

THE DYNAMICS OF THICKNESS SWELLING AND BOND STRENGTH LOSS OF DIFFERENT WOOD-BASED PANELS AT EXPOSURE TO HUMID CLIMATE AND IMMERSION INTO WATER

DINAMIKA SPREMINJANJA DEBELINSKEGA NABREKA IN KAKOVOSTI ZLEPLJENOSTI RAZLIČNIH LESNIH PLOŠČNIH KOMPOZITOV PRI VLAŽNI KLIMI IN POTOPITVI V VODO

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Abstract / Izvleček

Abstract: An important aspect of wood-based panel usability, especially for construction, load bearing purposes or when in use for longer time, is its resistance against water. The resistance against water is related to type of wood-based panel, morphological characteristics of the constituents that panel is made of, and from the resin that was used for bonding. In an experiment we used four different wood-based panels, namely MDF (urea-formaldehyde adhesive), particleboard (urea-formaldehyde adhesive), OSB (melamine-urea-formaldehyde adhesive) and beech plywood (melamine-urea-formaldehyde adhesive). All panels were immersed into water and exposed to a humid climate for 90 days. Thickness swelling, compression shear strength and shear strength were determined after 1, 5, 30 and 90 days. The results showed that the highest strength decrease was observed at immersion into water. The lowest compression shear strength after immersion into water and exposure to a humid climate was determined for MDF. The occurrence of constituent failure due to exposure to water was demonstrated through SEM analysis.

Keywords: plywood, OSB, particleboard, MDF, compression shear strength, shear strength, water, humid condition

Izvleček: Pomemben dejavnik uporabnosti lesnih ploščnih kompozitov pri gradnji in nosilnih konstrukcijah je odpornost le-teh proti delovanju vode. Odpornost proti delovanju vode je odvisna od vrste lesnega ploščnega kompozita, morfoloških lastnosti gradnika, iz katerega je plošča narejena, in lepila, uporabljenega za lepljenje. Za izvedbo raziskave smo uporabili štiri različne lesne ploščne kompozite in sicer MDF (urea-formaldehidno lepilo), iverno ploščo (urea-formaldehidno lepilo), OSB (melamin-urea-formaldehidno lepilo) in bukovo furnirno ploščo (melamin-urea-formaldehidno lepilo). Vse plošče so bile potopljene v vodo in izpostavljene vlažnim klimatskim pogojem. Določili smo debelinski nabrek, tlačni strig in strižno trdnost. Lastnosti so bile določene 1, 5, 30 in 90 dni po izpostavitvi. Največja sprememba trdnosti je bila ugotovljena pri preskušancih, potopljenih v vodo. Najnižja odpornost proti delovanju vode je bila ugotovljena pri MDF plošči. S SEM slikovno analizo smo prikazali nastanek razpok in porušitve zgradbe gradnikov.

Ključne besede: furnirna plošča, OSB, iverna plošča, MDF, tlačni strig, strižna trdnost, voda, vlažna klima

1 INTRODUCTION

1 UVOD

Adhesive plays an important role in wood-based composites. It is responsible for "keeping" the constituents in their position, offering protection against external factors (like water) and helping in transferring the load from one to another constituent. Due

to different constituent morphology and share of adhesive as well as differences in production processes, various between wood-based composites occur, and with these also their usability. When considering the usage of wood-based composites in construction and/or for external application, the quality of the bond and moisture resistance of panels is of vital importance. Looking to Eurocode 5 (EN 1995-1-1: 2004), the usability of a material depends on its load bearing capacity (strength and stiffness) and moisture resistance (service class). When water or moisture penetrates wood-based composites it results in

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expansion/swelling and displacement of the constituents. When the stresses that occur at water/moisture uptake are high enough to break the bonds between constituents, then this can lower the strength and in the worst case to the failure of the composite. The impact of irreversible thickness swelling on strength loss was determined by Suchsland (1973). Total thickness swelling of wood-based composites can be divided into two components, namely reversible swelling caused by wood, and irreversible swelling that is caused by the production process (Halligan, 1970). Dinwoodie (1978) exposed particleboard (PB) bonded with different adhesives to a high moisture climate and determined the decrease in internal bond strength, which was higher for urea-formaldehyde adhesive, compared to phenol-formaldehyde. A similar study was carried out by DeXin & Östman (1983) for tensile strength, and by Gillespie & River (1976) for plywood shear strength. The negative impact of moisture on the modulus of rupture (bending strength) and modulus of elasticity at OSB was determined by Wu & Suchsland (1997). As concluded by Fenghu & Fangtian (1997) the decrease in strength at exposure to a humid climate could be related to hydrolysis of the adhesive, and development of swelling stresses in the bond line. The degradation and failure of the adhesive bond was the main reason for the increase in creep at PB and MDF, as determined by Zhou et al. (2001). The occurrence of swelling stresses was also determined by Tarkov & Turner (1958), Niemz & Steinmetzler (1992), Medved et al. (2011). Wu & Piao (1999) researched the internal bond strength loss at OSB when exposed to different climate conditions and immersed into water. They determined that the increase in reversible swelling is linear, while the irreversible swelling at a moisture content of around 12% and above was more rapid. They also found that after exposure to high humidity and water the internal bond decreases, mainly due to an increase in irreversible swelling, with similar results reported by Mirski et al. (2012). The degradation of bending strength of different wood-based panels immersed in water was also examined by Norita et al. (2008), while the decrease in shear modulus with increasing relative humidity for UF bonded particleboard was determined by Kociszewski (2014).

