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Glued laminated panels as kitchen countertops

Lijepljene lamelirane ploče kao radne ploče u kuhinji

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ABSTRACT • *The present study was conducted to investigate the possibility of using PVA-glued laminated panels in place of conventional kitchen countertops namely 32 mm thick MDF and 38 mm thick particleboard. Three types of glued laminated panels were manufactured by laminating two 16 mm thick MDFs, two 16 mm thick particleboards, and three 12 mm thick particleboards at a pressure of 3 MPa , a temperature of 25 ^{0}C and variable pressing times of 20, 30, and 40 minutes. Bending and shear strengths, water absorption, and thickness swelling of the laminates were measured and compared with a 32 mm thick MDF and 38 mm thick particleboard. The results indicated that the glued laminated panels remained more dimensionally stable compared to the conventional kitchen countertops. Particleboard laminates had improved bending and shear strengths compared to 38 mm thick particleboard. The results of this study demonstrated that PVA-glued laminated panels could be used as kitchen countertops.*

Key words: *32 mm thick MDF**,** 38 mm thick particleboard**,** glued laminated panel**,** kitchen countertop*

SAŽETAK • *Istraživanje prikazano u radu provedeno je s ciljem ispitivanja mogućnosti uporabe lamelirane ploče lijepljene PVA ljepilom umjesto konvencionalnih kuhinjskih radnih ploča, MDF ploča debljine 32 mm i iverica debljine 38 mm. Tri tipa lijepljenih lameliranih ploča proizvedena su od dvije MDF ploče debljine 16 mm, dvije ploče iverice debljine 16 mm i tri ploče iverice debljine 12 mm pri tlaku prešanja 3 MPa i temperaturi 25 ^{0}C, uz promjenjivo vrijeme prešanja od 20, 30 i 40 minuta. Mjerene su čvrstoća savijanja i čvrstoća smicanja, apsorbcija vode te debljinsko bubrenje lamelirane ploče i uspoređeno sa svojstvima MDF ploče debljine 32 mm i iverice debljine 38 mm. Rezultati su pokazali da su lijepljene lamelirane ploče dimenzionalno stabilnije od konvencionalnih kuhinjskih ploča. Lamelirana ploča od iverice imala je bolju čvrstoću savijanja i smicanja od ploče iverice od 38 mm. Rezultati istraživanja pokazuju mogućnost uporabe lameliranih ploča lijepljenih PVA ljepilom za kuhinjske radne ploče.*

Ključne riječi: *MDF ploča debljine 32 mm, ploča iverica debljine 32 mm, lijepljena lamelirana ploča, kuhinjska radna ploča*

1 INTRODUCTION
1. UVOD

In kitchen cabinet industry, 38 mm thick particleboard and 32 mm thick medium density fiberboard (MDF) are the primary raw materials for the fabrication of kitchen countertops, i.e. kitchen worktops. However, due to the lack of thick panels, PVA-glued laminated panels are widely used by some cabinet industries to manufacture kitchen countertops. Glued laminated panels used for kitchen worktops refer to two or more layers of thin particleboards or MDFs laminated together to obtain the nominal 38 mm or 32 mm thicknesses. The materials are processed in a manner similar to

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wood-based sandwich panels, structural composites (SCLs), and glued laminated timbers (glulams). Many authors have studied the characteristics of these structural panels (Kawasaki et al. 1999; Aydin et al. 2004) but very few studies have been conducted regarding glued laminated panel fabrication (McNatt et al. 1984).

Most of kitchen cabinet industries use cold-setting poly (vinyl acetate) resin to fabricate glued laminated countertops. However, it is well known that PVA glue has limited water resistance (Pizzi 1983) and is not generally recommended for joints subjected to high temperature or high humidity (Sellers et al. 1988). In addition, Uysal et al. (2005) reported that PVA adhesive was unsuitable for the fabrication of laminated veneer lumber (LVL) used in wet conditions. They also reported that shear strength of the PVA-bonded LVL panels was less than that of UF or PF-bonded LVL panels.

Countertops are the most important parts of the kitchen cabinet requiring desired dimensional stability as well as adequate strength. Although the glued laminated countertops are laminated with a moisture resistance overlay, such as high pressure laminate (HPL), they may suffer lack of resistance to water due to PVA application. Therefore, this study was undertaken to evaluate the possibility of using PVA-glued laminated panels for kitchen countertops.

