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Analysis of Selected Mechanical Properties of Construction Wood KVH and Parallam 2.0 E

Analiza određenih mehaničkih svojstava konstrukcijskog drva KVH i uslojenog drva PSL

Original scientific paper · Izvorni znanstveni rad
Received – prispjelo: 1. 10. 2009.
Accepted – prihvaćeno: 24. 2. 2010.
*UDK: 630*812.7; 630*832.284; 630*863; 674.816.2*

ABSTRACT • *This paper summarizes the results of the analysis of selected physical and mechanical properties of construction wood KVH and composite material Parallam 2.0 E (below Parallam). The following properties were determined: bending strength, local modulus of elasticity in bending, modulus of elasticity in pure bending, modulus of elasticity in shear by the constant span method, compression strength along the grain, compression strength across the grain, tensile strength across the grain, density and moisture content. The determined values were compared to each other and the best material was evaluated. The analyzed materials showed not only different values of monitored properties but also different behavior in particular tests. The presented tables and diagrams show that Parallam demonstrates better strength properties in many cases than construction wood KVH but with respect to the high purchase price of Parallam a manifold higher difference was expected. Comparing both analyzed materials from the aspect of purchase costs, two-fold higher values of the majority of analyzed mechanical properties of Parallam as against the construction wood KVH are irrelevant. The price of construction wood KVH is about EUR 250, and the price of Parallam is about EUR 1540 per m*^{3}. *Such a high price is the main cause of the minimum use of Parallam as against construction wood KVH.*

Keywords: *construction materials, construction wood KVH, Parallam, bending strength, modulus of elasticity in bending, tensile strength, compression strength, density, moisture content*

SAŽETAK • *U radu se iznose rezultati istraživanja određenih fizikalnih i mehaničkih svojstava konstrukcijskoga cjelovitog drva KVH (*Konstruktionsvollholz*) i uslojenog drva PSL (*Parallel Strand Lumber*). Određivana su ova svojstva: savojna čvrstoća, lokalni modul elastičnosti pri savijanju, modul elastičnosti pri čistom savijanju, modul elastičnosti pri smicanju, određen metodom konstantnog luka, tlačna čvrstoća duž vlakanaca, tlačna čvrstoća okomito na vlakanca, vlačna čvrstoća okomito na vlakanca, gustoća drva i sadržaj vode. Dobivene su vrijednosti istraživanih materijala uspoređene i procijenjeno je koji materijal ima bolja svojstva. Ispitivani materijali nisu pokazali samo različita svojstva već su se u testovima određivanja pojedinih svojstava različito i ponašali. Rezultati prikazani u tablicama i na dijagramima pokazuju da uslojeno drvo PSL u većini slučajeva ima bolju čvrstoću od konstrukcijskog drva KVH, ali s obzirom na mnogo veću cijenu uslojenog drva PSL, očekivana je i veća razlika u svojstvima tih materijala. Analizirajući svojstva obaju materijala, zaključeno je da su dva puta veće vrijednosti gotovo svih svojstava čvrstoće uslojenog drva PSL zanemarive s obzirom na višestruko veću cijenu. Cijena konstrukcijskog drva KVH kreće se oko 250 eura/m*^{3}, *dok je cijena uslojenog drva PSL oko 1540 eura/m*^{3}. *Tako visoka cijena glavni je razlog mnogo rjeđe uporabe uslojenog drva PSL od konstrukcijskog drva KVH.*

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Ključne riječi: *konstrukcijski materijali, konstrukcijsko drvo KVH, uslojeno drvo PSL, savojna čvrstoća, modul elastičnosti pri savijanju, vlačna čvrstoća, tlačna čvrstoća, gustoća, sadržaj vode*

1 INTRODUCTION
1. UVOD

Wood belongs to the oldest materials used by man from time immemorial for various purposes particularly for the construction of shelters, houses as well as monumental buildings, bridges and other special-purpose constructions. Apart from advantageous mechanical and construction properties that are the cause of large use of wood in building construction, it should also be emphasized that wood is a natural, ecological and renewable base material.

Nevertheless, wood is a material showing different properties in different directions (depending on the direction of wood fibers). During the growth of a tree, various defects occur in the tree wood disturbing its homogeneity and affecting its properties. Thus, an endeavor to eliminate disadvantages of wood resulted in the development of new wood-based materials, which are technologically superior showing better properties. At present, wood and wood-based materials are steadily used in building industries for the manufacture of supporting structures of smaller, medium and large spans. Just for these reasons, a number of wood-based materials intended for building industries have been developed. From the aspect of sustainable management, wood is the building material of the future (Kolb, 2008; Vanìrek *et al.*, 2006).

The aim of this paper was to determine selected physical and mechanical properties of two construction materials (construction wood KVH Si in fair-face quality and Parallam) on the basis of destructive tests and comparisons of these materials also from the aspect of purchase prices).

Parallam (Parallel Strand Lumber or PSL) is mostly produced of the wood of southern pines (Douglas fir, Pinus ponderosa). Rotary-cut or round-up veneers are used for Parallam processing. Peeled logs or veneers, used for the production of plywood or laminated wood, are processed. Veneer sheets are subsequently dried and checked to eliminate stresses causing defects. After desiccation, veneer sheets are cut to strands 3 mm thick, 133 mm wide and up to 2.4 m long. Defective strands are sorted out. Particular strands are arranged in such a way that the direction of fibers is parallel and then a water-resistant phenol-formaldehyde adhesive is spread. Using the microwave heating the oriented strands of veneers are pressed in a continuous rolling press. The whole production process is controlled by programmed logical elements to provide the required final density correlating with strength properties (670-720 kg/m^3) as well as thickness, moisture and appearance.

Parallam is produced as a compact prism of a maximum cross section of 285 x 400 mm, which can be subsequently cut up and shortened to standard lengths up to 20 m. This material shows higher compression and tensile strength as compared with traditional wood. It is free of natural defects and non-homogeneities characteristic of natural wood. Parallam is stable in its dimensions. Shrinkage, warping and twisting are eliminated to minimum under conditions of its use (Hrázský and Král, 1999).

Construction solid wood KVH (Konstruktionsvollholz) is produced by the lengthwise wedge joint of building softwood sawn timber. Central-European coniferous species, such as Norway spruce, silver fir, poplar, Scotch pine and larch are used as original raw materials (Kuklík, 2006). According to the purpose, two kinds are produced differing particularly in the surface quality, viz. KVH of fair-face quality and KVH of substandard face quality. Requirements for utility properties and minimum production requirements are determined by the ČSN EN 385 Standard. Due to the cut type selection, cracks and splits as well as dry timber warping can be markedly eliminated. Thus, two types of cut are differentiated, and namely through heart and outside heart. At the fair-face quality of KVH-Si sawn timber heart-free cut is used. For the non-face quality of KVH-Nsi sawn timber and for all other cross sections heart cut is used (Timber Frame Houssing, 2006).

