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Studies on Mechanical Properties of Composite Materials Based on Thermo Modified Timber

Analiza mehaničkih svojstava kompozitnih materijala proizvedenih od toplinski obrađenog drva

Original scientific paper • Izvorni znanstveni rad
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ABSTRACT • *The paper presents the studies of the possibility of using thermo modified wood during the production process of composite materials. According to the studies, the influence of high-temperature processing of raw wood, without access of air oxygen, shows the feasibility of using this type of processing in the production of wood-cement composites to improve their performance properties. It is established that high-temperature pre-treatment significantly reduces the "cement poisons", such as water-soluble sugars in wood, reduces water absorption and swelling pressure development and, consequently, creates a composite material resistant to use under conditions of high humidity. A mathematical model was formulated that allows the determination of the ultimate strength of wood-concrete composite made from thermo modified wood particles according to the treatment temperature of the wood chips and the mixture ratio.*

Key words: *thermo modification, wood-filled composite, wood-concrete*

SAŽETAK • *U radu se iznose rezultati istraživanja mogućnosti uporabe toplinski obrađenog drva za proizvodnju kompozitnih materijala. Istraživanja su pokazala da utjecaj visoke temperature toplinske obrade na drvo, bez prisutnosti kisika, omogućuje primjenu tako obrađenog drva u proizvodnji drvo-cementnih kompozita kako bi se poboljšala njihova svojstva. Utvrđeno je da prethodna obrada drva visokim temperaturama znatno smanjuje "cementne otrove" kao što su vodotopljivi šećeri u drvu, smanjuje upijanje vode i pojavu tlaka bubrenja, što omogućuje proizvodnju kompozitnog materijala koji je otporan pri uporabi u uvjetima visoke vlažnosti. Izrađen je matematički model koji omogućuje određivanje čvrstoće kompozita drvo-beton proizvedenoga od topliski modificiranih drvnih čestica u ovisnosti o temperaturi obrade iverja i omjeru mješavine drva i betona.*

Ključne riječi: *toplinska modifikacija, kompoziti od drva, kompozitni materijal drvo-beton*

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1 INTRODUCTION
1. UVOD

In recent years, there has been an increasing interest in timber and related products for use in construction, because of the possibility of obtaining foundamentally new materials with improved properties - composites. However, besides good properties (low average density, ease of processing, in particular, with fragmentation, etc.), wood chips also have negative qualities that make it difficult to obtain a material of high strength (Nanazashvily, 1974, 1981, 1984, 1990): high chemical aggressiveness, significant volumetric humidity of deformation and development of swelling pressure, a significant anisotropy, high permeability, low adhesion relative to the cement stone; considerable resilience during compaction of the mixture.

Traditional methods of wood modification (mechanical, chemical) have practically exhausted its possibilities. So it is urgent to find and develop new technologies based mostly on physical impacts, for example high temperature without air access, which would improve the quality and competitiveness of wood products. At the same time, the well known technology of thermal wood modification (Pat. EP-0759137, 1998), which increases longevity (Jamsa and Viitaniemi, 2001), reduces water absorption and swelling of the wood (Calonego *et al*., 2010). However, in the manufacture of composite materials, this technology is still unexplored.

Therefore, the present study had the following objectives: to assess experimentally the effect of high temperature on physical properties, chemical composition and structure of the wood filler, and to develop recommendations for improving the manufacturing processes of wood-composite materials that enhance their mechanical properties.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

This paper presents the results of the properties of composite material, in which heat-treated wood particles are used as a filler, and cement is used as a binder (Razumov *et al*., 2009, 2010). Sheets of birch veneer were used to get wood particles of specific sizes. These sheets were cut and split into three fractions of wood chips with an average length of 20, 40 and 60 mm and a width ranging between 3 and 5 mm. For the manufacture of modified wood, concrete chips were used: not subjected to special types of processing; heat treated at various temperatures prior to the termination of mass loss.

Thus-obtained wood chips were subjected to heat treatment in the temperature range 160 – 220 °C prior to the termination of mass loss in the experimental vacuum-contact apparatus, consisting of a sealed chamber for heat treatment connected with the vacuum pump (Khasanshin *et al*., 2010). Heat supply to the treated material was carried out by contact method with the help of thermo joining surfaces, normally a perforated metal plate heated by filaments and thermally insulated on the side opposite to the processed material with porous and moisture-breathable material (Safin *et al*., 2009, 2010). While conducting thermo modification, the wood particles were heated to a certain temperature (between 160 and 220 °C) and weighed every half an hour. The end of treatment was determined when the decrease of the sample mass (wood chips), weighted at an interval of 30 minutes, was less than 3 %.

Treated in this way, wood chips were used for studying the properties of thermo modified wood as a filler in composite materials, as well as for the manufacture of wood-filled composite – wood concrete - in order to further study its mechanical properties.

Studies of thermo modified wood as a filler in composite materials were carried out based on the following main factors: wetting property – in composite compositions such as “wood - mineral binding substance” determines adhesive interaction between timber and binder; the content of water-soluble reduced substances - affects the cementation of mineral binders, water-absorption and swelling pressure - determines the development of internal-strain during operation of the composite and, hence, its longevity.

Studies on wetting property of thermo modified wood were conducted by determining the contact angle at rest drops using a microscope equipped with an optical graphometer. The study on the content of soluble reducing substances and the development of swelling pressure were carried out by Russian State standards 19222-84, and 21312-75 with the help of titrimetric analysis.

Samples of wood concrete were made by mixing wood chips (wood : cement in accordance with the weight 1:3, 1:2.5, 2:3) and cement mark 400 and water (water to cement ratio varied between 1:4 to 1:1 at intervals of 0.05) in certain proportions according to the experiment plan. These samples were molded in metal containers with the dimensions 100x100x100 mm and the mixture was sealed with the help of using the vibrating table for a previously defined time sufficient to complete the mixture shrinkage - 7 min. The molded mixture was kept in containers for a day and then it was removed and conditioned in the premises for 30 days to reach full cementation.

After that, samples were subjected to cyclical wetting and drying in order to study the negative impact of the swelling pressure of wood filler. At the same time, the samples were immersed in water at room temperature for 5 days, and dried in an oven at 105 °C to constant weight. There were 20 “wetting-drying” cycles, after which changes occurred in maximum compression strength.

In order to study composite materials based on the strength of compression, the Sz-5-1 testing machine was used. The purpose of these pilot studies was to investigate the variation of the strength characteristics of the composite material due to changes in the physical-chemical and physical-mechanical properties of wood filler in high-temperature heat treatment.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Results of experimental studies of thermo modified wood as a filler for composite materials are shown in Figures 1-3. Graphic analysis of the dependences in Figure 1 shows the reduction of the wetting property of wood with the increase of the treatment temperature, which may have a negative effect on the adhesive interaction between the wood and binder, meaning that creating a mixture requires a more thorough mixing of the components. However, the result of research of the content of water-soluble substances showed that thermo modification causes reduction of these substances, by more than 40 %, which in turn is beneficial to the strength of composite materials.

The results of experimental studies of thermo modified wood in the development of swelling pressure are shown in Figure 2. The graphs show that with the increase of the treatment temperature, swelling pressure of wood is significantly reduced, which applied to the wood-filler is a positive factor, and can lead to the improvement of performance properties of wood concrete.

As a result of studies for determining the crush strength of wood concrete made from heat-treated wood particles that were subjected to 20 wetting and

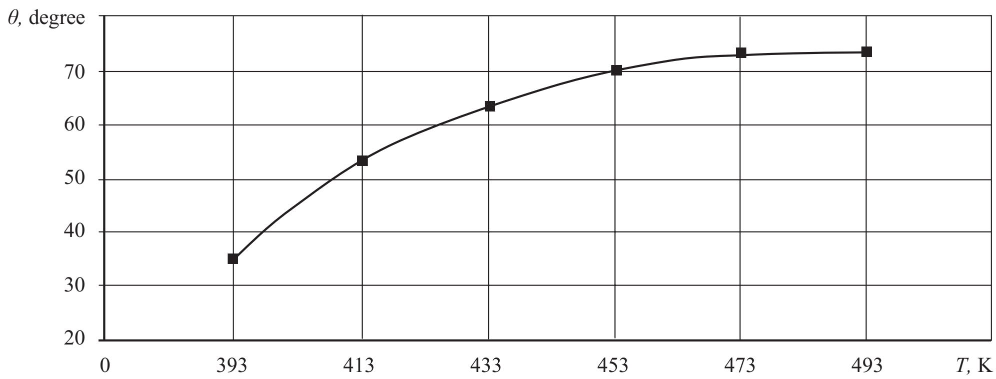

Figure 1 The dependence of the contact angle on the processing temperature
Slika 1. Ovisnost kontaktnog kuta o temperaturi obrade

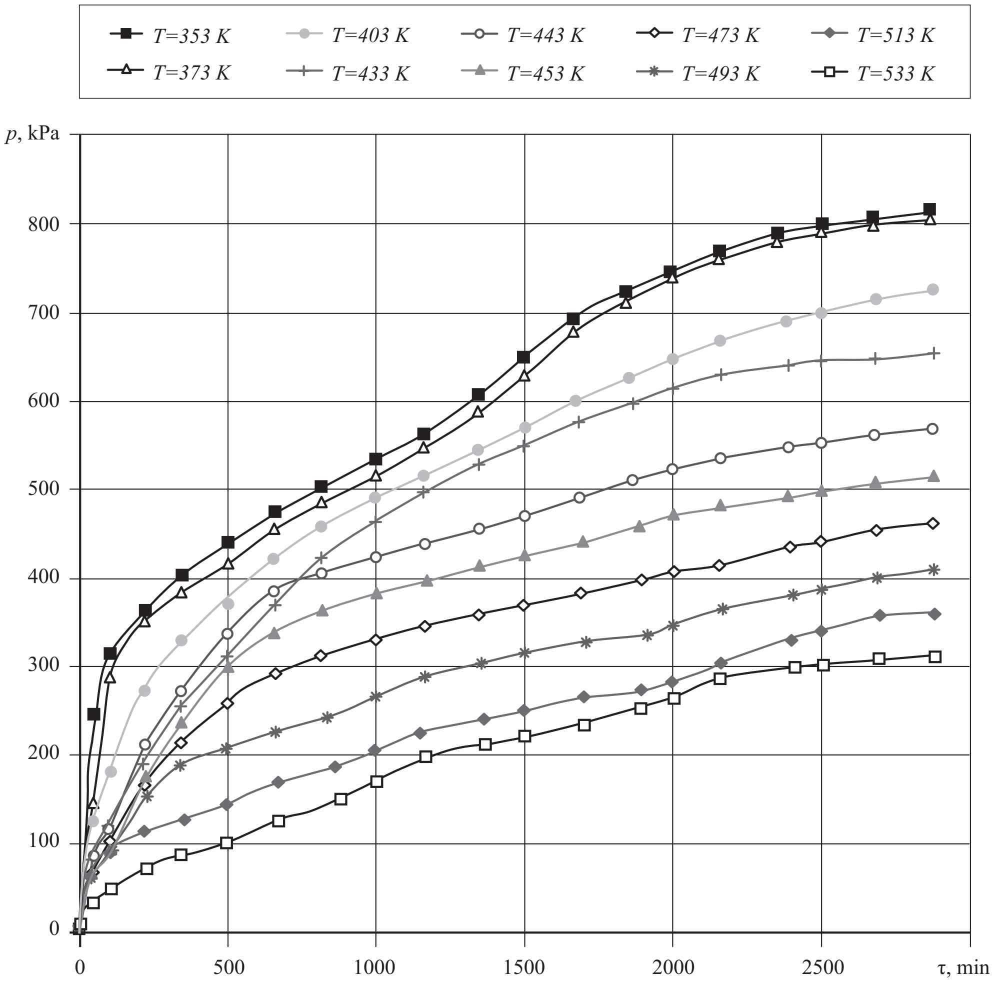

Figure 2 The development of swelling pressure of modified wood treated at different temperatures
Slika 2. Razvoj tlaka bubrenja u modificiranom drvu pri različitim temperaturama obrade

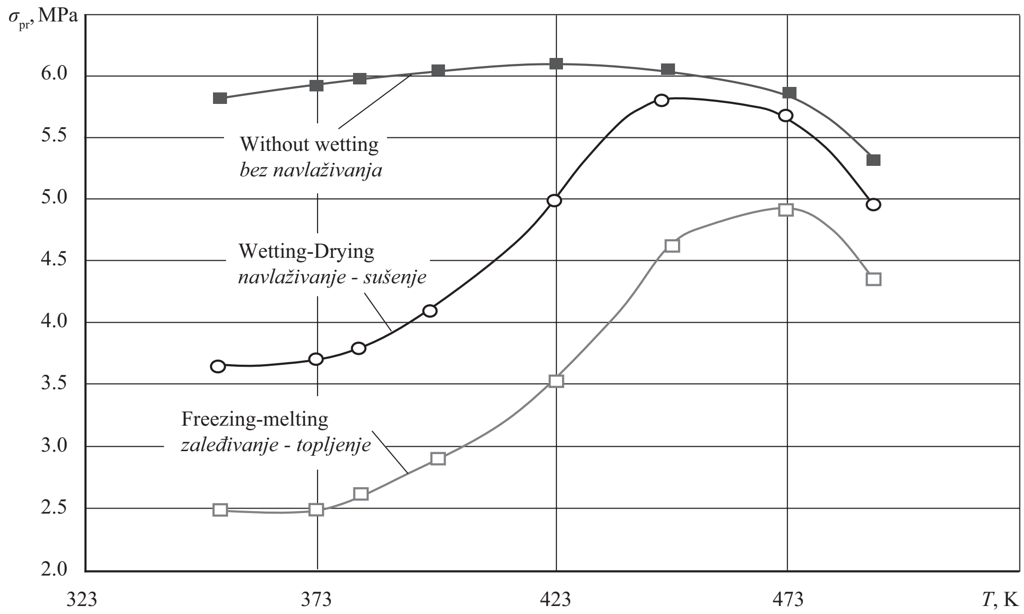

Figure 3 Maximum compression strength of wood concrete samples made from heat-treated wood particles
Slika 3. Maksimalna tlačna čvrstoća uzoraka kompozita drvo-beton izrađenih od toplinski obrađenih drvnih čestica

drying cycles, and 20 freezing and thawing cycles, graphical dependence was obtained as presented in Figure 3. The graph shows that the preliminary thermo modification of wood particles during the production process of wood concrete can significantly improve the performance properties of this material by heat impacts in the range 455 - 475 K and, consequently, expand the range of its use. To be specific, wood concrete may be used under conditions of high humidity.

During experimental studies, the influence was also determined of mixing ratio on the mechanical properties of wood concrete. Thus, as a result of processing the experimental data, it has been found that the thermal treatment of the chip reduces water-cement ratio (Figure 4), which can be explained by a significant reduction in water absorption of thermo modified wood particles as compared to the untreated ones. As a result of reconnaissance experiments, it was determined that the optimum water-cement ratio for heat-treated fillers was 0.45.

Figure 5 shows the dependence of ultimate strength in compression of wood concrete on the length of the chip. The analysis of the obtained dependence shows that the increase of compression strength occurs with the decrease of the size of wood filler, as a result of the increased contact area between wood particles and of increased thickness of the binder (cement) layer.

Processing the experimental results, the dependence of ultimate strength of the composite material in compression on the ratio of the mass of wood chips to the mass of the mineral-binder was obtained. The resulting dependence presented in Figure 6 shows a decrease in strength with the increase of wood content in relation to the binder.

As planned, based on the results of the experiment a mathematical model was formulated for wood-com-

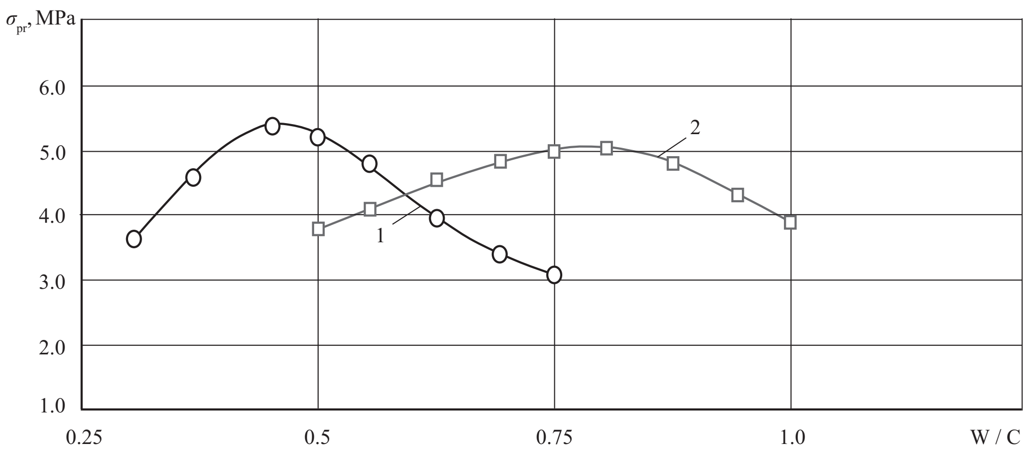

Figure 4 Changes in maximum compression strength of wood concrete depending on the "water-cement" ratio: 1 – filler, heat-treated at T = 473 K; 2 – filler, no specific treatment done
Slika 4. Promjene maksimalne tlačne čvrstoće kompozita drvo-beton u ovisnosti o omjeru vode i cementa: 1 – punilo toplinski obrađeno pri T = 473 K; 2 – punilo toplinski neobrađeno

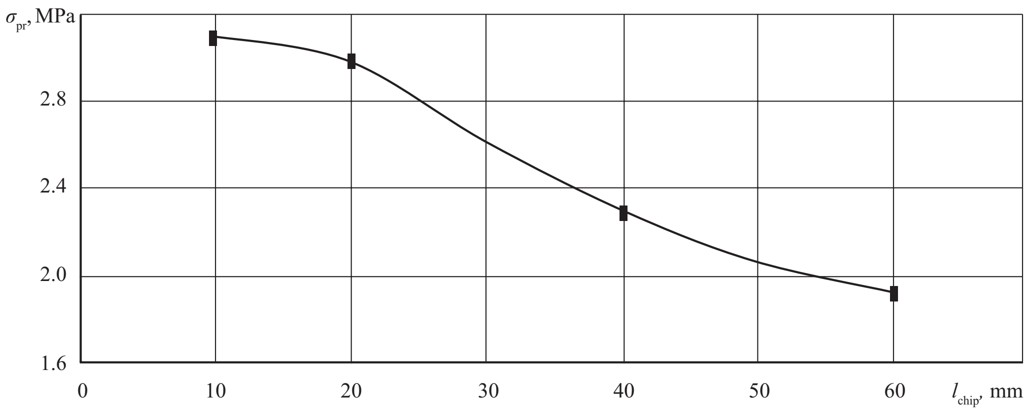

Figure 5 Maximum compression strength of wood concrete depending on the length of the chip
Slika 5. Maksimalna tlačna čvrstoća kompozita drvo-beton u ovisnosti o duljini iverja

posite material, which allows predicting the ultimate strength of the composite in compression, depending on the amont and treatment regime of wood filler. The obtained empirical equations show that the compression strength of wood concrete depends on use conditions, processing time and the amount of cement per surface unit of wood chips (thickness of cement rock).

The average value of the binder layer is determined by the relation of the initial components in the composition, density of packing, the nature and properties of the chip and binder, as well as the size and magnitude of the specific surface area of the filler. Hence, the thickness of interlayer cement in the contact zone in the structure of wood concrete can be approximately determined by using the empirical expression:

$$\delta = \frac{\alpha \cdot C \cdot K}{H \cdot S_{sp} \cdot \rho_c}, \quad (1)$$

Where C and H – consumption of cement and hogged chips per 1 m^3 of wood concrete, kg; α - coefficient taking into account the technological properties of wood-cement composites; ρ_c - the average density of cement, kg/m^3; S_{sp} - specific surface of hogged chips, m^2/kg; K - the output of cement slurry of normal thickness, part of the whole. In our studies, the coefficients have the following values: $\alpha = 1.25$, $K = 0.5$.

The specific surface area of wood particles S_{sp} of the filler can be determined by a formula that takes into account the surface edges and ends:

$$S_{sp} = \frac{2}{\rho} \cdot \left(\frac{1}{\ell} + \frac{1}{b} + \frac{1}{a} \right), \quad (2)$$

Where ρ - the average wood density in g/cm^3; *l, b, a* - the length, width, thickness, respectively, of a single particle of the chip in cm.

As a result of analytical and experimental studies, the expressions were obtained for the ultimate strength of wood concrete made from thermally modified wood particles depending on the conditions of exploitation:

- When operating in dry conditions (without wetting):

$$\sigma_{w/owetting} = 1.3453 + 0.0859 \cdot T - 0.0012 \cdot T^2 + 6.8085 \cdot 10^{-6} \cdot T^4 + 675 \cdot \delta + 50000 \cdot \delta^2 \quad (3)$$

- When operating in conditions of variable humidity (after 20 cycles of “wetting-drying”)

$$\sigma_{wwetting} = \frac{3.452 - 0.0498 \cdot T + 0.0002 \cdot T^2 - 2.6664 \cdot 10^{-7} \cdot T^3 + 5.7851 \cdot \delta + 30290.544 \cdot \delta^2}{1 - 0.0122 \cdot T + 3.5372 \cdot 10^{-5} \cdot T^2 + 30.3762 \cdot \delta} \quad (4)$$

Thus, the resulting mathematical model allows predicting the ultimate strength for wood concrete in compression depending on the amount and treatment regime of wood filler.

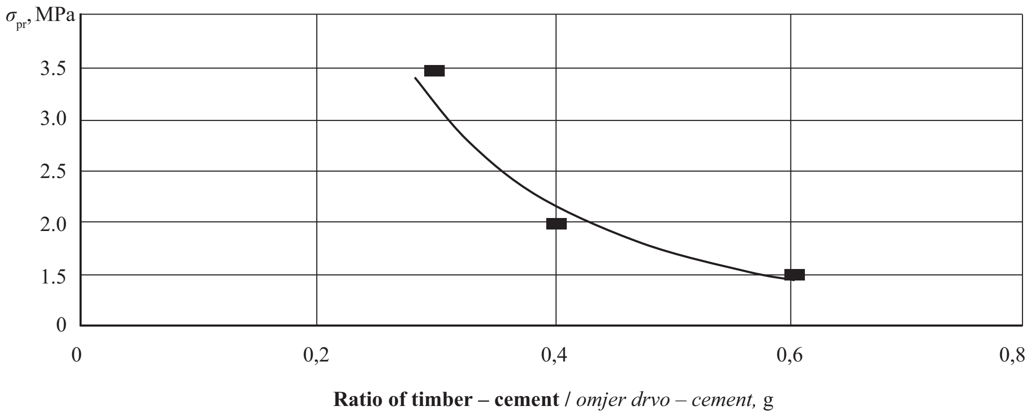

Figure 6 Maximum compression strength of wood concrete samples depending on “wood - cement” ratio
Slika 6. Maksimalna tlačna čvrstoća kompozita drvo-beton u ovisnosti o omjeru drva i cementa

4 CONCLUSION
4. ZAKLJUČAK

As a result of experimental studies, based on the basic properties of composite materials made from thermo modified wood and mineral binders, it was determined that this type of processing of wood chips could be used to improve the performance properties of the composite material. Thermal effects, in the temperature range 180-210 ºC, significantly improve the performance properties of wood concrete, increasing its resistance to moisture. Wood concrete made from wood particles, heat-treated without oxygen, is recommended to use when operating in wet conditions.

5 REFERENCES
5. LITERATURA

1. Calonego, F. W.; Severo, E.T.D.; Ballarin, A.W., 2010: Physical and mechanical properties of thermally modified wood from E. grandis. Eur. J. Wood Prod. DOI 10.1007/s00107-011-0568-5 http://dx.doi.org/10.1007/s00107-011-0568-5.
2. Jamsa, S.; Viitaniemi, P., 2001: Heat treatment of wood: better durability without chemicals. In: Rapp, A.O. Review on heat treatment of wood. In: Special seminar: environmental optimization of wood protection, Antibes, France. Proceedings, Antibes; COST ACTION E 22:21-26.
3. Nanazashvili, I. KH., 1974: Production of wood-concrete from waste wood / I.KH. Nanazashvili; M.K. Mardanov // Background information of COSTI of Ministry of industrial engineering USSR, p. 4-42.
4. Nanazashvili, I. KH., 1981: The effect of swelling pressure of wood filler made of larch and other conifers in the processes of structure formation of wood concrete / I. KH. Nanazashvili // Effective methods and equipment for precast concrete construction in the rural engineering: Works of CSRIE Pselstroy. M., p. 79-84.
5. Nanazashvili, I. KH., 1984: Wood-concrete is an effective construction material. / I.KH. Nanazashvili. M., 122 p.
6. Nanazashvili, I.KH. 1990: Construction materials from wood-cement composite. / I.KH. Nanazashvili. – 2nd edition, revised and amended. – L.: Stroyizdat, 415 p.
7. Pat. EP-0759137 (SE, DK, NL, GB, FR, DE), 1998: Method for processing of wood at elevated temperatures. VTT (VIITANIEMI, P., RANTA-MAUNUS, A., JAMSA, S. and Ek, P). Appl. EP95918005, 11.5.1995. Publ.4.2.1998. 10 p.
8. Safin, R.R.; Belyakov, E.A.; Khasanshin, R.R.; Razumov, E.Y. 2010: Imitation of oak wood by means of thermo modification. Design. Materials. Technology. 3 (14): 95-98.
9. Razumov, E.Y.; Kainov, P.A.; Safin, R.R.; Khasanshin, R.R., 2010: The study of chemical composition of wood subjected to thermo modification by IR spectrometer. // Bulletin of the Kazan Technological University, 9.
10. Razumov, E.Y., 2009: Composite materials based on modified sawdust treated with RF plasma /E.Y. Razumov; R.R. Safin; L.I. Aminov; R.R. Khasanshin // Wood working industry, 1: 24-26.
11. Safin, R.R., 2009: The study of vacuum-conductive process of modifying the heat treatment of wood / R.R. Safin; M.K. Gerasimov; D.A. Akhmetova; E.Y. Razumov // Wood-working industry, 3: 9-11.
12. Razumov, E.Y. 2009: Production of Cellulose Fibre, with the addition of wood pulp / E.Y. Razumov; E.I. Baigildeeva; V.A. Kashapov; L.G. Golubev // Wood-working Industry, 4: 9-10.
13. Safin, R.R., 2009: Plant for processing waste wood industries / Установка для переработки отходов древесных производств / R.R. Safin; A.E. Voronin; E.Y. Razumov; A.T. Sabirov // "Issues of modern science and practice" V.I. Vernadsky University, 5(19): 82-87.
14. Razumov, E.Y., 2009: Apparatus for thermal treatment of waste /E.Y. Razumov; R.R. Safin; M.A. Taimarov; K.Kh. Gilfanov // "Issues of modern science and practice" V.I. Vernadsky University, 5(19): 95-101.
15. Khasanshin, R.R., 2010: Thermo treatment of wood in the flue gases medium / R.R. Khasanshin; E.Y. Razumov; R.R. Safin; N.A. Oladishkina// Newsletter of Moscow State Forest University "Forest newsletter", 4 (73): 95-99.
16. Razumov, E.Y., 2010: Mathematical modeling of thermo treatment process/ E.Y. Razumov; N.A. Oladishkina; R.R. Safin // Proceedings of the XXIIIth International scientific conference "MMTT-23", SSTU, Saratov, p. 38-40.

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Models of Hybrid Springs for Ergonomic Seats and Mattresses

Modeli hibridnih opruga za ergonomska sjedala i madrace

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ABSTRACT • *An ergonomic seat or mattress has to provide optimal and uniform support for the body of a man or a woman with similar or slightly differing size centiles. It is a common opinion that spring systems in upholstered furniture are much more durable and more user-friendly than foam systems. The aim of this study was to develop a new construction of an upholstery spring of bilinear stiffness. On the basis of the conducted studies and analysis of their results, it was shown that traditional bonnell and barrel springs exhibit linear stiffness within the range of deflections of up to 70 % of their initial pitch. New spring designs change stiffness already at deflections of 34% of their pitch. Thanks to this fact they may be used in designs of seats and mattresses for individual users, patients or disabled individuals.*

Keywords: *ergonomics, hybrid spring, mattress, numerical analysis, seat, stiffness*

SAŽETAK • *Ergonomsko sjedište ili madrac mora osigurati optimalnu i ujednačenu potporu za tijelo muškarca ili žene sličnih ili neznatno različitih veličina. Uobičajeno je mišljenje da su opružni sustavi ojastučenog namještaja mnogo izdržljiviji i prilagodljiviji korisniku nego sustavi od pjene. Cilj je ovog rada bio razviti novu konstrukciju ojastučenog namještaja s oprugama bilinearne krutosti. Na temelju provedenih istraživanja i analiza dobivenih rezultata zabilježeno je da tradicionalne bonnell i barrel opruge pokazuju linearnu krutost u rasponu progiba do 70 % od početnog stanja. Opruge nove izvedbe mijenjaju krutost već pri progibu od 34 % od početnog stanja. Zahvaljujući toj činjenici, mogu se upotrebljavati u dizajniranju sjedala i madraca za pojedinačne korisnike, pacijente ili invalidne osobe.*

Ključne riječi: *ergonomija, hibridne opruge, madrac, numerička analiza, sjedalo, krutost*

1 INTRODUCTION
1. UVOD

Functional cushions and mattresses of upholstered furniture should provide the highest comfort of use, since they belong to the group of furniture, with which users have direct contact 14 to 18 hours a day. Thus an ergonomic seat or mattress has to provide optimal and uniform support for the body of a man or a woman with similar or slightly differing size centiles. Among the comfort-quantifying parameters of seats (and analogously also those of mattresses), the ones most frequently cited are: the average human/seat contact pressure, the maximum human/seat contact pressure, the human/seat contact-area size and the extent of symmetry of the human/seat contact-area (Ebe and Griffin, 2001; Grujicic *et al*., 2009; Kamijo *et al*., 1982; Lee *et al*., 1995; Milvojevich *et al*., 2000; Park and Kim, 1997; Park *et al*., 1998; Potter *et al*., 1998; Reed *et al*., 1991; Tewari and Prasad, 2000; Thakurta *et al*., 1995; Uenishi *et al*.,

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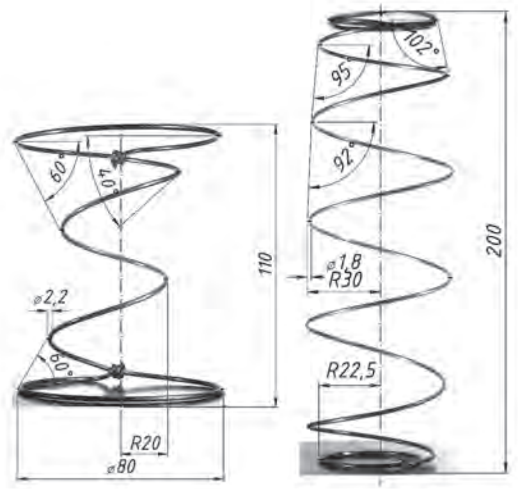
2000; Yun *et al*., 1992; Zhao *et al*., 1994). This comfort depends on the type of material used in the manufacture of seats. It is commonly and justly believed that spring systems in upholstered furniture are much more durable and more user-friendly in use than foam systems. However, a majority of literature items are research studies discussing mainly problems of selection, modeling and analyses of stiffness of foam systems in seats of upholstered furniture (Chow and Odell, 1994; Ebe and Griffin, 2001; Ferrarin *et al*., 2000; Gonga and Kyriakidesa, 2005; Grujicic *et al*., 2009; Linder-Ganz *et al*., 2005; Lusiak and Smardzewski, 2010; Silber *et al*., 2010; Schrodt *et al*., 2005; Smardzewski *et al*., 2008, 2010a,b; Smardzewski and Wiaderek, 2007; Vlaovic *et al*., 2008; Wiaderek and Smardzewski, 2010a,b) or modeling of new foam materials exhibiting auxetic properties (Alderson and Alderson, 2007; Bezazi and Scarpa, 2007, 2009; Brandel and Lakes, 2001; Choi and Lakes, 1992; Lakes, 1987, 1992; Prtre *et al*., 2006; Scarpa *et al*., 2004; Webber, 2008). It was repeatedly stressed in those studies that high comfort of use in case of seats and mattresses is ensured thanks to the application of materials with non-linear, progressive stiffness characteristics. Such characteristics result in a situation when, at slight loads, seats are very soft, they are subjected to considerable deflections and, when in contact with the body of the user, generate slight contact stresses. At increasing loads, the same seats increase their stiffness due to unproportional reduction of deflections. At the same time they equalize mean contact stress at the contact zone with the user's body (Chu, 2000; Smardzewski, 2009; Smardzewski *et al*., 2005, 2006; Smardzewski and Grbac, 1998; Smardzewski and Matwiej, 2007; Verver *et al*., 2004; Wang and Lakes, 2004; Wiaderek and Smardzewski, 2008). However, there is a lack of a wider discussion on the necessity of changes in shapes and stiffness characteristics of springs or spring panels. Several papers were devoted to this problem, indicating the need to replace springs of linear stiffness characteristics with progressive springs (Dzięgielewski and Smardzewski, 1995; Kapica and Smardzewski, 1994; Smardzewski, 1993a,b,c, 2006, 2008a,b, 2009; Smardzewski and Matwiej, 2006). These changes are required due to anthropotechnical aspects, imposing the necessity to take into consideration individual needs of healthy and disabled persons (Ambrose, 2004; Smardzewski, 2009; Smardzewski *et al*., 2005, 2010a; Vlaovic *et al*., 2008; Winkler, 2005).

The aim of this study was to develop virtual (numerical) models of new construction of an upholstery spring of bilinear stiffness to be used in seats and mattresses for users of different weight, height and physique. Such springs should be characterized by slight stiffness at small loads and high stiffness at large loads.

2 METHODS AND MATERIALS
2. METODE I MATERIJALI

In traditional mattresses, sofas or armchairs, panels composed of bonnell biconical springs or barrel springs placed in autonomic pockets are commonly used. They differ in pitch, diameters of inner and outer coils, the number and pitch of coils as well as the diameter of wire from which they were manufactured (Fig.1). Prior to the design process of new spring designs, it was decided to determine stiffness characteristics of springs presented in Figure 1. Springs were manufactured by a Polish mattress producer. A batch of 10 springs was selected from each type of springs for the uniaxial compression test. Testing was performed on a Zwick 1445 testing machine at 100 mm/min. load velocity. During the tests load forces were recorded accurate to 0.01 N and deflections were recorded accurate to 0.01 mm. Loading was interrupted at the deflection of 80 mm in case of bonnell springs and 150 mm for barrel springs. On the basis of evaluation of the recorded compression characteristics, bonnell springs were selected for further tests. It was also decided to verify how contact stress distribution changes at the contact of a child's body and the body of an adult with a mattress made from the above mentioned bonnell springs.



a) b)

Figure 1 Geometry of traditional upholstery springs: a) bonnell, b) barrel

Slika 1. Geometrija tradicionalnih opruga ojastučenog namještaja: a) *bonnell*, b) *barrel*

Using bonnell springs with the geometry presented in Figure 1a, a mattress of 150 x 900 x 2000 mm was manufactured in a Polish mattress factory. The mattress contained a spring core of 10 x 24 springs. The spring core was covered on both sides with felt of 5 mm in thickness and polyurethane foam T2535 of 20 mm in thickness, density of 25 kg/m^3 and stiffness of 3.5 kPa. The upholstery summer-winter layer on the summer side was made from an upholstery fabric (38 % polyester, 25 % cotton, 37 % polypropylene) quilted with cotton at 200 g/m^2, while on the winter side it was made from an upholstery fabric (46 % polyester, 54 % polypropylene) quilted with natural sheep wool at 250 g/m^2. An FSA Bed sensor mat by Vista Medical, Ltd. was placed on the surface of the summer side of the mattress (sensing area 762 x 1920 mm, poly thickness 4 mm, sensor dimensions 20.5 x 57.2 mm, sensor gap 3.4 x 3.1 mm, sensor arrangement 32 x 32, standard calibration range 13.3 kPa). It was calibrated prior to measurements and then the mat was coupled with a computer

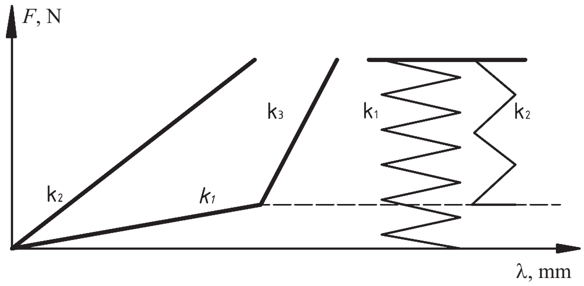


Figure 2 Stiffness of a parallel spring system
Slika 2. Krutost paralelnog sustava opruga

(Intel® Core™ i5 CPU, 2.53 GHz, RAM 4 GB, Windows 7). Load on the mattress was generated by a 3-year old boy of 14.5 kg and 985 mm and a 32-year old man of 76 kg and 1680 mm, both in a lateral recumbent position. Stresses were recorded for each user three times for 5 minutes with a frequency of 10 Hz and accurate to 0.133 kPa. From each measurement a total of 3 000 recordings were registered. For further analyses the recordings were selected, in which values of maximum stresses changed by max. 10 % in five hundred successive recordings. Taking into consideration the obtained distribution and maximum values of contact stresses on the basis of the discussion of results, new designs of biconical springs were developed.