The quality of the bond between constituents is an important property of wood-based composites, hence we investigated the decrease in compres-

sion shear strength and shear strength of different wood-based composites due to the immersion in water and exposure to a humid climate.

2 MATERIALS AND METHODS

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For the purpose of the investigation several commercially available wood-based composites were used (Table 1).

Table 1. Panel characteristics overview

Preglednica 1. Pregled lastnosti plošč

Panel type / Vrsta plošče	Label / Oznaka	Adhesive / Lepilo	Thickness / Debelina	Density / Gostota
Particleboard	PB-P2	UF	18 mm	700 kg·m ⁻³
OSB	OSB3	MUF	18 mm	600 kg·m ⁻³
MDF	MDF	UF	18 mm	730 kg·m ⁻³
Beech plywood	PW-B	MUF	18 mm	700 kg·m ⁻³

Panels 1500×800 mm² were cut to sample size 50×50 mm² (PB-P2, MDF, OSB3: internal bond and compression shear strength) and 150×25 mm² (PW-B: shear strength). After cutting, samples were exposed to normal climate conditions (temperature 20±1°C and relative air humidity 65±5%). After climatization some of the samples were tested for their strength properties while some them were exposed to humid climate conditions (temperature 20±1°C and relative air humidity 85±5%) or immersed in water. They were exposed to such conditions for 1, 5, 30 and 90 days. After this, the samples were tested for:

- Thickness swelling (TS) and water uptake (WU) according to EN 317; TS and WU were determined after immersion in water and after exposure to humid conditions. TS was determined using equation 1 and WU by equation 2.

$$TS_i = \frac{t_i - t_n}{t_n} \times 100 \quad (1)$$

$$WU_i = \frac{m_i - m_n}{m_n} \times 100 \quad (2)$$

where:

TS is the thickness swelling in %

WU is the water uptake in %

t_n is the thickness of samples before immersion/exposure (after climatization at normal conditions) in mm

t_i is the thickness of samples after immersion/exposure in mm

m_n is the mass of samples before immersion/exposure (after climatization at normal conditions) in g

m_i is the mass of samples after immersion/exposure in g

i is the time of immersion/exposure (1, 5, 30 and 90 days)

- Compression-shear strength (CS) according to DIN 52367 and NT Build 313; samples were placed in the compression-shear load equipment in such a manner that the equipment loading plane and sample symmetry plane coincide (figure 1). Compression-shear strength was determined for OSB3, PB-P2 and MDF, according to equation 3.

$$CS = \frac{F_{max}}{a \cdot b} \quad (3)$$

where:

CS is the compression-shear strength in $N \cdot mm^{-2}$

F_{max} is the maximum force in N

a is the length of samples in mm

b is the width of samples in mm

- Shear strength according to EN 314. Shear strength was determined for PW-B and was determined in the middle of the sample only. Shear strength was calculated by equation 4.

$$f_v = \frac{F}{a \cdot b} \quad (4)$$

where:

f_v is the shear strength in $N \cdot mm^{-2}$

F is the failing force in N

a is the length of shear area in mm

b is the width of shear area in mm

The usual method of bond quality determination for wood fibre- and wood particle-based composites is examining the internal bond (also known as tensile strength perpendicular to the plane), which gives information on the strength of the weakest layer in the panel. Although internal bond (IB) is the most important mechanical property there is a drawback to its

