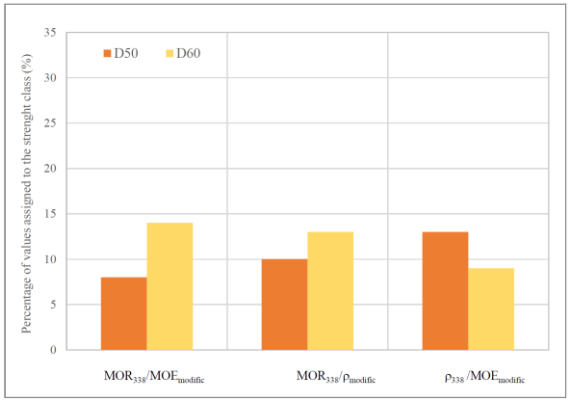


Fig. 17. Percentage of values assigned to a lower strength classes than are specify by the modified line

Table 7. The summary results of the strength grading (according to EN 338 [13] and modified strength classes)

Strength classes	**Percentage of values assigned to the strength class in relation to the dependencies and methods of the strength classification**					
	MOR/MOE		**MOR/ρ**		**ρ/MOE**	
	EN 338	**modification**	**EN 338**	**modification**	**EN 338**	**modification**
D30	33	6	8	8	27	2
D40	36	33	37	28	38	31
D50	31	40	55	39	35	38
D60	-	21	-	25	-	29
Total	100 %					

According to the results, a higher strength classes (D60) were obtained at the modified line. The significant increase of values in a higher strength classes can be caused by following:

- introducing of modified characteristic values of MOE_{modif} and ρ_{modif}. On the basis of new modified characteristic values, a higher MOR values were not undervalued,
- applying the quality visual grading in the chain - trees, logs, planks.

The characteristic values of beech structural timber according to EN 338 [3] and designed of modified values for strength classes D24 to D70 are shown in Table 8.

Table 8. The characteristic values of beech structural timber according to EN 338 [3] and designed of modified characteristic values for strength classes D24 to D70.

Parameter	**EN 338:2016 - Characteristic values of hardwoods "D" for the strength classes**						
	D24	**D30**	**D35**	**D40**	**D50**	**D60**	**D70**
$f_{m,k}$ in N/mm^2	24	30	35	40	50	60	70
$E_{m,0,mean}$ in N/mm^2	10,000	11,000	12,000	13,000	14,000	17,000	20,000
ρ_k in kg/m^3	485	530	540	550	620	700	800
Parameter	**Design of modified characteristic values (MOE_{modif} and ρ_{modif}) for the strength classes**						
	D24	**D30**	**D35**	**D40**	**D50**	**D60**	**D70**
$f_{m,k}$ in N/mm^2	24	30	35	40	50	60	70
$E_{m,0,mean}$ inN/mm^2	**8,500***	**10,000***	**10,500***	**11,000***	**13,000***	**14,000***	**17,000***
ρ_k in kg/m^3	**480***	530	540	550	**600***	**640***	**700***

* design of modified characteristic values

$f_{m,k}$ is the characteristic of bending strength, $E_{m,0,mean}$ is the mean modulus of elasticity parallel bending, and ρ_k is the characteristic of wood density.

4. CONCLUSION

The aim of the investigation was to determine the characteristic values of MOR, MOE and ρ_k of Slovak beech structural timber and to determine the strength classes.

Based on the experimental tests and obtained characteristic values of MOR_{384}, MOE_{384} and ρ_{384}, the Slovak beech structural timber assigned to the strength class D 40 according to EN 338 [3]. The results based on the experimental testing and grading analysis showed markedly higher value MOR_{384} than expected for value MOE_{384} and ρ_{384} according to EN 338 [3]. The experimental results indicate that the characteristic values of MOR_{384} are underestimated for the relevant values MOE_{384} and ρ_{384}.

The correlation analysis shown weak linear dependence MOR_{408} on ρ_{408} as well as MOR_{408} on MOE_{408}. The moderate linear dependence MOE_{408} on ρ_{408} (r = 0,60) was found.

The modified characteristic values MOE_{modif} ($E_{m,0,mean}$) and ρ_{modif} (ρ_k) were proposed for the strength classes from D24 to D70. The values of MOE_{modif} are a lower than MOE_{338} according to EN 338 [3] for all strength classes D24÷D70. The values of ρ_{modif} are a lower than ρ_k according to EN 338 [3] for a higher strength classes D50÷D70.

The MOR/MOE, MOR/ρ and ρ/MOE dependencies established with regard to destructive line according to EN 408 [17], characteristic line according to EN 384 [28], standard line according to EN 338 [3] and modified line according to the design of new characteristic values.

Strength classes "identical, +higher and –lower" were analysed according to the dependencies. The MOR_{338}/MOE_{338} dependence showed the low compliance (16 %) of experimental values with the values defined in EN 338 [3]. 78 % of the experimental values showed a higher MOR_{338} at the MOE_{338} than defined in EN 338 [3]. It indicates that the characteristic value of the bending strength is underestimated because the characteristic value of MOE_{338} is one of the basic parameters for grading the structural timber into the strength classes.

The MOR_{338}/MOE_{modif} dependence in relation to the modified characteristic values showed a higher compliance (29 %) of experimental values with the modified characteristic values and a higher level of grading balance. The significant quantity of the experimental values assigned to a higher strength class D60.

The modified characteristic values of MOE_{modif} and ρ_{modif} provide a more objective strength grading of the beech structural timber. The obtained results point out to reassessment of the characteristic values of Slovak beech structural timber in a wider context (in relation to the country of origin, the quality of timber, the number of selections etc.).

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