KVH construction wood is suitable for modern demanding constructions, whose purpose is to preserve natural aesthetic character. It is particularly used as building timber for frame and ceiling constructions. It is suitable for supporting structures of solid wooden constructions. Being manufactured in arbitrary lengths thanks to indented jointing it does not contain health-hazardous substances. KVH prisms are ideal for roof and supporting wooden elements (Král and Hrázský, 2006).

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The following physical and mechanical properties were determined of the construction wood KVH Si of fair-face quality and composite material Parallam: local modulus of elasticity in bending, modulus of elasticity in pure bending, modulus of elasticity in shear (calculated), bending strength, compression strength along the grain, compression strength across the grain (radial and tangential direction), tensile strength across the grain (radial and tangential direction).

The analyzed material Parallam was produced of ponderosa pine. It showed construction drawbacks in the form of numerous lengthwise cavities, generated in pressing veneer strands by imperfect compression. Thus prepared samples were not ideal.

The KVH material was produced of the construction spruce sawn timber of fair-face quality. With this material, perfect samples could be prepared thanks to the possibility of selection from a large number of stored KVH prisms in a plant producing wooden constructions.

Tests of properties were carried out in the Technical University Ostrava testing room and in the testing room of Mendel University of Agriculture and Forestry in Útìchov near Brno.

Standards and equipment, drawings, dimensions and numbers of samples used were as follows:

– CSN EN 408 Standard: Wooden constructions. Construction wood and glue-laminated wood. Determination of some physical and mechanical properties. CSI Praha 2004:32.

2.1 Determination of the local modulus of elasticity in bending (four-point bending)
2.1. Određivanje lokalnog modula elastičnosti pri savijanju (s četiri uporišne točke)

The shortest length of a test specimen has to be 19 times higher than the cross-section height.

Dimensions of the test specimen: 950 x 40 x 50 mm (Figure 4). Equipment: EU 40 press making possible four-point bending. Number of test specimens: 30 of each of the analyzed material.

Test specimens were loaded symmetrically by means of two loads at a span equal to 18 times the specimen height; the support distance was 900 mm. The loading was carried out at a constant speed. The speed of loading can not exceed the value of 0.003 h (mm/s). The value h is the hight of cross-section area at the bending test. Test specimens were simply supported. To prevent local galls in the place of supports and the impact of loads, stainless plates 2 mm thick and 20 mm long were inserted between test specimens and supports or loads.

Deformation w was measured in the centre of a measuring basis equal to 5 times the cross-section height. The highest load did not exceed 0.4 F_{max}. A mean fracture load F_{max} was determined from tests of 10 specimens of the respective material. Using values from a test of the local modulus of elasticity, the dependence was plotted of the load – deformation. Part of the diagram between 0.1 F_{max} and 0.4 F_{max} was used for a regression analysis.

A scheme of the test is given in Figure 1.

Bending strength according to the CSN EN 408 Standard is calculated as follows:

$$f_m = \frac{a \cdot F_{\max}}{2 \cdot W}, \text{ N/mm}^2$$

where:

$F_{\max}$ - maximum load / *maksimalno opterećenje*, N

a - distance between the point of load and the nearest support at the bending test / *udaljenost između točke opterećenja i najbliže točke uporišta*, mm

W - cross-section modulus / *modul poprečnog presjeka*, mm^3.

Local modulus of elasticity in bending according to the CSN EN 408 Standard is calculated as follows:

$$E_{m,l} = \frac{a \cdot l_1^2 \cdot (F_2 - F_1)}{16 \cdot I \cdot (w_2 - w_1)}, \text{ N/mm}^2$$

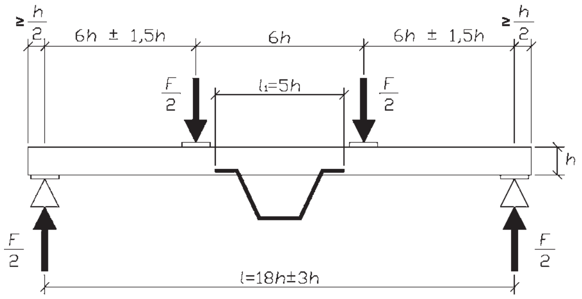


Figure 1 A scheme of the test of the four-point local MOE in bending
Slika 1. Shema određivanja lokalnog modula elastičnosti pri

where:

F_2 - F_1 - load increment in the straight-line part of the working diagram of load – deformation / *promjena opterećenja u pravocrtnom dijelu dijagrama opterećenje-deformacija*

w_2 - w_1 - deformation increment in mm corresponding to $F_2 – F_1$ / *promjena deformacije u milimetrima koja odgovara promjeni opterećenja*

l_1 - measuring basis to determine the modulus of elasticity / *mjerna osnova za određivanje modula elastičnosti*, mm

I - moment of inertia of cross-section / *moment inercije poprečnog presjeka*, mm^4

a - distance between the point of load and the nearest support at the bending test / *udaljenost između točke opterećenja i najbliže točke uporišta*, mm.

2.2 Determination of modulus of elasticity in pure bending (three-point bending)
2.2. Određivanje modula elastičnosti pri čistom savijanju (model savijanja s tri uporišne točke)

To determine the modulus of elasticity in pure bending the same test specimens were used as to determine the local modulus of elasticity in bending. The test specimens were loaded only by one load, namely in the centre of the span corresponding to the measuring basis as evident in Fig. 4. In this case l = l_1. It concerns a "three-point bending". The loading head speed was up to a value 0.0002 h (mm/s). The value h is the hight of cross-section at the bending test.

A scheme of the test is illustrated in Figure 3. To prevent the origin of a local gall in the place of supports

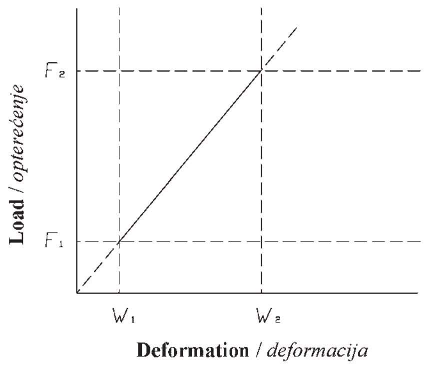


Figure 2 The diagram of load – deformation in the area of elastic deformation deformation
Slika 2. Dijagram opterećenje – deformacija u području elastične deformacije

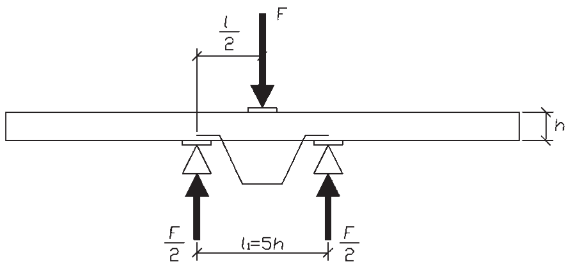


Figure 3 A scheme of the arrangement of the test of modulus of elasticity in pure bending (three-point bending)
Slika 3. Shema testa za određivanje modula elastičnosti pri čistom savijanju (savijanju s tri uporišne točke)

and the effect of loading weights, stainless plates 2 mm thick and 20 mm long were inserted between test specimens and supports or loads.