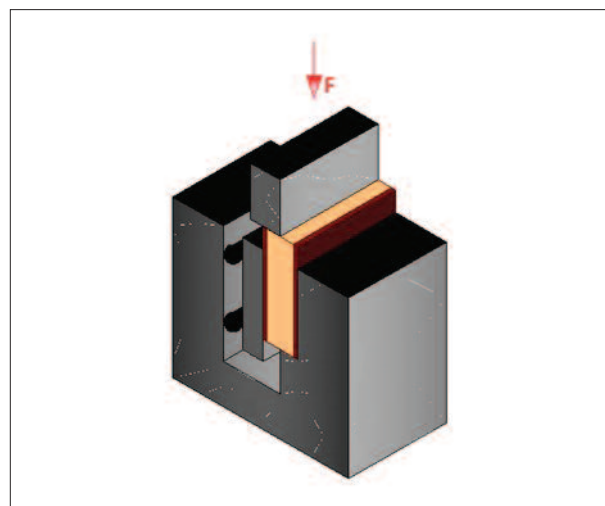


Figure 1. Schematic layout of compression shear strength determination

Slika 1. Shematski prikaz določanja tlačnega striga

examination, which is the preparation procedure. According to EN 319 the sample needs to be glued on two loading blocks with appropriate glue, and then 24 hours need to pass before testing in order for the adhesive to cure. An alternative method is thus preferred in order to evaluate the impact of immersion in water or exposure to a humid climate, one that does not require gluing of loading blocks to the surface. The test that was chosen, the compression shear strength test, is simple and can be applied immediately after exposure, with no need for sample preparation. Several authors (McNatt, 1973; Suzuki & Miyagawa, 2003; Wang et al., 1999) have determined the correlation between CS and IB, and found that with increasing IB the CS also increases. The main advantage of determination of IB is that the sample itself reveals the weak layer, because failure occurs in the weakest layer in the sample, while at CS test the breakage area is predefined (usually in the middle of the sample).

The tensile strength perpendicular to the plane (IB) according to EN 319 was thus determined in samples exposed to normal conditions.

3 RESULTS AND DISCUSSION

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The basic characteristics of the panels used, like thickness, density, IB (for PB-P2, OSB3 and MDF) and shear strength (for PW-B) are presented in table 2.

Table 2. Basic characteristic of tested panels (values in brackets represents the standard deviation)
Preglednica 2. Lastnosti preskušanih plošč (vrednosti v oklepajih predstavljajo vrednosti standardnega odklona)

Panel / Plošča	Thickness / Debelina	Density / Gostota	Internal bond strength / Razslojna trdnost	Compression-shear strength / Tlačni strig	Shear strength / Strižna trdnost
PB-P2	17.77 mm (0.038)	689 kg·m ⁻³ (15.123)	0.38 N·mm ⁻² (0.022)	1.36 N·mm ⁻² (0.063)	/
OSB3	17.45 mm (0.078)	584 kg·m ⁻³ (31.943)	0.37 N·mm ⁻² (0.047)	1.07 N·mm ⁻² (0.236)	/
MDF	17.86 mm (0.064)	722 kg·m ⁻³ (5.152)	0.39 N·mm ⁻² (0.062)	1.01 N·mm ⁻² (0.073)	/
PW-B	17.59 mm (0.045)	693 kg·m ⁻³ (8.838)	/		4.39 N·mm ⁻² (0.553)

As shown in table 2, the IB of PB-P2, OSB3 and MDF are similar, while the differences in CS are significant. Although strands are oriented only in the surface layer (OSB3) the impact of orientation is evident in the higher coefficient of variation (22.06%). The difference between the highest (parallel to strand orientation) and lowest value (perpendicular to strand orientation) is around 40%. The consti-

tuent orientation-based differences are less pronounced for PB-P2 and MDF (the coefficient of variation is 4.63% and 7.23%, respectively).

Immersion in water or exposure to a humid climate causes an increase in thickness (thickness swelling) (figure 2 and figure 3) and decrease of bond quality between constituents (figure 4, figure 5, figure 6 and figure 7).

