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INFLUENCE OF BEECH PARTICLE SIZE USED IN SURFACE LAYER ON BENDING STRENGTH OF THREE-LAYER PARTICLEBOARD

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Abstract

It is well known that wood species and particle size used influence the bending strength of the three-layer particleboard. The purpose of this research was to determine how the size of beech (*Fagus sylvatica* L.) particles influences the bending strength of the three-layer particleboard, where size of particles used was altered in surface layer only. Beech wood particles of five different sizes were used and blended with UF adhesive. The results show that the bending strength of boards increases with increasing particle specific surface area, increasing surface layer compaction ratio and surface layer density, while bending strength decreases with increasing surface covered with adhesive.

Key words: particleboard, bending strength, beech particles, particle size, surface layer compaction ratio, surface covered with adhesive

VPLIV VELIKOSTI BUKOVEGA IVERJA, UPORABLJENEGA V ZUNANJEM SLOJU NA UPOGIBNO TRDNOST TRISLOJNE IVERNE PLOŠČE

Izvleček

Znano je, da vrsta lesa in velikost iverja vplivata na upogibno trdnost trislojnih ivernih plošč. Namen posebej zasnovane raziskave je bil ugotoviti, kako velikost bukovega (*Fagus Sylvatica* L.) iverja vpliva na upogibno trdnost trislojnih ivernih plošč, če je velikost bukovega iverja spremenjena samo v zunanjem sloju. Uporabljeno je bilo bukovo iverje petih različnih velikosti. Iverje je bilo oblepljeno z UF lepilom. Rezultati meritev so pokazali, da upogibna trdnost ivernih plošč narašča z naraščanjem specifične površine iverja, faktorja zgostitve zunanjega sloja in prostorninske mase zunanjega sloja, medtem ko z naraščanjem oblepljenosti upogibna trdnost pada.

Ključne besede: iverna plošča, upogibna trdnost, bukovo iverje, velikost iverja, faktor zgostitve zunanjega sloja, stopnja oblepljenosti

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CONTENTS

1 INTRODUCTION
UVOD

Important indicators of particleboard quality are their mechanical and physical properties. To attain optimum board properties, some conditions such as shape and size of particles, type of adhesive used, gluing factor, share of individual layer etc. have to be fulfilled.

One of the most important properties of three–layer particleboard is certainly the bending strength. Since bending strength is influenced by the structure of surface layer, the most consideration should therefore be oriented into the structure of that layer; what means that such wood species and particle size should be chosen that contributes to achievement of higher bending strength.

From the beginning of the particleboard production until today, many investigations have been conducted in which the impact of different wood species used on particleboard properties has been researched. In the early 1960s, BUSCHBECK *et al*. (1961a, 1961b) determined that lower properties are obtained when wood species with higher density, such as beech, are used.

MOSLEMI (1974) also determined that bending strength is lower when beech or oak particles are used, which is, according to MOSLEMI, the effect of lower compaction of species with higher density.

KOLLMANN *et al*. (1975) reported that the most important factors influencing the properties of particleboards are wood species used and particle size. They determined that beech particles diminish the particleboard's properties, especially its bending strength and modulus of elasticity.

The impact of particle size on mechanical properties have also been investigated by LIIRI *et al*. (1977), NIEMZ AND BAUER (1991) and NIEMZ *et al*. (1992). They determined that the best bending strengths are achieved when longer and thicker particles are used.

Beside wood species used and particle size, ADCOCK IN IRLE, 2002; IRLE, 2000; JOSSIFOV, 1989; XU IN SUCHSLAND, 1998 determined that the compaction ratio, compression ratio and density are also important factors that influence the bending strength. They determined that with the increasing density and increasing compaction ratio the bending strength increases as well. The above-mentioned authors also noticed that compression ratio exceeding 1.3 could lead to cell wall damage.

The presented research is focused on determination of how beech (*Fagus sylvatica L.*) particles of different sizes influence bending strength of the three–layer particleboard, when experimental board structure is altered in surface layer only.