2 MATERIALS AND METHODS
2. MATERIJAL I METODE

2.1 Materials
2.1. Materijali

12 and 16 mm thick particleboards, and 16 mm thick MDF with mean densities of 0.61, 0.76, and 0.65 g cm^{-3} were selected to fabricate PVA-glued laminated panels. 38 mm thick particleboards and 32 mm thick MDFs with mean densities of 0.61 and 0.71 g cm^{-3} were used as control panels for comparison. Physical and mechanical properties of control panels are given in Table 1. The panels were provided from Oraman Wood Industrial Co.

PVA adhesive with a pH value of 4.52, solid content of 28% and viscosity of 0.42 cp provided from Shomal Adhesive Co. was used in the construction of laminated panels.

2.2 Glued laminated panel fabrication
2.2. Proizvodnja lamelirane ploče

For producing glued laminated panels, PVA was applied by uniformly brushing approximately 240 g m^{-2} on each laminate. Then, two 16 mm thick particleboards, two 16 mm thick medium density fiberboards, and three 12 mm thick particleboards were assembled together. The dimensions of the laminated panels were 500 × 500 mm. For gluing with cold-setting adhesives, such as PVA, extended assembly time may be required to ensure adequate adhesive wetting before pressure is applied (Sellers et al. 1985). Therefore, the pressure was applied approximately 10 minutes after adhesive application. The laminas were cold-pressed at 25 ^{0}C and 3 MPa for 20, 30, and 40 minutes. The glued laminated panels were subsequently conditioned at 65 % relative humidity and 20 ^{0}C for about 2 weeks.

2.3 Physical and mechanical testing
2.3. Ispitivanje fizikalnih i mehaničkih svojstava

Test specimens were cut from each laminated panel according to DIN 68763 specification. The dimensions of the specimens to test bending strength, shear strength, and thickness swelling and water absorption after 24h immersion were 250 × 50, 50 × 50, 20 × 20 and 20 × 20 mm, respectively. The bending and shear strengths, thickness swelling and water absorption of the laminates were measured according to DIN 52362, ASTM D 1037, and DIN 52364 specifications, respectively.

Data were analyzed using analysis of variance. Standard deviations were also computed from the data and are shown as error bars in each corresponding figure.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Bending strength
3.1. Čvrstoća savijanja

The results indicate that bending strength of all particleboard laminates, except 12 mm thick particleboard laminate, increases with increasing of the press time from 20 min to 30 min, and then remains approximately constant (Fig. 1). The MDF laminates have higher bending strength than particleboard laminates due to greater bond line strength caused by lower penetration of PVA glue into the MDF structure. However, the bending strength of 12 mm thick particleboard laminate fabricated at 30 min was abnormally high. This abnormal behavior can be explained by the fact that PVA glue cures completely within 30 min but excessive press time destroys the laminate structure, resulting in lower bending strength. Another explanation for this behavior is considered to be overpenetration of adhesive into laminate structure during increased press time. It appeared that bending strength of the MDF laminate increased with increase in the press time. All laminated panels, except laminated 12 mm thick particleboard fabricated at 20 minutes, had higher bending strengths than the 38 mm thick particleboard. Bending strength of the 32 mm thick MDF was higher than that of the glued laminated MDF (Table 1 and Fig. 1).

3.2 Shear strength
3.2. Čvrstoća na smik

It can be seen from Fig. 2 that glued laminated MDF had higher shear strength than glued laminated particleboard. The results also showed that shear strength of the laminated 16 mm thick particleboard was higher than that of laminated 12 mm thick particleboard. As it can be observed from Table 1 and Fig. 2, the particleboard laminates have higher mean values of shear strength compared to the 38 mm thick particleboard. In addition, shear strength of the MDF laminate was hi-

Table 1 Physical and mechanical properties of control panels
Tablica 1. Fizikalna i mehanička svojstva kontrolnih ploča