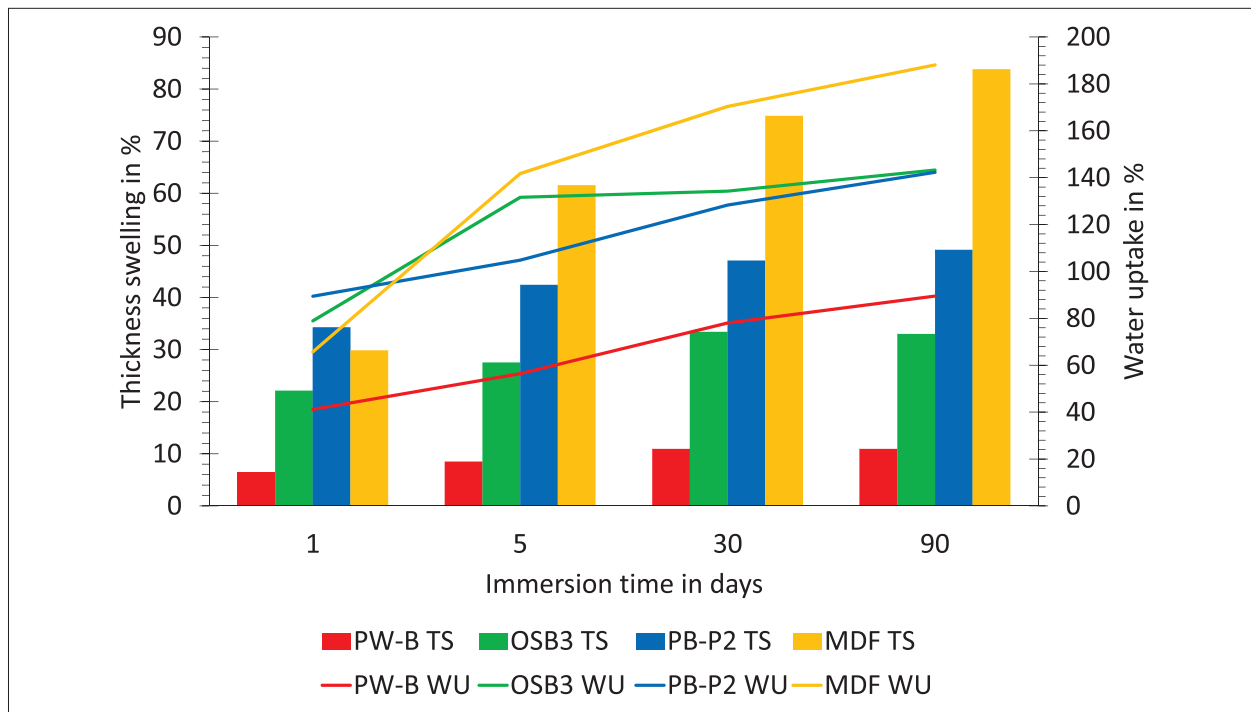


Figure 2. Thickness swelling (box) and water uptake (line) for immersion in water of beech plywood (PW-B), OSB (OSB3), particleboard (PB-P2) and MDF

Slika 2. Debelinski nabrek (stolpec) in vpijanje vode (črta) pri potopitvi v vodo bukove furnirne plošče (PW-B), OSB (OSB3), iverne plošče (PB-P2) in MDF