Deformation was measured in the span centre.

Modulus of elasticity in pure bending expressed in N/mm^2 is calculated according to the CSN EN 408 standard as follows:

$$E_{\mathrm{m,app}} = \frac{l_1^3 \cdot (F_2 - F_1)}{48 \cdot I \cdot (w_2 - w_1)}$$

where:
$F_2 - F_1$ - increment of load in the linear part of the load – deformation in N (Figure 2) / *promjena opterećenja u linearnom dijelu dijagrama opterećenje – deformacija u njutnima (sl. 2)*
$w_2 - w_1$ - increment of deformation (mm) corresponding to the increment of load F_2 - F_1 / *promjena deformacije u milimetrima koja odgovara promjeni opterećenja*
l_1 - length of a measuring basis to determine the modulus of elasticity / *mjerna osnova za određivanje modula elastičnosti*, mm
I - moment of cross-section inertia / *moment inercije poprečnog presjeka*, mm^4.

2.3 Determination of modulus of elasticity in shear by constant span method
2.3. Određivanje modula elastičnosti pri smicanju metodom konstantnog luka

Measurements of the modulus of elasticity in shear of construction wood and glued laminated wood are associated with considerable difficulties. Using a constant span method, it is possible to obtain values suitable for designing. This method is based on determination of the local modulus of elasticity in bending $E_{\mathrm{m,l}}$ and of the modulus of elasticity in pure bending $E_{\mathrm{m,app}}$ at the constant length of a test specimen and deduction of the effect of loading by pure bending from loading by bending and shear. Modulus of elasticity in shear can be expressed from both moduli of elasticity as follows:

$$G = \frac{k_g \cdot h^2}{l_1^2 \cdot \left(\frac{1}{E_{\mathrm{m,app}}} - \frac{1}{E_{\mathrm{m,l}}} \right)}$$

where
k_{g} - 1.2 (coefficient for square or rectangular cross-section / *koeficijent za kvadratni ili pravokutni poprečni presjek*)
$E_{\mathrm{m,l}}$ - modulus of elasticity / *modul elastičnosti*, N/mm^2
$E_{\mathrm{m,app}}$ - modulus of elasticity in pure bending / *modul elastičnosti pri čistom savijanju*, N/mm^2
l_1 - length of a measuring basis to determine the modulus of elasticity / *mjerna osnova za određivanje modula elastičnosti*, mm.

2.4 Determination of compression strength along the fiber (parallel to the grain)
2.4. Određivanje tlačne čvrstoće uzduž vlakanaca (paralelno s vlakancima)

Dimensions of a test specimen: 30 x 30 x 50 mm (Figure 4). Equipment: Zwick Z 050 testing machine. The number of test specimens: 15 pcs – Parallam, 20 pcs – KVH.

The test specimen was loaded in the sample centre using spherically seated loading heads enabling the application of a compression force free of bending. The loading was carried out at the constant speed of the loading head shift for the maximum loading to be achieved during 300 (± 120) s.

Compression strength along the fiber (parallel to the grain) is calculated according to the following relation:

$$f_{\mathrm{c,o}} = \frac{F_{\max}}{A}, \ \mathrm{N/mm^2}$$

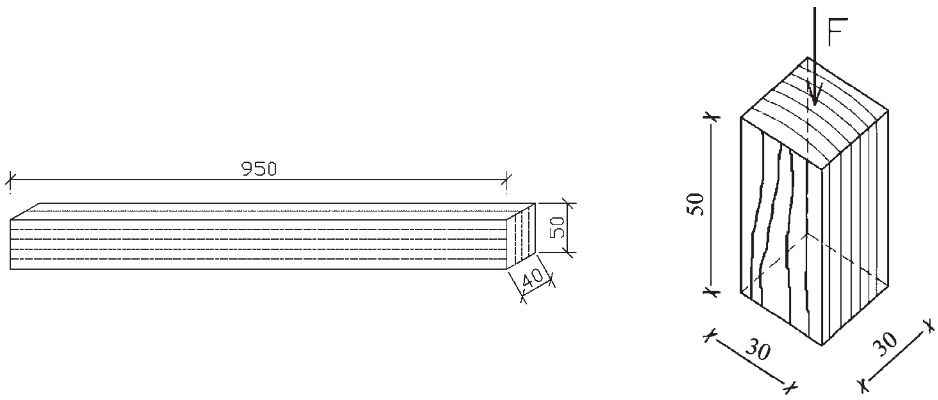


Figure 4 A test specimen to determine the 4-point MOE and compression strength along the fiber
Slika 4. Uzorak za određivanje modula elastičnosti pri savijanju s četiri uporišne točke i određivanje tlačne čvrstoće uzduž vlakanaca

where

F_{max} - maximum load / *maksimalno opterećenje*, N

A - cross-section area / *površina poprečnog presjeka*, mm^2.

2.5 Determination of compression strength across the fiber (perpendicular to the grain)
2.5. Određivanje tlačne čvrstoće okomito na vlakanca

Dimensions of a test specimen: 30 x 30 x 50 mm (Figure 5). Equipment: Zwick Z 050 testing machine. Number of test specimens: 15 pcs – Parallam, the direction of the force action is differentiated to the narrower and wider area of a veneer, 20 pcs – KVH radial direction, 20 pcs – KVH tangential direction.

Compression strength across the fiber $f_{c,90}$ is calculated according to the following relation:

$$F_{c,90} = \frac{F_{c,90,max}}{A}, \quad \text{N/mm}^2$$

where

F_{max} - maximum compression load across the wood fiber / *maksimalno tlačno opterećenje okomito na vlakanca*, N

A - cross-section area / *površina poprečnog presjeka*, mm^2

2.6 Determination of tensile strength across the fiber (perpendicular to the grain)
2.6. Određivanje vlačne čvrstoće okomito na vlakanca

For tensile tests, steel plates have to be stuck to test specimens by means of epoxy resin. The position of a test specimen during the test is guaranteed by gluing. Equipment: Zwick Z 050 testing machine. Test specimens were fixed by butt hinges. The speed of loading was set so that the highest load was to be achieved during 300 (± 120) s.

Dimensions of a test specimen: 120 x 60 x 20 mm (Figure 6). The number of test specimens: 15 pcs Parallam, the direction of the force action is differentiated to the narrower and wider area of a veneer, 15 pcs KVH – radial direction, 15 pcs KVH – tangential direction.