First, it was decided to design a structure and next to numerically verify stiffness of hybrid springs for seats with non-linear compression characteristics. It was assumed that the designed spring should be composed of two parallel linked elementary springs (Fig. 2). Then, compression characteristics of the whole system would also be composed of two segments, one presenting deflection of the element with stiffness k_1 to the moment when coils of the spring with stiffness k_2 settle on the foundation, and the other segment illustrating joint stiffness of both springs with stiffness $k_3 = k_1 + k_2$.

Traditional parallel systems of cylindrical or barrel springs are of little practical value both from the economic and practical point of view. In such a situation the weight of the box spring and the amount of labor required for its assembly increase. Thus an effective solution needs to be searched for by modeling the stiffness of one-piece hybrid conical springs. Progressive stiffness of the designed springs should provide high softness of the system at mild surface loads and considerable stiffness at the action of concentrated forces or forces of high intensity. For the described operation, conditions the minimum structural requirement is a spring composed of two outer cones with low stiffness and an inner spring (cylindrical or conical) of higher stiffness. The analytical solution for stiffness of conical springs was given for the first time by Timoshenko (Timoshenko and Young, 1962). However, that model may be applied for springs with a small pitch, where the coil angle and distances between coils are slight. In case of bonnell springs, there are large pitches, considerable coil angles and large distances between coils. The calculation method for such springs was presented in studies by Smardzewski (1993,a,b,c, 2006, 2008a,b), where stiffness of one spring cone is calculated from the equation:

$$k = \frac{1}{\dfrac{4 \cdot m \cdot n}{G \cdot r^4 \left(R_2^m - R_1^m\right)} \displaystyle\int_0^{R_2 - R_1} R^{m+2} dR} \tag{1}$$

Where:

$$R = \frac{R_2^m - R_1^m}{2\pi n} \cdot \alpha + R_1^m \tag{2}$$

R_1 – the biggest coil radius / *najveći polumjer namotaja*,
R_2 – the smallest coil radius / *najmanji polumjer namotaja*,
α – the angle of the coil spring / *kut namotaja opruge*,
n – number of spring coils / *broj namotaja opruge*,
G – Kirchhoff modulus / *Kirchhoffov modul*,
r – spring wire radius / *polumjer žice opruge*,
m – coefficient dependent on spring stiffness / *koeficijent ovisan o krutosti opruge.*

The above mentioned studies also presented the consistency of analytical solutions with the results of numerical calculations. Despite the fact that the developed mathematical formulas adequately describe the stiffness of modeled structures, from the point of view of practice in design offices, it may be difficult to apply. Thus, it was decided to conduct virtual modeling of spring shape in the Autodesk® Inventor® Professional 2011 environment with the use of computer-integrated CAD/CAE applications, well-known and commonly available to engineers. It was assumed that the dimensions of outer spring cones would be close to the dimensions of spring cones from Figure 1a, at: $2 \le n \le 4$, $R_1 = 20$ mm, $R_2 = 40$ mm, $G = 9 \cdot 10^4$ MPa, $1.4 \le 2r \le 2.2$ mm. On this basis, three models of hybrid springs to be used in a furniture seat were prepared with the dimensions as in Figure 3.

The models are characterized by an identical shape of the outer biconical spring. The difference consists in the shape of the 4-coil inner spring. Model A has an inner spring with coils expanding downwards at a 3° angle. Model B contains a cylindrical spring with an identical diameter of inner coils, while model C comprises a conical spring, which coils narrow downwards at an angle of 5°. A constant distance of 34.4 mm was maintained between the base of the biconical spring and the base of each of the inner springs. This distance results from the adopted assumption that, in case of seat springs within this range of deflections, the stiffness of spring $k_1 \le 0.3$ N/mm. This means that deflections amounting to approx. 1/3 pitch of the spring should be caused by loads of max. 10 N.

Each of the designs (a total of 9) was recorded in an STP file and as solids they were imported to the Autodesk® Algor® Professional 2011 system, performing calculations using the finite element method. Next, appropriate meshes were generated, composed of 20-node solid elements with mesh size of max. 0.5 mm (Fig. 4). Nodes of coils constituting the base of the biconical spring were steadily supported and placed on the Impact Plane surface. This surface made it possible to provide a comprehensive analysis of contact with all surfaces of spring coils. Compression loads were exerted by a stiff

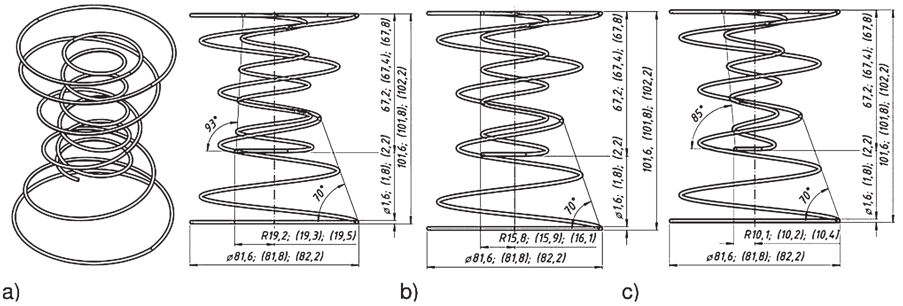


Figure 3 Geometry of hybrid springs type: a) A, b) B, c) C
Slika 3. Geometrija hibridnih opruga tipa: a) A, b) B, c) C

plate ($E = 2{\cdot}10^5$ MPa) placed over the upper spring coils. Moreover, the master and slave surfaces were defined for all plate-spring coil pairs in contact during compression. The plate was steadily supported in the horizontal plane providing freedom of movement in the vertical axis. Surface loads with the total value of 57.04 N were applied onto the upper plate surface, corresponding to the value of compressive force of a bonnell spring during the experimental tests.

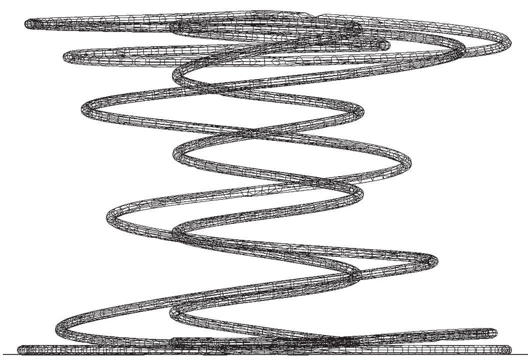


Figure 4 Mesh model of spring
Slika 4. Mrežasti model opruge

The wire material was spring steel with the modulus of elasticity $E = 9{\cdot}10^4$ MPa. The task was defined as non-linear taking into consideration considerable displacements, realizing 100 iterations within 1 second. As a result of calculation, stiffness characteristics were obtained for individual hybrid springs, and they were presented in the form of the dependence *force* = *f*(*displacement*).

The next step in the design process was to develop a spring structure with a non-linear compression characteristic, to be used in mattresses. Here the assumed spring stiffness was $k_1 \leq 0.2$N/mm. This means that deflection of approx. 1/2 pitch of a biconical spring should be caused by loads of max. 10 N. In view of the above recommendations, four successive spring designs were prepared with geometry and dimensions as in Figure 5. Wire with a diameter of 1.4 and 1.6 mm was used in the models. Model D is characterized by an identical shape of the outer biconical spring as that in models A, B and C. The difference consisted in the shape of the inner spring. This spring was composed of three coils expanding downwards at an angle of 3°. In model E, the geometry of the outer biconical spring was changed. The coil angle was increased from 70° to 75°, while the coil angle of the inner spring changed from 3° to 6°. Moreover, the distance between the base of the biconical spring and the base of each of the inner springs was increased to 50 mm. This distance was to provide greater free settlement of coils in the biconical spring than in the previous models. The method of preparation for numerical calculation in models D and E was identical as in case of models A, B and C.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Uniaxial compression of conical and barrel springs indicates a completely different character of

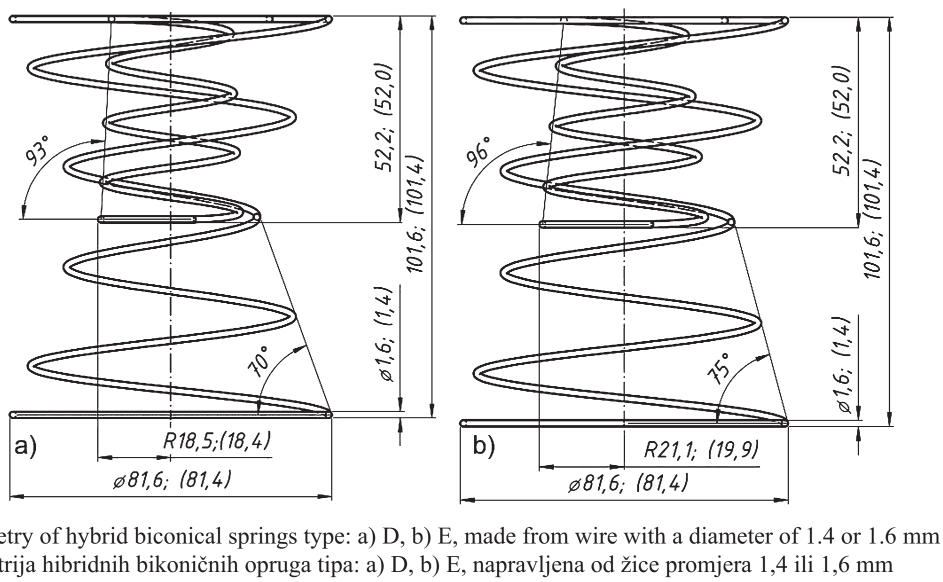


Figure 5 Geometry of hybrid biconical springs type: a) D, b) E, made from wire with a diameter of 1.4 or 1.6 mm
Slika 5. Geometrija hibridnih bikoničnih opruga tipa: a) D, b) E, napravljena od žice promjera 1,4 ili 1,6 mm

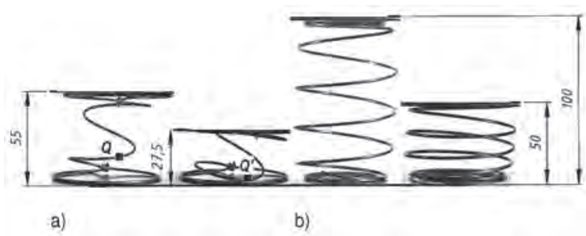


Figure 6 Geometry of deformed upholstery springs: a) bonnell, b) barrel springs
Slika 6. Geometrija deformirane opruge za ojastučeni namještaj: a) *bonnell* opruge, b) *barrel* opruge

work for each of these springs. Figure 6 presents forms of deformation for springs compressed to 50 % and 25 % of their initial pitch. As it can be seen in Figure 6a, coils of bonnell springs defectively settle onto the base within the range of deflections of approx. ¾ of spring pitch. Only when this boundary was exceeded, the first active coil settled on the base and it was only in one point Q. In case of a barrel spring (Fig. 6b), the gradual settlement of coils occurs only at a deflection exceeding 75 % of spring pitch.

Settlement of coils at such a considerable compression of springs results in a situation when their range of progression is practically shifted outside the range of design work. Figure 7 presents mean stiffness characteristics of bonnell and barrel springs determined in the uniaxial compression test. It can be clearly seen from this figure that within the range of displacements of up to 70 mm, a bonnell spring exhibits a linear dependence between force and deflection. Only when this value is exceeded, spring stiffness increases markedly. It is caused by the above mentioned settlement of coils and its support on the base. In contrast, a barrel spring exhibits a much lower, but instead completely linear stiffness characteristic.

Linearity of the design load section of compression characteristics in both springs results in a situation when the same mattress made from identical components and with identical dimensions may be too hard for a child and too soft for an adult. This is indicated by the results of measurements shown in Figure 8. It can be seen that the greatest contact stresses at the contact surface of the boy's body and the mattress concentrate at the head, the shoulder and the pelvis (Fig. 8a). At the site of support for the shoulder its maximum value was 8.79 kPa, while at the support site for the pelvis it was 9.86 kPa. At the body/mattress contact surface in case of the man, the greatest stresses were recorded at the height of the shoulder and head amounting to 12.13 kPa, while at the support site for the pelvis, stresses amounted to 6.79 kPa.

Guttmann (1946), Husain (1953) and Kosiak (1959, 1961) reported a relationship between the amount of pressure, duration of application and the development of tissue damage in canine and rat experiments. Kosiak (1959, 1961) stated that microscopic pathological changes were noted in tissues subjected to as little as 8 kPa for only one hour, although no changes were recorded in the animals that were subjected to pressures of 4.7 kPa for periods up to four hours. According to Hostensa *et al*. (2001), Landis (1930), Takahashi *et al*. (2010) pressures lower than 2.7 to 4 kPa are required to prevent capillary occlusion and pressure discomfort due to prolonged sitting. Reswick and Rogers (1976) developed a relationship between the maximum pressure being experienced by the supporting tissues and the time over which that maximum pressure was applied. If the pressure/time index fell above the curve, subjects exhibited pressure sore histories. If it fell in the acceptable zone, they did not show pressure problems. This classic study has served as the basis for clinical management practices until this day.

Loads of 4 - 8 kPa, as a criterion for comfort, were applied in many studies on designs of seats and mattresses (Brienza et al., 1996; Butcher and Thompson, 2009, 2010; Gross *et al*., 1994; Hamanami *et al*., 2004; Sacks, 1989; Seigler and Ahmadian, 2003; Smardzewski, 2009; Smardzewski et al., 2010a,b; Tewari and Prasad, 2000; Wang *et al*., 2004). On the basis of the presented literature data and those from Figure 8, it can be seen that the selected mattress was too hard for the user of a small weight, having a small body/mattress contact surface area. Also the man's body was inadequately supported. A too high disproportion of stresses in the shoulder and pelvis areas indicates that

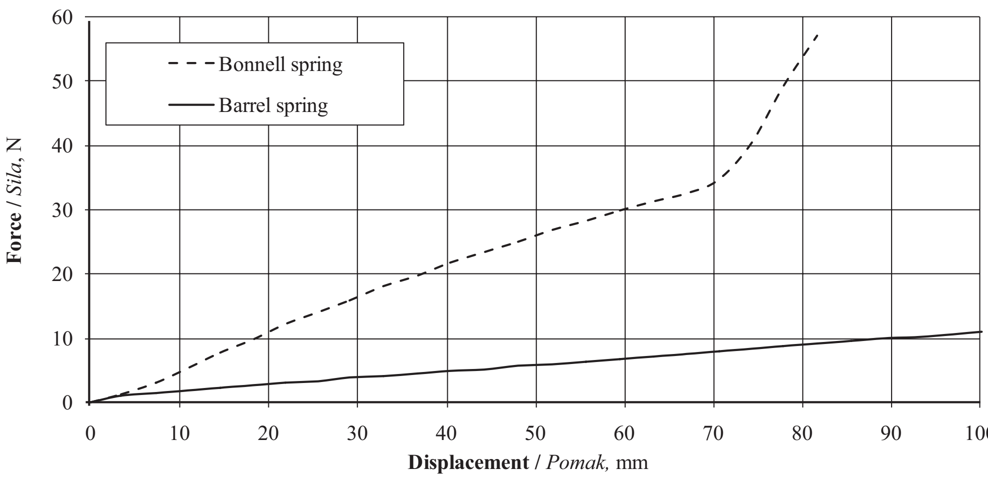


Figure 7 Stiffness of springs in the uniaxial compression test
Slika 7. Krutost opruga pri jednoosnome tlačnom ispitivanju

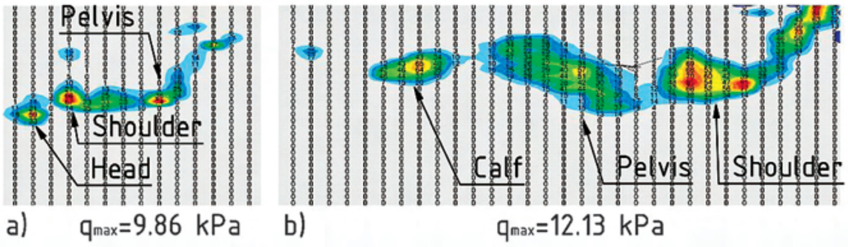


Figure 8 Distribution of contact stresses on the contact surface of the user's body with the mattress: a) a child, b) a man
Slika 8. Raspodjela kontaktnih naprezanja na dodirnoj površini korisnikova tijela i madraca: a) dijete, b) muškarac

springs of a linear stiffness, as those applied in the mattress, press too intensively on the shoulder and moderately on the pelvis.

In view of the above, designs for new, nonlinear springs - type A, B and C were prepared, whose calculated stiffness characteristics are shown in Figures 9, 10 and 11.

When comparing stiffness of springs modeled from wire with a diameter of 1.6 mm (Fig. 9), it can be seen that within the range of displacements from 0 to 34.4 mm only the biconical spring works. Its stiffness in this range of displacements overlaps with stiffness of the barrel spring. From the moment of contact of the first coils of the inner spring with the base stiffness, the whole system increases markedly. Here, the smallest slope of the curve was observed for model A, while it was the greatest for model C. This means that above a load of 7 N, deflections of the spring type A increase faster than those of spring type B, while deflections of spring type B increment faster than deflections of spring C. The two-rate nonlinear stiffness of springs results in a situation when, at a load of 20 N, a traditional bonnell spring deflects by 37 mm, spring type A by 48 mm, spring B by 45 mm, while spring C by 41 mm, respectively. An increase in load up to 40 N causes the bonnell spring to continue to deflect linearly to the value of 74 mm, while spring A to 69 mm, spring B to 60 mm and spring C to 52 mm. In order to better describe differences in stiffness of springs, two stiffness coefficients were defined. Coefficient k_1=(F_{7N}-

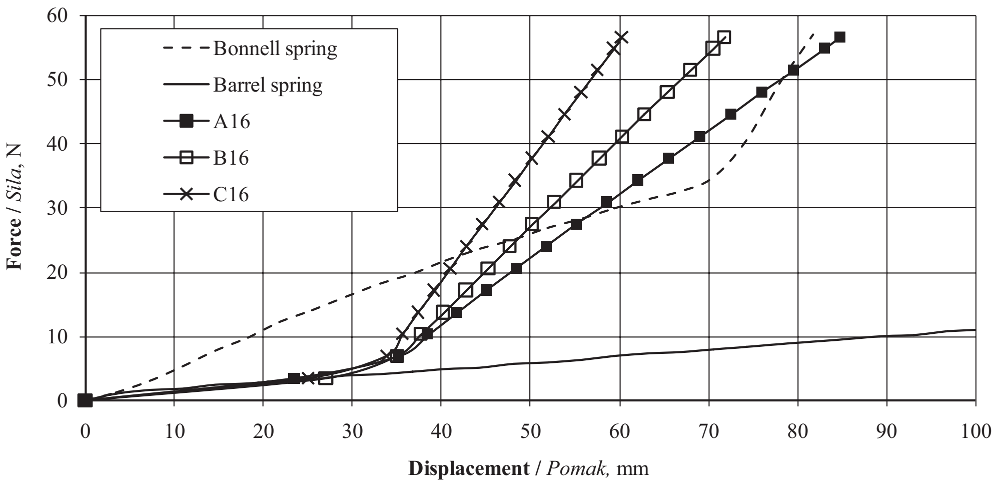


Figure 9 Stiffness of hybrid upholstery springs made from wire with a diameter of 1.6 mm
Slika 9. Krutost hibridnih opruga za ojastučeni namještaj napravljenih od žice promjera 1,6 mm

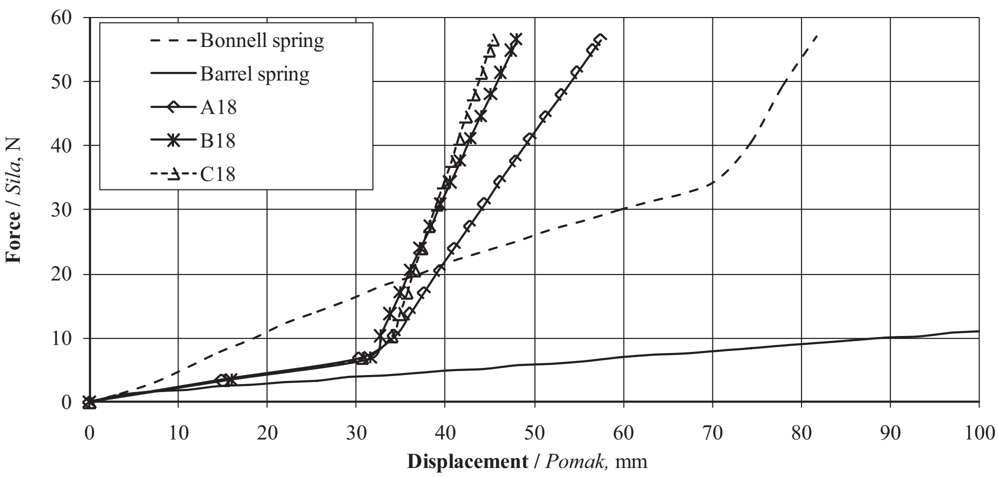


Figure 10 Stiffness of hybrid upholstery springs made from wire with a diameter of 1.8 mm
Slika 10. Krutost hibridnih opruga za ojastučeni namještaj napravljenih od žice promjera 1,8 mm

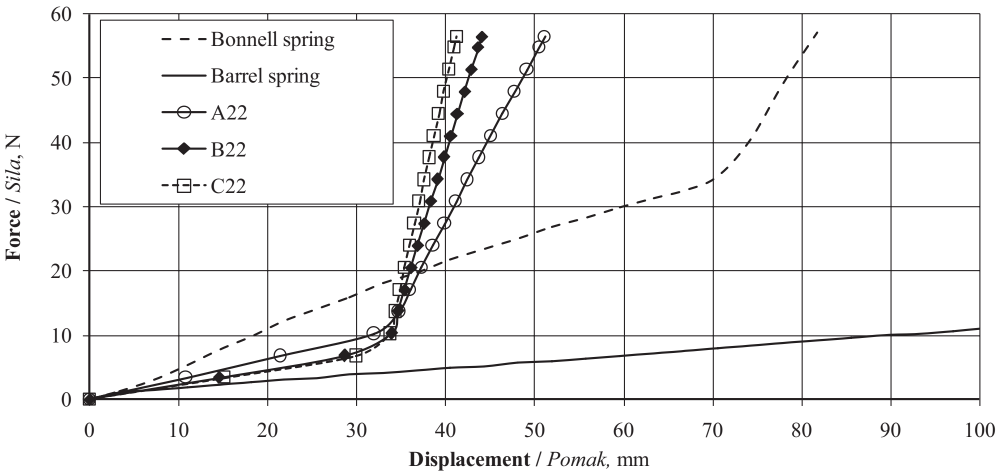


Figure 11 Stiffness of hybrid upholstery springs made from wire with a diameter of 2.2 mm
Slika 11. Krutost hibridnih opruga za ojastučeni namještaj napravljenih od žice promjera 2,2 mm

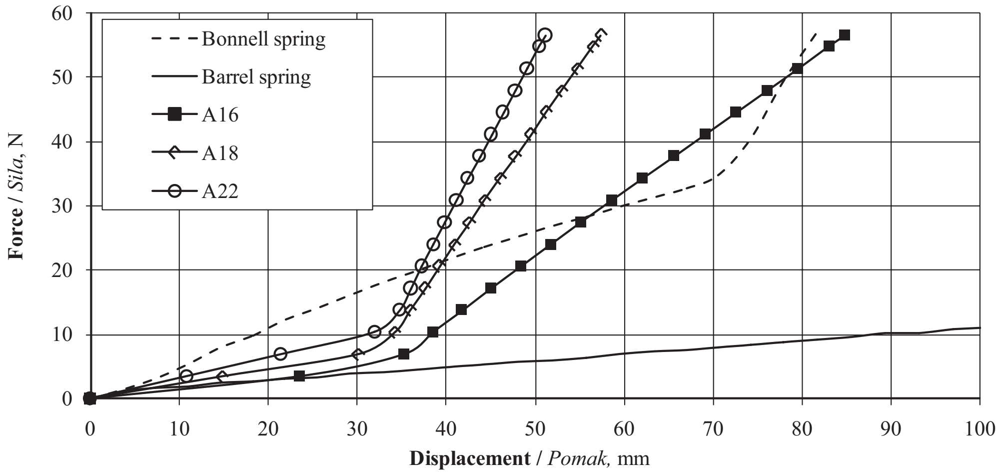


Figure 12 Stiffness of hybrid upholstery springs type A
Slika 12. Krutost hibridnih opruga za ojastučeni namještaj tipa A

F_{0N})/(λ_{7N}-λ_{0N}) (N/mm) for the first linear segment of the characteristic with a maximum load of 7 N and k_3=(F_{40N}-F_{10N})/(λ_{40N}-λ_{10N}) (N/mm) for the second segment, illustrating stiffness resultant from the outer biconical spring and the inner spring, with the maximum load of 40 N. As it can be seen from Figure 9, stiffness of the barrel spring is constant, amounting to k_1 = 0.11 N/mm, while it is k_1 = 0.55 N/mm for the bonnell spring. Still stiffness of all models of hybrid springs in the first range is 0.19 < $k_{1(A,B,C)}$ < 0.20 N/mm. In the second range of deflections, stiffness depends on the shape of the inner spring. For spring type A, the stiffness index k_{3A} is 0.99 N/mm, for spring B k_{3B}=1.36 N/mm, and for spring type C k_{3C}=1.87 N/mm.

Stiffness of springs modeled from wire with a diameter of 1.8 mm and 2.2 mm is presented in Figures 10 and 11. Also in these cases similar qualitative differences can be observed in stiffness of individual spring models. It is also of interest that their stiffness in the first range of displacements increased slightly. For models made from wire with a diameter of 1.8 mm, this stiffness falls within the range of 0.22 <$k_{1(A,B,C)}$ < 0.23 N/mm, while for models made from wire with a diameter of 2.2 mm, it is 0.23 < $k_{1(A,B,C)}$ <0.32 N/mm. Considerably greater quantitative differences are found in the second range of displacements, during the simultaneous compression of coils in the biconical and inner springs. As it can be seen in Figure 10, the stiffness index for individual springs is as follows: k_{3A}=2.01, k_{3B}=3.04 and k_{3C}=4.11 N/mm. In turn, for springs made from wire with a diameter of 2.2 mm (Fig.11), stiffness indexes for individual spring types are ordered as follows: k_{3A}=2.63, k_{3B}=4.57, k_{3C}=6.26 N/mm.

Taking into consideration the results of numerical calculations, it is obvious that the new models of upholstery springs in terms of their performance characteristics are much more attractive in comparison to bonnel or barrel (encased) springs used so far. A significant advantage of these springs is connected with their two-rate stiffness guaranteeing a greater potential for free modeling of stiffness in seats of armchairs depending on the needs of their users. Considering their anthropometric properties, particularly weight and dimensions of the body, a seat optimally supporting the body in the sitting position should be designed. Among the nine analyzed variants of springs, model A made from wire with a diameter of 1.6, 1.8 and 2.2 mm turned out to be the most practical structural solution. Advisability of this selection is confirmed by Figure 12. It can be seen from this figure that, when applying different wire diameters, the stiffness of springs in the initial range of coil settlement may easily be changed from 0.19 N/mm to 0.32 N/mm.

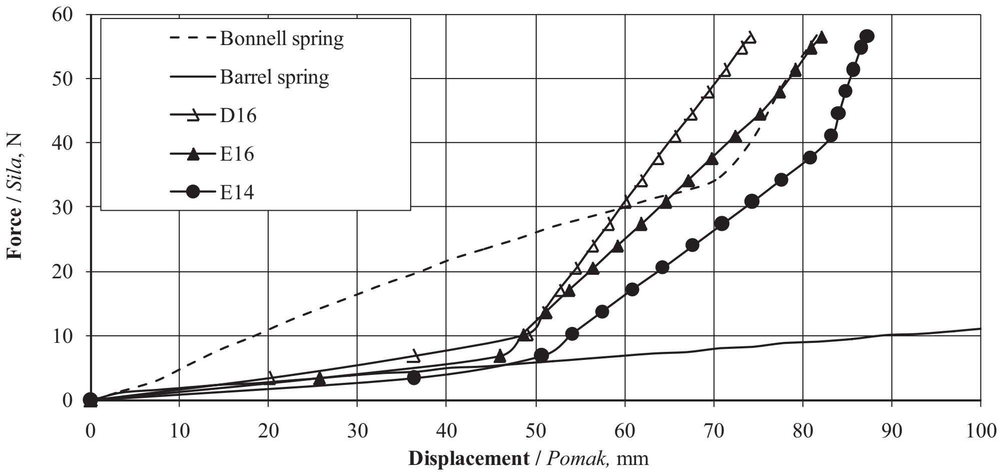


Figure 13 Stiffness of hybrid upholstery springs type D and E
Slika 13. Krutost hibridnih opruga za ojastučeni namještaj tipa D i E

In the second range of the experiment parameters, their stiffness increases from 0.99 N/mm to 2.63 N/mm. Thus, in terms of such a spectrum of spring stiffness, a structural solution may be selected, aimed at providing comfort and functionality to seating and resting furniture to a child, a woman or to a man. Due to their linear stiffness characteristics (Fig. 12), bonnell or barrel springs do not ensure such extensive possibilities.

Moreover, new designs were also developed for spring type D and E to be used in mattresses. Their nonlinear stiffness characteristics are presented in Figure 13, including characteristics of spring type D made from wire with a diameter of 1.6 mm and two characteristics of spring type E made from wire with a diameter of 1.4 and 1.6 mm.

We can see from Fig. 13 that the settlement of coils in the inner spring starts after the spring is compressed by approx. 50 mm. Here, depending on the spring model and wire diameter, the value of force causing this settlement varies. For spring type D this force was 10 N, while for spring type E 7 N or 8 N, depending on the diameter, it was made from i.e. 1.4 mm vs. 1.6 mm. In the first range of the spring operation, their stiffness was k_{1D}=0.19 N/mm, 0.14<k_{1E}<0.15 N/mm. It is obviously markedly lower than the stiffness of barrel springs, which is particularly significant in modeling of mattresses to be used by children and women. In the second stage of coil settlement, stiffness resultant from individual springs increased markedly. For spring type E it was 1.85 N/mm, while for spring type D made from wire with a diameter of 1.6 mm k_{3E}=1.28 N/mm. In case of spring type E made from wire with a diameter of 1.4 mm k_{3E}=1.08 N/mm. Moreover, this spring has an additional advantage. As it can be seen from Figure 13, before complete compression, it exhibits a three-rate stiffness characteristic. In the third range of work its stiffness is 4.18 N/mm.

The presented models of hybrid springs for mattresses differ from hybrid springs for seats in terms of the following characteristics: they exhibit a greater range of free coil settlement of outer springs, lower stiffness in the first and second range of work during uniaxial compression and in some cases three-stage stiffness characteristics. These advantages perfectly match the modeling of ergonomic mattresses adapted to individual needs of users. It is crucial particularly when the bed should be designed for use in boarding houses, students' hostels, hotels, hospitals, etc., where many individuals of different physique use the same mattress.

4 CONCLUSIONS
4. ZAKLJUČCI

On the basis of conducted tests and analyses of their results, the following conclusions and observations may be made:

- Traditional bonnell or barrel springs exhibit linear stiffness over a considerable range of design displacements of up to 70 mm,
- Tested mattresses made from bonnell springs by contact with the user's body cause disadvantageous pressures exceeding 8 kPa,
- Developed structures of hybrid springs are characterized by an advantageous nonlinear stiffness,
- In the design of seats, we may recommend springs model A made from wire with a diameter from 1.6 mm to 2.2 mm, while for mattresses we recommend springs type E made from wire with a diameter from 1.4 to 1.6 mm.

5 REFERENCES
5. LITERATURA

1. Alderson, A.; Alderson, K., 2007: Auxetic materials. Proc. IME G.J. Aero.Eng. 221: 565-575.
2. Ambrose, D.H., 2004: Developing random virtual human motions and risky work behaviors for studying anthropotechnical systems. U.S. Department of Health and Human Services Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory.
3. Autodesk® Inventor® Professional 2011: Help. Autodesk, Inc.
4. Autodesk® Algor® Professional 2011: Help. Autodesk, Inc.
5. Bezazi, A.; Scarpa, F., 2007: Mechanical behavior of conventional and negative Poisson's ratio thermoplastic polyurethane foams under compressive cyclic loading. Int. J. Fatigue. 29: 922-930 http://dx.doi.org/10.1016/j.ijfatigue.2006.07.015.

6. Bezazi, A.; Scarpa, F., 2009: Tensile fatigue of conventional and negative Poisson's ratio open cell PU foams. Int. J. Fatigue. 31: 488-494 http://dx.doi.org/10.1016/j.ijfatigue.2008.05.005.
7. Brandel, B.; Lakes, R.S., 2001: Negative Poisson's ratio polyethylene foams. J. Mater. Sci. 36: 5885-5893 http://dx.doi.org/10.1023/A:1012928726952.
8. Brienza, D.; Karg, P.; Brubaker, C., 1996: Seat cushion design for elderly wheelchair users based on minimization of soft tissue deformation using stiffness and pressure measurements. IEEE Transactions on Rehabilitation Engineering, 4(4): 320-328 http://dx.doi.org/10.1109/86.547933.
9. Butcher, M.; Thompson, G., 2009: Dressings can prevent pressure ulcers: fact or fallacy? The problem of pressure ulcer prevention. Wounds 5 (4): 80-93.
10. Butcher, M.; Thompson, G., 2010: Can the use of dressing materials actually prevent pressure ulcers: presenting the evidence. Wounds 6 (1): 119-125.
11. Choi, J.B.; Lakes, R.S., 1992: Nonlinear properties of polymer cellular materials with a negative Poisson's ratio. J. Mater. Sci. 27: 4678-4684 http://dx.doi.org/10.1007/BF01166005.
12. Chow, W.W.; Odell, E.I., 1994: Deformations and stress in soft body tissues of sitting person. J. Biomech Eng. 100: 79–87 http://dx.doi.org/10.1115/1.3426196.
13. Chu, S.J., 2000: Finite element analysis of contact stresses between a seat cushion and a human body. Science and Technology, 2000. KORUS 2000. Proceedings. The 4th Korea-Russia International Symposium. 3: 11-16.
14. Dzięgielewski, St.; Smardzewski, J., 1995: Computer evaluation and modeling of upholstered spring systems (in Polish). Komputerowa ocena i modelowanie formatek sprężynowych mebli tapicerowanych. Przemysł Drzewny Rok XLVI 4: 6-12.
15. Ebe, K.; Griffin, M., 2001: Factors affecting static seat cushion. Comfort Ergonomics, 44 (10): 901-921 http://dx.doi.org/10.1080/00140130110064685.
16. Ferrarin, M.; Andreoni, G.; Pedotti, A., 2000: Comparative biomechanical evaluation of different wheelchair seat cushions. Journal of Rehabilitation Research and Development, 37 (3): 315-324.
17. Gonga, L.; Kyriakidesa, S.; Triantafyllidisb, N., 2005: On the stability of Kelvin cell foams under compressive loads. Journal of the Mechanics and Physics of solids, 53: 771-794 http://dx.doi.org/10.1016/j.jmps.2004.10.007.
18. Gross, C.M.; Goonetilleke, R.S.; Menon, K.K.; Banaag, J.C.N.; Nair, C.M., 1994: The biomechanical assessment and prediction of seat comfort. In Lueder, R. and Noro, K. (Eds), Hard Facts About Soft Machines: The ergonomics of seating (London: Taylor & Francis): 231-253.
19. Grujicic, M.; Pandurangan, B.; Arakere, G.; Bell, W.C.; He, T.; Xie, X., 2009: Seat-cushion and soft-tissue material modeling and a finite element investigation of the seating comfort for passenger-vehicle occupants. Materials and Design 30: 4273-4285 http://dx.doi.org/10.1016/j.matdes.2009.04.028.
20. Guttmann, L., 1946: Rehabilitation after injuries to the spinal cord and cauda equina. Br J Phys Med, 9: 130-137.
21. Hamanami, K.; Tokuhiro, A.; Inoue, H., 2004: Finding the optimal setting of inflated air pressure for a multi-cell air cushion for wheelchair patients with spinal cord injury. Acta Med. Okyama, 58 (1): 37-44.
22. Hostensa, I.; Papaioannoub, G.; Spaepenb, A.; Ramona, H., 2001: Buttock and back pressure distribution tests on seats of mobile agricultural machinery. Applied Ergonomics 32: 347–355 http://dx.doi.org/10.1016/S0003-6870(01)00013-8.
23. Husain, T., 1953: An experimental study of some pressure effects on tissues, with reference to the bed-sore problem. J Pathol Bacteriol, 66 (2): 347-358 http://dx.doi.org/10.1002/path.1700660203.
24. Kamijo, K.; Tsujimura, H.; Obara, H.; Katsumata, M., 1982: Evaluation of seating comfort. In: SAE Conference, No. 820761.
25. Kapica, L.; Smardzewski, J., 1994: Influence of the geometry of dual conical springs on the stiffness of bonnell system (in Polish). Wpływ geometrii sprężyn dwustożkowych stosowanych w formatkach bonnell na ich sztywność. Przemysł Drzewny, Rok XLV 10: 1-3.
26. Kosiak, M., 1959: Etiology and pathology of ischemic ulcers. Arch Phys Med Rehabil, 40 (2): 62-69.
27. Kosiak, M., 1961: Etiology of decubitus ulcers. Arch Phys Med Rehabil, 42: 19-29.
28. Lakes, R.S., 1987: Foam Structures with a Negative Poisson's Ratio. Science. 235: 1038-1040 http://dx.doi.org/10.1126/science.235.4792.1038.
29. Lakes, R.S., 1992: Experimental Micromechanics Method for Conventional and Negative Poisson's Ratio Cellular Solids as Cosserat Continua. J.Eng. Mat. & Techn. 113: 148-155 http://dx.doi.org/10.1115/1.2903371.
30. Landis, E.M., 1930: Micro-injection studies of capillary blood pressure in human skin. Heart 15: 209-228.
31. Lee, J.; Grohs, T.; Milosic, M., 1995: Evaluation of objective measurement techniques for automotive seat comfort. In: SAE Conference, SAE No. 950142.
32. Linder-Ganz, E.; Yarnitzky, G.; Portnoy, S.; Yizhar, Z.; Gefen, A. 2005: Real-time finite element monitoring of internal. Stress in the bittlok during whellchasir sitting to prevent sores: verification and phantom results. II International Conference on Computational Bioengineering. Lisbon, Portugal, September 14-16.
33. Lusiak, A.; Smardzewski, J., 2010: Creative thinking in designing furniture for pre-school children. Annals of Warsaw University of Life Sciences SGGW, Forestry and Wood Technology 70: 270-278.
34. Milvojevich, A.; Stanciu, R.; Russ, A.; Blair, G.R.; Heumen, J.D., 2000: Investigating psychometric and body pressure distribution responses to automotive seating comfort. In: SAE Conference, SAE No. 2000.
35. Park, S.J.; Kim, C.B., 1997: The evaluation of seating comfort by objective measures. In: SAE Conference, SAE no. 970595.
36. Park, S.J.; Lee, Y.S.; Nahm, Y.E.; Lee, J.W.; Kim, J.S., 1998: Seating physical characteristics and subjective comfort: design considerations. In: SAE Conference, SAE No. 980653.
37. Prtre, M.T.; Erdemir, A.; Cavanagh, P.R., 2006: Determination of elastomeric foam parameters for simulations of complex loading. Computer Methods in Biomechanics and Biomedical Engineering. 9(4): 231-242 http://dx.doi.org/10.1080/10255840600747620.
38. Potter, D.W.; Fortier, C.J.; Rigby, W.A.; Stevenson, J.M., 1998: Development and analysis of a comparative evaluation methodology for office chairs. Proceedings, 30th Annual conference of the human factors association of Canada.
39. Reed, M.P.; Saito, M.; Kakishima, Y.; Lee, N.S.; Schneider, L.W., 1991: An investigation of driver discomfort and related seat design factors in extended-duration driving. In: SAE Conference, SAE No. 910117.
40. Reswick, J.; Rogers, J., 1976: Experience at rancho los amigos hospital with devices and techniques to prevent pressure sores. In Bedsore Biomechanics, Kennedy, Cowden & Scales (Eds .), Baltimore: University Park Press: 301-310.
41. Sacks, A.H., 1989: Theoretical prediction of a time-at-pressure curve for avoiding pressure sore. Journal of Rehabilitation Researchand Development Vol. 26: 27-33.
42. Scarpa, F.; Bullough, W.A.; Lumley, P., 2004: Trends in acoustic properties of iron particle seeded auxetic polyurethane foam. Proc IME CJ Mech. Eng. Sci. 218: 241-244.
43. Schrodt, M.; Benderoth, G.; Kuhhorn, A.; Silber, G., 2005: Hyperelastic Description of Polymer Soft Foams at Finite Deformations. Technische Mechanik, 25(3-4): 162-173.