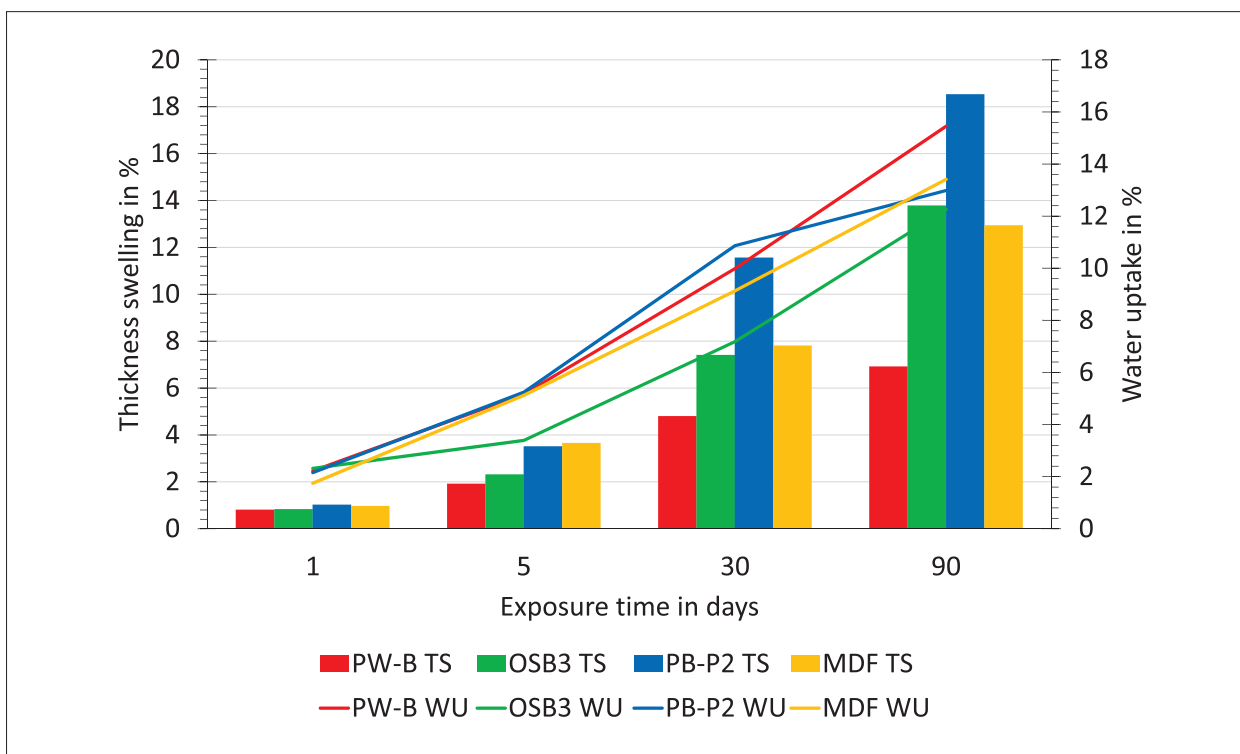


Figure 3. Thickness swelling (box) and water uptake (line) for exposure to a humid climate for beech plywood (PW-B), OSB (OSB3), particleboard (PB-P2) and MDF

Slika 3. Debelinski nabrek (stolpec) in vpijanje vode (črta) pri izpostavitvi vlažni klimi bukove furnirne plošče (PW-B), OSB (OSB3), iverne plošče (PB-P2) in MDF

A comparison of the thickness swelling and water uptake results shows differences between the panels and between the testing procedure. Looking only at the results for 1-day immersion (figure 2), the highest TS and WU can be determined for PB-P2 ($TS_1=34.28\%$; $WU_1=89.42\%$), but prolongation of immersion time reveals the highest TS and WU for MDF. The thickness swelling of MDF is 70% higher than that of PB-P2, and this could be related to the densification of constituents, panel density (especially the density profile) and production conditions. During pressing the wood constituents are pressed together (and thus the distance between wood constituents decreases, which also enables the creation of an adhesive bond between constituents) and compressed (with the creation of internal stresses). When panels are exposed to water the constituents start absorbing water and undergo the cell shape recovery procedure (Scharfetter, 1980). The more the constituents are pressed together and compressed (densified), the more resistance they have against water uptake. But when water breaks through the swelling intensity is

high, due more intense adhesive bond removal and the breakage of bonds between constituents.

Although higher densification results in more unreleased internal stresses and higher TS after immersion in water, it is more effective at resisting exposure to a humid climate. The TS of panels when exposed to a humid climate is significantly lower compared to TS after immersion in water. Water in its liquid state more easily penetrates cell lumens and the gaps between constituents compared to gaseous water molecules, which are attracted to wood through the exposed wood surface. The reason for the greater swelling of panels when immersed in water could also be related to the change in water pH value. As was determined by Medved et al. (2019), after 24-hour immersion the water pH value changes from normal to acid, which could affect the adhesive bond between constituents.

At exposure to humid conditions the thickness swelling of PB-P2 was significantly higher, and this could be related to lower compression of the core layer constituents.