2 MATERIALS AND METHODS
MATEIAL IN METODE

From fresh beech logs with moisture content between 60 and 70 %, particles were produced in laboratory chipper. Particles were then dried to moisture content approximately 10 % and by means of sieving separated into five different size classes that are characteristic of surface layer (Table 1).

Table 1: Particle size class, dimensions and specific surface area of beech particles
Preglednica 1: Velikostni razredi, dimenzije in specifična površina bukovega iverja

Particle size class	Thickness	Width	Length	Particle specific surface area
	mm	mm	mm	m^2/100 g
A	0.171	0.176	0.703	4.570
B	0.290	0.303	1.590	2.600
C	0.605	0.625	2.464	1.399
D	0.619	0.640	3.170	1.408
E	0.967	1.005	3.542	0.891

After separation of particles into size classes, the amount of 258 g of the UF adhesive was added to 980 g of particles for surface layer, while 255 g of UF adhesive was added to 1480 g of particles for core layer. Properties of adhesive used are presented in table 2.

Table 2: Properties of UF adhesive used
Preglednica 2: Lastnost uporabljenega UF lepila

Density	1,280 g/cm^3
Solid content	66%
pH value	8,15
Gel time	60 sec.
Viscosity	486 mPas

The board structure was altered in surface layer only, while the structure of core layer was equal for all experimental boards. Four boards for each particle size class of 500×500 mm were produced.

Mat was pressed at temperature 180° C and specific pressure 3 N/mm^2 to nominal thickness of 16 mm. Boards were then cooled and stored at temperature 20±2° C and relative humidity 65±5 %.

Bending strength was determined in accordance to SIST EN 310.

To determine the compaction ratio influence on bending strength of the three-layer particleboard, the surface layer density and surface layer compaction ratio were determined. Vertical density distribution data were compared both for surface layer density and surface layer compaction ratio. Vertical density distribution was determined by means of gamma rays (MEDVED, 2000). Surface layer compaction ratio (CR_{SL}) was calculated by the following equation:

$$CR_{SL} = \rho_{SL2} / \rho_{SL1} \qquad \text{... (1)}$$

where: - ρ_{SL2} means surface layer density after pressing and
- ρ_{SL1} surface layer mat density before pressing.

3 RESULTS AND DISCUSSION
REZULTATI IN RAZPRAVA

According to KOLLMANN *et al*., 1975; MALONEY, 1977; MOSLEMI, 1974 it can be predicted that particle size depends on fraction size, and that bending strength depends on size of particles used. These finding were also confirmed by presented research (Figure 1).

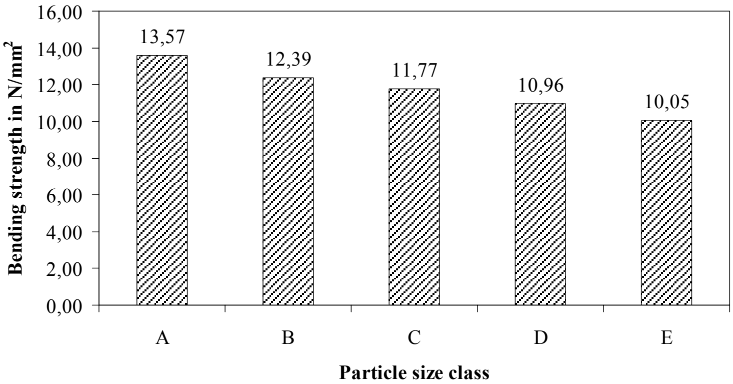

Figure 1: Bending strength with regard to the beech particle size class
Slika 1: Upogibna trdnost glede na velikostni razred bukovega iverja

Despite the determined correlation between particle size and bending strength it is hard to affirm that particle size is the most important factor that influences the bending strength. Particle size also influences surface covered with adhesive (MEDVED AND RESNIK, 2004), surface layer compaction ratio and surface layer density. The mutual effect of the mentioned factors is especially evident when bending strength of boards from particles class "C" and "D" is compared. Particles class "C" and "D" have almost identical thickness and specific surface area, while bending strength of particleboards from those two particle sizes are different. In boards from particles of class "C", higher surface layer compaction ratio and surface layer density were determined than in those from particles of class "D".