44. Seigler, M.; Ahmadian, M., 2003: Evaluation of an alternative seating technology for truck seats. Heavy Vehicle Systems. A Series of the Int. J. of Vehicle Design, 10 (3): 188-208.
45. Silber, G.; Alizadeh, M.; Salimi, M., 2010: Large deformation analysis for soft foams based on hyperelasticity, 26(3): 327-334.
46. Smardzewski, J., 1993a: Stiffness of the dual conical upholstery springs (in Polish). Sztywność dwustożkowych sprężyn tapicerskich. Przemysł Drzewny, Rok XLIV 2: 6-9.
47. Smardzewski, J., 1993b: Ergonomic assessment of the bonnell springs systems (in Polish) Ocena ergonomiczna formatek sprężynowych typu bonnell. Przemysł Drzewny, Rok XLIV 10: 5-7.
48. Smardzewski, J., 1993c: Ergonomic model of springs systems (in Polish). Model ergonomiczny formatki sprężynowej. Przemysł Drzewny, Rok XLIV 11: 6-8.
49. Smardzewski, J., 2006: Specificity of modeling of springs systems for upholstered furniture (in Polish). Specyfika modelowania układów sprężynowych mebli tapicerowanych. Proceedings of the conference, Polioptymalizacja i Komputerowe Wspomaganie Projektowania. Mielno, Poland: 169-177.
50. Smardzewski, J, 2008a: Furniture design. PWRiL Poznan. Chapter 8 pp: 523-591.
51. Smardzewski, J., 2008b: Stiffness modeling of dual conical upholstery spring. Annals of Warsaw University of Life Sciences SGGW, Forest and Wood Technology, 64: 247-252.
52. Smardzewski, J., 2009: Antropotechnical aspects of furniture design. Drvna industrija 60(1): 15-21.
53. Smardzewski, J.; Barańska-Woźny, J.; Wiaderek, K.; Prekrat, S.; Grbac I., 2010a: Mechanical and biomechanical criteria in furniture designing for 60+ users. Proceedings of the international conference, Wood is good - transfer of knowledge in practice as a way out of the crisis. Ambienta, Zagreb, Croatia: 113-122.
54. Smardzewski, J.; Grbac I., 1998: Numerical analysis of ergonomic function of upholstered furniture. Proceedings of the international conference. Ambienta, Zagreb, Croatia: 61-68.
55. Smardzewski, J.; Grbac, I.; Prekrat, S., 2008: Nonlinear mechanics of hyper elastic polyurethane furniture foams. Drvna industrija 59(1): 23-28.
56. Smardzewski, J.; Matwiej, Ł.; Grbac I., 2005: Anthropotechnical models in testing mattress. Electronic Journal of Polish Agricultural Universities, Wood Technology, Volume 8, Issue 3 Available http://www.ejpau.media.pl/volume8/issue3/art-38.html.
57. Smardzewski, J.; Matwiej, Ł., 2006: Rigidity of parallel springs systems in furniture mattresses. Proceedings of the international conference, Calunnickie Dni. Topolcany Slovakia, 126-131.
58. Smardzewski, J.; Matwiej, Ł., 2007: Analysis of the manbed mechanical system. Proceedings of the international conference, Calunnicke Dni, Teoria a prax. Zvolen Slovakia: 42-49.
59. Smardzewski, J.; Prekrat, S.; Pervan, S., 2010b: Research of Contact Stresses between Seat Cushion and Human Body. Drvna Industrija 61(2): 95-101.
60. Smardzewski, J.; Wiaderek, K.; Grbac I., 2006: Numerical analysis of contact problems of human body and elastic mattress. Proceedings of the international conference European Union – Challenges and perspectives for the woodprocessing industry. Ambienta, Zagreb, Croatia: 81-86.
61. Smardzewski, J.; Wiaderek, K., 2007: The analysis of the human body-seat mechanical system. Proceedings of the international conference, Calunnicke Dni, Teoria a prax. Zvolen, Slovakia: 50-55.
62. Takahashi, M.; Black, J.; Dealey, C.; Gefen, A., 2010: Pressure in context. International review. Pressure ulcer prevention: pressure, shear, friction and microclimate in context. A consensus document. London: Wounds International: 2-10.
63. Tewari, V.K.; Prasad, N., 2000: Optimum seat pan and back-rest parameters for a comfortable tractor seat. Ergonomics 43(2): 167-186 http://dx.doi.org/10.1080/001401300184549.
64. Timoshenko, S.; Young, D.H., 1962: Elements of Strength of Materials. Van Nostrand Reinhold Company, New York, Cincinnati, Toronto, London, Melbourne, pp:80-81.
65. Thakurta, K.; Koester, D.; Bush, N.; Bachle, S., 1995: Evaluating short and long term seating comfort. In: SAE Conference, SAE no. 950144.
66. Uenishi, K.; Fujihashi, K.; Imai, H., 2000: A seat ride evaluation method for transient vibrations. In: SAE Conference, SAE No. 2000-01-0641.
67. Verver, M.M.; Hoof, J.V.; Oomens, C.W.J.; Wismans, J.S.H.M.; Baaijens, F.P.T., 2004: A Finite Element Model of the Human Buttocks for Prediction of Seat Pressure Distributions, Computer Methods in Biomechanics and Biomedical Engineering, 7(4): 193-203 http://dx.doi.org/10.1080/10255840410001727832.
68. Vlaovic, Z.; Bogner, A.; Grbac, I., 2008: Comfort Evaluation as the Example of Anthropotechnical Furniture Design. Coll. Antropol. 32(1): 277-283.
69. Wang, Y.C.; Lakes, R.S., 2002: Analytical parametric analysis of the contact problem of human buttocks and negative Poisson's ratio foam cushions. International Journal of Solids and Structures 39: 4825–4838 http://dx.doi.org/10.1016/S0020-7683(02)00379-7.
70. Wang, X.; Wang, T.; Jiang, F.; Duan, Y., 2004: A two–dimensional modelling for human hip stress analysis. Biomed Eng. Appl. Basis Comm, 16: 32-36 http://dx.doi.org/10.4015/S1016237204000062.
71. Webber, R.S.; Alderson, K.; Evans, K.E., 2008: A novel fabrication route for auxetic polyethylene, part 2: Mechanical properties. Polym. Eng. Sci. 48: 1351-1358 http://dx.doi.org/10.1002/pen.21110.
72. Wiaderek, K.; Smardzewski, J., 2008: Analysis of the contact problem of human thighs and elastic seat cushion. Annals of Warsaw University of Life Sciences SGGW, Forest and Wood Technology, 66: 184-188.
73. Wiaderek, K.; Smardzewski, J., 2010a: Numerical evaluation of seat hardness, Annals of Warsaw University of Life Sciences SGGW, Forestry and Wood Technology 70: 305-311.
74. Wiaderek, K.; Smardzewski, J., 2010b: Modeling of foam seats in terms of comfortable relaxation furniture design. Proceedings of the international conference, Wood is good - transfer of knowledge in practice as a way out of the crisis. Ambienta, Zagreb, Croatia: 139-146.
75. Winkler, T., 2005: Computer Aided Design of Anthropotechnical systems (in Polish). Wydawnictwa Naukowo-Techniczne. Warszawa 2005.
76. Yun, M.H.; Donjes, L.; Freivalds, A., 1992: Using force sensitive resistors to evaluate the driver seating comfort. Adv Ind Ergon Safety IV: 403-410.
77. Zhao, L.Q.; Xia, Q.S.; Wu, X.T., 1994: Study of sitting comfort of automotive seats. SAEConference, SAE No. 945243.

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Selected Wood Properties of *Prunus Africana* (Hook) Grown in Kenya as Possible Reasons for its High Natural Durability

Odabrana svojstva drva *Prunus africana* iz Kenije i mogući razlozi njegove velike prirodne trajnosti

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ABSTRACT • *Studies were carried out on the influence of Prunus africana heartwood extractives on the growth of selected wood decay fungi. Also, wood chemical and mineral content, dimensional stability and anatomical features of P. africana were studied. Heartwood extractives were tested in 100 ppm and 500 ppm concentrations on white, brown rot, and blue stain fungi and growth inhibition was determined as a factor of time. Dimensional stability was determined by computing the swelling coefficient after the blocks were saturated with moisture. Klason lignin, Kürschner cellulose, extractive and ash contents were determined by standard procedures. Infrared analyses were performed using Perkin Elmer FTIR spectrometer. Microscopic examination was performed using an environmental scanning electron microscope. The results showed that the wood is dimensionally stable, and contains 12.7 % extractives, 37.6 % cellulose and 30.4 % lignin. Extractives deposited in vessels are highly soluble in dichloromethane and mainly composed of terpenes. Extractives were able to inhibit the growth of white rot fungi Coriolus versicolor, brown rot fungi Poria placenta and blue stain fungi Aureobasidium pullulans at different concentrations tested and could explain the high durability of Prunus africana wood species.*

Key words: *Prunus africana, heartwood, extractives, fungi, inhibition*

SAŽETAK • *Cilj rada bio je istražiti utjecaj ekstraktivnih tvari u drvu Prunus africana na pojavu i razvoj određenih vrsta gljiva koje uzrokuju trulež. Također, analiziran je kemijski i mineralni sastav drva P. africana, njegova dimenzijska stabilnost i anatomska obilježja. Ekstraktivi iz drva srži testirani su u koncentraciji 100 ppm i 500 ppm na gljive bijele truleži, smeđe truleži i plavila, a inhibicija rasta određena je kao faktor vremena. Dimenzijska je stabilnost određena izračunavanjem koeficijenta bubrenja nakon što su uzorci natopljeni vodom do zasićenja. Klason lignin, Kürschner celuloza, ekstraktivi i sastav pepela određeni su standardnim postupcima.*

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Infracrvena analiza provedena je upotrebom FTIR spektrometra Perkin Elmer. Mikroskopska istraživanja provedena su uz primjenu elektronskog mikroskopa. Rezultati su pokazali da je drvo P. africana dimenzijski stabilno, da sadržava 12,7 % ekstraktivnih tvari, 37,6 % celuloze i 30,4 % lignina. Ekstraktivne tvari pohranjene u trahejama vrlo su topljive u diklormetanu i uglavnom su sastavljene od terpena. Ekstraktivi su bili sposobni spriječiti razvoj gljive bijele truleži Coriolus versicolor, gljive smeđe truleži Poria placenta i gljive plave truleži Aureobasidium pullulans pri različitim koncentracijama, čime se može objasniti vrlo velika prirodna trajnost te vrste drva.

Ključne riječi: *Prunus africana, drvo srži, ekstraktivne tvari, gljive, sprečavanje rasta gljiva*

1 INTRODUCTION
1. UVOD

Prunus africana (Hook) occurs widely in tropical Africa. In Kenya, the plant is widely found in natural indigenous forests of Central and Rift Valley provinces. Wood of *P. africana* is widely used in Kenya for the construction of bridges and railway sleepers due to its high natural durability (Mburu, 2007). The heartwood is dark brown in color and described as resistant to termites and fungi (Mburu, 2007). Depletion of this wood species has raised concern in the Forestry Sector due to illegal exploitation evident in some parts of the country (Hitimana, 2000). In spite of the logging ban by the Kenyan government, farmers are encouraged to domesticate *P. africana*, a high value tree species, to ensure its continued existence. Traditionally, water extractives of *P. africana* bark are used orally to treat benign enlargement of the prostate gland in man (Bombardelli and Morazzoni, 1997; Stewart *et al.*, 2003; Catalano *et al.*, 1984; Breza *at al.,* 1998). Pentacyclic triterpenes (oleanolic and ursolic acids) are believed to inhibit the activity of glucosyl-transferase, an enzyme involved in the inflammation process (Dufour *et al.*, 1984; Bassi *et al*,. 1987; Barlet *et al.*, 1990; Bombardelli and Morazzoni, 1997).

There is no reported data on the influence of *P. africana* extractives on specific wood destroying fungi by taking time of inhibition as a factor. Similarly, other factors that influence durability of wood such as chemical composition and anatomical features have not been fully investigated. This study aimed at providing important technological information on *P. africana* wood and testing growth inhibition of aggressive white rot fungi, *Coriolus versicolor,* brown rot fungi *Poria placenta* and coloration fungi *Aureobasidium pullulans* by heartwood extractives.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1. Soxhlet extraction
2.1. Ekstrakcija *soxhleta*

Mature *P. africana* trees growing in Kimondi, Kapsabet forest, Kenya were sampled, felled and wood sawn into blocks measuring 5 mm × 20 mm × 25 mm. Heartwood and sapwood blocks, air dried to approximately 18 % MC, were separately ground to fine powder, passed through a 115-mesh sieve and dried at 60 °C to constant weight and 12 % MC before extraction. Drying at 60 °C instead of 103 °C has been shown to minimize extractive degradation (Neya *et al.*, 2004). Hexane, acetone, dichloromethane, water and a mixture of toluene/ethanol at the ratio of 2:1 (v/v) were used successively for soxhlet extraction of 50 g sample each for 15 hours at a rate of about 10-12 cycles per hour and replicated three times.

2.2 Fungal growth inhibition
2.2. Sprečavanje rasta gljiva

Mycelium was grown in 9 cm diameter Petri dishes filled with 20 ml of malt-agar sterilized medium, prepared by mixing 20 g of malt and 40 g of agar in one liter of distilled water containing 100 ppm or 500 ppm of heartwood extract only. Plates were inoculated by placing a small portion of a malt- agar freshly grown fungal colony of *C. versicolor*, *P. placenta* or *A. pullulans* at the centre of each petri dish and cultures were maintained at 22 °C and 70 % relative humidity. Growth was evaluated by measuring the mean of two perpendicular diameters of the colony every two days. Inhibition was computed using equation (1), when the diameter of control culture filled the petri-dish:

$$\textit{Growth inhibition}\ (\%) = 100 \times (1 - d_2/d_1) \quad (1)$$

Where d_2 is the diameter of the control culture and d_1 the diameter of the extract culture.

2.3 Determination of dimensional stability
2.3. Određivanje dimenzijske stabilnosti

Twenty four specimens of *P. africana* were cut into regular blocks of 60 mm × 20 mm × 20 mm (l, r, t) with the surfaces smoothened using hand planer, dried to constant weight and their lineal dimensions measured to the nearest 0.01 mm using veneer callipers for the determination of initial volume (V_1). The blocks were put in desiccators containing saturated copper sulphate solution and internal relative humidity greater than 80 %. The weights of the blocks were measured every two days until stabilization. The dimensions were measured along the initial axes and used to compute the swollen volume (V_2) and swelling coefficient (S) using the formula:

$$S(\%) = \frac{V_2 - V_1}{V_1} \times 100 \quad (2)$$

2.4 Chemical analysis and composition
2.4. Kemijska analiza i sastav

Heartwood powder was soxhlet extracted in series with ethanol and toluene/ethanol mixture at the ratio of 1:2 for 8 hours, then dried at 103 °C. Approximately 500 mg of extractive-free dry powder (m_2) was introduced in 10 ml of 72 % concentrated sulphuric acid at room temperature, stirred for 4 hours then diluted with 240 ml of distilled water and heated at 100

°C for 4 hours in an oil bath. The solution was left for 25 minutes to cool, filtered through a Buchner funnel, rinsed with hot water at 70 °C and the residue dried at 103 °C to constant weight (m_1). Klason lignin (*KL*) content was calculated using the formula:

$$KL(\%) = \frac{m_1}{m_2} \times 100 \quad (3)$$

Another heartwood powder sample was prepared by grinding, passed through 115-mesh sieve, soxhlet extracted in series with ethanol and toluene/ethanol mixture at the ratio of 1:2 for 8 hours, then dried at 103 °C. Ten grams of extractive free dry heartwood powder was refluxed three times in a 1:4 volume mixture of concentrated nitric acid and ethyl alcohol for 1 hour, the residue washed, dried and weighed as Kürschner cellulose. An additional one gram of dried heartwood powder (m_0) was heated in a furnace at 500 °C for 4 hours and ash generated weighed (m_a), and then percent ash content determined from the ratio m_a to m_0.

2.5 Anatomical and infrared analysis
2.5. Anatomska i infracrvena analiza

An environmental scanning electron microscope (ESEM Quanta 200) was used to examine microtomed transverse surface of heartwood test specimen and photomicrographs taken at different magnifications. The transverse surface was clearly marked to enable observation of the same area before and after extraction. Nine mg of dichloromethane heartwood extract was mixed homogeneously with 300 mg KBr and pressed at 450 bars for 5 minutes to form pellets and analyzed using Perkin Elmer FTIR spectrometer, SPECTRUM 2000 with spectra recorded on a wave range of 400 cm^{-1} to 4000 cm^{-1}.

3 RESULTS
3. REZULTATI

3.1. Amount of wood extractives and their effect on fungal growth
3.1. Količina ekstraktivnih tvari u drvu i njihov utjecaj na razvoj gljiva

Table 1 shows the amount of extractives in the heartwood and sapwood of *P. africana* through series extraction on the same batch of wood powder with different solvents of increasing polarity in the listed order.

Heartwood hexane extraction recorded the lowest percentage of 0.3 % extract followed by dichloromethane 0.4 %. Extract content of acetone, toluene/ethanol and water was above 3 %. Water leads with the highest extract content of more than 5 %. The naturally durable heartwood (Mburu, 2007) contained higher amount of extractives than the perishable sapwood, and it was therefore used for evaluation of durability. Figure 1 shows that heartwood extractives inhibited fungal growth and that the effect depended on the type of extract used and the concentration levels. Total growth inhibition was observed for the three tested fungi at concentration levels of 500 ppm dichloromethane extract. Toluene/ethanol and acetone extracts showed partial inhibition for the three fungi. Water extracts presented high inhibition activities at 500 ppm, while lower concentrations of 100 ppm lead to partial inhibition.

Table 1 Percent yield of wood extractives from *P. africana* heartwood and sapwood removed by different solvents
Tablica 1. Količina ekstraktivnih tvari u drvu srži i bjeljike izdvojena različitim otapalima

Solvent / *Otapalo*	**Amount of extractive, %** *Količina ekstraktivnih tvari, %*	
	Heartwood *Drvo srži*	Sapwood *Drvo bjeljike*
Hexane / *heksan*	0.3	0.3
Dichloromethane *diklormetan*	0.4	0.4
Acetone / *aceton*	3.0	2.9
Toluene/Ethanol toluen/etanol	3.4	3.0
Water / *voda*	5.6	5.1
Total / *ukupno*	12.7	11.7

Development of the mycelium on the malt-agar medium treated with toluene/ethanol, acetone or water extracts started after some inhibition period compared to that of the control. The period of mycelia growth inhibition increased with extract concentration for all the three test fungi. During this period, activity of the fungus was detected by formation of a colored area around the fungal inoculate with coloration increasing with the concentration of the extractive. Dichloromethane heartwood extracts showed higher growth inhibition to the three fungi than toluene/ethanol and acetone heartwood extractives even at low concentration. *A. pullulans,* which is a coloration fungi, showed the least resistance against all extractives, compared to *C. versicolor* and *P. placenta* white rot and brown rot fungi respectively.

3.2 Chemical composition
3.2. Kemijski sastav

The results of chemical analysis of wood showed that heartwood contains a relatively high lignin content, and low hemicelluloses and cellulose contents. Lignin has a complex, non-repetitive three-dimensional structure, which makes it resistant to attack by numerous micro-organisms. The chemical composition of *P. africana* heart wood in percentage was lignin 30.4, cellulose 37.6, hemicelluloses 18.5, extractives 12.7 and ash 0.8.

FTIR spectrum for *P. africana* dichloromethane heartwood extractives is presented in Figure 2. Transmittance (%*T*) Signals at 1690 cm^{-1} and 2600 cm^{-1} (broad absorption) are characteristic of carbonyl and hydroxyl groups respectively of carboxylic acid function. Hydroxyl groups of sugar unit appear at 3400 cm^{-1}, while strong absorption at 2860 cm^{-1} is characteristic of C-H vibrations present in aliphatic structure of terpenes (Catalano *et al.*, 1984).

3.3 Anatomical characteristics and dimensional stability
3.3. Obilježja anatomske građe i dimenzijska stabilnost

Heartwood features of *P. africana* are highlighted in Figure 3 manifesting a radial arrangement of solitary, paired or clustered vessels of up to 5 elements and

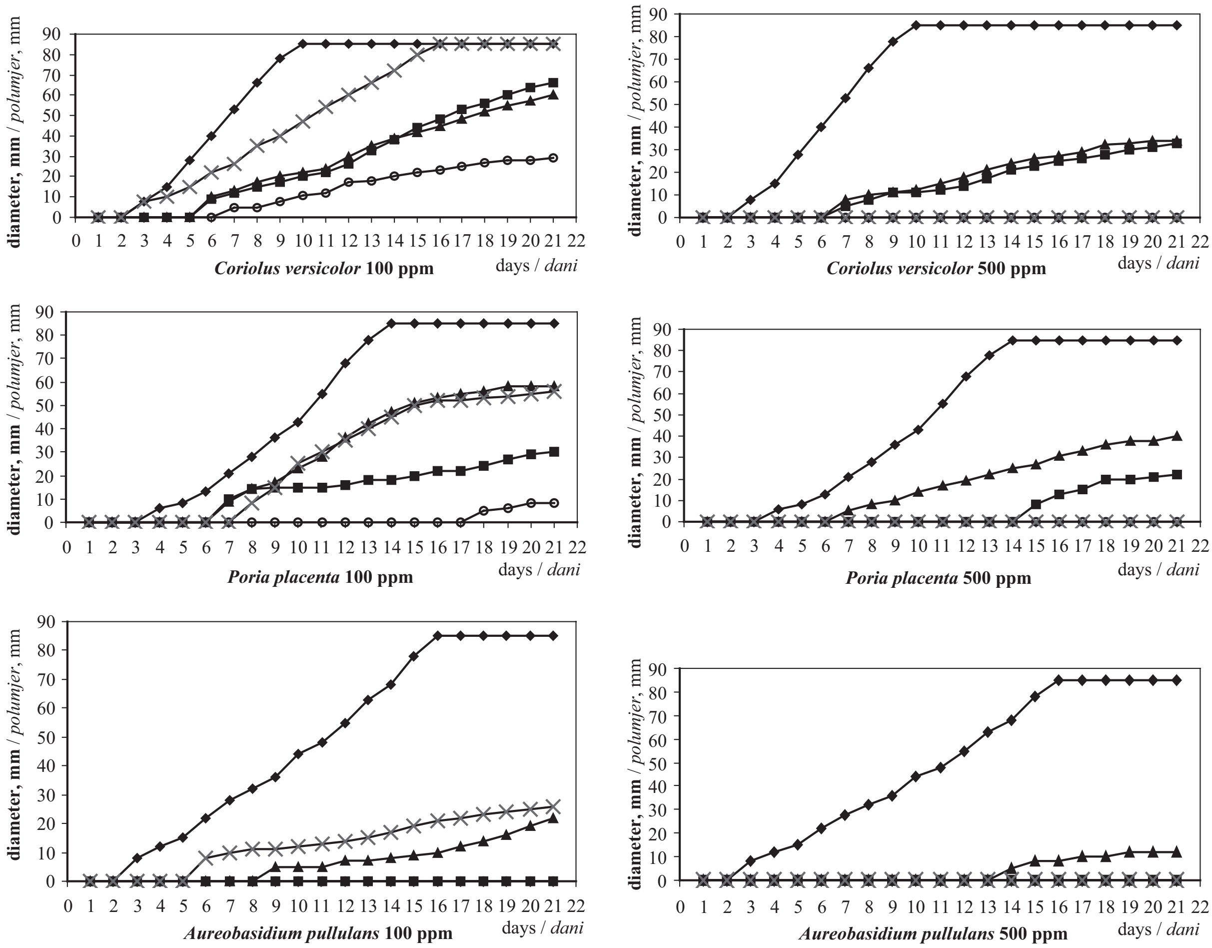


Figure 1 Inhibition of *C. versicolor*, *P. placenta* and *A. pullulans* growth by *P. africana* heartwood extractives from different solvents

Slika 1. Usporenje rasta gljiva *C. versicolor*, *P. placenta* i *A. pullulans* uz pomoć ekstraktivnih tvari dobivenih različitim otapalima iz srži drva *P. africana*

ranging in diameter between 50 μm and 150 μm. Abundant extractive deposits, thick-walled fibers measuring 10 μm and 30 μm, multiseriate rays 3 to 6 cells wide and 15 cells high, and low proportion of parenchyma cells associated with vessels characterize the cellular structure of the wood.

Most of the extractives deposited in the heartwood vessels were removed during extraction (Figure 3 (c) and (d)) and those from dichloromethane showed higher inhibition rate against growth of fungi indicating that extractives deposited in the vessels and rays contribute to the reported natural durability of *P. afri-*

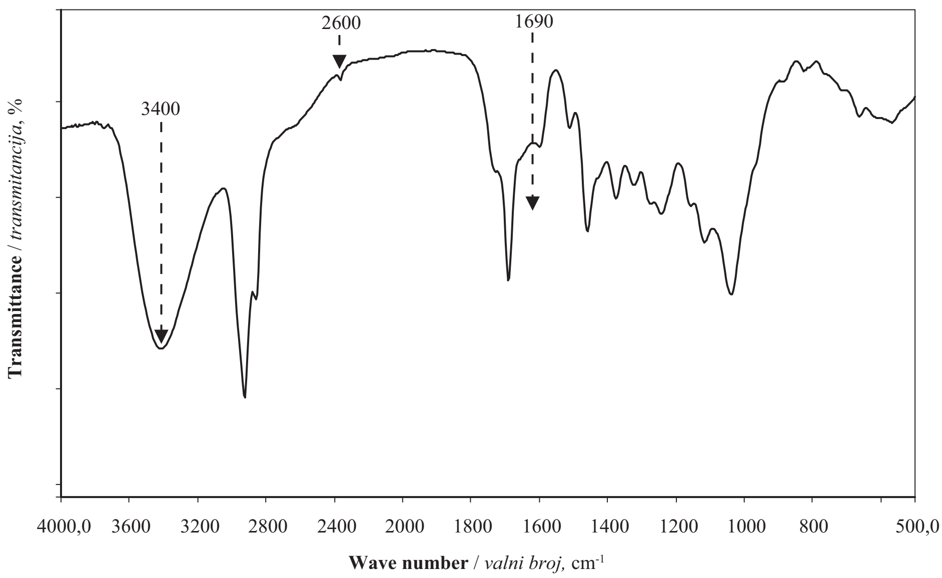


Figure 2 FTIR spectrum of *P. africana* dichloromethane heartwood extractives

Slika 2. FTIR spektar ekstraktivnih tvari dobivenih iz srži drva *P. africana* primjenom diklormetana kao otapala *cana* wood. Additionally, the relatively low mean swelling coefficient of 4.5 % indicates that *P.africana* heartwood is dimensionally stable since it picks less moisture. This partially explains inhibition of fungal growth by heartwood extractives and contribution to the high natural durability of this species even in the outdoor use.

4 DISCUSSION
4. RASPRAVA

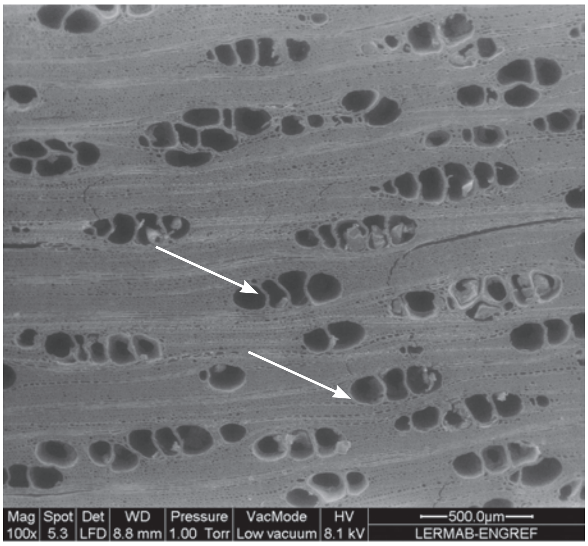
4.1 Wood extractives and their effect on fungal growth
4.1. Ekstraktivne tvari iz drva i njihov utjecaj na razvoj gljiva

The observed initial inhibition and subsequent fungal proliferation in the second and third week can be associated with detoxification of the agar medium by fungal enzymes (Neya *et al.*, 2004). This indicates that only toluene/ethanol, acetone and water heartwood extracts have inhibitory rather than toxicity properties. *P. africana* recorded high quantities of heartwood extracts at 12.7 % and as described in the literature of other tropical species, may be one of the reasons of high natural durability (Neya *et al.*, 2004).

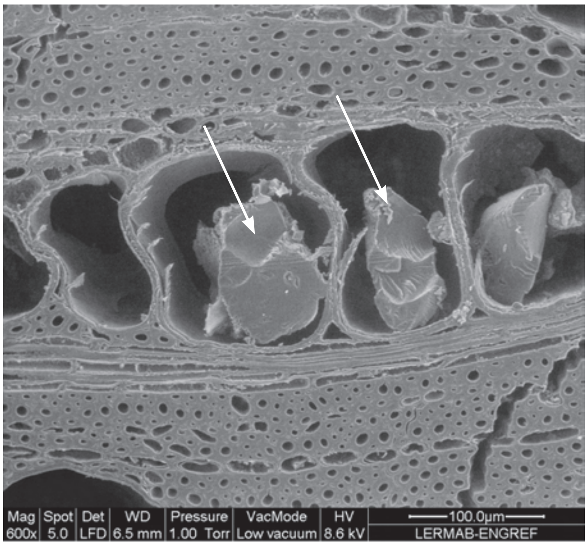
Since dichloromethane extractives inhibited the growth of fungi more than acetone, toluene/ethanol and water extracts, it indicates that extractives deposited in the vessels and rays also contribute to the reported natural durability of *P. africana* wood. The observed dimensional stability is linked to lower uptake of water, which can enhance natural durability of this species even in outdoor use.

4.2 Chemical composition and anatomical characteristics
4.2. Kemijski sastav i anatomska obilježja

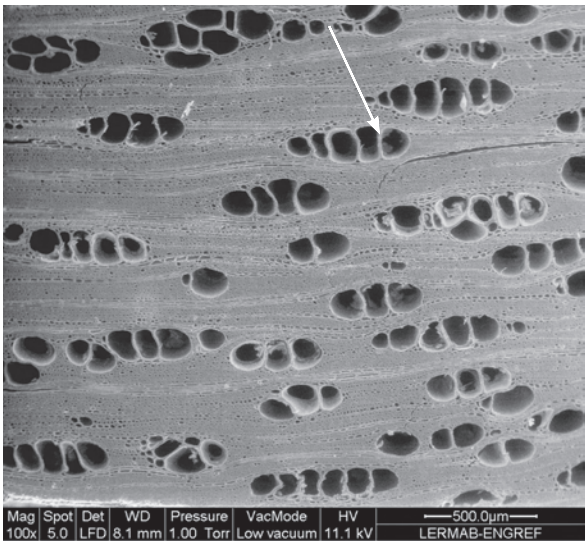
Heartwood contains a relatively high lignin content, and low hemicelluloses and cellulose contents. The only organisms capable of mineralizing lignin into



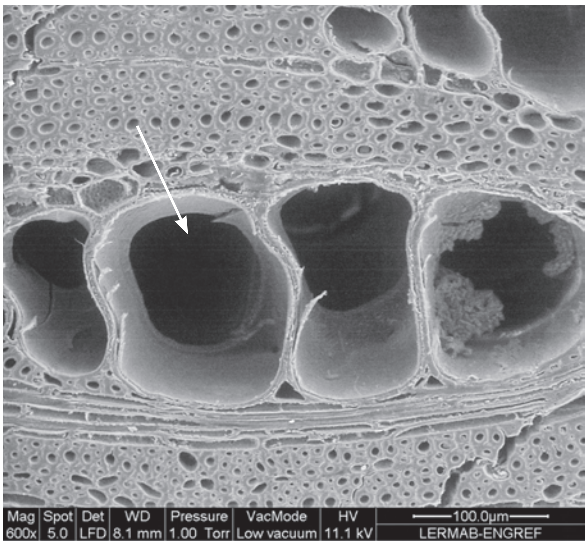
a) Radial arrangement of vessels
a) Radijalni raspored traheja



b) Extract deposits in vessels
b) Naslage ekstraktivnih tvari u trahejama



c) Vessels after extraction
c) Traheje nakon ekstrakcije



d) Vessels with extract deposit removed
d) Traheje nakon izdvajanja naslaga ekstraktivnih tvari

Figure 3 ESEM analysis of a transverse section of *P. africana* before and after dichloromethane extraction
Slika 3. Analiza ESEM poprečnog presjeka drva *P. africana* prije i nakon ekstrakcije diklormetanom

water and carbon dioxide are white-rot fungi (Anke *et al.*, 2006) due to its complex, non-repetitive three-dimensional structure. The high lignin content partly explains high resistance to the tested fungi species and hence the high natural durability of *P. Africana* (Mburu, 2007). The presence of oleanolic and ursolic acid and associated antifungal activities is consistent with previous findings on these extractives (Becker *et al.,* 2005; Deepak and Handa, 2000). Saponins derived from oleanolic acid are also described to possess antifungal properties against phytopathogenic fungi explaining the durability of heartwood to fungal degradation (Escalente *et al.,* 2002).