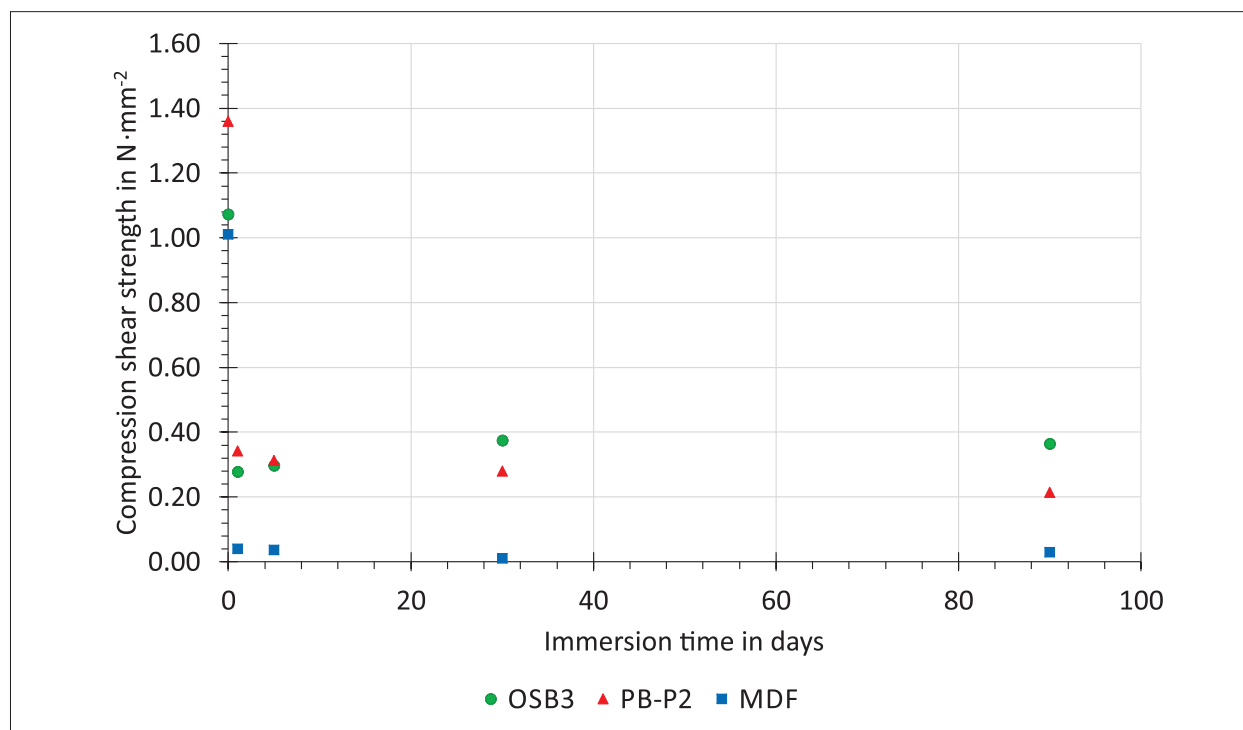


Figure 4. Compression shear strength of OSB (OSB3), particleboard (PB-P2) and MDF after immersion in water

Slika 4. Tlačni strig OSB (OSB3), iverne plošče (PB-P2) in MDF pri potopitvi v vodo

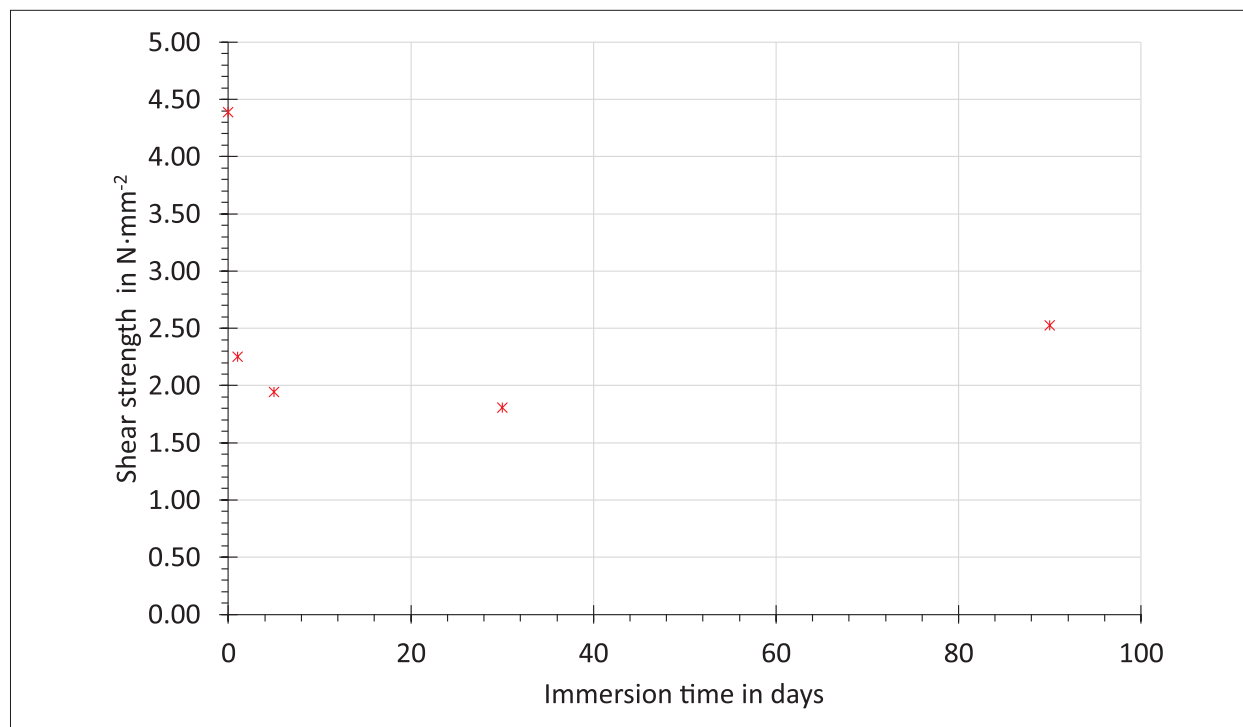


Figure 5. Shear strength of plywood after immersion in water

Slika 5. Strižna trdnost furnirne plošče pri potopitvi v vodo

The decrease in strength (CS and f_v) of panels immersed in water was higher compared to that seen with panels exposed to a humid climate, as shown in figure 4, figure 5, figure 6 and figure 7.