Tensile strength across the fiber is calculated according to the following equation:

$$F_{t,90} = \frac{F_{t,90,max}}{A}, \text{N/mm}^2$$

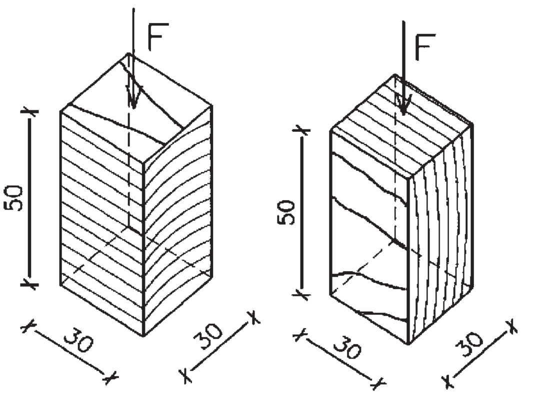
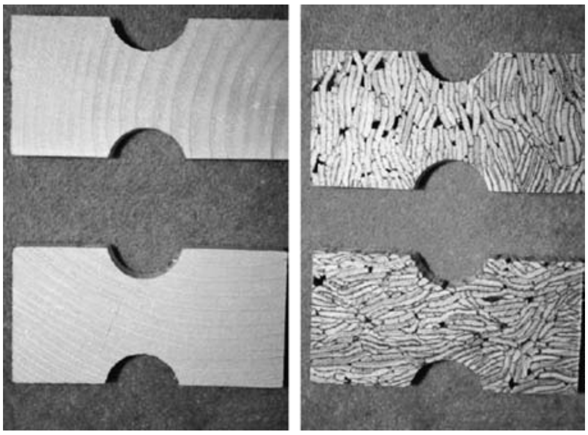


Figure 5 A test specimen to determine compression strength across the fiber (radial and tangential direction)
Slika 5. Uzorak za određivanje tlačne čvrstoće okomito na vlakanca (radijalni i tangencijalni smjer)



a) b)

Figure 6 A test specimen to determine tensile strength across the fiber a) KVH – radial and tangential direction; b) Parallam – narrower and wider area of a veneer
Slika 6. Uzorci za određivanje vlačne čvrstoće okomito na vlakanca: a) KVH – radijalni i tangencijalni smjer; b) uslojeno drvo PSL – uža i šira površina furnira

where:

$F_{t,90,max}$ - maximum tensile loading across the fiber / *maksimalno vlačno opterećenje okomito na vlakanca*, N

A - cross-section area / *površina poprečnog presjeka*, mm^2.

Materials used for the preparation of test specimens were stored for 3 months at the environmental temperature of 20°C and air humidity of about 62%. After sizing the materials, the samples were wrapped up in a steam-proof foil. In a testing room, the measurement of dimensions was carried out and the density and moisture of samples were determined according to following standards:

- CSN EN 322 Standard. Boards of wood. Determination of moisture. CSI Praha. 1994:8
- CSN EN 323 Standard. Boards of wood. Determination of density. CSI Praha. 1994:8
- CSN EN 325 Standard. Boards of wood. Determination of dimensions of test specimens. CSI Praha. 1995:8
- CSN EN 385 Standard. Construction wood extended by indented joints. Requirements for utility properties and minim manufacturing requirements. CSI Praha. 2002:20

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Determination of the local modulus of elasticity in bending
3.1. Određivanje lokalnog modula elastičnosti pri savijanju

The highest applied load in the test must not exceed 40% maximum force F_{max}. This load was determined on the basis of preliminary tests by four-point bending on 10 test specimens.

The scheme of the bending test is demonstrated in Figure 1. The basic characteristics of descriptive statistics to determine the maximum fracture load, bending strength and the local modulus of elasticity are given in Tabs. 1 and 2.

Table 1 Basic characteristics of descriptive statistics – determination of fracture load F_{max} to determine bending strength and the local modulus of elasticity of Parallam and KVH (n = 10)
Tablica 1. Osnovni podaci deskriptivne statistike – određivanje sile loma F_{max} radi utvrđivanja savojne čvrstoće i lokalnog modula elastičnosti za uslojeno drvo PSL i KVH (n = 10)

Statistical quantity *Statistička veličina*	**Parallam** / *Uslojeno drvo PSL*				**KVH** / *Konstrukcijsko cjelovito drvo*			
	F_{max} kN	f_m N/mm²	Deflection *Otklon* mm	Time *Vrijeme* s	F_{max} kN	f_m N/mm²	Deflection *Otklon* mm	Time *Vrijeme* s
$\bar{x}$	6.51	58.61	17.02	199.30	4.25	38.25	18.30	251.60
Standard deviation *standardna devijacija*	0.8793	7.9189	1.6546	11.7856	1.3483	12.1262	7.0304	100.2466
Variance /*varijanca*	0.7732	62.7089	2.7376	138.90	1.8179	147.0454	49.4272	10049.38
Acuteness / *oštrina*	0.8577	0.8612	0.4893	0.7839	-0.1678	-0.1773	4.5652	5.3718
Skewness / *asimetrija*	-0.0489	-0.0562	-0.1466	1.0445	0.7703	0.7686	1.8470	2.0909
Maximum / *maksimum*	8.09	72.8	19.81	224	6.60	59.36	35.80	508
Minimum / *minimum*	4.87	43.8	13.93	187	2.45	22.10	10.36	144
Median / *medijan*	6.49	58.4	17.09	198.50	4.00	36.025	17.125	226.0
Mode / *mod*	N/A	N/A	N/A	190	N/A	N/A	N/A	N/A
Confidence level (95%) *razina pouzdanosti*	0.6290	5.6648	1.1836	8.4309	0.9645	8.6746	5.0293	71.7121

Table 2 Basic characteristics of descriptive statistics – determination of the local modulus of elasticity (n = 20)
Tablica 2. Osnovni podaci deskriptivne statistike – određivanje lokalnog modula elastičnosti (n = 20)

Statistical quantity *Statistička veličina*	**Parallam** / *Uslojeno drvo PSL*				**KVH** / *Konstrukcijsko cjelovito drvo*			
	$w_{40\%}$ mm	$w_{10\%}$ mm	Time $w_{40\%}$ s	$E_{m,l}$ N/mm²	$w_{40\%}$ mm	$w_{10\%}$ mm	Time $w_{40\%}$ s	$E_{m,l}$ N/mm²
$\bar{x}$	0.526	0.121	48.40	14301.89	0.399	0.074	30	11263.90
Standard deviation *standardna devijacija*	0.1231	0.0224	6.4514	3392.991	0.0437	0.01667	4.3286	1097.1826
Variance / *varijanca*	0.0151	0.0005	41.6211	11512391	0.0019	0.0003	18.7368	1203809.6
Acuteness / *oštrina*	0.3844	0.9758	-0.0479	-0.5039	-0.6344	-1.5016	-0.7449	0.7591
Skewness / *asimetrija*	0.7766	0.7915	0.9460	0.2497	0.3135	0.1181	0.5018	0.2746
Maximum / *maksimum*	0.83	0.18	62	21093.80	0.49	0.1	39	13846.10
Minimum / *minimum*	0.35	0.09	40	8437.50	0.32	0.05	24	9000.00
Median / *medijan*	0.49	0.12	46.5	14627.60	0.38	0.075	29.5	11250.00
Mode / *mod*	0.62	0.12	48	14822.60	0.37	0.06	27	11612.09
Confidence level (95%) *razina pouzdanosti*	0.05761	0.0105	3.01193	1587.9690	0.0205	0.0078	2.02585	513.4973