Influence of particles size on bending strength should therefore be explained with surface layer compaction ratio (Figure 2), surface layer density (Figure 3) and surface covered with adhesive (Figure 4).

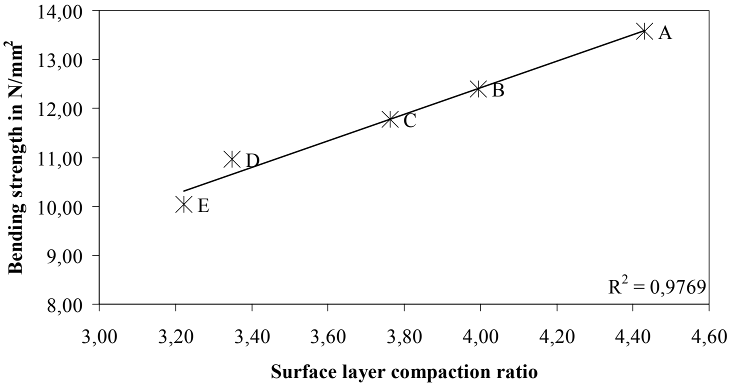

Figure 2: Correlation between surface layer compaction ratio and bending strength with regard to the beech particle size class

Slika 2: Odvisnost upogibne trdnosti od faktorja zgostitve zunanjega sloja glede na velikostni razred bukovega iverja

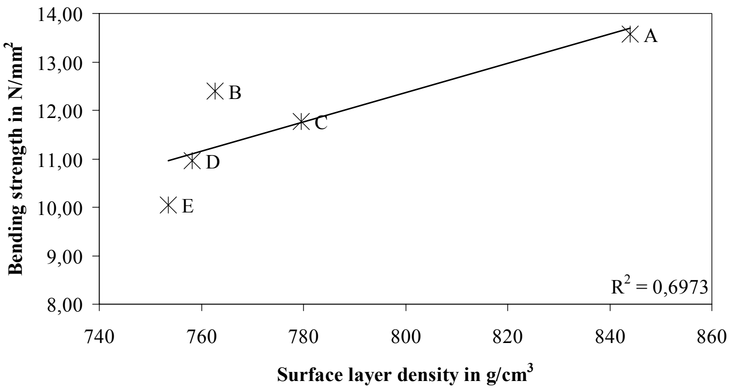

Figure 3: Correlation between surface layer density and bending strength with regard to the particle size class

Slika 3: Odvisnost upogibne trdnosti od prostorninske mase zunanjega sloja glede na velikostni razred bukovega iverja

It can be determined that bending strength increases with increasing compaction ratio. Better contact between particles is achieved at higher compaction, as there is less free space between particles, which could diminish the strength of particleboard. Correlation between density, compaction ratio and bending strength were also determined by KOLLMANN *et al*. (1974), MOSLEMI (1974a), MALONEY (1977) and NIEMZ (1993).

As mentioned before, surface covered with adhesive also has an impact on bending strength (Figure 4)

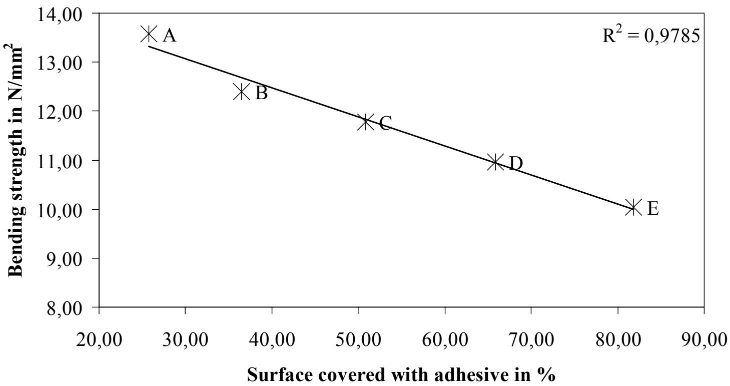

Figure 4: Correlation between surface covered with adhesive and bending strength with regard to the particle size class