5 CONCLUSION
5. ZAKLJUČAK

The results showed that the wood of *P. africana* is dimensionally stable, and contains a high amount of extractives and lignin, which may partly explain its high durability in outdoor use. Extractives deposited in wood vessels and rays are highly soluble in dichloromethane and also contain terpenes, as indicated by FTIR spectra measurements. Terpenes, which possess antifungal properties, may explain the high fungal growth inhibition of heartwood extractives against C. *versicolor*, *P. placenta* and *A. pullulans* in a sterile chamber. Different heartwood extractives were able to inhibit the growth of all test fungi at different concentrations tested. Inhibition period before mycelia growth increased with extract concentration while the rate of growth increased with time after detoxification of malt-agar by fungi. The heartwood extracts could be at the origin of the reported heartwood durability of *P.africana*.

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6 REFERENCES
6. LITERATURA

1. Anke, H.; Roland, W.; Weber, S., 2006: White-rots, chlorine and the environment - a tale of many twists. Mycologist 20(3): 83-89 http://dx.doi.org/10.1016/j.mycol.2006.03.011.
2. Barlet, A.; Albrecht, J.; Aubert, A., 1990: Efficacy of *Pygeum africanum* extract in the medical therapy of urination disorders due to benign prostatic hyperplasia: evaluation of objective and subjective parameters. A placebo controlled double blind multicenter study. Wien Klin Wochenschr 102: 667-673.
3. Bassi, P.; Artibani, W.; Deluca, V.; Zattoni, F.; Lembo, A., 1987: Standardized extract of *Pygeum africanum* in the treatment of benign prostatic hypertrophy. Minerva Urology Nefrology 39: 45-50.
4. Becker, H.; Scher, J. M.; Speakman, J. B.; Zapp, J., 2005: Bioactivity guided isolation of antimicrobial compounds from *Lythrum salicaria*. Fitoterapia 76:580-584 http://dx.doi.org/10.1016/j.fitote.2005.04.011.
5. Bombardelli, E.; Morazzoni, P., 1997: *Prunus africana* (Hook. f.). Kalkm Fitoterapia 68: 205-218.
6. Breza, J.; Drurny, O.; Borowka, A.; Hanus, T.; Petrik, R.; Blane, G.; Chadha-Boreham, H., 1998: Efficacy and adaptability of Tedenan (*Pygeum africanum*) in the treatment of benign prostatic hyperplasia (BPH): a multicenter trial in central Europe. Current Medical Research Opinion 14: 127-139 http://dx.doi.org/10.1185/03007999809113352.
7. Catalano, S.; Ferretti, M.; Marsili, A.; Morelli, I., 1984: New constituents of *Prunus africana* bark extract. Journal of Natural Products 47(5): 910 http://dx.doi.org/10.1021/np50035a039.
8. Deepak, M.; Handa, S. S., 2000: Anti-inflamatory activity and chemical composition of extract of *Verbena officinalis.* Phytother 14: 463-465. (Short communication) http://dx.doi.org/10.1002/1099-1573(200009)14:6<463::AID-PTR611>3.3.CO;2-7.
9. Dufour, B.; Choquenet, C.; Revol, M.; Faure, G.; Jorest, R., 1984: Controlled study of the effects of *Pygeum africanum* extract on the functional symptoms of prostatic adenoma. Ann Urol (Paris) 18: 193-195.
10. Escalente, M. A.; Santecchia, C. B.; Lopez, S. N.; Gattuso, M. A.; Ravelo, A. G.; Monache, F. D.; Sierra, M. G.; Zacchino, S. A., 2002: Isolation of antifungal saponins from *Phytolacca tetramera*, an Argentinean species in citric risk. Journal of Ethnnopharmacology 82: 29-34 http://dx.doi.org/10.1016/S0378-8741(02)00145-9.
11. Hitimana, J., 2000: Variations in structure, composition and regeneration within the Mt Elgon moist lower montane forest, Kenya. MPhil Thesis, Moi University, Eldoret, Kenya.
12. Mburu, F., 2007: Study and valorization of different Kenyan wood species. Ph.D Thesis, Universitè Henri Poincarè, Nancy-1, France.
13. Neya, B.; Mohamed, H.; Mathieu, P.; Gérardin, P., 2004: On the durability of *Burkea africana* heartwood: evidence of biocidal and hydrophobic properties responsible for durability. Annals of Forest Science 61(3): 277-282 http://dx.doi.org/10.1051/forest:2004020.
14. Stewart, A. P.; Ripley, P. H.; Hoegedal, P.; Klein, U., 2003: Investigation of diverse reactions following the use of Econor in pigs. Journal of Veterinary Pharmacology and Therapeutics 26:253.

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Content of Total Phenols in Red Heart and Wound-Associated Wood in Beech (*Fagus sylvatica* L.)

Sadržaj ukupnih fenola u crvenom srcu i ranjenom dijelu drva bukve (*Fagus sylvatica* L.)

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ABSTRACT • *The structure of wound-associated wood has been relatively well studied in beech, but only a little information about the occurrence of extractives and particular classes of compounds in these tissues is available. We examined the content of total phenols and variability in their distribution in sapwood, wound-wood and the reaction zones walling-off typical red heart and xylem altered by wounding in two beech trees, using spectrophotometric method. Significant differences in total phenols in different types of beech wood, as well as differences between trees, were confirmed. Concentrations of total phenols were markedly lower in red heart than in reaction zones and sapwood extracts. The content of total phenols was highest in extracts of the reaction zones formed as a direct response of sapwood to wounding. Differences in the content of total phenols in reaction zones walling-off typical red heart and directly wounded xylem indicate differences in their formation process, in alterations to surrounding tissues and in the characteristics of individual trees.*

Keywords: *phenols, spectrophotometry, reaction zone, Folin-Ciocalteu reagent, beech*

SAŽETAK • *Za drvo bukve relativno je dobro istražena struktura ranjenog drva, ali je dostupno malo informacija o pojavi određenih ekstraktiva i pojedinih klasa spojeva u tim tkivima. Primjenom spektrofotometrijske metode na dva smo bukova stabla istražili sadržaj ukupnih fenola i varijabilnost njihove raspodjele u drvu bijeljike, ranjenom drvu i reakcijskim zonama koje ograđuju tipična crvena srca i ksileme promijenjene zbog ranjavanja drva. Potvrđene su značajne razlike u ukupnim fenolima u različitim tipovima bukova drva, kao i razlike među stablima. Koncentracije ukupnih fenola znatno su niže u crvenom srcu nego u reakcijskim zonama i ekstraktima bjeljike. Sadržaj ukupnih fenola bio je najviši u ekstraktima reakcijskih zona formiranih kao izravan odgovor bjeljike na ranjavanje. Razlike u sadržaju ukupnih fenola u reakcijskim zonama koje ograđuju tipična crvena srca i izravno ranjen ksilem pokazuju razlike u procesu formiranja, u promjenama na okolnim tkivima i u obilježjima pojedinih stabala.*

Ključne riječi: *fenoli, spektrofotometrija, reakcijska zona, Folin-Ciocalteauov reagens, bukva*

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1 INTRODUCTION
1. UVOD

European beech (*Fagus sylvatica* L.) is an economically important tree species in Slovenian forests, where it represents approximately 31.8 % of wood stock (Anonymus, 2011). The economic importance of beech has increased in recent years because of the continuous demand for bright and evenly colored grades of logs and sawn timber (Pöhler *et al.*, 2006). However, the occurrence of red heart amongst older trees and the consequences of mechanical wounding to the lower parts of stems, which occurs during forestry operations in unevenly managed forests, decrease wood quality and even increase timber loss. Discolored beech wood has a lower value on the market today than unaffected wood, due to its unfavorable technological properties, including hard impregnation, problems in drying processes and veneer production and, finally, its esthetic deficiency (Koch *et al.*, 2000; Pöhler *et al.*, 2006).

Beech is therefore a tree species that develops discolored wood in the core of the stem, which is commonly referred to as red heart, red heartwood, facultatively colored heartwood, false heartwood or red core (Bosshard, 1974; Torelli, 1984; Shigo, 1986; Sachsse, 1991; Wernsdörfer *et al.*, 2005). Typical red heart is located in the central part of the stem, it is reddish to brownish, rounded and uniform in color or of cloudy appearance in cross-section (Sachsse, 1991). The formation and extent of red heart can be explained by the characteristics of an individual tree: age, diameter, live crown ratio, presence of broken branches and characteristics of growth site (Torelli, 1984).

The lower parts of the stems of trees in unevenly managed forests are regularly wounded, due to the use of heavy mechanization during forestry and logging operations. Such injuries are usually superficial to the stem, meaning that the bark is usually peeled off from the wood. The surface of the xylem cylinder is thus exposed to atmospheric conditions. This kind of wounding triggers changes in the wood that is already being formed at the time of wounding and the formation of wound-wood (Shigo, 1986). Both processes can be satisfactorily explained by the compartmentalization concept (Shigo, 1986; Dujesiefken and Liese, 2006). In directly wounded stems, discoloration can be compartmentalized on the surface of the stem (Grosser *et al.*, 1991) or can merge with the red heart, if present in the tree (Torelli, 2001). Wound-associated defects, as well as red heart, are walled off from sound sapwood by darker demarcations zones, called reaction zones (Shain, 1979; Schwarze and Baum, 2000).

The anatomy of discolored red heart, wound-associated discolored wood and reaction zones has been relatively well studied (Nečesany, 1958; Pearce, 1990; Schmitt and Liese, 1993; Torelli *et al.*, 1994; Schwarze and Baum, 2000; Merela *et al.*, 2005), but only a little information about the distribution and occurrence of extractives and particular classes of compounds in these tissues is available (Albert *et al.*, 2003; Hofmann *et al.*, 2008).

The aim of this study was to determine the content of total phenols by means of spectrophotometric analysis in the reaction zone of typical red heart and in tissues that are formed as a response of the wood to direct wounding.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

2.1 Reagents
2.1. Reagensi

Methanol of HPLC grade and Folin-Ciocalteu phenol reagent (2 N) were purchased from Sigma-Aldrich, sodium carbonate (anhydrous) was provided by Riedel-de Haën and gallic acid monohydrate, applied for calibration, was from Fluka.

2.2 Material
2.2. Materijal

Two mechanically wounded beech trees (*Fagus sylvatica* L.) growing on a gentle southwest slope of the urban forest of Rožnik in the City of Ljubljana were felled in February 2009. A diameter at breast height of tree No. 1 was 48 cm and of tree No. 2 it was 52 cm. Both trees had an approximately 3 m long mechanical wound extending from the bottom of the tree.

One set of discs was sampled from the lower wounded area and a second set of discs was taken from the upper part of the trees. From the wounded part of the stems, four disks of approximately 10 cm in thickness were dissected at distances of 1.0 m, 2.0 m and 3.0 m above the ground. Another four disks were removed at 5.0 m, 10 m, 20 m and 25 m above the ground, along the upper part of the stems.

The discs were transferred to a woodworking facility for further mechanical processing. After visual inspection, discs from the first group were dissected in a uniform way so that samples of sapwood, discolored wood, reaction zones and wound-wood were obtained. Radial samples, extending from bark to bark were cut from the discs of the second group. After removing the bark, these samples were dissected by chisel and hammer to obtain up to 14 sample blocks of different categories of wood tissue, i.e., sapwood, reaction zones and discolored wood (red heart). Reaction zones were carefully separated from sapwood and discolored wood in all discs. A number of samples of wound-associated tissues were defined by extent of the wound and its consequences. In the case of reaction zones and wound-wood, two samples were obtained per tissue. In each disk, 4-6 samples of sapwood and 2-4 samples of discolored wood were dissected. Only one sample of red heart was obtained in tree No. 2 from the disk at 25 m of height. A total of 157 wood samples were obtained from the two trees.

2.3 Extraction
2.3. Ekstrakcija

Individual samples were homogenized by the mill Retsch ZM 200, using a sieve with a 35 mesh screen. Milled wood was stored at minus 18 °C until further chemical analysis to prevent unwanted chemical reactions. Phenolic compounds were extracted from 2.5 g of each sample by 80 % methanol (*aq*) using a multi-position magnetic stirrer (IKA, RO 15) according to the protocol described by Albert *et al.* (2003). Wood extracts were filtered by Büchner funnel, Whatman GF-C filter paper and vacuum flask, and stored at minus 4 °C until further analysis.

2.4 Estimation of the content of total phenols
2.4. Procjena sadržaja ukupnih fenola

Total phenol content was determined colorimetrically by means of the Folin-Ciocalteu method following the procedure proposed by Scalbert *et al.* (Singleton and Rossi, 1965; 1989).

A volume of 2.5 ml of diluted Folin–Ciocalteu phenol reagent (1:9, v/v) was added to 0.5 ml of methanolic extracts and gallic acid solutions (*aq*). Within a period of 0.5 to 8.0 minutes, 2 ml of aqueous sodium carbonate (75 $g \cdot l^{-1}$) was added as well. The thus prepared samples were well shaken and incubated for two hours at room temperature. Absorbance was measured at 765 nm by Perkin-Elmer Lambda 2 spectrophotometer. Results were determined by standard curve with gallic acid (0-200 $mg \cdot l^{-1}$) and expressed as milligrams of gallic acid equivalents per gram of dry wood ($mg \cdot g_{dw}^{-1}$).

2.5 Statistics
2.5. Statistika

Total phenol content of beech wood extracts was compared by statistical methods, where significant differences were investigated by means of ANOVA at 0.95 interval of confidence. The contents of total phenols for different categories of discolored and wounded wood tissue were further compared by means of the multiple range test (LSD procedure). The contribution of individual tissue to the variation of total phenols was estimated by variance components analysis. A statistical software Statgraphics was applied for statistical data processing.

3 RESULTS
3. REZULTATI

The total phenol content for different categories of wood is presented separately for the upper and lower groups of samples for tree No. 1 and tree No. 2. In samples from the upper part of the stems (Fig. 1), which were free of wounds, the content of total phenols was significantly different among categories of tissue (ANOVA, $P = 0.0000$) and between trees (ANOVA, $P = 0.0003$) (Table 1).

Table 1 Average content of total phenols ($mg \cdot g_{dw}^{-1} \pm$ standard deviation) in sapwood and reactions zones surrounding red heart in the upper part of beech trees
Tablica 1. Prosječni sadržaj ukupnih fenola ($mg \cdot g_{dw}^{-1} \pm$ standardna devijacija) u bjeljici i reakcijskim zonama oko crvenog srca u gornjem dijelu bukovih stabala

Tree No. *Broj stabla*	**Sapwood** *Bjeljika* $mg \cdot g_{dw}^{-1}$	**Reaction zones** *Reakcijske zone* $mg \cdot g_{dw}^{-1}$	**Red heart** *Crveno srce* $mg \cdot g_{dw}^{-1}$
1	9.03 ± 2.64^a	9.78 ± 2.97^b	2.77 ± 0.71^c
2	6.75 ± 2.62^a	5.62 ± 1.41^b	1.78 ± 0.32^c

Values marked by a letter differ significantly at a 95% confidence level (LSD procedure) / *vrijednosti označene slovom signifikantno se razlikuju pri razini vjerojatnosti 95 %.*

The content of total phenols was significantly lower in red heart than in reaction zones and sapwood in both trees (Table 1). Reactions zones and sapwood did not differ in the content of total phenols at a 95 % confidence level (LSD) in the investigated trees (Table 1). The content of total phenols was significantly higher in tree No. 1 than in tree No. 2 in all examined tissues (Table 1). Peripheral sapwood samples contained a significantly lower amount of total phenols (6.59 $mg \cdot g^{-1}$) than sapwood samples near red heart (9.7 $mg \cdot g^{-1}$) at a 95 % confidence level (LSD test) (Fig. 1). The average content of total phenols in samples from the upper part of tree No. 1 was 7.51 mg g^{-1} and 5.60 $mg \cdot g^{-1}$ in tree No. 2. The contribution of wood tissue to the variation of total phenols was 43.82 %, whereas 17.34 % was ascribed to between-tree variability. Differences in the content of total phenols among discs sampled along the trees were not significant (Fig. 2).

The distribution of the content of total phenols in samples containing wounds (lower part of the stems) is shown in Table 2. In discs with mechanical wounds, the content of total phenols was significantly different among categories of tissue (ANOVA, $P = 0.0000$), irrespective of the tree. A significant difference in the content of total phenols between trees was found for reaction zones (Table 2).

The average content of total phenols in the investigated samples of both trees was significantly different and was highest in reaction zones (14.01 $mg \cdot g^{-1}$of absolutely dry wood), followed by sapwood (9.12 $mg \cdot g^{-1}$) and wound-wood (6.78 $mg \cdot g^{-1}$). Wound-associated discolored wood was present only in tree No. 2 and contained 1.78 mg of total phenols per 1 g of absolutely dry wood. The content of total phenols in different categories of tissue accounts for 51.32 % of its variability.

Table 2 Average content of total phenols (mg $g_{dw}^{-1} \pm$ standard deviation) in different categories of tissue from the wounded part of stems
Tablica 3. Prosječni sadržaj ukupnih fenola ($mg \cdot g_{dw}^{-1} \pm$ standardna devijacija) u različitim kategorijama tkiva od ranjenih dijelova debla

Tree No. *Broj stabla*	**Sapwood** / *Bjeljika* $mg \cdot g_{dw}^{-1}$	**Wound-wood** *Ranjeno drvo* $mg \cdot g_{dw}^{-1}$	**Reaction zones** *Reakcijske zone* $mg \cdot g_{dw}^{-1}$	**Discolored wood** *Drvo promijenjene boje* $mg \cdot g_{dw}^{-1}$
1	9.96 ± 3.42	6.79 ± 2.62	17.31 ± 1.43^a	/
2	8.00 ± 2.33	6.77 ± 3.31	11.27 ± 2.73^a	1.22 ± 0.37

Values marked by a letter differ significantly at a 95% confidence level (LSD procedure) /*vrijednosti označene slovom signifikantno se razlikuju pri razini vjerojatnosti 95 %.*

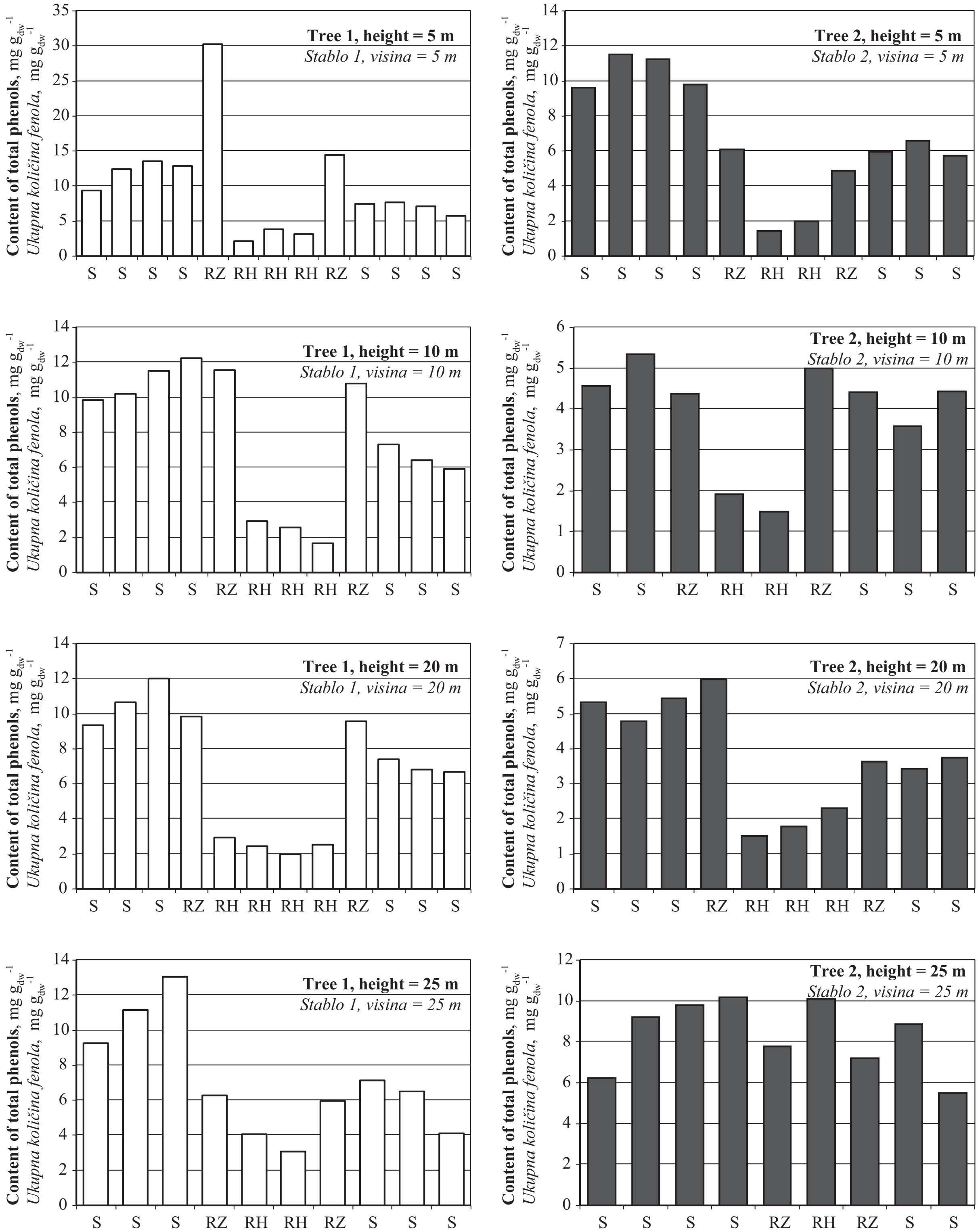

Figure 1 Radial profiles of the content of total phenols in sapwood (S), red heart (RH) and surrounding reaction zones (RZ) from the upper part of investigated beech stems

Slika 1. Radijalni profil sadržaja ukupnih fenola u bjeljici (S), crvenom srcu (RH) i okolnom reakcijskom drvu (RZ) od gornjeg dijela istraživanih bukovih debala

The average content of total phenols in reaction zones surrounding red heart (upper part of stems) was significantly lower than the content of phenols in reaction zones formed in the vicinity of the mechanical wound in the lower part of both stems (ANOVA, $P = 0.0000$) (Table 1, 2). The position of the reaction zone within the tree accounts for 58 % of the variability in the content of total phenols.

4 DISCUSSION
4. RASPRAVA

Our investigation revealed considerable variation in the content of total phenols in various wood tissues that had been altered by indirect or direct wounding and expands our understanding of the character of compartmentalization processes in beech.

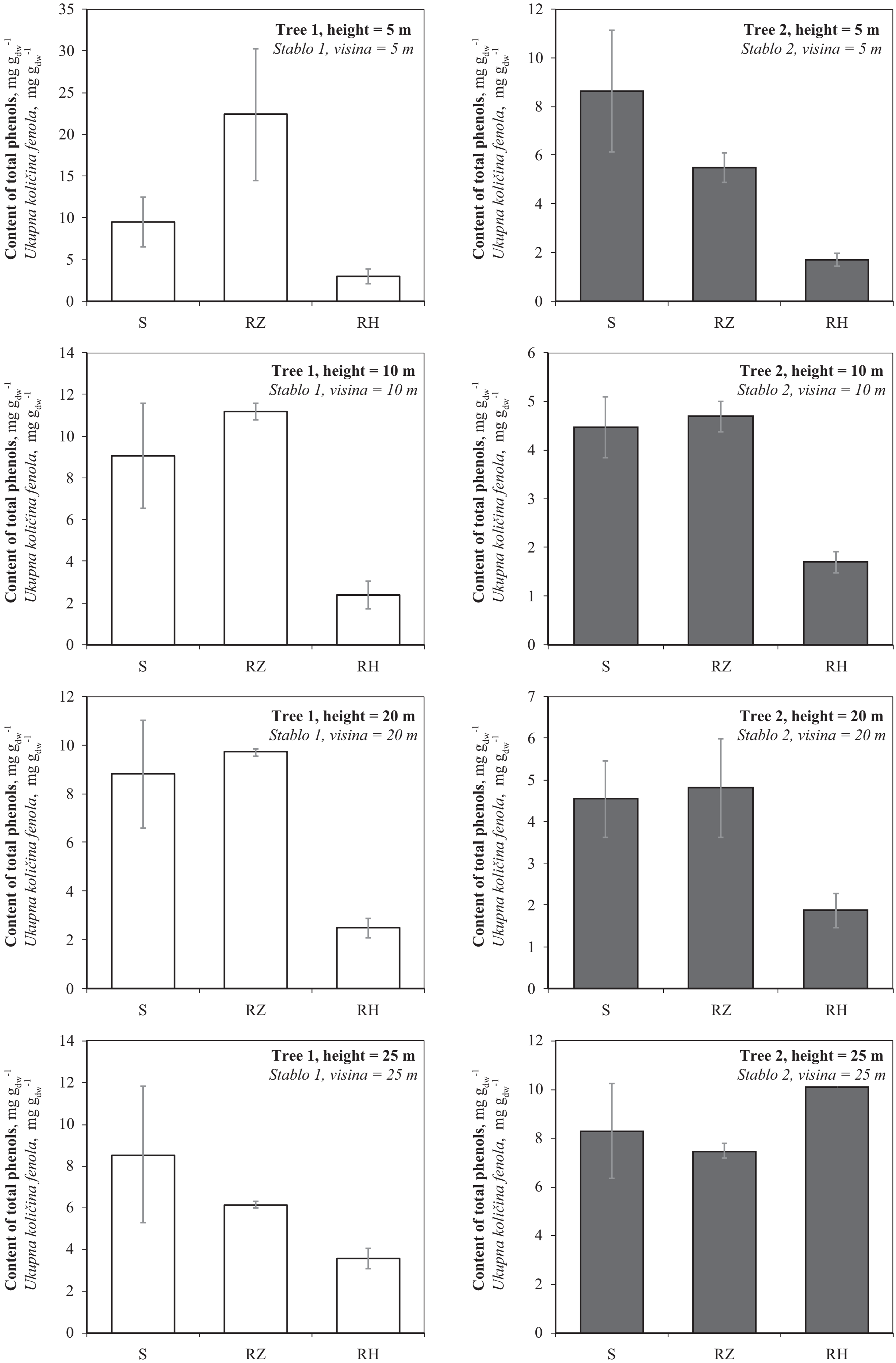

Figure 2 Average content of total phenols in red heart (RH), reaction zone (RZ) and sapwood (S) at different heights of investigated beech trees

Slika 2. Prosječni sadržaj ukupnih fenola u crvenom srcu (RH), reakcijskoj zoni (RZ) i bjeljici (S) na različitim visinama istraživanih bukovih stabala

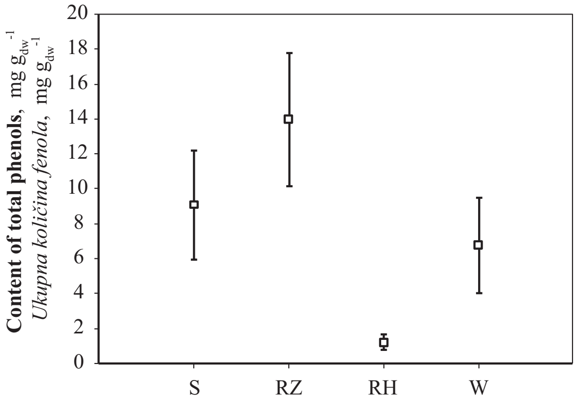

Figure 3 Average content of total phenols, supplemented by standard deviations, in different categories of wood tissues of directly wounded stems for two investigated trees.
S = sapwood, RZ = reaction zone, RH = red heart,
W = wound-wood
Slika 3. Prosječni sadržaj ukupnih fenola ($mg \cdot g_{dw}^{-1} \pm$ standardna devijacija) u različitim kategorijama tkiva izravno ranjenih dijelova debla za dva istraživana stabla: S – bjeljika, RZ – reakcijska zona, RH – crveno srce, W – ranjeno drvo

The content of total phenols of the group of samples with red heart differed more than samples that had been directly wounded. The content of total phenols in sapwood was higher than in red heart, whereas reaction zones and sapwood did not differ in this respect. The concentration of total phenols shows a rising trend from the peripheral towards the inner parts of sapwood, which supports the observations of Albert *et al.* (2003). They found a steep increase in the content of total phenols in white tissue, just before the red heartwood boundary and a sharp drop in the content of phenols in the tissues that correspond to the color-boundary (Albert *et al.*, 2003). White tissue, referred to as the dehydrated zone (Torelli, 1984) or transition zone (Hillis, 1987), was not distinguishable in our fresh discs and was therefore not dissected for extractions. It has been reported that the occurrence of this zone in *Fagus sylvatica* may have a seasonal character (Hillis, 1987). The occurrence of phenolics in sapwood of beech is in accordance with a report that flavan-3-ols, substances of a leucocyainidn type, taxifolin derivatives and proanthocyanidins are regularly present in sapwood (Dietrichs, 1964; Baum and Schwarze, 2002; Koch *et al.*, 2003; Hofmann *et al.*, 2004).

Typically, the discolored red heart of the investigated samples had the lowest amount of methanol soluble compounds, whereas the concentration of total phenolics increased abruptly in the peripheral tissues of red heart. This tissue was a clearly visible layer, referred to as the reaction zone (Shain, 1979; Pearce, 1996; Schwarze and Baum, 2000) or column boundary layer, which separates discolored wood from healthy sapwood (Shortle and Smith, 1990). The content of total phenols in the reaction zones surrounding the red heart of our samples was in contrast to the concentrations of total phenols determined at the color boundary by Albert *et al*. (2003). It has been suggested that in red heart-wooded beech, part of the phenols form *in situ* in the white tissue next to the color boundary, whereas their participation in the formation of colored materials via oxidation and polymerization explains the drop in concentration of total phenols behind the color-boundary and the low content in the red heart (Albert *et al.*, 2003).

The results of spectrophotometric analysis showed significant differences with regard to the quantity of soluble phenolic compounds in reaction zones surrounding typical red heart and those reaction zones associated with direct wounding of the stems. The almost two times higher concentration of soluble phenols in reaction zones associated with direct wounding supports the idea that these compartmentalization boundaries differ, among other things, in terms of their formation process (Baum and Schwarze, 2002) and alterations in adjacent discolored wood (Shortle and Smith, 1990; Shortle *et al.*, 1995).

The formation of typical red heart can be described as a two stage process (Torelli, 2003). The first stage is a dehydrating phase, characterized by age-related and physiological alterations of the wood, which include a decrease in water content, increase in the presence of gas and decrease in the vitality of the parenchyma cells. The second stage is the discoloring phase, which is decidedly facultative, depending on the potential entry of oxygen into the already existing dehydrated core (Torelli, 1984). Dead and broken branches, branch scars, forks or wounds in the crown are possible routes for oxygen entrance (Torelli, 1984; Wernsdörfer *et al.*, 2005). It is assumed, however, that oxygen is not the only factor involved in red heart formation but could act by affecting the activity of microorganisms (Sorz and Hietz, 2008).

Superficial wounding of the stem differs from the above described red heart formation in that direct wounding affects water saturated xylem containing vital parenchyma cells. Investigation of angiosperm species revealed that wounding triggers an initial physical dehydration of the wood, followed by a series of turbulent micro-environmental, anatomical and chemical changes, resulting in the formation of superficial discolored wood surrounded by apparent reaction zones (Grosser *et al.*, 1991; Pearce *et al.*, 1994; Barry *et al.*, 2000; Pearce, 2000; Schwarze and Baum, 2000; Oven *et al.*, 2008). Our results in relation to the content of total phenols show that reaction zones associated with wounds walled-off already decaying wood and exhibit a higher soluble phenol content, whereas reaction zones surrounding red heart revealed a lower phenol content. Our observations are in accordance with investigations on the response of *Acer rubrum* and *Acer saccharum* to wounding, revealing that a distinct boundary layer formed between sapwood and discolored wood infected by microorganisms, suggesting that the boundary layer may be formed only in response to infection (Shortle *et al.*, 1995).

5 CONCLUSIONS
5. ZAKLJUČCI

Our research confirmed significant differences in total phenols in different types of beech wood, as well as differences between trees. Concentrations of total phenols were markedly lower in red heart than in reaction zones and sapwood extracts. The content of total phenolics was highest in extracts of the reaction zone, especially in those that had been formed as a direct response of tissues to wounding. Relatively high amounts of polyphenols were found in sapwood extracts, whereas the content of total phenols was higher in older than in younger parts of sapwood. It should be stressed in conclusion that reaction zones in beech appear to be effective but not absolute compartmentalization boundaries (Schwarze and Baum, 2000). Their efficacy may be in part ascribed to individual phenolic compounds. Hydrophilic extractives from wound-associated wood of beech (*Fagus sylvatica* L.) could represent attractive substances for industrial production. Our recent research showed that extracts of wound-associated wood of beech inhibited the growth of some wood decaying fungi (Vek *et al.*, 2013) and, therefore, might be utilized as wood preservatives. It was also proven that some wood extractives have antioxidative properties (Pietarinen *et al.*, 2006) and can potentially be used as technical antioxidants. Our further research is directed towards identification and quantification of compounds in extracts of wound-associated wood of beech.

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6 REFERENCES
6. LITERATURA

1. Albert, L.; Hofmann, T.; Nemeth, Z. I.; Retfalvi, T.; Koloszar, J.; Varga, S.; Csepregi, I., 2003: Radial variation of total phenol content in beech (*Fagus sylvatica* L.) wood with and without red heartwood. Holz als Roh- und Werkstoff, 61 (3): 227-230.
2. Anonymus, 2011: Poročilo Zavoda za gozdove Slovenije o gozdovih za leto 2010. Ljubljana, Zavod za gozdove Slovenije.
3. Barry, K. M.; Pearce, R. B.; Mohammed, C. M., 2000: Properties of reaction zones associated with decay from pruning wounds in plantation-grown *Eucalyptus nitens*. Forest Pathol., 30 (5): 233-245 http://dx.doi.org/10.1046/j.1439-0329.2000.00206.x.
4. Baum, S.; Schwarze, F., 2002: Large-leaved lime (*Tilia platyphyllos*) has a low ability to compartmentalize decay fungi via reaction zone formation. New Phytologist, 154 (2): 481-490 http://dx.doi.org/10.1046/j.1469-8137.2002.00390.x.
5. Bosshard, H. H., 1974: Holzkunde. Band 2. Zur Bilogie, Physic und Chemie des Holzes., Basel, Stutgart, Birkhäuser Verlag.
6. Dietrichs, H. H., 1964: Chemisch-physilogische Untersuchungen über die Splint-Kern-Umwandlung der Rotbuche (*Fagus sylvatica* L.) - Ein Beitrag zur Frage der Holzverkernung. Mitteilungen der BFH 58.
7. Dujesiefken, D.; Liese, W., 2006: Die Wundreaktionen von Bäumen - CODIT haute. In: Dujesiefken D., Kockerbeck P. (Eds): Jahrbuch der Baumpflege 2006. Braunschweig, Thalacker Medien, pp. 21-40.
8. Grosser, D.; Lesnino, G.; Schulz, H., 1991: Histologische Untersuchungen über das Schutzholz einheimischer Laubbäume. Eur. J. Wood Prod., 49 (2): 65-73 http://dx.doi.org/10.1007/BF02662804.
9. Hillis, W. E., 1987: Heartwood and tree exudates. Berlin-New York, Springer-Verlag http://dx.doi.org/10.1007/978-3-642-72534-0.
10. Hofmann, T.; Albert, L.; Retfalvi, T., 2004: Quantitative TLC analysis of (+)-catechin and (-)-epicatechin from *Fagus sylvatica* L. with and without red heartwood. Journal of Planar Chromatography, 17: 350-354 http://dx.doi.org/10.1556/JPC.17.2004.5.5.
11. Hofmann, T.; Albert, L.; Retfalvi, T.; Visi-Rajczi, E.; Brolly, G., 2008: TLC analysis of the in-vitro reaction of beech (*Fagus sylvatica* L.) wood enzyme extract with catechins. Journal of Planar Chromatography, 21 (2): 83-88 http://dx.doi.org/10.1556/JPC.21.2008.2.2.
12. Koch, G.; Bauch, J.; Puls, J.; Schwab, E.; Welling, J., 2000: Vorbeugung gegen verfärbungen von rotbuche. Holz-Zentralblatt, 126: 74-75.
13. Koch, G.; Puls, J.; Bauch, J., 2003: Topochemical characterisation of phenolic extractives in discoloured beechwood (*Fagus sylvatica* L.). Holzforschung, 57 (4): 339-345 http://dx.doi.org/10.1515/HF.2003.051.
14. Merela, M.; Straže, A.; Zupančič, M.; Torelli, N.; Oven, P., 2005: Osnovna gostota, permeabilnost in zgradba reakcijskih con pri bukvi. Les, 57 (1-2): 11-16.
15. Nečesany, V., 1958: Jadro buku. Struktura, vznilka vyvyoj. Bratislava, Slovenskej Akademie Vied.
16. Oven, P.; Merela, M.; Mikac, U.; Sersa, I., 2008: 3D magnetic resonance microscopy of a wounded beech branch. Holzforschung, 62 (3): 322-328 http://dx.doi.org/10.1515/HF.2008.022.
17. Pearce, R. B., 1990: Occurrence of decay-associated xylem suberization in a range of woody species. European Journal of Forest Pathology, 20 (5): 275-289 http://dx.doi.org/10.1111/j.1439-0329.1990.tb01140.x.
18. Pearce, R. B., 1996: Antimicrobial defences in the wood of living trees. New Phytologist, 132 (2): 203-233 http://dx.doi.org/10.1111/j.1469-8137.1996.tb01842.x.
19. Pearce, R. B., 2000: Decay development and its restriction in trees. Journal of Arboriculture, 26 (1): 1-11.
20. Pearce, R. B.; Sumer, S.; Doran, S. J.; Carpenter, T. A.; Hall, L. D., 1994: Non-invasive imaging of fungal colonization and host response in the living sapwood of sycamore (*Acer pseudoplatanus* L.) Using Nuclear-Magnetic-Resonance. Physiol. Mol. Plant Pathol., 45 (5): 359-384 http://dx.doi.org/10.1016/S0885-5765(05)80065-7.
21. Pietarinen, S.; Willför, S.; Ahotupa, M.; Hemming, J.; Holmbom, B., 2006: Knotwood and bark extracts: strong antioxidants from waste materials. Journal of Wood Science, 52 (5): 436-444 http://dx.doi.org/10.1007/s10086-005-0780-1.
22. Pöhler, E.; Klingner, R.; Kunniger, T., 2006: Beech (*Fagus sylvatica* L.) - Technological properties, adhesion behaviour and colour stability with and without coatings of the red heartwood. Ann. For. Sci., 63 (2): 129-137 http://dx.doi.org/10.1051/forest:2005105.
23. Sachsse, H., 1991: Kerntypen der Rotbuche. Forstarchiv, (62): 238-242.
24. Scalbert, A.; Monties, B.; Janin, G., 1989: Tannins in wood: Comparison of different estimation methods. J. Agric. Food Chem., 37 (5): 1324-1329 http://dx.doi.org/10.1021/jf00089a026.
25. Schmitt, U.; Liese, W., 1993: Response of xylem parenchyma by suberization in some hardwoods after mechanical injury. Trees - Structure and Function, 8 (1): 23-30.