Panel type *Vrsta ploče*	**Bending strength** *Čvrstoća savijanja* MPa	**Shear strength** *Čvrstoća na smik* MPa	**Water absorption** *Apsorpcija vode* %	**Thickness swelling** *Debljinsko bubrenje* %
38 mm thick particleboard *iverica debljine 38 mm*	9.72 (0.47)	1.2 (0.08)	105.17 (3.44)	25.93 (0.61)
32 mm thick MDF *MDF debljine 32 mm*	38.08 (0.72)	2.88 (0.28)	65.85 (8.2)	24.6 (0.67)

*Values in parentheses are standard deviations. *(Vrijednosti u zagradi standardne su devijacije.)*

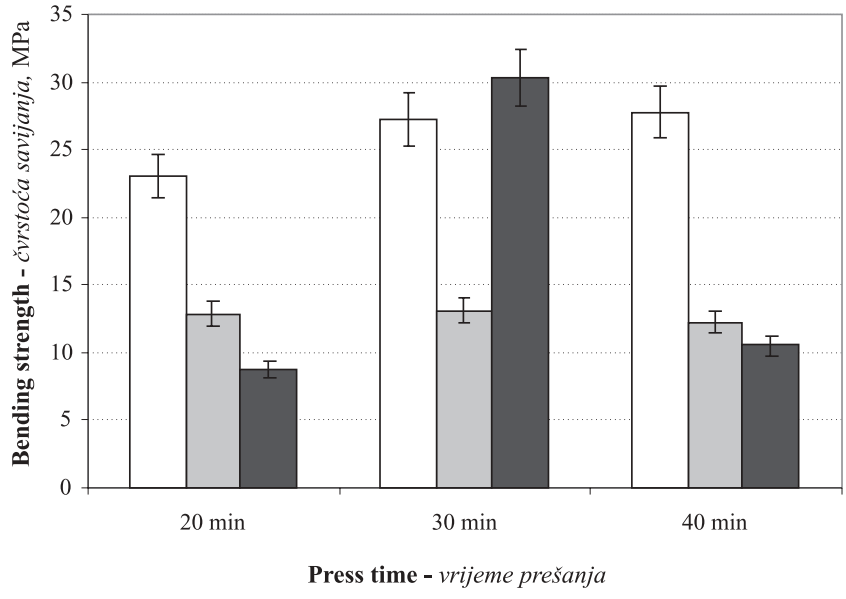

Figure 1 Bending strength of glued laminated panels, ■ – laminated 12 mm thick particleboard, ■ – laminated 16 mm thick particleboard, □ – laminated 16 mm thick MDF
Slika 1. Čvrstoća savijanja lijepljenih lameliranih ploča, ■ – lamelirana ploča od iverice debljine 12 mm, ■ – lamelirana ploča od iverice debljine 16 mm, □ – lamelirana ploča od MDF ploča debljine 16 mm

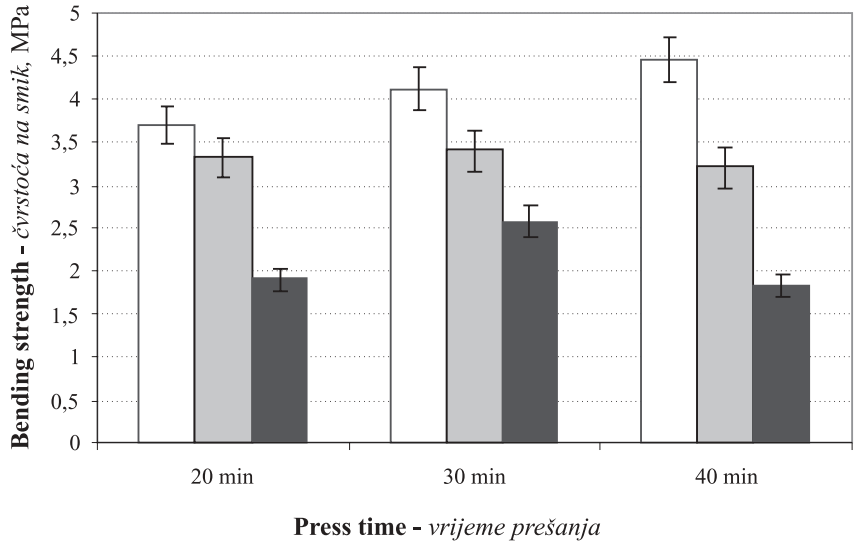

Figure 2 Shear strength of glued laminated panels, ■ – laminated 12 mm thick particleboard, ■ laminated 16 mm thick particleboard, □ – laminated 16 mm thick MDF
Slika 2. Čvrstoća na smik lijepljenih lameliranih ploča, ■ – lamelirana ploča od iverice debljine 12 mm, ■ – lamelirana ploča od iverice debljine 16 mm, □ – lamelirana ploča od MDF ploča debljine 16 mm