Table 3 Values of forces F_1 and F_2 calculated from mean values of loading forces F (see Tab. 1)
Tablica 3. Vrijednosti sila F_1 i F_2 izračunanih iz srednjih vrijednosti sila opterećenja F (tabl. 1)

Material / *Materijal*	$F_1 = 0.1\ F_{max}$	$F_2 = 0.4\ F_{max}$
Parallam PSL / *Uslojeno drvo PSL*	0.65 kN	2.6 kN
KVH / *Konstrukcijsko cjelovito drvo*	0.42 kN	1.7 kN

Table 4 Basic characteristics of descriptive statistics – determination of modulus of elasticity in pure bending of Parallam and KVH (n = 20)
Tablica 4. Osnovni podaci deskriptivne statistike – određivanje modula elastičnosti pri čistom savijanju za uslojeno drvo PSL i KVH (n = 20)

Statistical quantity *Statistička veličina*	**Parallam** / *Uslojeno drvo PSL*				**KVH** / *Konstrukcijsko cjelovito drvo*			
	$w_{40\%}$ mm	$w_{10\%}$ mm	Time $w_{40\%}$ s	$E_{m,app}$ N/mm^2	$w_{40\%}$ mm	$w_{10\%}$ mm	Time $w_{40\%}$ s	$E_{m,app}$ N/mm^2
$\bar{x}$	0.40	0.11	126.85	5738.02	0.43	0.13	71.10	3629.37
Standard deviation *standardna devijacija*	0.1442	0.0601	20.3219	1730.8540	0.0907	0.0461	24.7320	916.3646
Variance / *varijanca*	0.0208	0.0036	412.9763	2995855.4	0.0082	0.0021	611.6737	839724.05
Acuteness / *oštrina*	1.1531	-0.2231	9.9753	0.0149	-1.0543	-1.0671	-1.4891	1.9015
Skewness / *asimetrija*	0.6179	-0.0598	-2.7979	0.6523	-0.0949	0.0398	-0.4844	1.2965
Maximum / *maksimum*	0.77	0.23	147	8961.40	0.59	0.21	100	6225.80
Minimum / *minimum*	0.18	0.01	52	2821.00	0.27	0.06	34	2564.10
Median / *medijan*	0.375	0.115	133	5447.70	0.45	0.13	80	3390.80
Mode / *mod*	0.37	0.1	135	8961.40	0.48	0.11	80	4000.00
Confidence level (95%) *razina pouzdanosti*	0.0675	0.0281	9.5109	810.0646	0.0424	0.0216	11.5749	428.8718

3.2 Determination of modulus of elasticity in pure bending
3.2. Određivanje modula elastičnosti pri čistom savijanju

The basic characteristics of descriptive statistics to determine the modulus of elasticity in pure bending of Parallam and construction wood KVH are given in Tab. 4.

3.3 Determination of modulus of elasticity in shear by constant span method
3.3. Određivanje modula elastičnosti pri smicanju metodom konstantnog luka

The basic characteristics of descriptive statistics to determine the modulus of elasticity in shear of materials Parallam and construction wood KVH are given in Tab. 5.

3.4 Determination of the bending strength
3.4. Određivanje savojne čvrstoće

The basic characteristics of descriptive statistics to determine the bending strength of Parallam and construction wood KVH are given in Tab. 6.

3.5 Determination of compression strength along the fiber (parallel to the grain)
3.5. Određivanje tlačne čvrstoće uzduž vlakanaca (paralelno s vlakancima)

The basic characteristics of descriptive statistics to determine compression strength along the fiber of materials Parallam and construction wood KVH are given in Tab. 7.

3.6 Determination of compression strength across the fiber (perpendicular to the grain)
3.6. Određivanje tlačne čvrstoće okomito na vlakanca

The basic characteristics of descriptive statistics to determine compression strength across the fiber of construction wood KVH in radial and tangential direction are given in Tab. 8.

The basic characteristics of descriptive statistics to determine compression strength across the wood fiber of Parallam with respect to the wider and narrower face of a veneer are given in Tab. 8.

3.7 Determination of tensile strength across the fiber
3.7. Određivanje vlačne čvrstoće okomito na vlakanca

The basic characteristics of descriptive statistics to determine tensile strength across the fiber of construction wood KVH in radial and tangential direction are given in Tab. 10.

The basic characteristics of descriptive statistics to determine tensile strength across the fiber of Parallam with respect to the wider and narrower face of a veneer are given in Tab.11.

3.8 Comparison of the determined mean values of analyzed materials Parallam and KVH
3.8. Usporedba dobivenih vrijednosti za istraživane materijale

Determination of physical and mechanical properties of construction wood KVH and composite material Parallam was carried out according to the CSN EN 408 Standard Wooden construction. Construction wood and glue-laminated timber. Determination of some physical and mechanical properties.

Based on Tab. 12, it is evident that as against construction wood KVH, Parallam is characterized by markedly higher density (703 kg/m^3). With respect to this higher density, it also reaches higher strength values, particularly of bending strength f_m (59.31 N/mm^2), compression strength parallel to the grain (along the fi-

Table 5 Basic characteristics of descriptive statistics – determination of modulus of elasticity in shear by constant span method of Parallam and KVH (n = 20)
Tablica 5. Osnovni podaci deskriptivne statistike – određivanje modula elastičnosti pri smicanju metodom konstantnog luka za uslojeno drvo PSL i KVH (n = 20)