26. Schwarze, F. W. M. R.; Baum, S., 2000: Mechanisms of reaction zone penetration by decay fungi in wood of beech (*Fagus sylvatica*). New Phytologist, 146 (1): 129-140 http://dx.doi.org/10.1046/j.1469-8137.2000.00624.x.
27. Shain, L., 1979: Dynamic responses of differentiated sapwood to injury and infection. USA, American Phytopathological Society: Symposium on wood decay in living trees, 69 (10): 1143-1147.
28. Shigo, A. L., 1986: A new tree biology - Dictionary. Durham, New Hamshire, Shigo and Trees Associates.
29. Shortle, W. C.; Smith, K. T., 1990: Decay column boundary layer formation in maple. Biodegradation Research, 3: 377-389.
30. Shortle, W. C.; Smith, K. T.; Dudzik, K. R.; Parker, S., 1995: Response of maple sapwood to injury and infection. European Journal of Forest Pathology, 25 (5): 241-252 http://dx.doi.org/10.1111/j.1439-0329.1995.tb01009.x.
31. Singleton, V. L.; Rossi, J. A., Jr., 1965: Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture, 16 (3): 144-158.
32. Sorz, J.; Hietz, P., 2008: Is oxygen involved in beech (*Fagus sylvatica*) red heartwood formation? Trees - Structure and Function, 22 (2): 175-185.
33. Torelli, N., 1984: The ecology of discolored wood as illustrated by beech (*Fagus sylvatica* L.). IAWA Bulletin, 5 (2): 121-127.
34. Torelli, N., 2001: Odziv drevja na globoke in površinske poškodbe na primeru bukve (*Fagus sylvatica* L.) s poudarkom na nastanku in ekologiji ranitvenega lesa ("rdeče srce"). Pregled = Response of trees on deep and superficial wounds as illustrated by beech (*Fagus sylvatica* L.) with particular emphasis on aetiology and ecology of wound initiated discoloured wood ("red hearth"). A review. Gozdarski vestnik, 59 (2): 85-94.
35. Torelli, N., 2003: Ojedritev - vloga in proces. Les, 55: 368-379.
36. Torelli, N.; Križaj, B.; Oven, P., 1994: Barrier zone (CODIT) and wound-associated wood in beech (*Fagus sylvatica* L.). Holzforschung und Holzverwertung, 46 (3): 49-51.
37. Vek, V.; Oven, P.; Humar, M., 2013: Phenolic extractives of wound-associated wood of beech and their fungicidal effect. International Biodeterioration & Biodegradation, 77 (0): 91-97. In press http://dx.doi.org/10.1016/j.ibiod.2012.10.013.
38. Wernsdörfer, H.; Constant, T.; Mothe, F.; Badia, M. A.; Nepveu, G.; Seeling, U., 2005: Detailed analysis of the geometric relationship between external traits and the shape of red heartwood in beech trees (*Fagus sylvatica* L.). Trees, 19 (4): 482-491 http://dx.doi.org/10.1007/s00468-005-0410-y.

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Influence of Gluing Technology on Physical and Mechanical Properties of Laminated Veneer Lumber

Utjecaj tehnologije lijepljenja na fizikalna i mehanička svojstva lamelirane drvne građe

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ABSTRACT • *This paper presents the analysis of the influence of conventional hot (CH) and high frequency (HF) gluing on relevant physical and mechanical properties of Laminated Veneer Lumber (LVL) made from beech peeled veneer with the thickness of 2.1 mm. Student's T-test was applied to determine the significance of differences between mean values of results obtained for the two different treatments. A significant difference has been determined for the thickness loss, density, moisture and bending strength, while no statistically significant difference has been established for the modulus of elasticity and shear strength of gluing between the means of the tested samples.*

Key words*: laminated veneer lumber, hot gluing, high frequency gluing, physical properties, mechanical properties*

SAŽETAK • *U radu je istraživan utjecaj klasičnoga vrućeg (KV) i visokofrekventnog (VF) lijepljenja na neka relevantna fizikalna i mehanička svojstva uzoraka lamelirane drvne građe (LVL) dobivene od listova ljuštenoga bukova furnira debljine 2,1 mm. Prikazani su i analizirani dobiveni rezultati. Primijenjen je T-test za određivanje značajnosti razlike artimetičkih sredina dvaju skupova uzoraka. Za smanjenje debljine, gustoću, sadržaj vode i čvrstoću na savijanje utvrđena je signifikantna razlika, a za modul elastičnosti i čvrstoću lijepljenja nije utvrđena signifikantna razlika artimetičkih sredina ispitivanih uzoraka izrađenih primjenom različitih tehnologija lijepljenja.*

Ključne riječi: *lamelirana drvna građa, klasično vruće lijepljenje, visokofrekventno lijepljenje, fizikalna svojstva, mehanička svojstva*

1 INTRODUCTION
1. UVOD

In wood industry, gluing is the most commonly used technological procedure for wood bonding. Different heating procedures and wood gluing have been developed recently. Two procedures are the most often applied in industry: indirect (contacting) – conventional hot gluing (CH), direct (dielectric) – high frequency (HF) gluing. The essential differences between CH and HF gluing are in the type of heating, temperature and moisture gradients and gluing time. The experiment

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was performed to analyze relevant physical and mechanical properties of laminated specimens obtained by the two different gluing procedures.

In recent years, the use of laminated elements made of glued sheets of veneer or laminated solid wood has increased considerably. Such laminated elements have good mechanical and rheological properties and better form stability than the products made of one piece of solid wood. Laminated veneer lumber (LVL) is made from peeled veneers of different thickness and types of wood. Veneer sheets are usually equally oriented and they are bonded by waterproof glue. In practice, LVL products are manufactured using conventional CH gluing and HF gluing. Several experiments have shown that the thickness losses of HF glued products differ more than those manufactured by CH gluing (Resnik *et al*. 1994, Resnik *et al.,* 1995). Different thickness losses during CH and HF gluing result in different physical and mechanical properties of the LVL, so that such products behave quite differently in climate changes and with long-term use. Armstrong (1982) has shown that the change in moisture by 1 % below the hygroscopic limit affects the change of bending strength by 4 %. The change in wood density from 700 kg/m^3 to 800 kg/m^3 has resulted in the increase of the bending strength from 125 N/mm^2 to 135 N/mm^2.

The aim of this paper is to analyze the influences of CH and HF gluing on relevant physical and mechanical properties of LVL made from beach peeled veneer.

2 MATERIALS AND METHODS
2. MATERIJAL I METODE

First-class peeled beech veneer (*Fagus Sylvatica* L.), was used to create a sample of LVL specimens. Sheets of the size 550 mm x 550 mm and thickness of 2.1 mm were prepared. Moisture content was determined by gravimetric method according to EN 322 and it averaged 5.5 %. To minimize the effect of defects of wood structure and different density values on the experiment results, the veneer sheets for the production of LVL specimens were selected and graded. Veneer sheets were visually inspected and sheets without bumps, cracks, curling, and discoloration with more or less the same thickness were selected. The density of each sheet of veneer was calculated, and veneer sheets of approximately the same density were used in the experiment.

Melamine-urea-formaldehyde glue MELDUR H97, produced by Melamin Kočevje, was used for gluing LVL specimens. The glue was prepared according to the manufacturer's recipe. Glue mixture was spread over veneer manually by a roller in the quantity of 180 g/m^2, and the open assembly time was about 5 minutes. The specific gluing pressure was 1.8 MPa.

LVL panels were made of seven veneer sheets. LVL test panels were glued together in a hydraulic press, with the possibility of conventional conductive heating and heating in a high frequency electricity field (HF). The surface of press panels was 600 mm x 600 mm (Figure 1). The bonding temperature was 125 °C (as recommended by the glue manufacturer). The time of bonding was determined by measuring the time of reaching the temperature in the middle of the panel, between the 3rd and 4th sheet of veneer. The basic time needed for curing glue was added to the time of bonding.

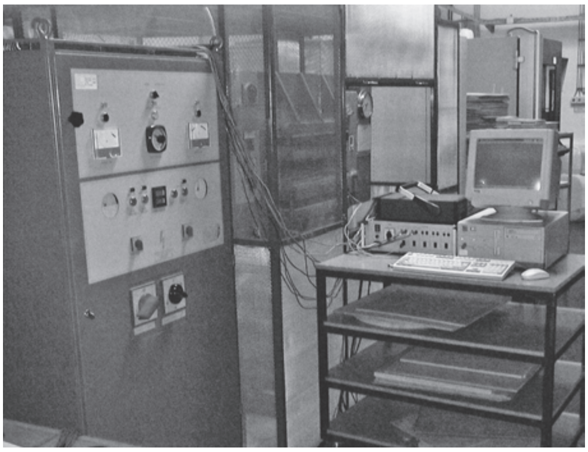

Figure 1 Hydraulic conventional and HF press with a device for measuring temperature
Slika 1. Klasična hidraulična preša i visokofrekventna preša s uređajem za mjerenje temperature

Temperature changes were measured by thermocouples connected to a digital multi-channel instrument MI 7852 ISKRA AMPER. HF generator was used for HF gluing. The working frequency of the generator was 4.75 +0.5 MHz, nominal power 6–18 kW and electrical field between electrodes was 800 V/cm. The output power of 12 kW and the power of anode flow current of 1A were used.

When the temperature in the middle of the plate reached 125 °C, the generator was switched on and off in equal time intervals. When the generator was switched off, the temperature between the 3rd and 4th sheet of veneer was measured. The diagram flow of the temperature between the 3rd and 4th sheet is shown in Figure 2.

Eight LVL boards have been glued during each gluing procedure using the same gluing pressure of 1.8 MPa and the same final temperature of 125 °C. Gluing (curing) time in conventional hot procedure was 13 minutes, and in the HF gluing 7 minutes. After the gluing, the panels were conditioned for 48 hours in an air-conditioned chamber. Panels obtained by conventional hot glue are marked with CH and panels obtained by HF bonding are marked with HF.

After the air conditioning in standard climate, standard samples were taken from each plate for the determination of relevant physical and mechanical properties. Then the prepared specimens were returned to the chamber with the standard air conditioning (T = 20 °C and φ = 65 %) and held up there until the direct testing.

Some relevant physical and mechanical properties of laminated specimens were determined after standard conditioning according to the corresponding standard methods.

ρ	density (kg/m^3)	EN 322: 1996
w	moisture content (%)	EN 323: 1996

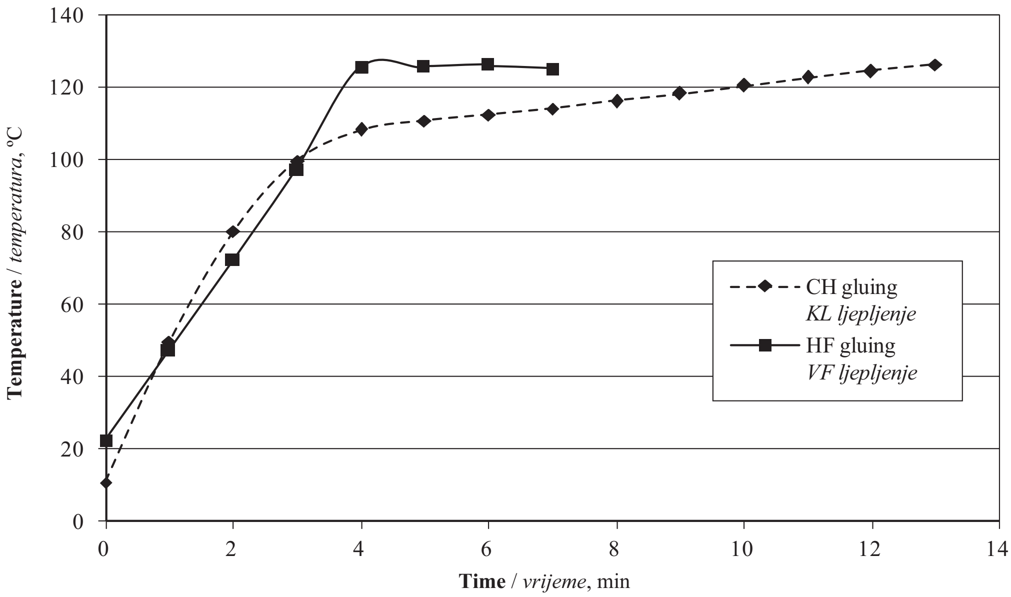

Figure 2 Dependence of temperature in the middle of the specimen on gluing procedure time
Slika 2. Ovisnost temperature u središtu uzorka o trajanju procesa lijepljenja

σ_{bs} bending strength (N/mm²) EN 310: 1993
E_m modulus of elasticity (N/mm²) EN 310: 1993
σ_{ss} shear strength (N/mm²) EN 314-1: 1993
TL thickness loss (%)

Thickness loss (*TL*) is a deformation that occurs when wood is glued and it results from the pressure and other gluing factors. The size of the deformation in certain types of wood are mostly affected by wood moisture content, temperature of gluing and the time of pressure application during gluing.

Higher thickness loss affects the stresses in the adhesive joint and gives a lower strength and stability of glued joints. Also, thickness loss affects physical and mechanical properties of laminated elements.

Thickness loss was determined twice: immediately after bonding and after conditioning in a standard climate.

Thickness loss is defined by the following equation:

$$TL = \frac{\sum_{i=1}^{7} d_i - d_k}{\sum_{i=1}^{7} d_i} \cdot 100\,\% \qquad (1)$$

Where:
TL – thickness loss / *smanjenje debljine* (%),
$\sum_{i=1}^{7} d_i$ – the sum of thickness of sheets in the panel before gluing / *zbroj debljine furnirskih listova u ploči prije lijepljenja* (mm),
d_k – final panel thickness / *konačna debljina ploče* (mm).

Since MUF glue belongs to the category of waterproof adhesives, we applied two criteria to test its water resistance. In the first case, the specimens were immersed in water with the temperature of (20 ± 3) °C for 24 hours before the testing. The second treatment consisted of cooking in boiling water for 4 hours, then drying at a temperature of (60 ± 3) °C for 16 hours, then again cooking in hot water for 4 hours and cooling in water with the temperature of (20 ± 3) °C for two hours. Then the shear strength was determined. Time to fracture was 30 ± 5 seconds. After drying, the percentage of failure at the adhesive or wood was assessed with the accuracy of 5 %.

Our specimens consist of seven veneer sheets and the strength is determined by adhesive layer near the middle of the sample, i.e. at the third layer of glue.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Statistical analysis was performed by Student's *T*-test for testing the hypothesis whether the means of the two sets were significantly different. One set consisted of specimens glued by HF method, and the other set of specimens were glued with the standard procedure of CH gluing. In both cases we had the same number of specimens so that the number of degrees of freedom was

$$\nu = n_{HF} + n_{CH} - 2 \qquad (2)$$

Rejection region was taken with the double *T*-test. Statistics *T* was calculated in excel by the equation:

$$T_{test} = \frac{\overline{X}_{HF} - \overline{X}_{CH}}{S^* \sqrt{\frac{1}{n_{HF}} + \frac{1}{n_{CH}}}} \qquad (3)$$

Where
$\overline{X}$ – average / *srednja vrijednost*,
n – number of specimens / *broj uzoraka*,
S^{*2} – variance calculated by the equation (4) / *varijanca izračunana iz jednadžbe (4)*

$$S^{*2} = \frac{(n_{HF} - 1)S^{*2}_{HF} + (n_{CH} - 1)S^{*2}_{CH}}{n_{HF} + n_{CH} - 2} \qquad (4)$$

If $|T_{test}| \le t_{\nu;\,0.975}$, null hypothesis is not rejected. If $|T_{test}| > t_{\nu;\,0.975}$, null hypothesis is rejected with the risk

Table 1 Physical and mechanical properties that have shown significant difference established by *T* test between two methods of gluing
Tablica 1. Fizikalna i mehanička svojstva za koja je T-testom utvrđena signifikantna razlika među skupinama uzoraka lijepljenih dvjema različitim tehnologijama

Properties *Svojstva*	***HF***	***CH***	***v***	$t_{v\ 0.0975}$	T_{test}
TL, %	5.4	7.1	14	2.145	6.130
ρ, kg/m³	743.69	757.27	94	1.986	5.793
w, %	9.85	9.49	94	1.986	8.487
σ_{bs}, N/mm²	129.9	137.8	46	2.0129	2.922

Legend / *Legenda*: *TL* – thickness loss / *smanjenje debljine*; ρ – density / *gustoća*; *w* – moisture content / *sadržaj vode*; σ_{bs} – bending strength / *čvrstoća na savijanje*

of 5 % and it is said that the difference in means is significant.

Table 1 provides an overview of the results of the studied physical and mechanical properties of the produced LVL where significant difference in mean values was established.

The LVL's thickness loss affects the formation of glued joint, hygroscopic behavior (swelling and shrinkage), density, thermal and electrical properties, as well as the strength of material. Greater loss of thickness causes higher internal stress and lower stability of the glued joint. The average value of thickness loss in the conventional hot gluing of LVL was 7.1 %, whereas in HF gluing it was 5.4 %, which makes a difference of 1.7 %.

Wood is amorphous material (due to the amorphous areas of lignin between the high molecular cellulose), and if exposed to the temperature of 70 °C and higher, it gets plastically deformed. At this temperature, the cellulose crystal grids oscillate so that the cohesive forces are reduced and mobility of bound water increases.

The viscosity of lignin and pectin decreases; thermally unstable polyoses decompose (Scallan, 1974). Under the influence of external pressure, the inner surfaces get closer and establish new hydrogen relations between hydroxyl groups, which are located on the surface and wall of the cell.

The water content in wood has an important impact on the loss of thickness under pressure. An increase in water content to the hygroscopic limit reduces the temperature of plastification and increases the deformation. The water penetrates between the crystals of cellulose weakening the bond among them. In addition, water dissolves pectic substances and polyoses and thus further weakens the intermolecular connections, which increases the deformation (Gorišek, 1987).

The movements of heat and water in different gluing procedures are different. During hot gluing, the adhesive joint is heated from the outer layers toward the centre. The heat is transferred to the outer layer of wood from the press plates, resulting in more intense heating of layers - glued elements closer to the presser plates. Its intensity decreases with the distance from the presser plates. This gradient in temperature affects the water transfer in the glued specimen.

At a certain temperature and pressure, water turns into steam. In the outer layers the vapor has a higher pressure and temperature with respect to the centre of the glued element. One part of the steam evaporates into the environment, while the other, due to differences in vapor pressures, moves toward the centre of the specimen. When the vapor reaches the layers with lower temperature, it condensates. This results in a gradient of moisture from the centre toward the outer layers. Due to high temperatures in the outer layers, the moisture rapidly decreases, which results in greater plastic deformation in the outer layers than in the inner layers.

In the case of HF gluing, the temperature and moisture distribution is different. The heat is generated inside the material, which results in an almost uniform temperature distribution. Due to different dielectric properties, the wood temperature increases slower than the glue temperature, which is desirable for gluing. A part of the heat from the outer layers is transferred to press plates and the surrounding air. This approximately uniform temperature distribution causes a quick moisture distribution, which becomes uniform as well. Therefore the residual stresses are reduced and the loss of thickness is uniform in the entire cross-section.

The gluing time has an important effect on the loss of thickness. The temperature diagram flow (Fig. 2) shows that the gluing time at the temperatures above 100°C is about 10 minutes in the case of conventional gluing, and only 3.5 minutes in the case of HF gluing. This results in greater plastic deformations in conventional gluing than in HF gluing. If during the application of pressure, wood moisture remains approximately the same, and the temperature of wood increases, total thickness loss will depend on the time of exposure to elevated temperature. All other parameters of gluing in the experiment were the same in both cases and could not significantly affect the outcome.

Density of wood is an important physical property of wood. Density of layered glued wood is greater than the density of solid wood with the same moisture content. Nikolić (1988) reports an increase in density of 18 to 20 %, Mesić (1998) of 13 to 20 %. In our experiment, the density of specimens with HF gluing increased by 4.7 %, and with conventional gluing by 6.7 %. A slightly higher density in the case of conventional gluing is the result of a greater loss of thickness.

Density also depends on the moisture content of wood. The HF glued specimens have slightly higher moisture content than the conventionally glued specimens. This is the reason why the difference in density is not higher.

Moisture content below the hygroscopic limits has a significant effect on the mechanical properties of wood. Armstrong (1982) found that the change in moisture content of 1 % causes the change of bending strength (4 %), elastic modulus (1.5 %) and compressive strength (5 %).

Laminated glued elements are often loaded by the transverse load, and therefore the bending strength

Table 2 Mechanical properties for which *T*-test revealed no significant differences
Tablica 2. Mehanička svojstva za koja *T*-testom nije utvrđena signifikantna razlika među skupinama uzoraka lijepljenih dvjema različitim tehnologijama

Properties *Svojstva*	**HF**	**CH**	**v**	$t_{v\ 0.975}$	T_{test}
E_m, N/mm²	13978	14015	46	2.0129	0.17
σ_{st-1}, N/mm²	7.83	7.39	28	2.0484	1.0565
σ_{st-2}, N/mm²	9.85	9.49	28	2.0484	1.0048

E_m – modulus of elasticity / *modul elastičnosti*; σ_{ss-1} – shear strength after soaking in water / *smicajna čvrstoća nakon namakanja u vodi*; σ_{ss-2} – shear strength after boiling in water / *smicajna čvrstoća nakon kuhanja u vodi*

is the most crucial mechanical property for dimensioning of elements. The average bending strength of LVL glued with conventional procedure was higher by 6.1 % than LVL glued with HF gluing procedure. The density and moisture content of wood have a major effect on bending strength. The density of conventionally glued specimens was higher by about 1.8 % compared to the density of HF glued specimens. Humidity of the conventionally glued specimens was 3.8 % lower than the HF glued specimens.

Table 2 provides a brief overview of the results of the studied physical and mechanical properties of the LVL samples where no significant difference in mean values was established.

The experiment showed a negligible difference in the elastic modulus (0.3 %). With respect to higher density and lower moisture of standard glued samples, one would expect a greater difference in elastic modulus.

Bending strength and bond strength of LVL specimens, glued by both procedures, are very high. This shows that the gluing process and selection of veneer sheets were performed correctly, which resulted in a low coefficient of variation for E_m in both gluing processes.

For glued structures exposed to changing humidity, the European standard (EN 314-1:1993) requires testing of shear strength in two regimes. The first regime implies soaking in the water at room temperature (20 ± 3) °C, and then testing the shear strength of the glue bond. If the strength is adequate, than the second regime is applied, i.e. cyclic cooking of samples and then testing the shear strength. The shear strength in the middle of the glue bond was higher for HF glued specimens in both regimes (6.0 % higher in soaking regime and 4.6 % higher in cooking regime).

Rowell (1996) found that the strength of the glue bond depends on many factors, the two most important being the adhesive properties and adhesion. Adhesion of glue-wood primarily depends on surface wetting, glue penetration, porosity, pH, humidity, %, surface condition and anatomical directions.

Klašnja and Kopitović (1992) have shown that the temperature is a key factor in forming a watertight glue bond. According to Bradly and Kamke (1988) better glue spillage at higher temperatures, due to the reduction of viscosity, results in better penetration of glue into the wood. They found that the variability of the anatomical structure of wood is the most influential factor for glue penetration.

Reduction of shear strength after the cyclic cooking for both process of gluing was nearly equal, about 35 %. A better shear strength of HF glued specimens is not statistically significant. In the process of HF gluing, the glue heats up faster, resulting in a rapid reduction of viscosity. In this case the glue hardens quicker and penetrates slower into the wood (Resnik *et al*., 1997). The distribution of moisture content and temperature across the section is balanced, giving a bond without significant residual stresses.

On the other hand, in the case of conventional hot gluing, the heat and moisture move from the outer layers toward the centre. Less time is required to heat the middle layers than the external layers, due to slower transfer of heat by conduction. Different temperature gradient creates substantial moisture gradient over the intersection of elements, and higher humidity in the middle layers.

Šernek (1999) has shown that by gluing beech veneer sheets 2.2 mm thick in three-layer plywood with a conventional hot and HF gluing using UF glue, the moisture of veneer had a significant impact on the depth of penetration of UF glue, as well as on the shear strength. He found that optimal moisture content for the conventional gluing is somewhere between 4.1 and 5.7 %, and for the HF gluing between 5.7 and 9.2 %.

The values of shear strength were about 3 N/mm² for both gluing procedures.

In our experiments relatively high shear strength of the glue bond was reached, most probably due to the thickness of the specimens.

Slightly higher strength of HF glued samples in our experiment was primarily a consequence of higher increase of temperature in HF heating, smaller thickness loss and smaller internal stresses, which are very important in the process of relaxation after gluing.

4 CONCLUSIONS
4. ZAKLJUČCI

The results of this experiment confirmed that the technological process of gluing affects the physical and mechanical properties of LVL. The conventional hot and HF gluing leads to different dynamics in heating the glue layer, and therefore the time of gluing, moisture and temperature gradients and residual stresses are all considerably different.

These differences affect the amount of the total deformation and the relationship between the elastic and plastic deformation, i.e. the loss of thickness. All these caused the difference in other physical and mechanical properties.

There was a significant difference (α = 0.05) in the mean values of the following physical and mechanical properties of HF and conventionally glued specimens: loss of thickness, density, moisture and bending strength. The elastic modulus and shear strength showed no statistically significant differences.

5 REFERENCES
5. LITERATURA

1. Armstrong, L. D., 1982: Mechanical properties of wood. Research. Melbourne, CSIRO Australia. Division for Forest Products: 82 pp.
2. Boyd, J. D.; Foster, R. C., 1975: Microfibrilis in primary and secondary wall growth develop trellis configuration. Can. J. Bot., 53: 2687-2701.
3. Bradly, D. E.; Kamke, F. A., 1988. Effect of hot-pressing parameters on resin penetration. Forest Production Journal, 38, 11/12:63–68.
4. Gorišek, Ž., 1987: Vpliv parjenja na fizikalne lastnosti bukovine. Les, 39, 7/8: 181-188.
5. Klašnja, B.; Kopitović, S., 1992: Lignin-phenol-formaldehyde resins as adhesives in the production of plywood. Holz als Roh- und Werkstoff. 50, 7-8: 282-285.
6. Lu, X.; Pizzi A., 1998: Curing conditions effects on the characteristics of thermosetting adhesives-bonded wood joint – Part 1: Substrate influence on TTT and CHT curing diagrams of wood adhesives. Holz als Roh-und Werkstoff, 56:339-346 http://dx.doi.org/10.1007/s001070050330.
7. Mešić, N., 1998: Furniri i furnirske i stolarske ploče. Sarajevo, 386 pp.
8. Nikolić, M.S., 1988: Furniri i slojevite ploče. Beograd, Građevinska knjiga: 414 pp.
9. Resnik, J.; Šega, B., 1994: Thickness loss during the hot pressing of 3-layerd wood boards made of fir lamellas vs. wood preparation and pressing parameters. In: The first international conference on the development of wood science/technology and forestry, Great Missenden.
10. Resnik, J.; Tesovnik, F., 1995: Thickness loss when gluing veneer sheets into boards in the hot press or by high frequency, Holz als Roh - und Werkstoff, 53: 113-115 http://dx.doi.org/10.1007/BF02716405.
11. Resnik, J.; Šernek, M.; Kamke, F. A., 1997: High-frequency heating of wood with moisture content gradient. Wood and fibre science 29, 3: 264-271.
12. Rowell, R. M., 1966: Chemical Modification of Wood for Improved Adhesion in Composites. Wood Adhesives, For. Prod. Soc., Madison, WI. P.56-60.
13. Scallan, A. M., 1974: The structure of the cell wall of wood-a consequence of anisotropic intermicrofibrillar bonding. Wood Science and Technology, 6: 266-271.
14. Šernek, M., 1999: Vpliv bistvenih dejavnikov na penetracijo in trdnost UF lepilnega spoja pri lepljenju bukovine. M.sc. Thesis. Ljubljana, Univerza v Ljubljani, BF, Oddelek za lesarstvo: 108 pp.
15. Šernek, M.; Resnik, J.; Kamke, F. A., 1999: Penetration of liquid urea-formaldehyde adhesive into beech wood. Wood and fibre science 31, 1:41-48.

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Some of the Physical Properties of UV Jet Printed Furniture Surfaces

Neka fizikalna obilježja površine namještaja obrađene UV printanjem

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ABSTRACT • *This study researches some physical properties of furniture surfaces on which UV jet printing is applied. To this end, UV protected digital printing ink was applied on melamine faced chipboard (MFC) and Printpan (Pp) panels and their surface resistance to cold liquids (TS 12720), hot liquids (TS 4980), dry heat (TS EN 12722), wet heat (TS EN 12721), water vapor (TS EN 438-2), glowing cigarette (TS 4756), and abrasion (TS 4755) was identified. As a result, it was found that UV jet printing ink applied on melamine faced chipboard and printpan panels is not resistant to cold liquid, water vapor, glowing cigarette and abrasion but relatively resistant to hot liquid, dry heat and wet heat.*

Keywords: *UV jet printing method, UV curable digital printing ink, melamine faced chipboard, printpan, physical properties*

SAŽETAK • *U radu se prikazuju rezultati istraživanja nekih fizikalnih obilježja površine namještaja obrađene UV printanjem. Zaštitno UV digitalno printanje primijenjeno je na pločama ivericama (MFC) i printpan pločama (Pp) te je ispitana otpornost njihove površine na hladne tekućine (TS 12720), vruće tekućine (TS 4980), suho zagrijavanje (TS EN 12722), vlažno zagrijavanje (TS EN 12721), vodenu paru (TS EN 438-2), upaljenu cigaretu (TS 4756) i abraziju (TS 4755). Rezultati su pokazali da površine ploča iverica s melaminskom folijom i printpan ploča obrađenih UV printanjem nisu otporne na hladne tekućine, vodenu paru, upaljenu cigaretu i abraziju, a relativno su otporne na vruće tekućine, suho zagrijavanje i vlažno zagrijavanje.*

Ključne riječi: *metoda UV printanja, UV tinta za digitalno printanje, ploča iverica s melaminskom folijom, printpan, fizikalna obilježja*

1 INTRODUCTION
1. UVOD

Today in furniture industry, particularly in mass production modular furniture systems, the pre-coated wooden composite boards are mostly being used. The main reason for using these boards is that they have already been coated or painted, and hence there is no need for coating and finishing processes in furniture manufacturing processes. Therefore, it is possible to reach higher productive capacities with lower investments. The melamine impregnated paper, plastic coatings and paint systems are most commonly used as surfacing material in these boards (Istek *et al*., 2010).

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The most commonly used chipboard is the one coated with melamine impregnated paper (MFC). Painted chipboards (Pp), known as printpan in the market, whose surfaces are painted straight and figured with the direct press technique, have recently been increasingly used in furniture industry.

As furniture is also a product of fashion, boards with a large variety of surface colors and figures are produced in order to meet the taste of different consumers. Due to costumer oriented marketing approach, rapidly changing tastes and tough competitive conditions, it is necessary to meet the needs of all consumers. However, board production technology and economic factors do not enable a great variety of figures and production in little amounts in these wooden composite materials (Chapman, 2006). To solve this contradiction, producers searched for different solutions and digital printing technology started to be used in furniture industry. Digital printing method could be implemented swiftly and a wide variety of colors and figures could be used. With the development of ultraviolet (UV) curable digital printing ink, this technology has been used more widely. The use ranges from press and advertisements to textiles, handcrafts and even furniture industry. It is preferred as it can be applied to every kind of surface regardless of material and shape, which enables quick production, and provides high quality in terms of image and aesthetics. This method, also called "green technology", is preferred because its harmful environmental effects are very few particularly with the use of entirely UV curable inks that make no use of harmful volatile solvents. (Işmal, 2003).

UV curable digital printing ink used in press technologies gives a decorative value to the surface although it does not constitute a layer such as paint or varnish. This ink, which replaces the other common upper surface applications, is the best material that one can possibly desire or dream of. By means of this printing method, every picture could be applied on furniture surfaces. For decorative purposes, it is used on cupboard doors and on parts where visual aesthetics are required. With this technology, all kinds of customer needs can be met at very short notice and tailor made furniture can be produced, at the satisfaction of customers.

Developments in technology and science enable the production of new materials, and all new materials should go through a performance test in order to determine their area of use. For manufacturers, it is important to use the right material in the right place; and for end-users it is important to know the properties and limits of the material in order to use them properly. In order to prevent the consumers and country economy to suffer a loss, some upper surface tests are applied to see the resistance of furniture surfaces against the effects they could be exposed to. This can give the answer to the questions such as: "Which material can be used in which area? and "What kind of effects it can resist?"

Several studies were carried out to examine surface resistance of wood finishes to dry heat, wet heat, glowing cigarette, abrasion and scratch (Sönmez, 1989; Kaygın, 1997; Örts *et al*., 2002; Budakçı *et al*., 2009) but this is not the case with printed inks. Akgün (2008) has surveyed the dry film thicknesses, glossiness, hardness, and surface resistances to cold liquids of UV varnish with nanoparticles and conventional varnish layers. It has been shown that the UV varnish system is the most durable kind of varnish against all the liquids used in the study. Although there are some studies in the literature particularly in the field of typography, no academic study on UV jet printing technology applied on furniture surfaces has been found.

The aim of this study is to determine the surface performances of melamine faced chipboard and printpan surfaces, on which the new UV jet printing technology was applied, and their resistance to some physical effects.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Materials
2.1. Materijali

In this study, melamine faced chipboard (MFC) and painted panel (Pp) (Printpan) have been used as wooden based substrate to make digital printing over. Boards are supplied from Kastamonu Entegre INC. The cream colored melamine faced chipboard, used as test specimen, has the thickness of 8 mm and density of 0.8 g/cm^3. The cream colored Printpan board has the thickness of 8 mm and density of 0.7 g/cm^3.

Blue colored UV curable digital printing ink (Sericol ZN 001) is used in the printing process.

For determining the resistance of surfaces to cold liquids, 96 % (*v*/v) ethanol, 10 % (*m*/*m*) acetic acid, acetone, milk and olive oil were used in accordance with TS EN 12720 standards. For determining the resistance of surfaces to hot liquids, tea (92.5 °C), instant coffee (94 °C) and distilled water (98 °C) (TS 4980) were used.

2.2 Methods
2.2. Metode

4 pieces of flat surfaces sized 50x100 cm were cut from each of the 8 mm thick melamine coated chipboard and printpan panels and these pieces were acclimatized for a week at the temperature of 23±2 °C, and 50±5 % relative humidity. Average surface roughness (*R*a) of the boards was measured by using TR200 roughness tester. Twenty random measurements of the surface of each board were taken at a tracing speed of 1.5 mm/s over 200 mm span. Average surface roughness of the MFC and Pp panels were measured as 5.028 μm and 6.459 μm, respectively. After that, two layers of UV curable digital printing ink were applied on melamine faced chipboard and printpan surface in Zünd UVjet 215-plus digital printing machine. Thicknesses of the panels were measured before and after printing by using digital micrometer with the sensitivity of 0.001 mm. Thirty random measurements of each board were taken and the result of these measurements showed that the ink layer thickness on the MFC was 0.03 mm and the ink layer thickness on Pp was 0.01

mm. Specimens were cut off from these pieces in required measures and used for each experiment.