gher than that of the control panel 32 mm thick MDF. A positive relationship between press time and shear strength of the MDF laminate was observed, whereas shear strength of the 12 mm thick particleboard laminate increased at first and then decreased as the press time increased.

3.3 Water absorption
3.3. Apsorpcija vode

As shown in Fig 3, the glued laminated MDF is higher water resistant than the glued laminated particleboard. The MDF laminate showed a different behavior in comparison with the particleboard laminate. In contrast to the particleboard laminate, a positive relationship between press time and water resistance of the MDF laminate was observed. This may be attributed to complete curing of PVA adhesive due to the increased press time. The negative relationship between press time and water resistance of particleboard laminates may be due to collapse in the laminate structure. Despite low water resistance of the PVA adhesive, water absorption content of the glued laminated panels was lower compared to control panels, 32 mm thick MDF and 38 mm thick particleboard (see Table 1 and Fig. 3). This behavior shows that water absorption is seldom caused directly by the adhesive used for gluing laminates, but rather directly by the rigidity of the adhesive connection (River et al. 1991).

3.4 Thickness swelling
3.4. Debljinsko bubrenje

Figure 4 illustrates the effect of press time on thickness swelling of glued laminated panels. The results showed that the MDF laminate was more dimensionally stable than the particleboard laminate. Similar to water absorption, dimensional stability of the MDF laminate improved as press time increased. Dimensional stability of particleboard laminates was adversely correlated to press time. Adverse influence of press time on dimensional stability of particleboard laminates is explained by structural failure in the particleboard.

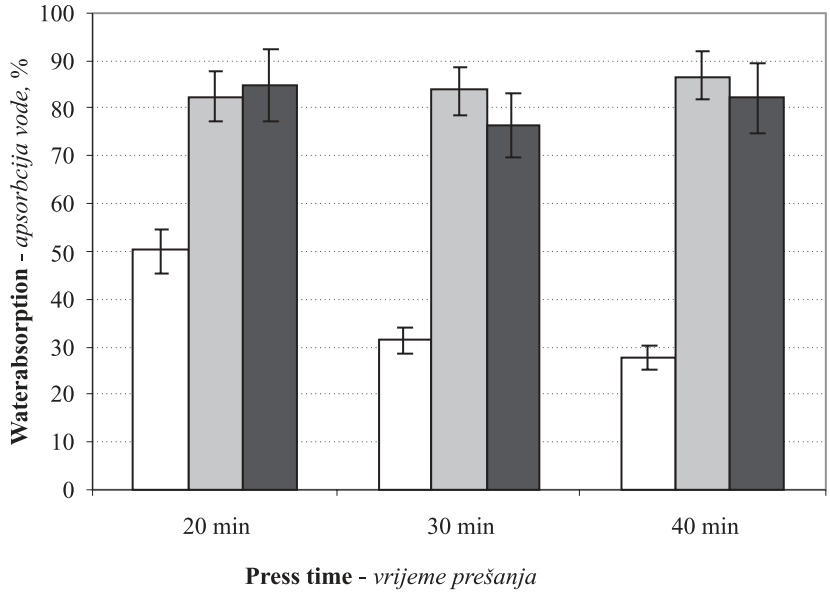

Figure 3 Water absorption of glued laminated panels, ■ – laminated 12 mm thick particleboard, ■ – laminated 16 mm thick particleboard , □ – laminated 16 mm thick MDF
Slika 3. Apsorpcija vode lijepljenih lameliranih ploča, ■ – lamelirana ploča od iverice debljine 12 mm, ■ – lamelirana ploča od iverice debljine 16 mm, □ – lamelirana ploča od MDF ploča debljine 16 mm