Slika 4: Odvisnost upogibne trdnosti od stopnje oblepljenosti iverja glede na velikostni razred bukovega iverja

With increasing surface covered with adhesive, bending strength decreases. Despite the smallest surface covered with adhesive determined in particles of class A, the greatest bending strength was determined when thinner particles were used. The greatest bending strength is the result of higher surface layer density and optimal cohesion–adhesion forces.

Higher density of layer means that there are less free spaces and that more bonding sites between particles that transmit forces to other particles are created. Due to higher density of surface layer when particles of class "A" are used (almost 0,850 g/cm^3) and higher compaction ratio it can be assumed that particles are optimally bonded together.

When particles of class "B" were used, approximately the same surface layer density was determined (between 0,75 in 0,78 g/cm^3). The results shows that with increasing size of used beech particles, the surface covered with adhesive increases, while bending strength decreases. It can be assumed that the bending strength decrease is the outcome of decreased cohesion strength of the bond. The surface covered with adhesive is in particles of class "E" approximately 80 %, which could lead to a lesser bond and therefore lower cohesion strength of the adhesive bond between particles. Due to approximately the same surface layer it can be assumed that bending strength is more correlated to the adhesive penetration and to the amount of adhesive on particle surface, i.e. to the cohesion–adhesion strength of bond between adhesive and particles.

Bending strength depends on the size of particles, compaction ratio, density and surface covered with adhesive. When particles of equal size are used and the depth of penetration is the same, the bending strength is more dependent on the surface layer density. As determined, the bending strength increases with the increasing surface layer density.

When the boards are of approximately the same surface layer density and the same particle size, the bending strength is more dependent on the surface covered with adhesive and adhesive/particle connection.

4 CONCLUSION
ZAKLJUČKI

It was determined that the bending strength of three layer particleboards, where beech particles of different sizes were used in surface layer only, depends on size of particles used, on surface layer compaction ratio, on density of surface layer as well as on surface covered with adhesive.

As determined by this research, the bending strength of three layer particleboard increases with increasing surface layer density and surface layer compaction ratio, and that bending strength decreases with increasing surface covered with adhesive.

The properties of three-layer particleboard, especially the bending strength, depend on the contact between particles and the connection between adhesive and particles.

5 POVZETEK

Namen predstavljenega prispevka je predstaviti, kako iverje bukve (Fagus sylvatica L.) različnih velikosti vpliva na upogibno trdnost trislojnih ivernih plošč. Velikost bukovega iverja smo spreminjali samo v zunanjem sloju, medtem ko je preostala zgradba iverja v srednjem sloju nespremenjena. Za izdelavo plošč smo uporabili urea–formaldehidno lepilo. Iverje smo izdelali iz sveže bukove hlodovine v laboratorijskih razmerah. Za izdelavo plošč smo uporabili iverje petih različnih velikosti. Debelina uporabljenih iveri je bila med 0,17 in 0,97 mm. Tako kot iveri so bile tudi plošče izdelane v laboratorijskih razmerah. Upogibno trdnost plošč smo ugotavljali v skladu s standardom SIST EN 310.

Ugotovili smo, da je upogibna trdnost plošč odvisna tako od velikosti uporabljenega iverja kot od faktorja zgostitve zunanjega sloja, prostorninske mase zunanjega sloja in stopnje oblepljenosti iverja.

Glede na rezultate lahko ugotovimo, da upogibna trdnost narašča z naraščanjem faktorja zgostitve in prostorninske mase zunanjega sloja, kar je predvsem posledica večanja kontakta med ivermi. Ugotovili smo tudi, da z naraščanjem stopnje obljepljenosti iverja upogibna trdnost trislojnih ivernih plošč pada, kar je predvsem posledica slabše povezanosti lepilo/iver.

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