The resistance of experiment sample surfaces to cold liquids (TS 12720), hot liquids (TS 4980), dry heat (TS EN 12722), wet heat (TS EN 12721), water vapor (TS EN 438-2), glowing cigarette (TS 4756) and abrasion (TS 4755) was determined in accordance with the relevant standards.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Surface resistance to cold and hot liquids
3.1. Otpornost površine na hladne i vruće tekućine

The changes that cold and hot liquids made on sample surfaces reveal differences depending on the kind of material, kind of liquid, and the pH value of the liquid. The change of surface impact categories depending on the kind of liquid are given in Figure 1. Based on the obtained data, when MFC and UV jet printing was applied on printpan (Pp-UV), surfaces have shown the best surface performance against cold test liquids applied to the surfaces, confirming that MFC-UV is the least durable surface. The durability of melamine faced clipboard is the result of the fact that the melamine resin on the board surface is resistant to liquids due to its hydrophobic character. The reason of low durability of MFC-UV surface might be that the liquids that remained on the surface, not being able to penetrate into the material due to the hydrophobic character of MFC surface, deform the structure of the ink and lead to further distortion. Acetic acid has led to the utmost distortion of surfaces. Being a good solvent due to its acidic character (Hakdiyen, 1972), acetic acid has led to dramatic distortion.

The changes that hot liquids made on sample surfaces reveal differences depending on material and liquid type (Figure 1). While it is confirmed that Pp-UV and MFC surfaces are the most durable surfaces against hot liquids, it is determined that Printpan is the least durable surface. The reason for Pp-UV surface to be more resistant than the Printpan surface might be that Printpan material absorbs the liquid and the remaining liquid has less strong effect on the ink layer. Since the melamine resin on the MFC surface is hydrophobic and resistant to heat (Sönmez and Budakçı, 2004), it can be concluded that MFC shows the best performance against hot liquids.

3.2 Surface resistance to dry and wet heat
3.2. Otpornost površina na suho i vlažno zagrijavanje

The resistance of surfaces to dry and wet heat in terms of material type is given in Figure 2. In the classification of surfaces, the temperature is determined at which they take the highest evaluation category value 5.

The resistance temperature of Printpan surface against dry heat is 100 °C, of PP-UV and MFC-UV surface it is 120 °C and of MFC it is 140 °C. It can be stated that the resistance of UV curable ink to dry heat is 120 °C. MFC surface has shown the utmost surface performance against dry heat. The reason for this is that the melamine formaldehyde resin is resistant to heat up to 130 °C (Whelan, 1994).

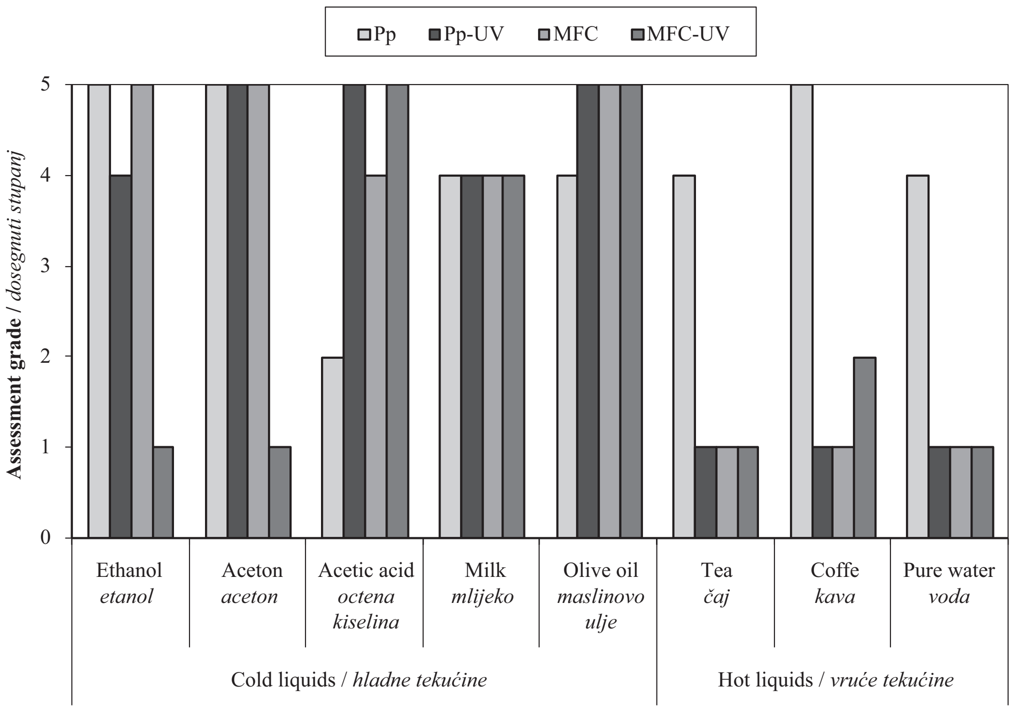

Figure 1 Surface resistance to cold and hot liquids in terms of material and liquid type (Pp – Printpan, Pp-UV – UV printed printpan, MFC – Melamine faced chipboard, MFC-UV – UV printed MFC; surface impact category number 5 indicates that it is the most durable surface)
Slika 1. Otpornost površina na različite hladne i vruće tekućine (Pp – *printpan* ploča, Pp-UV – UV printana ploča, MFC – ploča iverica s melaminskom folijom, MFC-UV – UV printana MFC; ocjena 5 označava površine najbolje otpornosti)

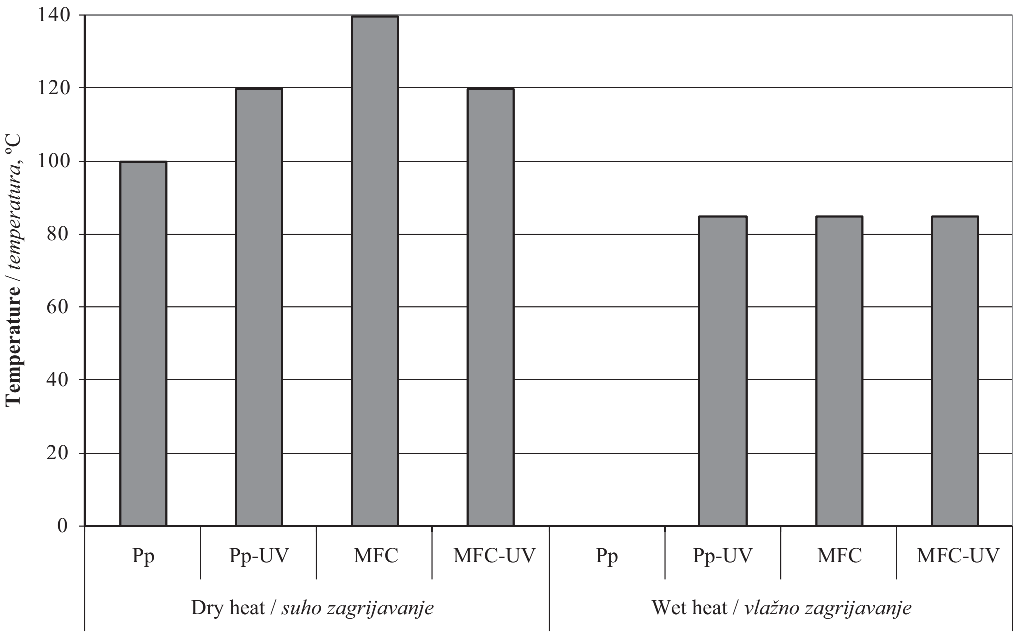

Figure 2 The resistance of surfaces to dry and wet heat in terms of material type
Slika 2. Otpornost površina na suho i vlažno zagrijavanje

It is determined that the Pp surface is the least durable surface regarding its resistance to wet heat. There is no value shown in Figure 2 because Pp surface falls into the lowest resistance category even at the lowest temperature (55 °C) specified in the standard. It is shown that other surfaces are rather more durable (85 °C) than Printpan surface. It can be argued that distortion originated because melting occurred on the acrylic paint surface within the thermoplastic structure used in the Printpan surface. Due to the relatively lower water absorption of the other surfaces, it can be argued that the heat had hardly any impact on the material and, therefore, the distortionary effect occurred in rather high temperatures.

3.3 Surface Resistance to water vapor
3.3. Otpornost površina na vodenu paru

Pp-UV and MFC-UV surfaces have fallen into the weakest impact category (grade 1) being unable to show any resistance to water vapor. It can be asserted that distortion occurred on the surface as the digital printing ink was not durable against water and heat. The results of abrasion experiment that was conducted (see section 3.5) also reveal that ink could not be sufficiently adsorbed by the surfaces and that the adhesion strength was low, hence, in this situation, the steam might have led to distortions on the surface by having a higher impact in between the material and the ink. It is shown that Pp and MFC surfaces are relatively more resistant to water vapor (grade 2) than the other two surfaces.

3.4 Surface resistance to glowing cigarette
3.4. Otpornost površina na upaljenu cigaretu

Glowing cigarette shows similar impacts on sample surfaces. Since glowing cigarette leads to carbonization on Pp, Pp-UV and MFC-UV surfaces, it is determined that these surfaces fall into the least durable surface category (grade 1). It is detected that MFC surface is relatively more durable against glowing cigarette (grade 2). Browning and explicit marks have occurred on MFC surface. This happened because the melamine resin on the surface is more resistant to heat than paint on the surface of Pp or the ink (Whelan, 1994). The reason for carbonization on other surfaces is because the UV dried digital print ink and paint on printpan surface are not resistant to fire. This is an expected result as the temperature of the tip of a glowing cigarette is approximately 288 °C (Smith *et al*., 2008) and this temperature caused damage on the surface of the boards.

3.5 Abrasive resistance
3.5. Otpornost na abraziju

The results of abrasion experiment showed that MFC is more durable than the other surfaces. While Pp, Pp-UV and MFC-UV corroded after 25 cycles, MFC corroded after 300 cycles. The basic requirement for durable coating performance on the surface of wood-based panels is a good adhesion between the panel surface and the coating material (Istek *et al*., 2012). It is possible to say that since UV ink and paint on Printpan surface cannot penetrate into the panel adequately and since their adhesion strength is low (Walker and Lindström, 2010) , they are not resistant to abrasion.

4 CONCLUSION
4. ZAKLJUČAK

- It is determined that, although Pp, Pp-UV and MFC surfaces show minor changes regarding the resistance to cold liquids in terms of reactive type, they are durable in general terms and that MFC-UV surface is relatively less durable.
- It is established that Pp-UV, MFC and MFC-UV surfaces are durable against hot liquids while Pp surface is not durable.

- It is indicated that the Pp surface is not durable against wet heat and that the resistance of other surfaces to wet heat is 85 °C. It is specified that the surfaces are relatively more durable against dry heat (120 °C).
- It is detected that all the surfaces are not resistant to water vapor and glowing cigarette.
- While MFC surface is more durable against abrasion, it is confirmed that because of low adhesion strength of UV curable ink, the other surfaces are not durable.

As a result, since the UV curable ink is not very durable, it is advised that it should not be used in productions where it could be exposed to strong chemicals (table, desk, etc.) and in places, such as bathrooms, etc., where it could be exposed to water vapor. In these environments, it could be used by applying varnish as a protective layer. To this end, water based varnish could be used. When cleaning the products in which UV curable digital printing ink has been used, strong cleansers should not be used. Since the digital printing ink applied on printpan surface would show better performance, the use of printpan as substrate and for decorative purposes on cupboard doors would be convenient.

5 REFERENCES
5. LITERATURA

1. Akgün, E., 2008: Comparison of conventional varnishes with nanolacke UV varnish with respect to resistance properties, M.Sc.Thesis, p.1, Zonguldak Karaelmas University, Zonguldak.
2. Budakçı, M.; Sönmez, A.; Esen, R., 2009: Investigation the resistance of wooden varnishes to steam and wet heat. 5. International Advanced Technologies Symposium (IATS'09), 13-15 May 2009, Karabük, Turkey.
3. Chapman, K. M., 2006: "Wood-based panels: particleboard, fibreboards and oriented strand board" Primary Wood Processing, 2nd Ed, Walker, J.F., Springer, The Nederlands, pp. 427-475.
4. Hakdiyen, I., 1972: General and Technical Chemistry, Text Book, Birsen Bookstore Publications, Istanbul, pp. 263-268.
5. Istek, A.; Aydemir, D.; Aksu, S., 2010: The effect of decor paper and resin type on the physical, mechanical, and surface quality properties of particleboards coated with ipregnated decor paper. BioResources 5(2): 1074-1083.
6. Istek, A.; Aydemir, D.; Eroglu, H., 2012: Surface properties of mdf coated with calcite/clay and effects of fire retardants on these properties. Maderas. Ciencia y tecnología, 14(2): 135-144.
7. Işmal, Ö. E., 2003: Textile Digital (Ink jet) Printing Technologies Basic Principles and Development Process. Turkish Textiles Foundation Publications No: 2, pp. 65-66, Meta Press Publication Services, Izmir.
8. Kaygın, B., 1997: Durability properties of opaque paints used on wooden surfaces. M.Sc. Thesis, p. 97, Zonguldak Karaelmas University, Zonguldak.
9. Örs, Y.; Küreli, I.; Söğütlü, C., 2002: The determine of the abrasive and scratching strengths of various wood materials used for kitchen workbench tables in residences. Gazi Üniversity Journal of Science 15(2): 475-484.
10. Smith, E.; Christopherson, J.; Adams, G.L., 2008: The Wood Shake and Shingle Roof Hazard. University of Nevada Cooperative Extension Fact Sheet 94-26.
11. Sönmez, A., 1989: Durability of varnishes used on surfaces of wooden furniture against important physical mechanical and chemical effects. Ph.D. Thesis, p. 92, Gazi University, Ankara.
12. Sönmez, A.; Budakçı, M., 2004: Finishing processes in woodworks II., Gazi University Faculty of Technical Education, Ankara, pp. 25-27.
13. ***TS 4755. 1986: Furniture Surfaces- Determination of Abrasive Resistance. T.S.E., Ankara, pp. 1-4.
14. ***TS 4756. 1986: Furniture Surfaces- Determination of Resistance to Glowing Cigarette. T.S.E, Ankara, pp. 1-2.
15. ***TS 4980. 1986: Furniture Surfaces- Determination of Resistance to Hot Liquid. T.S.E, Ankara, pp. 1-3.
16. ***TS EN 12720. 2002: Furniture - Assessment of surface resistance to cold liquids. T.S.E., Ankara, pp. 1-7.
17. ***TS EN 12721. 2002: Furniture - Assessment of surface resistance to wet heat. T.S.E., Ankara, pp. 1-7.
18. ***TS EN 12722. 2002: Furniture - Assessment of surface resistance to dry heat. T.S.E., Ankara, pp. 1-8.
19. ***TS EN 438-2. 2007: High-pressure decorative laminates (HPL) - Sheets based on thermosetting resins (usually called laminates) - Part 2: Determination of properties, T.S.E., Ankara, pp. 14-16.
20. Walker, P.; Lindström, M., 2010: UV-Curable Large Format Printers: Technology Test & Guide. Digital Dots Special Report, Digital Dots Ltd., UK.
21. Whelan, T., 1994: Polymer Technology Dictionery. Chapman & Hal, London, p. 242 http://dx.doi.org/10.1007/978-94-011-1292-5.

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18.2
Hydromat TK-MP 250

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Sustainable Development and Green Buildings

Održivi razvoj i zelena gradnja

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ABSTRACT • *Global sustainability goals have led to the development of the green building movement. The Green Building Program, stemming from the movement, has had unprecedented success as it provides a quantifiable metric to people's efforts towards sustainable development. Sustainable development and green buildings are often used interchangeably. Although, sustainable development and green buildings are related, they are not the same. This paper provides an overview of how green building relates to sustainable development practices. Sustainability also governs decisions concerning building materials. A comprehensive explanation of what constitutes a green building material is discussed and how renewable material like wood fare in the deciding criteria. There are many green building rating systems in place. United States Green Building Council administered Leadership in Energy and Environment Design (LEED) is the global market leader in the rating systems. LEED is a commendable and grand effort in moving towards sustainable development by converting the built environment green. However, it does have certain pitfalls and challenges. Some of these challenges are with respect to policies on material selection and performance monitoring. The materials used in a project are considered at a common starting point and no consideration is given to the life cycle performance of the material. Statements concerning sustainability require validation, and Life Cycle Analysis (LCA) is a tool that can provide such validity. This paper presents how beneficial it can be, when included, in the bigger scheme of green building rating systems and introduces an integrated design concept for green buildings.*

Key words: *LEED, life cycle analysis, wood*

SAŽETAK • *Ciljevi održivosti društva i građana svijeta doveli su do razvoja pokreta zelene gradnje. Programi zelene gradnje, koji proizlaze iz pokreta, imali su neviđen uspjeh jer su osiguravali mjerljive veličine za uspješnost u naporima za održivi razvoj. Održivi razvoj i zelena gradnja često se upotrebljavaju u istom značenju. Iako su održivi razvoj i zelena gradnja povezani, oni nisu isto. U ovom je radu dan pregled kako se zelena gradnja odnosi prema praksi održivog razvoja. Održivost također utječe na odluke koje se odnose na materijal za gradnju. U radu se daje opsežno objašnjenje što je to zeleni građevni materijal se te navodi kako je obnovljivi materijal poput drva često među odlučujućim kriterijima pri gradnji. Postoje mnogi rejting sustavi zelene gradnje. Savjet za zelenu gradnju SAD-a upravljao je skupinom Vodstvo u energetici i zaštiti okoliša (LEED), koja je globalni tržišni lider u rejting sustavima. LEED skupina simbolizira vrlo pohvalan i velik trud u kretanju prema održivom razvoju pretvaranjem izgrađenog okoliša u zeleno. No tu su i neke zamke i izazovi. Neki od tih izazova odnose se na pravila odabira materijala i praćenje učinaka gradnje. Materijali koji se koriste u projektu razmatrani su s obzirom na zajedničko polazište, no nije razmatran i njihov životni ciklus. Izjave o održivosti zahtijevaju dokaz valjanosti, a analiza životnog ciklusa (LCA) alat je koji može dati takav dokaz. Rad pokazuje kako uključivanje takve analize u većim shemama rejting sustava zelene gradnje može biti korisno, kao i uvođenje integriranog koncepta dizajna zelenih zgrada.*

Ključne riječi: *LEED, analiza životnog ciklusa, drvo*

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1 INTRODUCTION
1. UVOD

Climate change and its disastrous consequences are stimulating the transformation towards a sustainable development, with its increasing economic efficiency, protection and restoration of ecological systems and improvement of human well-being. The maintenance of natural resources is a subject that often appears when sustainable development is considered. In addition, with increasing world population and economic development of various nations, the strain on resources is increasing. As economic development and environment are linked, the realization has set in to conserve energy and resources. Globally, infrastructure and building construction consumes 60 % of the raw materials extracted from the Earth (Bribian *et al*., 2011, MMSD, 2002). From this volume, building accounts for 40 %, in other words 24 % of these global extractions. In the US, with 4 % of world's population, the consumption of resources is at a staggering 25 % of total resources available in the world (Teller and Bergman 2010). A majority of these resources (60 % according to USGBC) are consumed in the building industry. In Europe, the per capita mineral extractions for buildings are approximately 4.8 tons per year (Wadel, 2009) Consumption of non-renewable and non-replenishable minerals will be detrimental to the environment and will have catastrophic effect on humans. In addition to that, energy consumption during and in use of building is enormous. In the US, the built environment accounts for 65 % of all energy consumption (USGBC 2010). In the European Union (EU) the corresponding number is 42 % (Nelson 2002). In addition, carbon dioxide (CO_2) emissions from the built environment accounts for roughly 35-40 % of total emissions, both in the US as well as in the EU (Environmental Information Administration 2008, Nelson 2002). Not only do buildings consist of a multitude of products, and therefore technical and biological nutrients, they also have an important and wide-ranging impact on water and energy cycles, air quality (indoor and outdoor), and fauna and flora, as well as on social and economic factors. The increased use of resources that cause pollution and emissions, highlight the need to save and conserve energy for sustainable development.

In engineering, sustainable design is a design ideology, which harbors the notion of sustainable human and societal development. Sustainable development can be defined in various ways. Every individual will approach the issue of sustainability in a different manner depending upon various factors, such as, sustainability goals, background, awareness, and economic conditions. Sustainability is providing opportunity of development to the future generation, in terms of resources. One of the key aspects in sustainability is sustainable construction. Sustainable construction practices are such that they are based on ecological principles, with no environmental impacts, have a closed material loop, and have full integration into the landscape after the service life of the structure is over. The concept of green buildings is the measure of our efforts in attaining that idealistic sustainable construction practices. According to Environmental Protection Agency (EPA) in the US, Green Building is the "practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building life-cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction." This definition has evolved over the years. "Green Buildings" is an ever evolving, dynamic term. Green Building is the status of our efforts in attaining sustainability in construction practices. As technology evolves and new materials are developed, the status of our efforts are also changing. Hence, the essence of green buildings is changing. The aim of this paper is to discuss sustainability with respect to green buildings, its importance in one of the world's leading Green Building program - Leadership in Energy and Environmental Design (LEED) certification from the perspective of sustainable material selection, and governing policies in LEED. Furthermore, the role of life cycle assessment (LCA) in assessing the sustainability claims of green buildings and building materials is introduced. Moreover, the potential for including LCA in the scheme of Green Building rating system is critically evaluated.

2 SUSTAINABILITY WITH RESPECT TO BUILDING MATERIALS
2. ODRŽIVOST S OBZIROM NA MATERIJALE ZA GRADNJU

Sustainability is increasingly becoming a key consideration of building practitioners with the goal of increasing economic efficiency, protecting, and restoring ecological systems and improving human well-being. To achieve sustainability, the following objectives should be met:

1. Minimize consumption of matter and energy;
2. Reusability and recyclability of the material;
3. Human satisfaction;
4. Minimum environmental impacts and embodied energy.

It is important to minimize the consumption, as while a material is consumed, its chances for future use are diminishing; hence, its potential utility to future generation is lost (Roberts, 1994). Another aspect of minimizing the consumption is either reusing the same material or recycling the material to mold into a different or similar building product. This also ties into the third criteria i.e., meeting a certain level of end-user satisfaction (Pearce *at al*., 1995). Trade-offs are inevitable when deciding on a material, and mostly are between resource consumption and human satisfaction. Human satisfaction level also changes with time and is correlated to various external factors, such as, costs, ensuring human comfort, safety and enriching the human spirit (Day, 1990). Human satisfaction level is also driven by the sustainability goal that in turn dictates the material selection process. Addressing the need of human satisfaction is very important. Another important aspect of material selection is its environmental costs and energy associated at various steps of its manufacturing process. However, to define a green material, numerous factors have to be considered.

2.1 Evaluation of building materials on "greenness"
2.1. Ocjena materijala za gradnju kao "zelenoga"

The most general criteria for evaluating building materials are resource management, pollution or indoor environmental quality (IEQ), and performance (Milani, 2005; Spiegel and Meadows, 2006). The resources used by a material include all the components and energy used to extract, process, transport, use, and dispose/ recycle it. The energy used to produce it or process it to usable form, known as embodied (or embedded) energy can be particularly large for building materials. Pollution includes all the emissions of the mines and factories used to produce the material, as well as the emissions of use – formaldehyde and emissions from products used to clean and maintain the material – along with the pollution resulting from its final incineration or land-filling (Milani, 2005). Performance refers to how well the material does its intended job. Materials with low durability, no matter how benignly produced, can hardly qualify as green. Durability is defined as the ability of a building or any of its components to perform the required functions in a service environment over a period of time without unforeseen cost for maintenance or repair. Wood is durable material, which has to be accompanied with appropriate building applications and design. The natural durability of wood has been proven by the multitude of buildings that have stood for centuries. While wood natural bio-based attributes make it a sustainable building material, it also makes wood vulnerable to decay and wood destroying insects. Proper design, installation and detailing are critical to ensure long-term durability. When wood is used in exposed applications, or in areas where it is subjected to moisture and insects, it must be protected with mechanical barriers, coatings and, in some instances, preservative treatments. For materials like insulation, performance goes beyond durability, since good thermal performance, for example, can actively save resources and energy.

These three evaluation categories, resources, performance, and pollution overlap considerably. Consider a sheathing material, for example the performance of that material, will influence the resources and energy they use in operation. Construction materials live much longer than most other materials (Milani, 2005; Wadel, 2009). Approximately, 60 % of the materials extracted out of earth's crust end up in the built environment (Wadel, 2009; Bribian *et al*., 2011) and they have a life cycle, mostly related to the time when the building is in operation. This tends to make durability and performance somewhat more important than for many other kinds of products. Figure 1, compiled from inputs from Malin (1999, 2002), Milani (2005) and Spiegel and Meadows (2006), presents various phases of material, which are the base of evaluations. "Greenness" of a material is evaluated on four distinct levels:

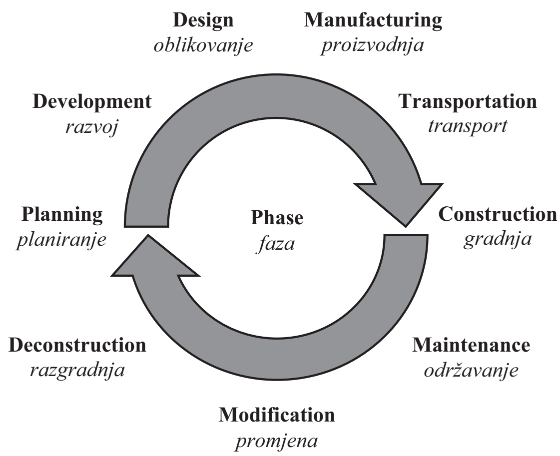

Figure 1 Various phases of a material life cycle
Slika 1. Faze životnog ciklusa materijala

- Raw-Material Phase (resource limitation, resource extraction, transportation);
- Manufacturing Level (waste reduction, pollution prevention, recycled content, embodied energy reduction, use of natural materials);
- Operation level (reduction in construction waste, energy efficiency, longer life/ durability, occupant health, water treatment/conservation, use of non-toxic or less-toxic materials, renewable energy systems);
- Disposal (reusability, recyclability, biodegradability).

3 GREEN BUILDING RATING SYSTEMS
3. REJTING SUSTAVI ZELENE GRADNJE

The green building movement addresses a broad array of areas such as energy efficiency, water management, material production, construction issues, occupant health quality, air quality management, recycling, reusability, and waste management (Bowyer, 2008). This vast array of its coverage could be one of the reasons for its unprecedented success. Currently there are more than 40 green building programs in the US. In the residential sector, many independent organizations led an initiative in their local jurisdiction and municipalities across the US. Some examples of these are the green building movement in Denver, Colorado; Kitsap County and King County, Washington; the Baltimore suburban builders association; the Earth craft houses program in Atlanta; Austin Green builder program, and Wisconsin green built program. The National Association of Homebuilders (NAHB) was proactive and took note of these increasing initiatives towards green construction, and as a result issued guidance available to its 800 state and local associations, educating and informing them how to create their own green building program. Encouraged by its enormous success and a need for standardization, NAHB designed its own green building program in 2008, called the National Green Building Program (NAHB 2010). Since its inception, it has emerged to be the market leader in the residential sector. However, in the commercial arena, the market leader is the US Green Building Council (USGBC) administered program called the Leadership in Energy and Environmental Design (LEED) followed by Green Globes. Since foundation of the NAHB rating system, LEED has also diversified itself in an effort to enter the residential sector. To earn certification under the LEED program, a building must meet certain prerequisites and performance benchmarks within each category.

The World Green Building Council recognizes 25 countries in Europe that have green building councils. With its strong focus on zero net resource consumption and passive solutions, Europe is widely recognized as a global leader in minimizing the use of resources and energy. The United Kingdom was the first country to develop a major green building rating system called the Building Research Establishment Environmental Assessment (BREEAM). Germany and France have their own green building rating systems. In Eastern Europe, LEED is also gaining popularity (Sinha and Kutnar, 2012).

3.1 LEED rating system
3.1. Rejting sustav LEED

The LEED rating system is administered by United States Green Building Council (USGBC). LEED is a voluntary rating system to ensure a superior environmental performance of a building over its life time. LEED was developed to evaluate the performance of construction and design from a standpoint of sustainability in 1998 for commercial constructions. Since its inception, LEED has evolved and improved through several revisions. LEED 2009 is the current version, while discussions are currently underway for LEED 2012. LEED 2009 contains the following specific rating systems: 1) New Construction (NC); 2) Existing Buildings: Operations and Maintenance; 3) Commercial Interiors; 4) Core and Shell; 5) Retail; 6) Healthcare; 7) Homes; and 8) Neighborhood Development. Each of the rating systems is composed of 100 points, which are divided among five categories: Sustainable Sites (26); Water Efficiency (10); Energy and Atmosphere (35); Materials and Resources (14); and Indoor Environmental Quality (15). Additionally, up to 10 bonus points are possible through innovative design and consideration of regional priorities. Each category in LEED 2009 has certain prerequisites that are mandatory for all projects and are not eligible for points. The points are then distributed across major categories and are assigned in a progressive way for incremental level of documented efforts to increase environmental performance. The LEED system rates buildings at four levels - certified, silver, gold, and platinum, with the following credit requirements:

- Certified - 40 - 49 points
- Silver - 50 - 59 points
- Gold - 60 - 79 points
- Platinum - 80 points and above

Currently, the LEED rating system is a nationally accepted benchmark for design, construction and operation of high-performance green buildings and is used to evaluate a significant portion of new construction within the United States. In the commercial arena in the United States, LEED is the market leader, with 90 % of all certified buildings being LEED certified. It can be argued that the LEED system is also a global leader in green building. The LEED International Roundtable is composed of representatives from 21 countries who work to provide global consistency in regional approaches to green building. Each of these 21 countries utilizes LEED rating systems that are catered to the local conditions in their country. Additionally, LEED has registered projects in 133 countries. The percentage of new construction projects evaluated by LEED (for New Construction) has markedly increased throughout the last decade, as various stakeholders recognize the need to validate their achievements for sustainable construction. The green building concept and sustainable design are growing phenomenon in engineering, which has an unprecedented growth rate and acceptability. In 2006, studies showed that about 20 % of the designers have been involved in projects that have resulted in LEED certification as opposed to only 10 % in 2003 (BDC, 2011). It is projected that by the end of 2013, 94 % of the current architectural and engineering firms would be extensively working on green projects (Bernstein and Bowerbank, 2008). In the future, it is speculated that green building rating systems will move towards performance-based systems and have a performance monitoring protocol in place. The fact that the energy supply and resources are diminishing; coupled with the increased awareness in people to contribute towards sustainability is helping drive this rapid growth in green buildings. People like to see their efforts validated by an agency and USGBC through LEED is providing that. Furthermore, despite dominance of Buildings Research Establishment Environmental Assessment Methodology (BREEAM) in the European green building performance market, LEED is gaining some traction. Various projects all over Europe are adopting LEED measures. Several buildings have been already LEED certified in Italy, England, Poland, the Czech Republic, Bulgaria, and Portugal.

3.2 Questionable ratings in LEED
3.2. Dvojbeni rejtinzi u LEED-u

3.2.1 LEED – Materials
3.2.1. LEED – materijali

The USGBC, although a grand and comprehensive effort towards sustainable design, has certain pitfalls in terms of how it rates the materials. There are provisions in LEED and other primary green building programs, which could result in significant negative impact on wood and wood products as a building material (Bowyer, 2008). The LEED rating system rates the material at the same level while being used in the building. All materials are considered at an equal footing and their life history does not have an impact on the rating credits. Materials like, concrete and wood are considered equal. However, life cycle analysis have shown that wood has less embodied energy than concrete or steel because it is a biological renewable material (Puettman *et al*., 2005), while the raw materials to make cement and then concrete is a product of energy intensive mining (PCA, 2002; van Oss and Padovani, 2002; Rajendran and Gambatese, 2007). Steel is preferred over wood and concrete, because of its recyclability and recycled content (USG-

BC, 2009). Steel, although it is recyclable, has higher environmental impacts than wood because the raw material has to be mined and then steel has to be extracted in a furnace (IISI, 2000). Many experts (Bowyer, 2008) consider this viewpoint, by which more importance is given to steel, as a serious error from an environmental standpoint.

LEED assigns extra credit for materials that are "rapidly renewable" (LEED-NC, 2009). The criterion of rapid renewability with respect to wood is 10-year turn around period. For trees with a smaller rotation time of 10 years or less, those credits can be attained. However, for longer rotation crops valuable credits cannot be obtained. Wood is a renewable material, with some trees having a smaller rotation cycle and some trees having a higher rotation period. Bamboo, for e.g., is a rapidly growing tree as compared to maple and hence, so bamboo flooring is preferred over maple flooring in LEED. The scientific background of this preference has been heavily challenged (Bowyer, 2007) and there is ongoing debate as to whether to change the category of "rapidly renewable" to "renewable" (YP-FPG, 2008). This will give wood as a building material clear advantage as it is a renewable material. Besides, wood is causing less emissions of CO_2 and generates less waste compared to the alternative materials (Petersen and Solberg, 2005).

A challenge that LEED faces is to ensure that the wood coming into the project has been grown and harvested in a sustainable manner. Forest Certification ensures this. Forest Certification has a two-fold objective in the LEED program. It provides evidence that the wood has been grown and harvested in environmentally and socially responsible manner, and determines whether wood might qualify for credits as a "renewable" material. It will also ensure that wood harvested illegally (outside the US) will not receive any credits. There are many forest certification schemes prevalent in the US. Currently, Forest Stewardship Council (FSC) is the only one recognized by the USGBC (LEED-NC, 2009). Alternative programs, although similar in their efforts to promote responsible forest management, are not recognized. With FSC wood being limited, it is difficult to earn credits for certified wood. Moreover, it is only wood that requires external validation or certification, while other materials in LEED do not (LEED, 2009), despite social and environmental impacts associated with other materials (Bowyer, 2007, 2008).

3.2.2 LEED – Performance
3.2.2. LEED – izvedba

Besides its ambiguity in rating materials, the performance of the LEED program has also been challenged (Torcellini, 2004; Bowyer, 2008; Bribian *et al*., 2011). The LEED program is a not performance based rating system. Rather, it is a checklist of provision, which is supposed to ensure performance. There are no provisions for performance monitoring in LEED. As a result, a question is often posed – "Does the LEED program help in reducing energy consumption and improve energy performance of building?" The LEED program has been around long enough to assess the changes. Various studies have tried to answer this. Torcellini *et al*. (2004) conducted an overview of six sustainable buildings in the USA to compare the results to predicted energy savings. Analysis showed that all buildings performed worse than predicted, but all managed a substantial saving compared to a comparable code-compliant building. The deviation from the predicted savings was due to higher than expected occupant loads and systems not performing together as designed. Turner (2006) compared 11 buildings in the Cascadia Region, USA and found all buildings performed better than their baseline. In other words, buildings performed better than their non-green code-compliant counterparts. Fowler and Rauch (2008) investigated 12 Federal Buildings, all designed with energy conservation approach and found that they saved 25-30 % more energy that similar US commercial buildings. Baylon and Storm (2008) examined the characteristics of LEED commercial buildings in the US Pacific Northwest, and compared them to regional non-LEED buildings. The mean energy use per floor area for the 12 LEED buildings was 10 % lower than the 39 similar non-LEED buildings in the same region.

Diamond *et al*. (2006) investigated 21 LEED-certified (LEED-NC Version 2.0/2.1) buildings using the modeled energy data for the as-designed and baseline building as submitted to the USGBC. On average, for the 18 buildings that had both simulated whole building design and actual energy use data, energy use was 1 % lower than modeling predictions (which were 27 % below baseline). However, there was large variability (standard deviation, s.d. 46 %), and some performed better than predicted, while others performed worse. Further, the number of LEED energy credits obtained in the certification did not correlate with the actual energy use per floor area. Newsham *et al*. (2009) reported similar results. The authors studied 100 LEED certified buildings, compared the results to commercial US buildings, and reported that LEED buildings used 18–39 % less energy per floor area than their conventional counterparts, confirmed by statistical analysis. However, 28–35 % of LEED buildings used more energy than their conventional counterparts. Similar to Diamond et al. (2006), Newsham *et al*. (2009) did not find any correlation between the certification level (Silver, Gold, Platinum) and the measured energy performance. Therefore, they recommended that although green buildings contribute to significant energy savings, more work is needed to define the scope of the rating systems and design a plan to be consistent at a generic level as well as at the individual building level.

4 LIFE CYCLE ASSESSMENT (LCA) – POTENTIAL GREEN BUILDING RATING SYSTEM
4. OCJENA ŽIVOTNOG CIKLUSA (LCA) – POTENCIJALNI REJTING SUSTAV ZELENE GRADNJE

Life-cycle assessment (LCA) is a rational, quantified approach to determining specific environmental impacts of a product or system through its entire life cycle.

As solutions are sought to reduce the impacts of buildings, LCA is seen as an objective measure for comparing building designs. LCA clearly has an important role to play in assessing the sustainability of green buildings and it is a valuable tool in decision-making.