Statistical quantity *Statistička veličina*	**Parallam** / *Uslojeno drvo PSL*			**KVH** / *Konstrukcijsko cjelovito drvo*		
	Modulus of elasticity in pure bending *Modul elastičnosti pri čistom savijanju* N/mm^2	Local modulus of elasticity *Lokalni modul elastičnosti* N/mm^2	Modulus of elasticity in shear *Modul elastičnosti pri smicanju* N/mm^2	Modulus of elasticity in pure bending *Modul elastičnosti pri čistom savijanju* N/mm^2	Local modulus of elasticity *Lokalni modul elastičnosti* N/mm^2	Modulus of elasticity in shear *Modul elastičnosti pri smicanju* N/mm^2
$\bar{x}$	5737.51	14301.92	528.62	3629.42	11263.90	250.53
Standard deviation *standardna devijacija*	1730.8650	3393.0301	276.4720	916.3157	1097.1826	78.8424
Variance / *varijanca*	2995893.51	11512653.0	76436.77	839634.4	1203809.6	6216.12
Acuteness / *oštrina*	0.0115	-0.5039	0.6706	1.9020	0.7591	0.2261
Skewness / *asimetrija*	0.6536	0.2497	1.1337	1.2967	0.2746	1.0243
Maximum / *maksimum*	8961.40	21093.8	1134.70	6225.80	13846.10	425.60
Minimum / *minimum*	2821.00	8437.50	171.60	2564.10	9000.00	157.90
Median / *medijan*	5438.70	14627.60	485.90	3390.80	11250.00	232.65
Mode / *mod*	8961.40	14822.60	N/A	4000.00	11612.90	N/A
Confidence level (95%) *razina pouzdanosti*	810.0697	1587.9869	129.3929	428.8489	513.4975	36.8994

ber) $f_{c,0}$ (49.25 N/mm^2), compression strength perpendicular to the grain (across the fiber) $f_{c,90}$ (2.83-3.67 N/mm^2), local modulus of elasticity in bending $E_{m,l}$ (14 301.92 N/mm^2), modulus of elasticity in pure bending $E_{m,app}$ (5737.51 N/mm^2) and modulus of elasticity in shear G (528.62 N/mm^2).

Only in case of tensile strength perpendicular to the grain $f_{c,90}$ with respect to the wider and narrower face of a veneer determined in Parallam or in radial and tangential direction determined in construction wood KVH, higher values were determined in KVH (3.41-1.70 N/mm^2).

Table 6 Basic characteristics of descriptive statistics – determination of the bending strength of Parallam and KVH (n = 20)
Tablica 6. Osnovni podaci deskriptivne statistike – određivanje savojne čvrstoće za uslojeno drvo PSL i KVH (n = 20)

Statistical quantity *Statistička veličina*	**Parallam** / Uslojeno drvo PSL				**KVH** / Konstrukcijsko cjelovito drvo			
	Force F *Sila F* kN	f_m N/mm^2	Deflection *Otklon* mm	Time *Vrijeme* s	Force F *Sila F* kN	f_m N/mm^2	Deflection *Otklon* mm	Time *Vrijeme* s
$\bar{x}$	6.59	59.31	17.67	216.10	5.66	50.96	23.05	285.10
Standard deviation *standardna devijacija*	1.2681	11.3701	1.9336	19.7561	1.0558	9.5104	5.8787	66.1353
Variance / *varijanca*	1.6081	129.2786	3.7499	390.3053	1.1148	90.4485	34.5585	4373.8842
Acuteness / *oštrina*	-0.6032	-0.6478	0.7341	-1.1418	-1.4940	-1.5031	-0.7688	-0.8239
Skewness / *asimetrija*	0.3488	0.3319	-0.1840	-0.0856	-0.1493	-0.1548	0.6030	0.5716
Maximum / *maksimum*	9.27	83.04	21.85	247	7.34	65.99	34.63	407
Minimum / *minimum*	4.67	42.03	13.30	185	4.01	36.10	14.27	190
Median / *medijan*	6.74	60.71	17.73	215.50	6.08	54.93	21.59	259.50
Mode / *mod*	6.02	54.18	N/A	204	6.33	N/A	N/A	N/A
Confidence level (95%) *razina pouzdanosti*	0.5935	5.3214	0.9062	9.2461	0.4941	4.4510	2.7513	30.9523

Table 7 Basic characteristics of descriptive statistics – determination of compression strength along the wood fiber of materials Parallam and KVH (n = 20)
Tablica 7. Osnovni podaci deskriptivne statistike – određivanje tlačne čvrstoće uzduž vlakanaca za uslojeno drvo PSL i KVH (n = 20)

Statistical quantity / *Statistička veličina*	**Parallam** / *Uslojeno drvo PSL*			**KVH** / *Konstrukcijsko cjelovito drvo*		
	Loading force F_{max} *Sila opterećenja* kN	Compression strength $f_{c,0}$ *Tlačna čvrstoća* N/mm²	Deformation - Compression *Deformacija - stlačenje* mm	Loading force F_{max} *Sila opterećenja* kN	Compression strength $f_{c,0}$ *Tlačna čvrstoća* N/mm²	Deformation - Compression *Deformacija - stlačenje* mm
$\bar{x}$	77.37	49.25	1.27	34.50	37.81	0.42
Standard deviation *standardna devijacija*	13.9547	8.8825	0.3332	2.3519	2.5526	0.0855
Variance / *varijanca*	194.7350	78.8981	0.1110	5.5316	6.5158	0.0073
Acuteness / *oštrina*	-1.7231	-1.7234	1.3068	0.3403	0.3746	-0.5093
Skewness / *asimetrija*	0.1307	0.1307	1.4885	-0.3933	-0.4274	0.5901
Maximum / *maksimum*	97.84	62.28	2.09	38.16	41.84	0.60
Minimum / *minimum*	57.07	36.33	0.86	28.78	31.56	0.31
Median / *medijan*	72.96	46.44	1.15	34.72	38.07	0.41
Mode / *mod*	N/A	N/A	1.14	N/A	N/A	0.31
Confidence level (95%) *razina pouzdanosti*	6.5310	4.1571	0.1559	1.1007	1.1947	0.0399

Analyzed materials showed not only different values of monitored mechanical properties but they also showed different behavior in actual tests.

For example, in the implementation of the bending strength tests, total fracture of a specimen occurred in Parallam only in two cases. With other specimens deformations occurred and, however, the course of the material fracture was not as dramatic as in case of KVH. In these bending tests, no visible deformations occurred in Parallam in the upper part of a test specimen in the place of pressed fibers. On the other hand, this deformation was clearly evident in KVH.

In the analysis of tensile strength across the grain in KVH, the rupture of specimens occurred in both directions (radial and tangential). Nevertheless, the typical rupture of specimens in Parallam did occur. Only lower values were found (see Tab. 12). In tests of compression strength perpendicular to the grain (across the fiber), deformations became evident by the minimum change in the specimen height.