For all the selected panels immersion in water resulted in a significant decrease in strength after only one day immersion. The loss in strength for plywood after 24-hour immersion was 49%, while for OSB and PB it was 74% and 75%, respectively, and the highest loss was for MDF (96%). Prolongation of immersion time had no significant impact on CS and f_v . The results of one-way ANOVA with Tukey post-hoc tests showed no significant difference (at $\alpha=0,05$) between CS in relation to water immersion time (for PW-B, OSB and MDF). With regard to PB-P2, statistically significant differences were found between CS after 1- and 5-day immersion and CS after 30- and 90-day immersion.

The results for CS and f_v support those for lower TS after exposure to a humid climate. After the first day of exposure to a humid climate, the recorded loss in strength for PW-B, OSB and PB was below 3.5%, while for MDF, the average value, was similar to the reference panel (figure 6 and figure 7).

The decrease in strength after 90 days of exposure to a humid condition was between 38% (at PB-P2 and PW-B) and 56% (at MDF). Statistical analysis of the strength results for MDF shows significant differences ($\alpha=0,05$) at exposures longer than five days, for PB-P2 at exposures longer than 30 days, and for PW-B at 90 days exposure. For OSB, the differences in strength related to exposure time were not significant ($\alpha=0,05$).

The loss in strength of panels immersed in water is also related to the change in moisture, which is significantly higher compared to that seen in panels exposed to a humid climate. The results (figure 2 and figure 3) show that WU for panels exposed to a humid climate for 90 days is significantly lower than WU for panels immersed in water for just one day. Since less water penetrated (at exposure to a humid climate) into and between the constituents, less constituent shape recovery occurred and there was less adhesive bond failure, and thus a smaller loss of strength.

The rate of the decrease in strength (strength difference divided by time) for MDF when exposed to a humid climate was (on average) $0.321 \text{ N}\cdot\text{mm}^{-2}$

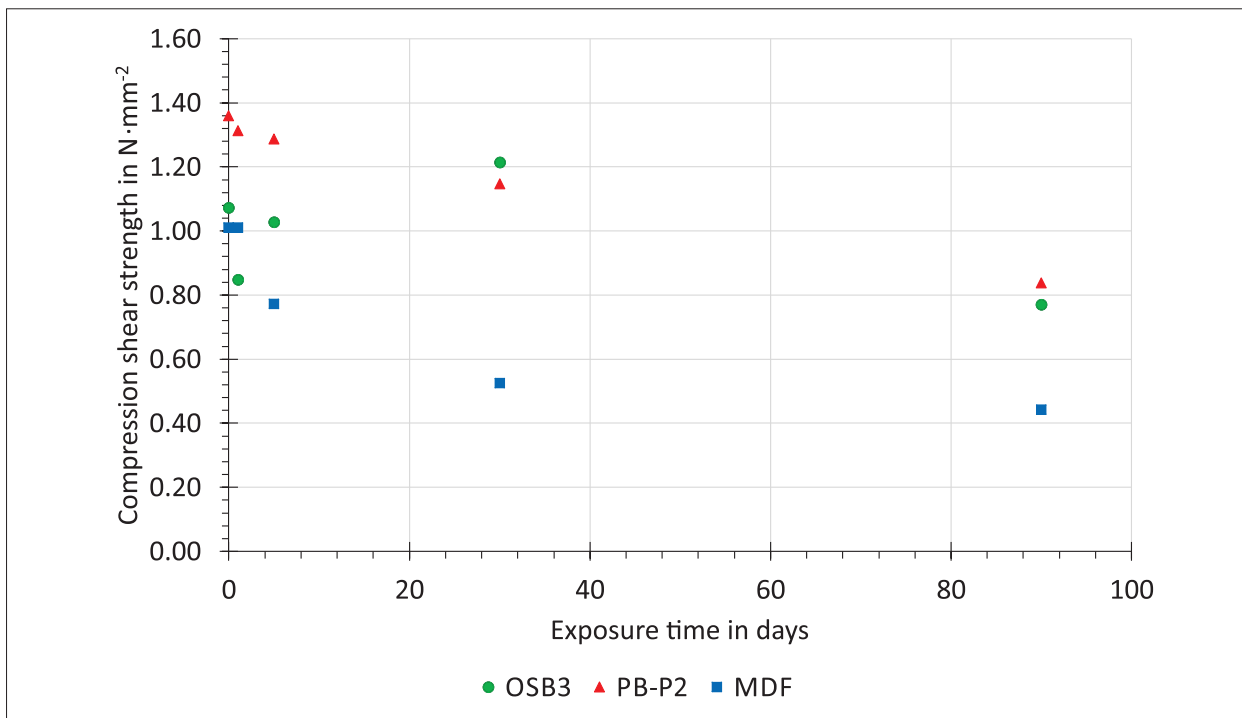


Figure 6. Compression shear strength of OSB (OSB3), particleboard (PB-P2) and MDF after exposure to a humid climate