Studies found LCA to have started in 1960s (Hunt *et al*., 1992), however, it gain prominence in the 1990s (Bribian *et al*., 2009). From the time, when LCA analysis was developed till today, numerous methodologies to classify, characterize, and normalize environmental effects have been developed. The most common, for example CML 2 (2000), IPCC Greenhouse gas emissions, Ecopoints 97 and Eco-indicator 99 (PRé Consultants, 2010), are focused on the following indicators: acidification, eutrophication, thinning the ozone layer, various types of ecotoxicity, air contaminations, usage of resources and greenhouse gas emissions. At first, LCA analysis was mostly focused on environmental effects like acidification and eutrophication, while more recently mostly on greenhouse gas emissions, which are also called carbon footprint. The carbon footprint is expressed in terms of the amount of emitted carbon dioxide or its equivalent of other greenhouse gases. In Europe, carbon footprint is gaining its importance and it can be expected that it will become necessary information accompanying products and services.

The LCA methodology involves four steps (Environmental, 1997; ISO 14040, 2006; Puettmann *et al*., 2010). The goal and scope definition step spells out the purpose of the study and its breadth and depth. The second step, Life Cycle Inventory (LCI) quantifies the environmental inputs and outputs associated with a product over its entire life cycle. Inventory analysis entails quantifying the inventory flows for a product system. Inventory flows include inputs of water, energy, and raw materials, and releases to air, land, and water. However, these inputs and outputs are not of great interest (Lippiatt, 1998). More important are their consequences, or impacts on the environment. Thus, the next LCA step, impact assessment (LCIA), characterizes these inventory flows in relation to a set of environmental impacts as identified in LCI. Finally, the interpretation step combines environmental impact in accordance with the goals of the study (Environmental, 1997).

For a product, the life cycle starts with procuring the raw material, primary processing, secondary processing or manufacturing, packaging, shipping and handling, installation, in-use energy consumption, maintenance, and end-of-life strategies. Figure 2 shows the various stages of a product lifecycle and system boundaries. LCA is performed at various stages (Figure 2). For example, Cradle-to-Gate refers to life cycle assessment from raw material stage to the point it is shipped out to the field. Similarly, cradle-to-grave involves LCA of all stages of the product or the material, starting from raw material procurement to end-of-life strategies. For buildings, the life cycle generally starts with extraction of raw resources from the natural environment or recovery of materials from a previous use. The raw resources are then manufactured into useable products, such as steel, concrete, etc. The finished products are then shipped to the site consuming energy in the process. On the site, the products are assembled into a building. During the service life of the building, it consumes energy. In due course of time renovation or retrofit is performed on the building, which uses materials and energy. Finally, the building is removed/demolished and its materials disposed of either as construction waste or recycled for reuse. Each of these steps consumes energy and materials and produces waste. The purpose of the LCA quantifies how a building product or system affects the environment during each phase of its life. Examples of parameters that may be quantified include: energy consumption, resource use, greenhouse gas production, solid waste generation, and pollution generation.

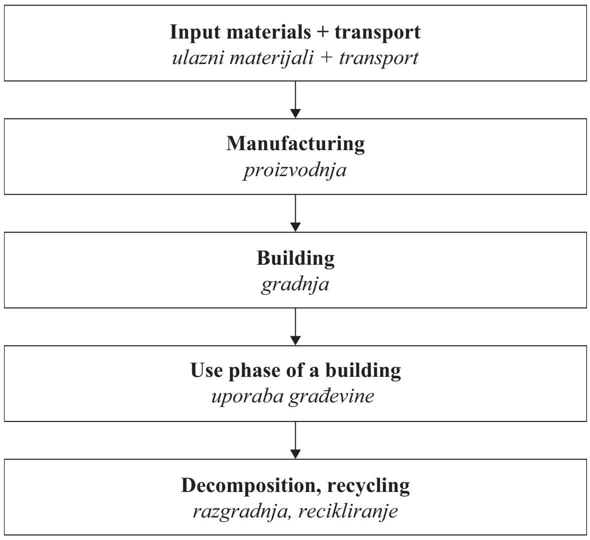

Figure 2 Simplified presentation of LCA variants, system boundaries
Slika 2. Pojednostavnjena prezentacija varijanti LCA, granice sustava

The adoption of life-cycle approach to design, where not only current energy concerns are accounted for, but also long-term energy, environmental, and social impacts, should lead to an integrated approach to design. A building uses most of its energy during its service life, which is about 90 % of the total life cycle energy (Citherlet and Defaux, 2007; Newsham *et al*., 2009). This is the stage where a structural engineer has least impact. However, as building energy use has become more efficient, the role of structural engineer has become more and more important. A structural engineer has primary input during the design, construction and end-of-life stages, where a significant energy reduction can result in buildings with less environmental impacts. A structural engineer, if involved in planning, can have significant impact in all aspects of the building life-cycle. Structural engineers must be forthright, educate themselves in LCA and sustainability so that they can be decision-makers, and be able to make their contribution to reducing the project's environmental impact (Webster, 2005).

As the influence of green building programs continues to increase and the field matures, the primary green building programs will shift to use of LCA as a means of using science and consistent methodology to inform green building decisions (Bowyer, 2008) and move towards an integrated design process, since the design of a building is a complex process involving multitudes of disciplines and expertise. However, transparent and standardized approach to LCA is needed to assess the ecological and environmental consequences of the use phase of the buildings. Namely, the values can differ significantly among different studies. The use of different input data, functional units, allocation methods, reference systems and other assumptions, complicates comparisons of LCA green building studies. To be sustainable in a holistic way, an integrated design process should be adopted. Each system or discipline in a project has some effect on another system in varying degrees. Moreover, the total environmental impact could be reduced by involving each aspect of the project from the onset. The first step is to form an integrated, multidisciplinary design team of owners, architects, structural engineers, civil engineers, geotechnical engineers, landscape designers, maintenance or operations staff, general contractor and key subcontractors, cost consultants, and end-use representatives. Green building construction must integrate building professionals, so that they work together for the common goal of sustainability. This integration must begin at the pre-design phase and continue through to post-occupancy, in order to optimize the building performance. Integrated design is a critical component in reducing costs in the construction of green buildings.

4.1 Wood as a building material
4.1. Drvo kao građevni materijal

Wood is a material of choice in many countries for residential and light commercial buildings. 90 % of the residential buildings in the US are wood-frame construction. Japan is also not far behind. The use of wood in green buildings fits well with the previously mentioned criteria for green building materials. Wood is a renewable resource, manufactured in nature using a large quantity of solar energy. Hence, no fossil fuels are required for manufacturing of wood. When waste wood is burned, it provides an independent source of energy. Energy from waste wood is solar energy, which has been stored in the wood for a few years. As a result, the embodied energy of wood is miniscule as compared to other building materials. Wood can be recycled, but not in the extensive manner of materials like metals and glass. The production of wood is generally non-polluting at all stages although there have been instances in the past with polluted sites from chemical preservative processes (Buchanan, 2006, 2010). Another reason for building in wood is the increase in the pool of carbon stored in wood and wood products. This is very important from a climate change standpoint. Green building programs do not give proper credit to wood and its low embodied energy (Bowyer, 2008). As a result wood products are often overlooked by architects, builders, and contractors. Within the green building sector, the wood industry must innovate and try to improve their market by creating a niche for new structural products.

5 CONCLUSION
5. ZAKLJUČAK

Sustainability is increasingly becoming a key consideration of building practitioners, policy makers, and industry alike, since the world is moving towards zero-energy construction. When buildings have net zero energy consumption, the effect of embodied energy and greenhouse gas emissions become important. A zero energy house can be built with different materials and construction methods that create different cumulative carbon footprint. Wood products can have very low or negative carbon footprint. Therefore, the utilization of wood, the most important renewable material, in all aspects of human existence appears to be the most effective way to optimize the use of resources and to reduce the environmental impact associated with mankind's activities. Typically, the use of wood products results in lower emissions and thus a lower overall environmental impact. However, to achieve sustainable development, certain criteria within a framework of economic, environmental and social systems must be followed. Only effective use of wood through the whole value chain from forest management and multiple use of forest resources through new wood and fiber-based materials and processing technologies to new end-use concepts, e.g. in the area of construction, can lead to sustainable development. Therefore, research, development and innovation related to "green" buildings should focus on LCA analysis in all product stages, from primary processing and use to disposal, and integrate knowledge and experience from various disciplines, engaging scientists from areas like engineering, material science, forestry, environmental science, architecture, marketing, and business. The activities should be oriented towards new product development from renewable materials, and utilization of the whole wood value chain, engineering solutions, and cradle2cradle concept.

6 REFERENCES
6. LITERATURA

1. Baylon, D.; Storm, P., 2008: Comparison of commercial LEED buildings and non-LEED buildings within the 2002-2004 Pacific Northwest commercial building stock, in: ACEEE Summer Study on Energy Efficiency of Buildings, American Council for an Energy-Efficient Economy (Washington DC, USA): 4-1, 4-12.
2. Bernstein, H.; Bowerbank, A., 2008: "Global Green Building Trends: Market Growth and Perspectives." Around the World. McGraw-Hill Construction; pp. 48.
3. Bowyer, J.L., 2008: The green Movement and the forest products industry. Forest Prod. J. 58(7/8): 6-13.
4. Bowyer, J.L., 2007: The green building programs-are they really green?. Forest Prod. J. 57(9): 6-17.
5. Bowyer, J.; Shmulsky, R.; Haygreen, J., 2007: Forest Products and Wood Science - an Introduction, 5th edition. Ames: Blackwell Publishing, 558 pp.

6. Bribian, I.Z.; Uson, A.A.; Scarpellini, S., 2009: Life cycle assessment in buildings: State-of-the-art and simplified LCA methodology as a complement for building certification Ignacio. Build. Environ. 44: 2510-2520 http://dx.doi.org/10.1016/j.buildenv.2009.05.001.
7. Bribian, I.Z.; Capilla, A.V.; Uson, A.A., 2011: Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. Build Environ 46: 1133-1140 http://dx.doi.org/10.1016/j.buildenv.2010.12.002.
8. Buchanan, A.H., 2006: Can Timber Buildings Help Reduce Global CO2 Emissions? *Proceedings, World Conference on Timber Engineering*. Portland, Oregon, USA.
9. Buchanan, A.H., 2010: Energy and CO2 advantages of wood for sustainable buildings. *Proceedings, World Conference on Timber Engineering*. Riva-del-Garda, Italy.
10. Building Design and Construction (BDC), 2011: "Green Buildings and the Bottom Line." Oak Brook, I.L. Build. Environ. 46: 1133-1140.
11. Citherlet, S.; Defaux, T., 2007: Energy and environmental comparison of three variants of a single family house during its whole life span. Build. Environ. 42: 591-598 http://dx.doi.org/10.1016/j.buildenv.2005.09.025.
12. Day, C., 1990: Places of the soul. Aquarian Press, San Francisco, CA.
13. Diamond, R.; Opitz, M.; Hicks, T.; Vonneida, B.; Herrera, S., 2006: Evaluating the energy performance of the first generation of LEED-certified commercial buildings, in: ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy (Washington DC, USA): 3-41, 3-52.
14. Fowler, K.M.; Rauch, E.M., 2008: Assessing green building performance: a post occupancy evaluation of 12 GSA Buildings, Pacific Northwest National Laboratory Report number PNNL-17393, 2008.
15. International Iron and Steel Institution (IISI), 2000: "Worldwide LCI database for steel industry products." IISI, Brussels, Belgium.
16. International Organization for Standardization (ISO), 1997: "Environmental management – Life cycle assessment – Principles and framework." ISO 14040, Geneva, Switzerland.
17. ISO 14040, 2006: Environmental management – Life cycle assessment – Requirements and guidelines.
18. James, S.; Lahti, T., 2004: The Natural Step for Communities: How Cities and Towns can Change to Sustainable Practices. Gabriola Island, BC: New Society Publishers
19. Kibert, C.J., 2004: Green Buildings: An overview of progress. J. Land Use 19(2): 491-502.
20. Lippiatt, B.C., 1998: BEES 1.0: Building for environmental and economic sustainability. Technical manual and user guide, NISTIR 6144, NIST, Gaithersburg, Md.
21. Malin, N., 1999: Environmentally Responsible Building Materials Selection. In C. J. Kibert (Ed.), *Reshaping the Built Environment: Ecology, ethics, and environment*. Washington DC/Covelo, California: Island Press.
22. Malin, N., 2002: Life-Cycle Assessment for Buildings: Seeking the Holy Grail. *Environmental Building News*, 11(3).
23. Matos, G.; Wagner, L., 1998: "Consumption of materials in the United States, 1900–1995." Annu. Rev. Energy Environ. 23: 107-22 http://dx.doi.org/10.1146/annurev.energy.23.1.107.
24. Milani, B., 2005: Building materials in a green economy: Community-based strategies for dematerialization. PhD Dissertation , University of Toronto, Canada.
25. Mining, Minerals and Sustainable Development (MMSD), 2002: "Breaking new ground: The report of the Mining, Minerals, and Sustainable Development Project." Mining, Minerals, and Sustainable Development. (MMSD), Earthscan for International Institute for Environment Development (IIED) and World Business Council for Sustainable Development (WBCSD).
26. NAHB, 2010: National Association of Home Builders.
27. Nelson, W., 2002: Compressed Earth Blocks. In J. F. Kennedy, M. G. Smith & C. Wanek (Eds.), The Art of Natural Building (pp. 138-142). Gabriola Island BC: New Society Publishers.
28. Newsham, G.R.; Mancini, S.; Birt, B.J., 2009: "Do LEED-certified buildings save energy? Yes, but...". Energy Build. 41: 897-905 http://dx.doi.org/10.1016/j.enbuild.2009.03.014.
29. Pearce, A., Makarand, H.; Vanegas, J., 1995: "A Decision Support System for Construction Materials Selection Using Sustainability as a Criterion." In: Proceedings of the *28th Annual Conference, National Conference of States on Building Codes and Standards*. Albuquerque, New Mexico, November 1-4.
30. Petersen, A.K.; Solberg, B., 2005: Environmental and economic impacts of substitution between wood products and alternative materials: a review of micro-level anayses from Norway and Sweden. Forest Policy Econom. 7: 249-259 http://dx.doi.org/10.1016/S1389-9341(03)00063-7.
31. Portland Cement Association (PCA), 2002: Environmental life cycle inventory of Portland cement concrete. Appendix: Life cycle inventory of Portland cement manufacture. PCA, Skokie, IL.
32. PRé Consultants, 2010: Impact assessment methods. http://www.pre.nl/simapro/impact_assessment_methods.htm#EP97.
33. Puettmann, M.E.; Wilson, J.B., 2005: Life-cycle Analysis of Wood Products: Cradle-to-gate LCI of Residential Wood Building Material. Wood Fiber Sci. 37: 18-29.
34. Rajendran, S.; Gambatese, J.A., 2007: Solid Waste Generation in Asphalt and Reinforced Concrete Roadway Life Cycles. J. Infrastruct. Sys. 13(2): 88-96 http://dx.doi.org/10.1061/(ASCE)1076-0342(2007)13:2(88).
35. Rees, W.E., 1990: The ecology of sustainable development. The ecologist 20(1): 18-23.
36. Roberts, D.V., 1994: Sustainable development – A challenge for the engineering profession. In Ellis, MD ed. The role of engineering in sustainable development. American Association of Engineering Societies, Washington DC: 44-61.
37. Spiegel, R.; Meadows, D., 2006: Green Building Materials – A guide to product selection and specification. 2nd edition. John Wiley and Sons, Virginia, USA.
38. Sinha, A.; Kutnar, A., 2012. Green Building Rating System – Leadership in Energy and Environmental Design (LEED): Significance for wood industry. LesWood. 64(1/2): 1-5.
39. Todd, J.A.; Crawley, D.; Geissler, S.; Lindsey, G., 2001: Comparative assessment of environmental performance tools and the role of the Green Building Challenge. Build. Res. Inform. 29(5): 324-335 http://dx.doi.org/10.1080/09613210110064268.
40. Torcellini, P.A.; Deru, M.; Griffith, B.; Long, N.; Pless, S.; Judkoff, R., 2004: Lessons learned from the field evaluation of six high-performance buildings, in: ACEEE Summer Study on Energy Efficiency of Buildings, American Council for an Energy-Efficient Economy (Washington DC, USA): 3-325, 3-337.

41. Trusty, W.; Horst, S., 2002: Integrating LCA Tools in Green Building Rating Systems. In Environmental Building News (Ed.), The Austin Papers: Best of the 2002 International Green Building Conference (pp. 53–57). Brattleboro VT: BuildingGreen Inc.
42. Trusty, W.; Meil, J.K., 1999: *Building Life Cycle Assessment: Residential case study.* Paper presented at the Mainstreaming Green, AIA Environment Committee conference on green building and design, Chattanooga, TN.
43. Trusty, W.; Meil, J.K.; Norris, G.A., (1998, October 1998). *ATHENA: A LCA decision support tool for the building community.* Paper presented at the Green Building Challenge '98, Vancouver.
44. Turner, C., 2006: LEED building performance in the Cascadia Region: a post occupancy evaluation report, 2006 (retrieved 18.09.08, from http://www.usgbc.org/chapters/cascadia/docs/pdf/POE_REPORT_2006.pdf).
45. U.S. Environmental Protection Agency. (October 28, 2009). Green Building Basic Information. Retrieved December 10, 2009, from http://www.epa.gov/greenbuilding/pubs/about.htm
46. United States Green Building Council (USGBC), 2009: New Construction and Major Renovation Reference Guide. USGBC, Washington D.C.
47. Van Oss, H.G.; Padovani, A.C., 2002: Cement manufacture and the environment. Part I: Chemistry and technology. J. Ind. Ecol. 6(1): 89-105 http://dx.doi.org/10.1162/108819802320971650.
48. Wadel, G., 2009: Sustainability in industrialized architecture: Modular lightweight construction applied to housing (La sostenibilidad en la construcción industrializada. La construcción modular ligera aplicada a la vivienda). Doctoral Thesis. Polytechnic University of Catalonia-Department of Architectural Constructions;. Available online at: http://www.tdx.cat/ TDX-0122110-180946.
49. Webster, 2005: Research Congress.
50. YPFPG, 2008: Assessing USGBC's Policy Options for Forest Certification & the Use of Wood and Other Bio-based Materials. A summary report prepared by the Yale Program on Forest Policy and Governance February 25, 2008.
51. Yudelson, J., 2009: "Green Building through Integrated Design." Syracuse, NY: McGraw-Hill Publishing.

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CE Marking of Structural Timber: the European Standardization Framework and its Effects on Italian Manufacturers

CE oznaka strukturne građe: Europski okvir normizacije i njegovi učinci na talijanske proizvođače

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ABSTRACT • *Structural timber has been used for centuries in construction and represents a traditional building component in many countries of the European Union. Nowadays, the interest in its use has been renewed due to several factors such as: ease of processing, relative lightness, mechanical performance, sustainability and decorative appearance. On March 2011, the European Parliament adopted the Regulation (EU) No. 305/2011 (known as CPR), laying down harmonized conditions for the marketing of construction products. According to CPR's dispositions, since January 1st 2012 CE marking of structural solid timber has been mandatory. While on one hand for the building sector enterprises this implies remarkable challenges, on the other hand it will allow a better valorization of structural timber. In this context, the present work illustrates the European standardization framework for CE marking of structural timber, particularly with respect to the visual grading method applicable to solid wood products and to the Italian experience in adopting the new rules.*

Keywords: *structural timber, normative framework, CE marking, visual grading, machine grading*

SAŽETAK • *Strukturna se drvna građa stoljećima upotrebljava u graditeljstvu i čini tradicionalnu sastavnicu gradnje u mnogim zemljama Europske Unije. Danas nekoliko činitelja pridonosi obnovi zanimanja za uporabu strukturne drvne građe, među kojima su jednostavnost obrade, relativna lakoća, mehanička svojstva drva, obnovljivost i dekorativan izgled drvne građe. U ožujku 2011. godine Europski je parlament usvojio Uredbu EU No 305/2011 (poznatu kao CPR), kojom su usklađeni uvjeti za prodaju građevnih proizvoda. Prema dispozicijama CPR-a od 1. siječnja 2012, za strukturno masivno drvo obvezna je oznaka CE. Iako za poduzeća građevnog sektora to podrazumijeva mnoge izazove, to će omogućiti i bolju valorizaciju strukturne građe. U tom kontekstu ovaj rad ilustrira Europski okvir normizacije za CE oznaku strukturne građe, s posebnim naglaskom na vizualnoj metodi ocjenjivanja kvalitete koja je primjenjiva za proizvode od masivnog drva, te s osvrtom na talijanska iskustva u usvajanju novih pravila.*

Ključne riječi: *strukturna građa, normativni okvir, oznaka CE, vizualno ocjenjivanje kvalitete, mehanizirano razvrstavanje*

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1 INTRODUCTION
1. UVOD

Structural timber has been used for centuries in construction and represents a traditional building component in many countries of the European Union (Giordano, 1997; Moffet *et al.*, 2003; Pryce, 2005). Nowadays, the interest in its use has been renewed due to several factors such as: ease of processing, relative lightness, good mechanical performance (particularly in terms of strength to weight ratio), sustainability, recyclability, decorative aspect, etc. (Anonymous, 2006; Kolb, 2008).

On March 2011 the European Parliament adopted the Regulation (EU) No. 305/2011 (CPR, acronym for Construction Products Regulation) repealing the Construction Products Directive 89/106/EEC (CPD)[1]. As stated by Article 1, the Regulation "[…] *lays down conditions for the placing or making available on the market of construction products by establishing harmonized rules on how to express the performance of construction products in relation to their essential characteristics and on the use of CE marking on those products"*. As a construction product[2], structural timber[3] (Figure 1) is subjected to CPR's dispositions. In particular since January 1st 2012, it can be placed on the market only if CE[4] marked.

Through CE-marking, the manufacturer states that a specific product meets the essential requirements of the European legislation and assumes the corresponding responsibility. The product properties must be declared on the product itself, on the packaging or attached to the delivery documentation and a declaration of conformity must be delivered to the customer. As for the CE marking of structural timber, grading represents a fundamental factor, but grading system managing and product traceability are also relevant topics.

The implementation of a CE marking system also requires the involvement of a notified body to certify the attestation of conformity requirements. Furthermore, the notified body carries out an annual audit for verifying the manufacturer's capability to meet the different requirements.

The cost of the implementation of a CE marking system depends on company size and production volume. As a general rule it can be esteemed around 4,000-6,000 euro for most of the small and medium enterprises producing structural timber, including the audit costs and the support of an external consultant.

CE marking obligation implies remarkable challenges for carpentry enterprises, nonetheless it represents a relevant step for increasing the reliability of structural timber. In this context, the present work aims to illustrate the European standardization framework for CE marking of structural timber, with particular respect to the visual grading method applicable to solid wood products. The current Italian situation is also reported in order to illustrate how the CE marking obligation interacts with the reality of an EU country. On the whole, the analysis of such a complex framework can be useful for the industrial and scientific communities of new countries acceding into EU.

Figure 1 Rectangular (left) and irregular (right) cross section timber for structural use is subjected to CE marking obligation since January 1st 2012
Slika 1. Strukturna građe pravokutnoga (lijevo) i nepravilnoga (desno) poprečnog presjeka od 1. siječnja 2012. obvezno mora imati oznaku CE

2 CE MARKING OF STRUCTURAL TIMBER: THE STANDARDIZATION FRAMEWORK
2. CE OZNAKA STRUKTURNE GRAĐE: OKVIR NORMIZACIJE

Figure 2 shows the relations between different normative instruments regulating grading and CE marking of structural timber.

As shown, CE marking of structural timber arises from Regulation (EU) No. 305/2011 (CPR), which lays down the conditions for construction products marketing within the European Union. In particular, the CPR states the dispositions for CE marking according to the general principles set by Regulation (EC) No. 765/2008.

According to CPR Regulation, CE marking shall guarantee the conformity with harmonized standards when available. To this day, the latter list update has been published by the Official Journal of the European Union C 246, Volume 54, August 24rd 2011. For structural timber two options are envisaged on the basis of its rectangular and irregular cross section.

2.1 Structural timber with rectangular cross section
2.1. Strukturna građa pravokutnoga poprečnog presjeka

According to the above mentioned list, classification of structural timber with rectangular cross section shall be performed in accordance with EN 14081-1. This standard specifies the general requirements for visual and machine strength grading of structural timber with rectangular cross section shaped by sawing,

[1] CPR is currently into force, but several Articles will apply only from 1 July 2013. Therefore, even if the Construction Products Directive is already repealed, construction products manufactured in accordance with it before 1 July 2013 are compliant with the CPR.
[2] CPR defines construction product as "any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works".
[3] The present paper deals with structural solid timber, while for glue laminated timber other standards and requirements apply.
[4] Acronym for Conformité Europeénne.

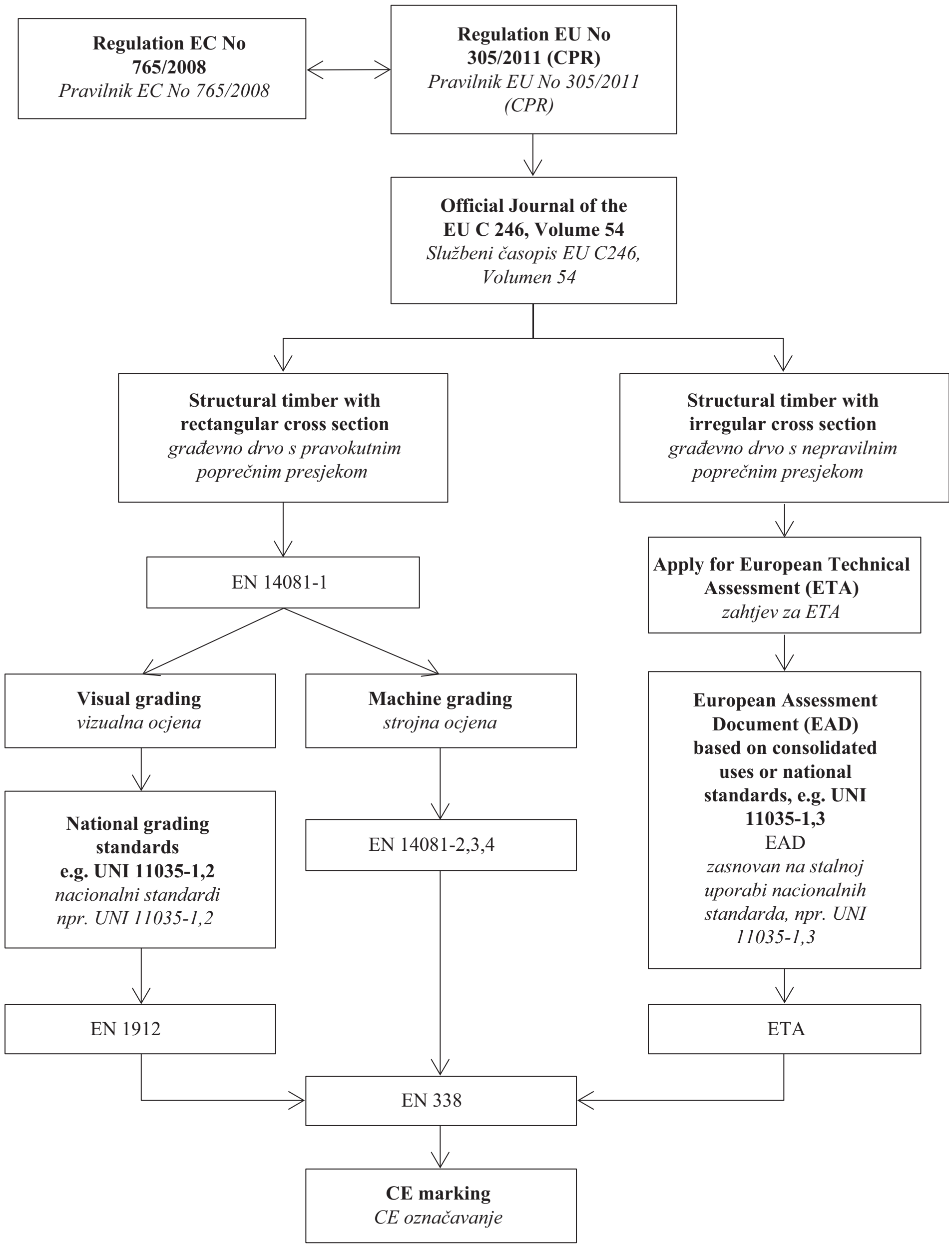

Figure 2 Scheme of standardization framework for CE marking of structural timber
Slika 2. Shema okvira normizacije za CE oznaku strukturne građe

CE Identification number of FPC certification body	
Producer identification Marking year FPC certificate number	
EN 14081-1	
Structural timber	
Strength class	C24 (S10)
Species code	Spruce (PCAB)
Grading standard	EN 338 and DIN 4074-1
Reaction to fire	D-s2, d0
Durability class	4

Figure 3 Example of information to be reported on documentation accompanying CE marked structural timber
Slika 3. Primjer informacije na dokumentaciji uz strukturnu građu koja nosi oznaku CE

planing or other methods, and having deviations from the target sizes corresponding to EN 336.

Visual strength grading
Razvrstavanje prema vizualnoj procjeni čvrstoće

Nowadays several visual-grading national standards are in use in the European countries. This variability has arisen because structural timber assortments can differ in terms of species, geographic origin, dimensional requirements, uses, material quality, historic influences and traditions. Due to these specific parameters, it is impossible to lay down a single standard suitable for all Members of the European Union. For this reason EN 14081-1 just gives some basic principles to be followed by national standards when laying down requirements.

EN 1912 lists the various national standards that meet the EN 14081-1 requirements. According to EN 1912, the choice of enforceable national standard de-

Table 1 Example of correspondence between national grades and strength classes of the EN 338 (modified from Table 1 of EN 1912)
Tablica 1. Primjer usporedbe nacionalnog razvrstavanja i razreda čvrstoće prema EN 338 (modificirana tablica 1. iz EN 1912)

National grade* *Nacionalni razred*	**Grading rule publishing country** *Zemlja koja je objavila pravilo razvrstavanja*	**Species commercial name** *Komercijalni naziv vrste*	**Source** *Podrijetlo*	**EN 1912 botanical identification**** *Botanička identifikacija prema EN 1912*		**EN 338 Strength class** *Razred čvrstoće prema EN 338*
ST-II	France *Francuska*	Larch *ariš*	France *Francuska*	15	→	**C24**
S10	Germany, Austria and Czech Republic *Njemačka, Austrija i Češka Republika*	Larch *ariš*	Central, Northern and Eastern Europe *Središnja, Sjeverna i Istočna Europa*	15	→	
T2	Nordic countires *nordijske države*	Larch *ariš*	Northern and North Eastern Europe *Sjeverna i Sjeveroistočna Europa*	15	→	

* The grades listed in the table are specified in the Annex A of EN 1912, which reports grade, grading rule and grading rule publishing standard / *razredi u tablici specificirani su u prilogu A norme EN 1912, koji prikazuje razrede, pravilo razvrstavanja i normu kojom je propisano pravilo razvrstavanja*
** Tables 3 and 4 of EN 1912 report the correspondence between species botanical name and identification number / *tablice 3. i 4. norme EN 1912 prikazuju vezu između botaničkog naziva vrste drva i identifikacijskog broja*

pends on species and provenance of the wood constituting the structural element to be graded. For instance, beams made of larch from France must be graded using the French standard NF B 52-001, while beams made of beech from Germany with DIN 4074-1.

The visual grading procedure is similar for the various national standards and basically states which characteristics (knots, grain slope, etc.) must be assessed and the limit values for their acceptance, so that a timber element can be assigned to a certain grade.

Once the grade is assigned, the EN 1912 allows finding the correspondence between the national grade and the harmonized strength class included in the standard EN 338. In detail, EN 1912 takes into account a combination of three factors (wood species, geographical origin and national grade) to individuate the correspondent strength class of EN 338 (Table 1).

The system of strength classes codified by EN 338 applies both to softwood and hardwood structural timber. EN 338 reports the characteristic values[5] of resistance, stiffness and density for each strength class (Table 2).

Furthermore, EN 338 indicates the rules for the allocation of a timber population[6] to a strength class. Firstly, characteristic values of bending strength, modulus of elasticity and density shall be determined in accordance with EN 384. Then, a timber population may be assigned to a certain strength class if its characteristic values of bending strength and density equal or exceed the values given for that class and if its characteristic mean Modulus of Elasticity in bending equals or exceeds 95% of the value given for that class.

Machine strength grading
Mehanizirano razvrstavanje

According to the physical laws of materials elasticity (Pellerin and Ross, 2002; Anonymous, 2011), instruments for non-destructive machine grading of structural timber exploit dynamic methods to evaluate the behavior of wood subjected to different types of stress.

Some instruments use natural or inducted, longitudinal or transversal, vibrations produced by stressing a wood element in different ways. In these cases the modulus of elasticity of a timber element is determined by measuring the oscillation extent.

Another possibility is offered by the analysis of wave propagation time inside wood: sonic or ultrasonic waves (the latter typically between 10 and 60 MHz) are transmitted to the end of the element (for instance by impact or using a piezoelectric drill emitting ultrasounds). Induced signals are received by a transducer placed on the other end of the element. Measuring the time elapsed between the impulse start and stop allows calculating the ratio between time and length of the covered distance, determining the propagation speed inside wood. Then, on the basis of wood density, by means of simple formulae, it is possible to calculate its dynamic modulus of elasticity.

It should be noted that strength classes of EN 338 report characteristic values for static elastic modulus determined by bending strength tests performed on elements in use dimensions. Therefore, when adopting a machine grading method, a correlation between dynamic and elastic modulus must be established in order to determine the correspondent EN 338 strength class for

[5] A characteristic value is *"Generally a value that corresponds to a fractile of the statistical distribution of a timber property. For strength properties, modulus of elasticity and density, the fractile is the 5-percentile. For modulus of elasticity, the mean value is also a characteristic value"*, as reported by EN 384.
[6] Timber for which the characteristic values are relevant. The timber population is defined by parameters such as species or species grouping (combination of species), source and strength grade.

Table 2 Example of characteristic values of C27 and D35 strength classes reported in the EN 338 (modified from Table 1 of EN 338)
Tablica 2. Primjer karakterisitčnih vrijednosti razreda čvrtoće C27 i D35 obuhvaćenih normom EN 338 (modificirana tablica 1. norme EN 338)

	Strength classes *Razredi čvrstoće*	
	Softwood species *Meke vrste drva*	**Hardwood species** *Tvrde vrste drva*
	C27	D35
Strength properties, N/mm² / *Čvrstoća, N/mm²*		
Bending / *savijanje*	27	35
Tension parallel / *vlačna čvrstoća, paralelno*	16	21
Tension perpendicular / *vlačna čvrstoća, okomito*	0.4	0.6
Compression parallel / *tlačna čvrstoća, paralelno*	22	25
Compression perpendicular / *tlačna čvrstoća, okomito*	2.6	8.1
Shear / *smicanje*	4.0	4.0
Stiffness properties, kN/mm² / *Krutost, kN/mm²*		
Mean Modulus of Elasticity parallel / *prosječni modul elastičnosti, paralelno*	11.5	12
5 % Modulus of Elasticity parallel / *5 % modul elastičnosti, paralelno*	7.7	10.1
Mean Modulus of Elasticity perpendicular / *prosječni modul elastičnosti okomito*	0.38	0.80
Mean shear modulus / *prosječni modul smicanja*	0.72	0.75
Density, kg/m³ / *gustoća, kg/m³*		
5 % Density / *5 % gustoća*	370	540
Mean density / *prosječna gustoća*	450	650

the same wood material. Hence, machine grading instruments require initial tests for establishing a correlation between their outputs and each type of graded wood.

In short, nowadays two machine grading systems are commonly used: output controlled and machine controlled. Both systems require a visual override inspection for evaluating the strength-reducing characteristics that are not automatically sensed by the machine. Apart from this common aspect, they are suited for different applications.

The output-controlled system is suitable for sawmill grading limited sizes, species and grades and working in repeated production runs of around one shift. This allows controlling the output of the system by testing specimens from the daily production. Together with statistical procedures, test results are used to monitor and adjust the machine settings.

On the other side, the machine controlled system is suited when, due to the large number of sizes, species and grades, it is not possible to perform the above mentioned daily tests. This system requires a strict control of the machine and remarkable research efforts aimed at determining the right settings.

As illustrated in Figure 2, machine grading must be performed according to EN 14081 Part 1, which specifies the general requirements, and to Parts 2, 3 and 4, which respectively lay down the additional requirements for initial type testing, for factory production control and the grading settings for machine controlled systems.

2.2 Structural timber with irregular cross section
2.2. Strukturna građa nepravilnoga poprečnog presjeka

To this day, timber elements with irregular section have been considered neither in the EN 14081-1 nor in other harmonized standards. Such a situation is envisaged by CPR, which prescribes the possibility of placing the CE marking on these products provided they have received a European Technical Assessment (ETA). This includes the declaration of product performance (by levels, classes or in a descriptive manner) for its intended use. Furthermore, it specifies the technical details necessary for the implementation of the system of assessment and verification of performance constancy. The procedure for obtaining an ETA is described in CPR's Annex II and can be summarized in three main steps.