Table 8 Basic characteristics of descriptive statistics – determination of compression strength across the wood fiber of KVH (n = 20)
Tablica 8. Osnovni podaci deskriptivne statistike – određivanje tlačne čvrstoće okomito na vlakanaca za KVH (n = 20)

Statistical quantity / *Statistička veličina*	**Material – KVH** / *Materijal – konstrukcijsko cjelovito drvo*			
	Radial direction / *Radijalni smjer*		**Tangential direction** / *Tangencijalni smjer*	
	Loading force F_{max} *Sila opterećenja* kN	Compression strength $f_{c,90}$ *Tlačna čvrstoća* N/mm²	Loading force F_{max} *Sila opterećenja* kN	Compression strength $f_{c,90}$ *Tlačna čvrstoća* N/mm²
$\bar{x}$	1.94	2.16	1.88	2.07
Standard deviation *standardna devijacija*	0.1543	0.1723	0.3296	0.3602
Variance / *varijanca*	0.0238	0.0297	0.1086	0.1297
Acuteness / *oštrina*	0.0596	-0.0311	2.4833	2.0721
Skewness / *asimetrija*	-0.1391	-0.1517	1.2420	1.1365
Maximum / *maksimum*	2.20	2.44	2.85	3.10
Minimum / *minimum*	1.61	1.79	1.50	1.63
Median / *medijan*	1.94	2.16	1.87	2.04
Mode / *mod*	1.84	2.04	2.07	1.71
Confidence level (95%) *razina pouzdanosti*	0.0722	0.0806	0.1542	0.1686

Table 9 Basic characteristics of descriptive statistics – determination of compression strength across the wood fiber of Parallam ($n = 20$)
Tablica 9. Osnovni podaci deskriptivne statistike – određivanje tlačne čvrstoće okomito na vlakanaca za uslojeno drvo PSL ($n = 20$)

Statistical quantity *Statistička veličina*	**Parallam** / *Uslojeno drvo PSL*			
	Wider face of a veneer *Šira strana furnira*		**Narrower face of a veneer** *Uža strana furnira*	
	Loading force F_{max} *Sila opterećenja* kN	Compression strength $f_{c,90}$ *Tlačna čvrstoća* N/mm^2	Loading force F_{max} *Sila opterećenja* kN	Compression strength $f_{c,90}$ *Tlačna čvrstoća* N/mm^2
$\bar{x}$	2.55	2.83	3.31	3.67
Standard deviation / *standardna devijacija*	0.5989	0.6630	1.0109	1.1191
Variance / *varijanca*	0.3588	0.4395	1.0220	1.2552
Acuteness / *oštrina*	-0.3804	-0.3918	0.0120	0.0316
Skewness / *asimetrija*	0.3906	0.3805	0.5638	0.5686
Maximum / *maksimum*	3.70	4.10	5.41	6.00
Minimum / *minimum*	1.71	1.90	1.80	2.00
Median / *medijan*	2.61	2.90	3.16	3.50
Mode / *mod*	2.70	3.00	3.61	4.00
Confidence level / *razina pouzdanosti* (95%)	0.3317	0.3671	0.5598	0.6197

Parallam demonstrated higher strength properties as against KVH although the prepared specimens of KVH were in perfect condition. Parallam showed a certain construction deficiency in the form of lengthwise cavities, generated in its manufacture by continuous faulty compression of particular veneer strands. These cavities cannot logically transfer any load. We assume that this construction drawback of Parallam occurred just in test specimens of small dimensions used in these destructive tests of selected mechanical properties.

Although Parallam generally shows higher values of the majority of mechanical properties as against construction wood KVH, these differences would be even higher in favor of Parallam, if these tests could be realized on specimens of construction dimensions. In these specimens, the construction deficiency of Parallam 2.0 E mentioned above would be distributed within the cross-section and in KVH, and the presence of various wood defects would become evident.

Table 10 Basic characteristics of descriptive statistics – determination of tensile strength across the fiber of KVH in radial and tangential direction
Tablica 10. Osnovni podaci deskriptivne statistike – određivanje vlačne čvrstoće okomito na vlakanaca za KVH u radijalnome i tangencijalnom smjeru

Statistical quantity *Statistička veličina*	**Material – KVH** / *Materijal – konstrukcijsko cjelovito drvo*			
	Radial direction / *Radijalni smjer*		**Tangential direction** / *Tangencijalni smjer*	
	Loading force F_{max} *Sila opterećenja* kN	Tensile strength $\perp f_{c,90}$ *Vlačna čvrstoća* N/mm^2	Loading force F_{max} *Sila opterećenja* kN	Tensile strength $\perp f_{c,90}$ *Vlačna čvrstoća* N/mm^2
$\bar{x}$	2.26	3.41	1.12	1.70
Standard deviation *standardna devijacija*	0.6807	1.0301	0.2226	0.3346
Variance / *varijanca*	0.4634	1.0611	0.0496	0.1119
Acuteness / *oštrina*	1.0662	1.1981	-0.0732	-0.0173
Skewness / *asimetrija*	0.0098	-0.0946	0.5475	0.6112
Maximum / *maksimum*	3.61	5.41	1.60	2.43
Minimum / *minimum*	0.78	1.11	0.76	1.17
Median / *medijan*	2.15	3.23	1.06	1.60
Mode / *mod*	2.35	N/A	0.97	1.99
Confidence level (95%) *razina pouzdanosti*	0.3770	0.5705	0.1233	0.1853

Table 11 Basic characteristics of descriptive statistics to determine tensile strength perpendicular to the grain (across the fiber) with respect to the wider and narrower face of a veneer – Parallam
Tablica 11. Osnovni podaci deskriptivne statistike za određivanje vlačne čvrstoće okomito na vlakanaca za uslojeno drvo PSL s obzirom na užu i širu stranu furnira

Statistical quantity *Statistička veličina*	**Parallam** / *Uslojeno drvo PSL*			
	Wider face of a veneer *Šira strana furnira*		**Narrower face of a veneer** *Uža strana furnira*	
	Loading force F_{max} *Sila opterećenja* kN	Tensile strength $\perp f_{c,90}$ *Vlačna čvrstoća* N/mm²	Loading force F_{max} *Sila opterećenja* kN	Tensile strength $\perp f_{c,90}$ *Vlačna čvrstoća* N/mm²
$\bar{x}$	0.56	0.87	1.02	1.56
Standard deviation / *standardna devijacija*	0.1179	0.1817	0.12923	0.1976
Variance / *varijanca*	0.0139	0.0330	0.0167	0.0390
Acuteness / *oštrina*	-0.0514	-0.0678	-1.1217	-1.0837
Skewness / *asimetrija*	-0.4455	-0.4269	0.0155	0.0057
Maximum / *maksimum*	0.75	1.16	1.22	1.88
Minimum / *minimum*	0.32	0.49	0.84	1.28
Median / *medijan*	0.58	0.89	1.04	1.59
Mode / *mod*	0.65	0.93	0.85	N/A
Confidence level (95%) *razina pouzdanosti*	0.0653	0.1006	0.0716	0.1094

Table 12 Mean values of selected physical and mechanical properties of analyzed materials KVH and Parallam
Tablica 12. Srednje vrijednosti određenih fizikalnih i mehaničkih svojstava istraživanih materijala – konstrukcijskoga cjelovitog drva i PSL uslojenog drva