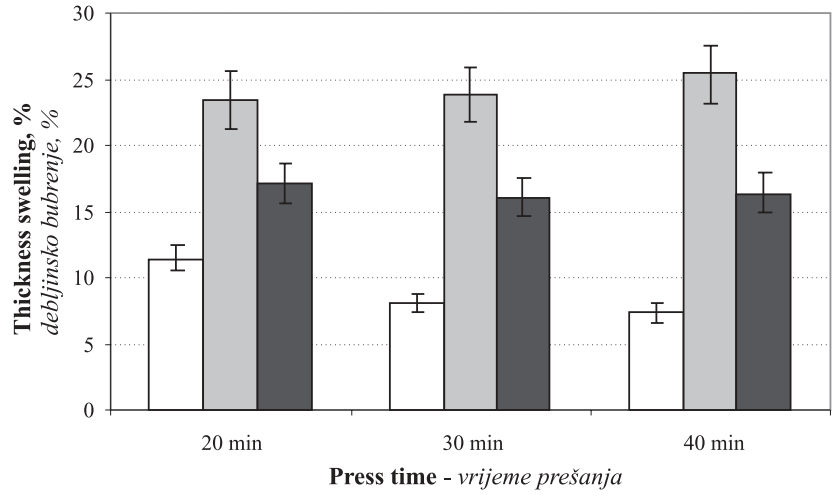

Figure 4 Thickness swelling of glued laminated panels, ■ – laminated 12 mm thick particleboard, ■ – laminated 16 mm thick particleboard, □ – laminated 16 mm thick MDF
Slika 4. Debljinsko bubrenje lijepljenih lameliranih ploča, ■ – lamelirana ploča od iverice debljine 12 mm, ■ – lamelirana ploča od iverice debljine 16 mm, □ – lamelirana ploča od MDF ploča debljine 16 mm

Particleboard laminates remained more stable than 38 mm thick particleboard. In the 38 mm particleboard, higher porous structure in the core layer in comparison with the glued laminated panels allows easy penetration and uptake of water, resulting in high water absorption as well as thickness swelling. In addition, the MDF laminates showed lower thickness swelling compared to the 32 mm thick MDF.

4 CONCLUSIONS
4. ZAKLJUČCI

The results of this study revealed that the MDF laminates had higher values of bending and shear strengths in comparison with particleboard laminates. This behavior is explained by less absorption of PVA glue with MDF, resulting in higher glueline strength of the laminates. All mean thickness swelling and water absorption values for the MDF laminates were lower than those of particleboard laminates. The reason for this behavior is attributed to better water resistance performance of medium density fiberboard in comparison with particleboard. This is also thought to occur because of higher strength of adhesive connection in the MDF laminates.

The 12 mm thick particleboard laminate showed lower strength but better water resistance than the 16 mm thick particleboard laminate; however, the 12 mm thick particleboard laminate fabricated at press time of 30 min had abnormally high bending strength. The reason for this abnormal behavior is relatively unclear. However, this is assumed to be due to complete curing of PVA glue at press time of 30 min, resulting in higher joining strength in the fabricated laminate. In addition, excessive press time, namely 40 min is expected to destroy the laminate structure. The overpenetration of glue into the laminate structure during press time of 40 min caused by low surface quality of the used laminates is another explanation for decreasing of the laminate strength at that press time.

From comparison between properties of the laminated panels fabricated at different press times, it can be seen that all properties of the MDF laminates improve as the press time increases, whereas those of laminated particleboard panels remain almost constant or slightly decrease with the increase of press time. However, the highest strength value of 12 mm laminated particleboard panel is attained when the press time of 30 min is applied.

Lower performance of particleboard laminates at press time of 40 min is attributed to the overpentration of glue into the particleboard laminate structure caused by low surface quality of particleboard panels.

On the basis of the data obtained in this study, almost all types of particleboard laminates can be substituted for 38 mm particleboard as kitchen countertops. All properties of the MDF laminate, except bending strength, were found to be higher than those of the 32 mm thick MDF. Thus, the MDF laminates fabricated in this study can be used as kitchen worktops instead of 32 mm MDF.

Aside from press time, the performance of glued laminated panels is also affected by several other factors, such as pressure and press temperature. Therefore, further studies for selecting proper press conditions to improve performance of the laminates are recommended.

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