Firstly, the manufacturer who wants to obtain an ETA, must apply to a Technical Assessment Body (TAB), a body designated by Member States. In particular, he must submit a technical file describing the product, its intended use and giving details of the factory production control (FPC).

Secondly, accepting the above request, the organization of TABs draws up and adopts a specific European Assessment Document (EAD). It contains, at least, a general description of the construction product, the list of its essential characteristics, methods and criteria for assessing the product performance. On the basis of the adopted EAD, the responsible TAB issues the relative ETA; starting from this point, the manufacturer can place the CE marking on its product according to ETA prescriptions.

It should be underlined that obtaining an ETA can require a period of a year and that it costs tens of thousands euro. Therefore, in order to share the costs, ETAs are often required by enterprises grouped in a consortium.

3. THE ITALIAN CONTEXT
3. TALIJANSKI OKRUŽENJE

The CE marking obligation for structural timber has determined several rebounds on the Italian wood

Table 3 Italian species and grades with their corresponding harmonized strength classes to be included in the next draft of EN 1912
Tablica 3. Talijanske vrste drva i razredi u usporedbi s ujednačenim razredima čvrstoće koje bi trebale biti uvrštene u sljedeći tekst norme EN 1912

EN 338 strength class *Razredi čvrstoće*	**Italian grading rule** *Talijansko pravilo razvrstavanja*	**Italian national grade** *Talijanski nacionalni razred*	**Species commercial name** *Komercijalni naziv vrste*	**Source** *Podrijetlo*	**EN 1912 Botanical identification** *Botanička identifikacija*	**Comments** *Komentari*
C30	UNI 11035-1,2	S1	Douglas fir *duglazija*	Italy *Italija*	54	Maximum width and thickness 100 mm *najveća širina i debljina 100 mm*
C24	UNI 11035-1,2	S2 and better	Corsican pine *korzikanski bor*	Italy *Italija*	39	-
C24	UNI 11035-1,2	S2 and better	Spruce&fir *smreka/jela*	Italy *Italija*	1, 22	-
C22	UNI 11035-1,2	S2 and better	Larch *ariš*	Italy *Italija*	15	-
C22	UNI 11035-1,2	S2 and better	Douglas fir *duglazija*	Italy *Italija*	54	-
C18	UNI 11035-1,2	S3	Larch *ariš*	Italy *Italija*	15	-
C18	UNI 11035-1,2	S3	Spruce&fir *smreka/jela*	Italy *Italija*	1, 22	-
C14	UNI 11035-1,2	S3	Corsican pine *korzikanski bor*	Italy *Italija*	39	-
D24	UNI 11035-1,2	S	Sweet chestnut *kesten*	Italy *Italija*	79	Maximum thickness 100 mm *najveća debljina 100 mm*

sector. Reflecting the European standardization framework, the implications are different for structural timber with rectangular or irregular cross section.

The Italian national standard for visual grading of structural timber with rectangular cross section is the UNI 11035-1 and 2. The first part brings terminology and measurement of the characteristics, while the second part sets the rules for visual strength grading.

The inclusion of these standard into EN 1912 allows the grading and CE marking of structural Italian timber of several species, i.e. Norway spruce, silver fir, larch, Douglas fir, Corsican pine and sweet chestnut (Table 3).

Nonetheless, at the moment the species and grades to be included in the EN 1912 do not fully represent the production and potential of the Italian timber sector. Therefore, different Italian organizations and research bodies[7] are carrying out further characterization activities in order to include higher strength classes for the Italian timber in the EN 1912. This will enable a better valorization of the national timber resources (Brunetti *et al.,* 2011).

With respect to the structural timber with irregular cross section, it should be underlined that it boasts a long tradition in the Italian architecture (Giordano, 1997). In carpentry, this timber is used in the form of two main assortments:

Figure 4 “Uso fiume” spruce beams (left) and trusses realized by assembling “Uso Fiume” larch beams (right)
Slika 4. Smrekove grede *Uso fiume* (lijevo) i rešetka sastavljena od arišovih greda *Uso fiume* (desno)

- “Uso Fiume” (UF) beams: produced by parallel sawing of the log on four faces. They present wanes on their whole length, while their cross section is constant from end to end.
- “Uso Trieste” (UT) beams: produced by sawing of the log on four faces following its natural taper. They present wanes on their whole length, while their cross section gets narrow from end to end.

In order to valorize these assortments, in Italy the “*Quality Consortium for Uso Fiume and Trieste beams*” has been recently founded, and it currently consists of ten manufacturers located in the north-east of the country. The Consortium applied for an ETA in order to certify its products basing on the national standard UNI 11035-3. ETA was issued on June 24rd 2011 and therefore affiliated

[7] The main organizations and research Bodies involved in these researches are the National Research Council, Federlegno-arredo and several Italian Universities.

manufacturers are now able to place CE marking on their beams made of Norway spruce or silver fir.

Similarly, "Consorzio Servizi Legno Sughero – Chestnut Uso Fiume Technical Committee" applied for an ETA for certifying UF chestnut beams. ETA was recently issued and now these products can be CE marked by manufacturers affiliated to the Consortium. Further activities are also in progress aimed at determining the characteristics values of Italian larch timber, in order to obtain a specific ETA for UF beams made of this species.

Finally, some portable instruments are currently undergoing a certification process for machine grading of Italian timber (Nocetti *et. al.*, 2010). Once certified, their effective diffusion among the carpentry enterprises will be related both to their efficiency and cost. In fact, with few exceptions, the Italian carpentry enterprises are mainly family-owned business belonging to the group of small and micro enterprises[8] (Anonymous, 2009), and grading machines could result too expensive in relation to their financial resources.

4 CONCLUSIONS
4. ZAKLJUČCI

The obligation of CE marking for solid wood structural timber entered into force on January 1st 2012. On one side, this represents a challenge for carpentry enterprises, in particular for the micro and small-sized enterprises; on the other side, it will allow the valorization of structural timber in its different forms, including the most traditional ones, which in the last period suffered the competition of engineered materials.

In fact, in order to be competitive with other construction products, nowadays structural timber should guarantee certified performance and specific moisture content. By means of computer numerical control (CNC) machines, pre-cut roof frames can be supplied, thus saving working time and installation costs.

With respect to Italy, the research efforts performed in the last several years make now possible CE marking of structural timber with rectangular or irregular cross section of different species coming from the national forests. Although this is of vital importance for the Italian carpentry enterprises, other issues are still open, such as the CE marking of Uso Fiume beams produced using wood coming from foreign countries.

On the whole, the recent introduction of CE marking obligation generated a wide scenario still in rapid evolution: several researches are in progress in order to enlarge the range of certifiable Italian structural timber, both in terms of strength classes and wooden species; the efficiency of small and micro enterprises in meeting the requirements of CE marking is still to be verified; the diffusion of machine grading instruments requires an adequate promotion activity. Hopefully, the whole of these factors will contribute to move the Italian carpentry sector to improve the dynamics and competitiveness on the market.

5 REFERENCES
5. LITERATURA

1. Brunetti, M.; Cerullo, S.; Lucchetti, M.; Nocetti, M.; Togni, M., 2011: Italian structural timber enters into Europe. Technical-normative situation for assortments with rectangular cross section (In Italian). Arealegno 56(11): 52-55.
2. Giordano, G., 1997: Wood anthology (in Italian). Vol. I. Reggio Emilia, Consorzio LEGNOLEGNO.
3. Kolb, J., 2008: Systems in timber engineering. Germany, Lignum DGhF.
4. Nocetti, M.; Bacher, M.; Brunetti, M.; Crivellaro, A.; Van de Kuilen, JW. G., 2010: Machine grading of Italian structural timber: preliminary results on different wood species. WCTE 2010 - 11th World Conference on Timber Engineering, Riva del Garda.
5. Moffet, M.; Fazio, M.W.; Wodehouse, L., 2003: A world history of architecture. London, Laurence King Publishing.
6. Pryce, W., 2005: Architecture in wood: a world history. London, Thames&Hudson.
7. Pellerin, R.F.; Ross, R.J., 2002: Nondestructive evaluation of wood. Madison, Forest Products Society
8. Anonymous, 2011: 17th International nondestructive testing and evaluation of wood symposium - Proceedings. Sopron, University of West Hungary.
9. Anonymous, 2009: Inter-Bois Project, 2009. White book on transalpine forest-wood chain. Torino, Regione Piemonte.
10. Anonymous, 2006: Tackle climate change: use wood. Brussels, CEI-Bois.
11. COMMISSION RECOMMENDATION of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises.
12. EN 336:2003 Structural timber - Sizes, permitted deviations.
13. EN 338:2009 Structural timber - Strength classes.
14. EN 384:2010 Structural timber - Determination of characteristic values of mechanical properties and density.
15. EN 408:2010 Timber structures - Structural timber and glued laminated timber - Determination of some physical and mechanical properties.
16. EN 1912:2012 Structural timber - Strength classes - Assignment of visual grades and species.
17. EN 14081-1:2005+A1:2011 Timber structures - Strength graded structural timber with rectangular cross section - Part 1: General requirements.
18. EN 14081-2:2010 Timber structures - Strength graded structural timber with rectangular cross section - Part 2: Machine grading; additional requirements for initial type testing.
19. EN 14081-3:2005 Timber structures - Strength graded structural timber with rectangular cross section - Part 3: Machine grading; additional requirements for factory production control.
20. EN 14081-4:2009 Timber structures - Strength graded structural timber with rectangular cross section - Part 4:

[8] According to the Recommendation of the European Commission of May 6 2003, a small enterprise is defined as "*an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed 10 million €*";a microenterprise is defined as "*an enterprise which employs fewer than 10 persons and whose annual turnover and/or annual balance sheet total does not exceed 2 million €*".

Machine grading - Grading machine settings for machine controlled systems.
21. DIN4074-1 Ausgabe 2008,12 Sortierung von Holznach der Tragfähigkeit, Nadelschnittholz, 2003.
22. NF B 52-001 Août 2011 Règles d'utilisation du bois dans les constructions; Classement visuel pour employen structure pour les principales essences résineuses et feuillues.
23. UNI 11035-1:2010 Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica - Parte 1: Terminologia e misurazione delle caratteristiche.
24. UNI 11035-2:2010 Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica - Parte 2: Regole per la classificazione a vista secondo la resistenza meccanica e valori caratteristici per tipi di legname strutturale.
25. UNI 11035-3:2010 Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica – Parte 3: Travi Uso Fiume e Uso Trieste.
26. REGULATION (EU) No 305/2011 of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC.
27. REGULATION (EC) No 765/2008 of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93.

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Demografske promjene – promjene zahtjeva potrošača

Demographic change – changing customer demands

Institut za drvnu tehnologiju (njem. *Institut für Holztechnolologie Dresden, IHD*) iz Dresdena organizirao je, deveti put, savjetovanje *Dani namještaja u Dresdenu* (*Möbeltage in Dresden*), održano 28. i 29. studenog 2012. godine. Ta se manifastacija održava svake druge godine i posvećena je ekonomskome i tehnološkom razvoju, kao i ekološkim zahtjevima proizvodnje namještaja i unutrašnjeg uređenja. Na savjetovanju 2012. godine glavna su tema bile demografske promjene i njihov utjecaj na promijenjene zahtjeve kupaca. Organizator je nastojao, kao i na prijašnjim danima namještaja, organizirati razmjenu iskustava između istraživačkog sektora s područja znanosti i obrazovanja te onoga s područja proizvodnje i trgovine namještaja i unutarnjeg opremanja. Iz naslova je moguće razaznati temu nadahnutu produljenjem životnog vijeka ljudi, a time i porastom broja starije populacije koja ima neka ograničenja u upotrebi predmeta, pa tako i namještaja, koji zahtijevaju novo definiranje zahtjeva potrošača koji do sada nisu uzeti u obzir. Ta je činjenica osobito važna proizvođačima materijala i okova za namještaj, stručnjacima koji se bave projektiranjem i izradom namještaja i opreme objekata, kao i stručnjacima s područja ekonomije i marketinga.

Slika 1. Pozivnica za savjetovanje

Jörn Holzmann iz izdavačke kuće Ferdinand Holzmann Verlag, Hamburg održao je uvodno predavanje o trendovima budućeg razvoja industrije namještaja. Naveo je razloge stagnacije i propadanja tržišta namještaja i načine mogućeg oporavka. Istaknuo je da je 2008. godine u Njemačkoj bilo 38,8 % ljudi od 50 godina i starijih, a da će ih 2018. godine biti 46,4 %, te da se industrija namještaja mora prilagoditi tome. Dipl. ing. Andreas Ruf iz novoosnovanog Udruženja njemačke industrije pokućstva (Verband der Deutschen Wohnmöbelindustrie) održao je predavanje o novoj logistici za industriju namještaja i o njezinim budućim izazovima. Istaknuo je probleme do kojih dolazi u lancu opskrbe i predložio moderan logistički koncept koji će se razraditi i isprobati u praksi u sklopu zajedničkog projekta s Visokom školom Ostwestfalen-Lippe. Felix Doerr iz tvrtke Europa Möbel-Verbund GmbH iz Fahrenzhausena održao je zanimljivo predavanje s temom *Kako reagiraju stacionarne trgovine namještajem na izazove interneta i koju zadaću na tom području moraju ispuniti udruženja.* Na primjeru mreže EMV (Europa Möbel-Verbund, GmbH), koju čini oko 600 trgovina namještaja i koja je aktivna u više europskih zemalja, gospodin Doerr je pokazao koje su prednosti korištenja internetom što ih imaju stacionarne trgovine u reklamiranju i prodaji namještaja. Dr. Sergej Gromov iz tvrtke BSM Engineering, Moskva, bivši student Tehničkog univerziteta u Dresdenu, održao je predavanje o razvoju i trendovima ruskog tržišta namještaja. Govorio je o aktualnom stanju tržišta namještaja u Rusiji, o njegovoj strukturi, prednostima i nedostacima za industriju namještaja zbog ulaska Rusije u World Trade Organization (WTO) te je istaknuo kratkoročne i dugoročne mjere koje ruska industrija namještaja mora poduzeti.

Nakon ekonomsko-marketinških tema kojima je opisano stanje u drvoprerađivačkoj struci, prva u nizu predavanja koja su definirala probleme vezane za problematiku uporabe proizvoda uvjetovanih demografskim promjenama održala je Suzane Trabandt. Njezino se istraživanje odnosi na analizu starije populacije koja boravi u staračkim domovima i njihovih potreba, a obuhvaća razdoblje od 1999. godine do danas, s predviđanjima do 2030. godine. U izlaganju je istaknula

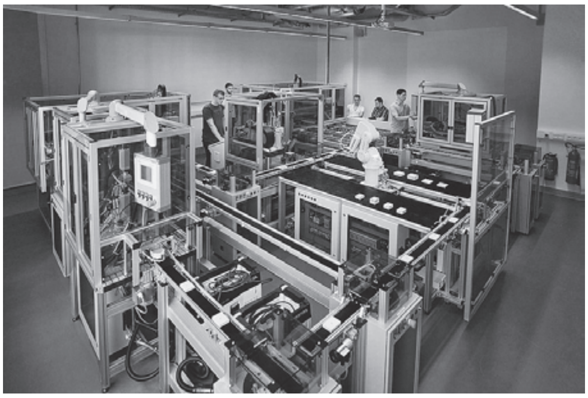
Slika 2. CAD laboratorij

Slika 3. Stereoprojektor za 3D prezentaciju

značenje porasta broja ostarjelih osoba te heterogeni i rasipajući raspored podataka stanja vezanoga za zdravlje i platežnu mogućnost spomenute populacije kao dva bitna kriterija u definiranju projektnog zadatka za namještaj i opremu objekata. Iako se pri spominjanju starije populacije misli na dob 65+, ona je u istraživanja uključila i dobnu skupinu 55+, što je pomoglo pri redefiniranju potreba koje treba uzeti u obzir već u fazi stvaranja idejnog rješenja namještaja i opreme objekata za ljude starije dobi, kojoj će uskoro pripadati i dobna skupina 55+. Iz izlaganja Ulrike Rau slušateljstvo je dobilo uvid u povijesni razvoj promjena starije populacije, promatranih sa stajališta njihova antropometrijskoga i zdravstvenog statusa, koje, prema njezinu mišljenju, najviše utječu na definiranje kriterija koji bi se trebali uzeti u obzir pri projektiranju namještaja i unutarnjeg opremanja prostora za stariju populaciju. Problemi pri saginjanju, čučanju i klečanju za osobe od 40 do 85 godina, prema njezinim iskustvima, postoje već i u 40-godišnjaka, no postotak tih problema naglo raste u dobnoj skupini od 70 do 85 godina. Zbog navedenoga, ona ističe nužnost primjene načela inkluzivnog dizajna, što potkrepljuje primjerima na inoviranim proizvodima, jednako kao i na primjeru redizajna namještaja hotelskih soba i javnog prostora. Andreas Gelhard predstavio je projekt razvoja polunaslonjača koji su namijenjeni kućnoj i javnoj uporabi za starije osobe. Posebna je pozornost pridana oblikovanju naslona za ruke, koji olakšavaju dizanje i sjedanje. U suradnji s institutom IHD iz Dresdena, tvrtka Göhler proizvela je polunaslonjač s ugrađenim mjernim uređajem. Mjerenjem su dobivene veličine i raspored naprezanja pri sjedanju, iz čega je izvedena definicija ponašanja korisnika starije dobi, a prema dobivenim rezultatima, oblikovan je i konstruiran polunaslonjač koji omogućuje ustajanje i sjedanje uz manje naprezanje korisnika. Prof. dr. Aleksander Petutschnigg i prof. dr. Günter Grall dolaze iz obrazovnog sektora, a predstavili su projekt pod naslovom *Izazovi demografskog razvoja – namještaj iz Kuchla*. Rezultat projekta bili su novodizajnirani proizvodi darovitih studenata drvne tehnologije i dizajna s Fachhochschulle Salzburg. Predstavljena su inovativna rješenja namještaja za sjedenje i ležanje koji je bio izložen na sajmu namještaja u Kölnu. U sklopu istraživanja strukture zaposlenih u drvoprerađivačkoj struci, Jan Kurth iz udruženja za drvo i namještaj obradio je temu također vezanu za obrazovanje. Riječ je o strukturi zaposlenih prema starosnoj dobi i obrazovanju usporedbom stanja u 2009. godini i s projekcijom za 2060. godinu. Poput prethodnih govornika, naglasio je povećanu razinu starije populacije te trend smanjenja broja učenika u školama. To je potkrijepio podatkom iz 1992. godine, kada je djece školske dobi bilo 9,3 milijuna, s maksimalnim porastom na 10,2 milijuna u 2007. godini, no otada krivulja neprestano pada te današnji broj školske populacije iznosi 9,7 milijuna, a projekcija za 2020. godinu predviđa 8,7 milijuna učenika. Posebno je naglasio zabrinutost odmaka rezultata u usporedbi s ostalim strukama. U drvoprerađivačkoj je struci u skupini od 22 do 33 godine manji broj radnika, a povećan je u skupini od 43 do 50 godina. Rješenje tog problema jest popularizacija struke i njezino približavanje mladima, što je moguće ostvariti zajedničkim aktivnostima udruženja za drvo i namještaj i županija.

Predavanja koja su uslijedila odnosila su se na uporabu materijala i utjecaj demografskih promjena na

Slika 4. 3D printer



Slika 5. CIM laboratorij

njihov razvoj. Wilfried Gatzke, ekspert za područje namještaja, govorio je o problematici uporabnih svojstava novih površina u proizvodnji kuhinja. Istaknuo je velik broj reklamacija na području kuhinjskog namještaja. Osim lošeg projektiranja i sastavljanja, uzrok reklamacija su uporabna svojstva različitih novih materijala koji se primjenjuju u proizvodnji kuhinja. Istaknuo je važnost normi DIN 68 930 i DIN 68 861 pri ispitivanju uporabnih svojstava kuhinjskog namještaja, ali i probleme u sudskim tumačenjima zahtjeva navedenih u normama. Dipl. ing. Reinhard Bäckmann, vlasnik i direktor istoimene savjetodavne tvrtke, održao je predavanje o dinamici inovacija materijala za namještaj. Prikazao je strukturu uporabe materijala za namještaj današnjice i dao pregled trendova u budućnosti. Tehnologija materijala u industriji namještaja, prema riječima ing. Bäckmanna, sljedećih će godina ostvariti brzu promjenu od klasičnih ka inovativnim i od pasivnih ka aktivnim materijalima poput LED dioda ugrađenih u rubove. Dipl. ing Marcus Beyer iz tvrtke Dekordruck Leipzig održao je predavanje o novim zahtjevima vezanima za dekorativne folije sa završnim efektom (*finiš folije*) koje se primjenjuju za oblaganje površina namještaja. U posljednje dvije godine na tržištu su se pojavile strukturirane folije s tzv. 3D efektom. Kada je površina trodimenzionalno tiskana i može se osjetiti dodirom, govori se o haptičkom dekoru, odnosno o haptičkim folijama o čijim je svojstvima i postupcima obrade govorio ing. Beyer. Završni referat s područja primjene materijala za namještaj održao je Roman Lang, koji je na primjeru o utjecaju razvoja okova na oblikovanje i konstrukcije namještaja održao predavanje i fotografijama potkrijepio izbor novih okova tvrtke Häfele za višefunkcionalni namještaj namijenjen malim prostorima.

Iako se u prvi mah čini da tema o buci nije usko povezana s temom savjetovanja, govoreći o utjecaju buke na zdravlje, a time i na promjene određene demografske skupine, dr. Hans-Werner Hoffmeister upozorio je na problem aktivne i pasivne buke nastale zbog vibracija pri obradi drva koja utječe na povećanje broja ljudi s problemima sluha. Od ukupnog broja bolesti stečenih na radu, ta vrsta čini 40 %. U radu su iznesena rješenja za prigušenje buke u obradnim centrima.

Dvjestotinjak sudionika konferencije sudjelovalo je u raspravama postavljajući pitanja vezana za izlaganja koja su se odnosila na nove potrebe tržišta i oblikovna rješenja proizvoda, s naglaskom na antropometriji, na odabir materijala i postupaka obrade te na edukaciju mladih stručnjaka. Savjetovanje nije moglo dati odgovore na sva pitanja vezana za utjecaj demografskih promjena na budućnost drvoprerađivačke struke, no ispunilo je svoju zadaću definirajući problematiku i dajući polazišta za daljnji razvoj.

Ljubazni domaćini, s direktorom prof. dr. Andreasom Hänselom na čelu, omogućili su sudionicima razgledavanje izvrsno opremljenog prostora Berufsakademie. U sklopu akademije nalaze se laboratoriji za finalnu strojnu i površinsku obradu, za kemiju i fiziku drva te za ispitivanje tehničkih svojstava drva i anatomiju te ERP, CAD, CIM, CAQ i 3D-Print laboratorij. Unutar zgrade djeluje i radionica opremljena standardnim strojevima složenima po logičnom slijedu obrade, koja čini tvrtku u malom. U radionici su strojevi za obradu drva i drvnih ploča te za površinsku obradu i lijepljenje. Osim velikog broja ručnih strojeva, radionica posjeduje i dva obradna centra. U njoj studenti na standardnim strojevima ili na drugim posebnim strojevima izrađuju svoje završne radove i imaju priliku sudjelovati u rješavanju tehnoloških problema te problema održavanja i upravljanja proizvodnjom kako bi bili spremi za praksu. Teško je bilo sakriti oduševljenje pri razgledavanju CAD i 3D-Print laboratorija dok nas je u obilazak vodio dr. Dirk Siebrecht. CAD laboratorij opremljen je s 21 grafičkom radnom stanicom, serverom, ploterom i sustavom za komunikaciju između nastavnika i studenata, projektorom za 3D prezentaciju i 3D printerom. Oprema za laboratorije uglavnom je nabavljena sredstvima europskog fonda za regionalni razvoj.

izv. prof. dr. sc. Silvana Prekrat
prof. dr. sc. Vlatka Jirouš Rajković

Novi dizajn – ponovo pronalaženje smisla dizajna

New Design – Reinvent the Meaning of Design

Pod naslovom *New Design - Reinvent the Meaning of Design* 13. prosinca 2012. održana je u Ljubljani 2. međunarodna konferencija. Na konferenciji su prezentirani radovi iz Slovenije, Hrvatske, Bosne i Hercegovine, Kosova, Srbije, Portugala i Poljske, a održan je i okrugli stol s temom *New design* na kojemu se raspravljalo o novoj ulozi dizajna na kojemu su sudjelovali predstavnici Slovenije, Hrvatske i Portugala.

Uz konferenciju je po drugi put također održana izložba radova studenata koji su se natjecali za najbolji rad prezentiran u obliku postera. Izložba je jedan od ciljeva platforme A.L.I.C.E., koju je uz Šumarski fakultet u Zagrebu potpisalo 12 fakulteta iz Slovenije, Bosne i Hercegovine, Hrvatske, Kosova, Srbije, Španjolske, Rusije i SAD-a. U sklopu platforme A.L.I.C.E. djeluju i CEEPUS partneri, a to su:

Academy of Design in Ljubljana, associate member of University of Primorska, Slovenia

Academy of Fine Arts Sarajevo, Bosnia and Herzegovina

University of Split, Arts Academy, Department of Visual Communications, Croatia

University of Zagreb, Faculty of Forestry, Croatia

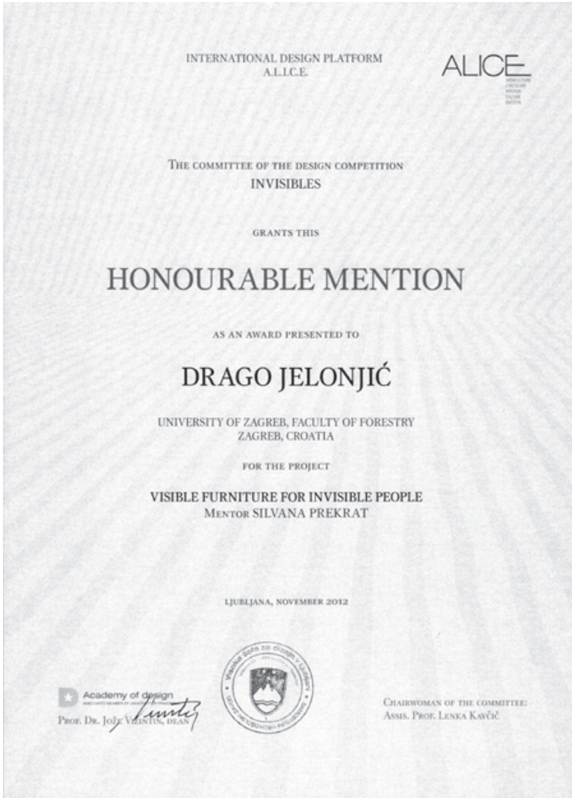
The college of textile – Design, Technology and Management – DTM, Belgrade, Serbia

Department of Furniture Design, Poznan University of Life Sciences, Poland

Faculty of Natural Sciences and Engineering, Department of Textiles, Ljubljana, Slovenia.

Naslov izložbe zadan je prošlogodišnjom temom konferencije – *Invisibles*. Pod pojmom nevidljivih razumijevaju se sve one marginalne grupacije društva kao što su siromašni, stariji, osobe s posebnim potrebama i ljudi koji se zbog bilo kojih razloga ne mogu koristiti novodizajniranim predmetima, interijerima ili eksterijerima. Analizom je, nažalost, dokazano da u svijetu oni čine većinu.

Međunarodna komisija odabrala je i ocijenila devet radova koji su prezentirani na izložbi. Prva je nagrada pripala radu pod naslovom Renovation of Y. Benou's farm – Visible History, a otišla je u Saint-Petersburg, na Stud Institute of DESIGN & ART, s kojega dolaze autor Stanislav Medvedev i njegov mentor Vladimir Sanzharov. Među ostalim radovima, istaknut je i rad studenta Šumarskog fakulteta Sveučilišta u Zagrebu Drage Jelonjića s naslovom *Visible furniture for invisible people*, koji je dobio počasno priznanje.


INTERNATIONAL DESIGN PLATFORM
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ALICE

THE COMMITTEE OF THE DESIGN COMPETITION
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HONOURABLE MENTION

AS AN AWARD PRESENTED TO

DRAGO JELONJIĆ

UNIVERSITY OF ZAGREB, FACULTY OF FORESTRY
ZAGREB, CROATIA

FOR THE PROJECT

VISIBLE FURNITURE FOR INVISIBLE PEOPLE
MENTOR SILVANA PREKRAT

LJUBLJANA, NOVEMBER 2012

Academy of design

CHAIRWOMAN OF THE COMMITTEE:
ASSIS. PROF. LENKA KAVČIČ

izv. prof. dr. sc. Silvana Prekrat

KOTO

UDK: 674.031.798

NAZIVI

Drvo trgovačkog naziva koto pripada botaničkim vrstama *Pterygota macrocarpa* K. Schum i *Pterygota bequaertii* De Wild iz porodice *Sterculiaceae*. Ostali nazivi su koto (Njemačka, Obala Bjelokosti), akodiakédé, bofo ouale, bontue, pohoure, waré (Obala Bjelokosti), pterygota (Njemačka, Velika Britanija), awari, kyere, wawampe (Gana), efok, kion (Kamerun).

NALAZIŠTE

Vrsta drveta koto raste na obalama zapadne Afrike. Rasprostranjena je u Obali Bjelokosti, Gani i Kamerunu. Uspijeva i na području tropskih nizinskih i trajnozelenih nizinskih šuma.

STABLO

Stabla drveta koto obično narastu od 25 do 40 m visoko, s dužinom čistih debala od 15 do 25 m. Promjer deblovine je od 0,6 do 1,2 m. Debla su cilindrična. Kora im je blijedožućkasta, glatka, raspucana, debljine do 1,5 cm.

DRVO

Makroskopska obilježja

Koto je difuzno porozno drvo. Srž drva obično je bijeložućkasta ili siva. Bjeljika je nešto bljeđa.

Granica goda je uočljiva, često označena vrpcama aksijalnog parenhima. Velike traheje, drvni traci i tangentne vrpce aksijalnog parenhima na poprečnom su presjeku dobro vidljive. U drvu blistača vidljive su sjajne mrlje visokih drvnih trakova. Žice drva su usukane. Kut usukanosti žice varira i na radijalnom presjeku drva stvara manje-više vrpčastu sliku.

Mikroskopska obilježja

Traheje su pretežno raspoređene pojedinačno ili u kratkim radijalnim nizovima (2 – 3 pore).

Na 1 mm^2 poprečnog presjeka može se naći 1...2...4 pora. Promjer traheja iznosi 95...180...240 mikrometara. Volumni udio traheja u građi drva je oko 10 %. Traheje u srži nisu ispunjene tilama.

Aksijalni je parenhim apotrahealan i paratrahealan (oskudan i vazicentričan). Volumni udio aksijalnog parenhima u građi drva iznosi oko 23 %. Trake aksijalnog parenhima široke su 3...4...6 stanica. U stanicama aksijalnog parenhima i drvnih trakova nalaze se kristali u obliku romba i silikati. Drvni su traci višeredni, heterocelularni, difuzno raspoređeni. Visina im je 640...1150...2220 μm, a širina 20...60...95 μm. Gustoća drvnih trakova iznosi od 3 do 5 na milimetar. Volumni udio drvnih trakova u građi drva iznosi oko 20 %. Drvna su vlakanca libriformska, a traheide vlaknaste. Duljina vlakanaca iznosi 1,265...1,785...2,780 mm, a promjer im je 7,0...19,0...30,0 μm. Debljina staničnih stijenki drvnih vlakanaca iznosi 2,0...3,0...5,0 μm. Volumni je udio vlakanaca u građi drva oko 47 %.

Fizička svojstva

Gustoća standardno suhog drva, ρ_o	460...500...570 kg/m^3
Gustoća prosušenog drva, ρ_{12-15}	490...530...600 kg/m^3
Gustoća sirovog drva, ρ_s	900...950 kg/m^3
Poroznost	67 %
Radijalno utezanje, β_r	3,6...4,0...4,8 %
Tangentno utezanje, β_t	6,3...7,7...8,3 %
Volumno utezanje, β_v	9,9...11,9...13,3 %

Mehanička svojstva

Čvrstoća na tlak	35... 51...61,5 MPa
Čvrstoća na vlak, paralelno s vlakancima	57...85,5...150 MPa
Čvrstoća na savijanje	62,5...86,55...110 MPa
Čvrstoća na smik	5,0...7,0...9,5 MPa
Tvrdoća (prema Brinellu)	
paralelno s vlakancima	36...46...61 MPa
okomito na vlakanca, radijalno	18...19...29 MPa
okomito na vlakanca, tangentno	13...22...43 MPa
Modul elastičnosti	oko 9,0 GPa

TEHNOLOŠKA SVOJSTVA

Obradivost

Drvo se dobro obrađuje strojnim i ručnim alatima. Za blanjanje alati moraju biti vrlo oštri da bi se spriječilo trganje (usukane) žice. Drvo dobro drži čavle i vijke, no ipak je prije upotrebe vijaka i čavala drvo potrebno predbušiti jer je sklono pucanju. Drvo se lako lijepi, lakira i politira. Kako bi se spriječilo prerano žućenje prirodne boje drva, preporučuju se UV premazi.

Sušenje

Drvo se lako suši. Zbog visokoga početnog sadržaja vode preporučuje se sporo kontrolirano sušenje. Suprotno tome, sušenje treba biti dovoljno brzo da se spriječi diskoloracija površine. Sklonost vitoperenju i rasucavanju malena je do umjerena.

Trajnost i zaštita

Srž drva koto prirodno je slabe trajnosti i pripada razredu otpornosti 5 (HRN EN 350-1, 2005). Drvo nije otporno na insekte ni na gljive uzročnice truleži. Koto je permeabilno drvo, lako se impregnira zaštitnim sredstvima i pripada razredu mogućnosti zaštite (permeabilnosti) 1 (HRN EN 350-2, 2005).

Uporaba

Drvo koto ugrađuje se u interijere. Posebno je prikladno za proizvodnju dekorativnih furnira. Furniri prirodne boje mogu zamijeniti jasen ili druge svijetle vrste drva, ili pak, ako je drvo pareno, može zamijeniti hrastovinu. Iskorištava se za proizvodnju namještaja i drvenih obloga. Tokarski proizvodi i manje nosive drvene konstrukcije u industriji aviona izrađivale su se od drva koto.

Sirovina

Drvo na tržište dolazi u obliku trupaca, koji moraju biti preventivno premazani zaštitnim sredstvom.

Slične vrste drva

Pterogyta horsfieldii Kosterm.
Antiaris africana Engl.
Sterculia oblonga Mast.
Triplochiton scleroxylon K. Schum.

Literatura

1. Wagenführ, R.; Scheiber, C., 1974: HOLZATLAS, VEB Fachbuchverlag, Leipzig, 477-478.
2. ***Woods of the world, 1994, Tree talk, Inc., 431 Pine Street, Burlington, VT 05402.
3. ***HRN EN 350-1, 2005: Trajnost drva i proizvoda iz drva – Prirodna trajnost masivnog drva – 1. dio: Upute o temeljnim načelima ispitivanja i razredbe prirodne trajnosti drva (EN 350-1:1994).
4. ***HRN EN 350-2, 2005: Trajnost drva i proizvoda na osnovi drva – Prirodna trajnost masivnog drva – 2. dio (EN 350-2:1994).
5. Richter, H. G.; Dallwitz, M. J. (2000 onwards): 'Commercial timbers: descriptions, illustrations, identification, and information retrieval.' In English, French, German, and Spanish. Version: 4th May 2000. http://biodiversity.uno.edu/delta/.

prof. dr. sc. Jelena Trajković
doc. dr. sc. Bogoslav Šefc

BIBLIOGRAFIJA ČLANAKA, STRUČNIH INFORMACIJA I IZVJEŠTAJA OBJAVLJENIH U DRVNOJ INDUSTRIJI, U VOLUMENU 63 (2012), UDK I ODK

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BIBLIOGRAPHY OF ARTICLES, REWIEVS, TECHNICAL INFORMATION AND REPORTS PUBLISHED IN THE "DRVNA INDUSTRIJA" JOURNAL IN VOLUME 63 (2012 YEAR), UDC AND ODC

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Bihar, Z.; Šefc, B.: Bibliography of Articles, Rewievs, Techical information and Reports published in the "Wood industry" in volume 62 (2012), UDC and ODC, No. 1, pp 62-66.

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Prekrat, S.; Jajčinović, M.: News from the profession, excursion of students from Wood science department to Elgrad company and to Eggers exibition, No. 2, pp 147-148.

Grbac, I.; Domljan, D.; Littvay, I.: Fairs and exibitions, IMM COLOGNE 2012, Metropolis for business elites, No. 2, pp 149-154.

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Primjer
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Primjeri

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Web stranice
***1997: "Guide to Punctuation" (online), University of Sussex, www.informatics.sussex.ac.uk/department/docs/punctuation/node00.html. First published 1997 (pristupljeno 27. siječnja 2010).

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Wilson, J.W.; Wellwood, R.W. 1965: Intra-increment chemical properties of certain western Canadian coniferous species. U: W. A. Cote, Jr. (Ed.): Cellular Ultrastructure of Woody Plants. Syracuse, N.Y., Syracuse Univ. Press, pp. 551-559.

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