<table>
<tr><th></th><th>Unit
Jedinica</th><th colspan="2">Parallam
Uslojeno drvo PSL</th><th colspan="2">KVH
Konstrukcijsko cjelovito drvo</th></tr>
<tr><td>Physical properties / Fizikalna svojstva</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Density / Gustoća</td><td>kg/m³</td><td colspan="2">703</td><td colspan="2">432</td></tr>
<tr><td>Moisture / Sadržaj vode</td><td>%</td><td colspan="2">10.9</td><td colspan="2">11.9</td></tr>
<tr><td>Mechanical properties / Mehanička svojstva</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Bending strength f_m / Savojna čvrstoća f_m</td><td>N/mm²</td><td colspan="2">59.31</td><td colspan="2">50.96</td></tr>
<tr><td>Compression strength ∥ $f_{c,o}$
Tlačna čvrstoća ∥ $f_{c,o}$</td><td>N/mm²</td><td colspan="2">49.25</td><td colspan="2">37.81</td></tr>
<tr><td rowspan="2">Compression strength ⊥ $f_{c,90}$
Tlačna čvrstoća ⊥ $f_{c,90}$</td><td rowspan="2">N/mm²</td><td>wider face of a veneer
šira strana furnira</td><td>2.83</td><td>radial direction
radijalni smjer</td><td>2.16</td></tr>
<tr><td>narrower face of a veneer
uža strana furnira</td><td>3.67</td><td>tangential direction
tangencijalni smjer</td><td>2.07</td></tr>
<tr><td rowspan="2">Tensile strength ⊥ $f_{t,90}$
Vlačna čvrstoća ⊥ $f_{t,90}$</td><td rowspan="2">N/mm²</td><td>wider face of a veneer
šira strana furnira</td><td>0.87</td><td>radial direction
radijalni smjer</td><td>3.41</td></tr>
<tr><td>narrower face of a veneer
uža strana furnira</td><td>1.56</td><td>tangential direction
tangencijalni smjer</td><td>1.70</td></tr>
<tr><td>Local MOE $E_{m,l}$ / Lokalni MOE $E_{m,l}$</td><td>N/mm²</td><td colspan="2">14301.92</td><td colspan="2">11263.90</td></tr>
<tr><td>MOE in pure bending $E_{m,app}$
MOE pri čistom savijanju $E_{m,app}$</td><td>N/mm²</td><td colspan="2">5737.51</td><td colspan="2">3629.42</td></tr>
<tr><td>Modulus of elasticity in shear G
Modul elastičnosti pri smicanju G</td><td>N/mm²</td><td colspan="2">528.62</td><td colspan="2">250.53</td></tr>
</table>

4 CONCLUSION
4. ZAKLJUČAK

The aim of this paper was to determine selected physical and mechanical properties of two different construction materials with the same possibilities of using on the basis of destructive tests and comparison of analyzed materials Parallam 2.0 E and construction wood KVH Si in fair -face quality.

Tests of strength properties were carried out according to the CSN EN 408 Standard "Wooden construction. Construction wood and glue-laminated timber. Determination of some physical and mechanical properties", tests of physical properties according to the CSN EN 322 Standard (Determination of moisture content) and CSN EN 323 Standard (Determination of density).

The mean values including the basic characteristics of descriptive statistics of analyzed materials Parallam and construction wood KVH are presented in Tabs. 1-11, and mean values of analyzed properties of Parallam and KVH are presented in Tab. 12. Based on Tab. 12, it is evident that as against construction wood KVH, Parallam is characterized by markedly higher density (703 kg/m^3). With respect to this higher density it also reaches higher strength values, particularly of bending strength f_m (59.31 N/mm^2), compression strength parallel to the grain (along the fiber) $f_{c,0}$ (49.25 N/mm^2), compression strength perpendicular to the grain (across the fiber) $f_{c,90}$ (2.83-3.67 N/mm^2), local modulus of elasticity in bending $E_{m,l}$ (14 301.92 N/mm^2), modulus of elasticity in pure bending $E_{m,app}$ (5737.51 N/mm^2) and modulus of elasticity in shear G (528.62 N/mm^2). Only in case of tensile strength perpendicular to the grain $f_{c,90}$ with respect to the wider and narrower face of a veneer determined in Parallam or in radial and tangential direction determined in construction wood KVH, higher values were determined in KVH (3.41-1.70 N/mm^2).

The analyzed materials showed not only different values of monitored mechanical properties but they also showed different behavior in actual tests. For example, in the implementation of the bending strength tests, total fracture of a specimen occurred in Parallam only in two cases, while in KVH in all specimens.

When comparing both analyzed materials from the aspect of purchase costs, it is necessary to state that about double values of the majority of analyzed mechanical properties of Parallam as against construction wood KVH are insignificant. The price of 1 m^3 of construction wood KVH is about EUR 250 and the price of Parallam is about EUR 1540/m^3, converted from GBP according to the current exchange rate and calculated from the purchase price free of delivery costs from the UK to the CR. This high price is the main reason of the minimum use of Parallam as against construction wood KVH, the processing of which shows a steady increase.

5 REFERENCES
5. LITERATURA

1. Hrázský, J.; Král, P., 1999: Progresivní konstrukční materiály (*Progressive construction materials*). In: Truhlářské listy (2):10-12.
2. Kolb, J., 2008: Holzbau mit system. Tragkonstruktion und Schichtaufbau der Bauteile. Birkhäuser Verlag. 319 p.
3. Král, P.; Hrázský, J., 2006: Kompozitní materiály na bázi dřeva. Část 2: Dýhy a vrstvené masivní materiály (*Wood-based composite materials. Part 2. Veneers and laminated massive materials*). MZLU v Brnì. 210 pp.
4. Kuklík, P., 2006: Dřevěné konstrukce (*Timber construction*). IC CKAIT Praha. 171 p.
5. Vanìrek, J. et al. 2006: Kovové a dřevěné materiály (*Metal and wooden materials*). FAST VUT Brno. 127 pp.
6. *** CSN EN 322. Desky ze dřeva. Zjišt'ování vlhkosti (*Boards of wood. Determination of moisture content*). CSI Praha. 1994: 8.
7. *** CSN EN 323. Desky ze dřeva. Zjišt'ování hustoty (*Boards of wood. Determination of density*). CSI Praha. 1994: 8.
8. *** CSN EN 325. Desky ze dřeva. Stanovení rozměrů zkušebních těles (*Boards of wood. Determination of dimensions of specimens*). CSI Praha. 1995:8.
9. *** CSN EN 385 Konstrukční dřevo nastavované zubovitým spojem. Požadavky na užitné vlastnosti a minimální výrobní požadavky (*Construction wood extended by indented joints. Demands for utility properties and minimuám manufacturing requirements*). CSI Praha. 2002: 20.
10. *** CSN EN 408 Dřevěné konstrukce. Konstrukční dřevo a lepené lamelové dřevo. Stanovení některých fyzikálních a mechanických vlastností (*Wood structures. Construction timber and glue-laminated timber. Determination of some physical and mechanical properties*). CSI Praha. 2004: 32.
11. *** Timber Frame Houssing, 2006: UK structural recommendations. Trada technology. 104 p.

Acknowledgement
Zahvala

The paper was supported by the Czech Republic Ministry of Education, Youth and Sports, Project No. MSM 6515648902.

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