Slika 6. Tlačni strig OSB (OSB3), iverne plošče (PB-P2) in MDF pri izpostavitvi vlažnim klimatskim pogojem

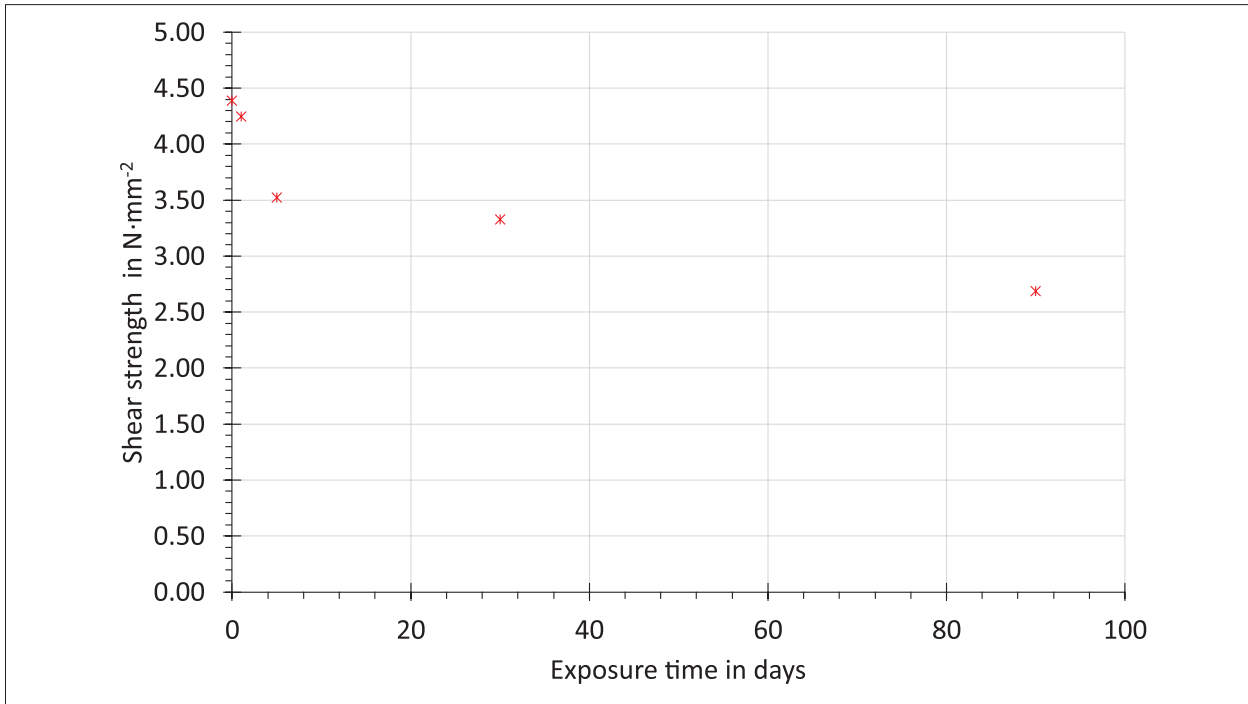


Figure 7. Shear strength of plywood after exposure to a humid climate

Slika 7. Strižna trdnost furnirne plošče pri izpostavitvi vlažnim klimatskim pogojem

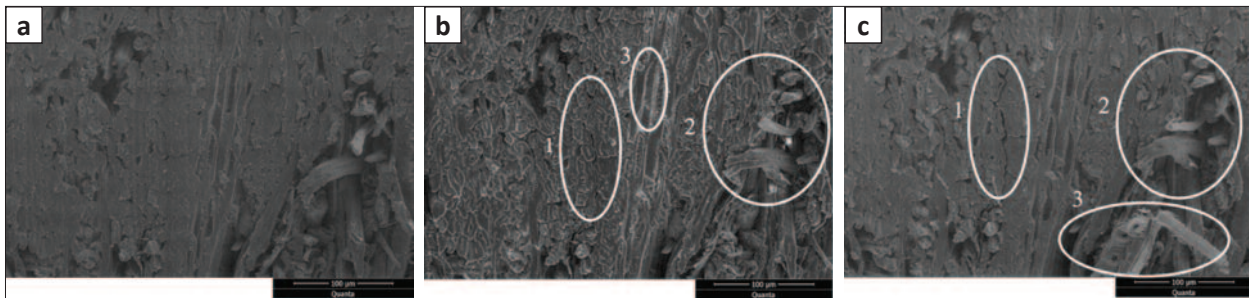


Figure 8. SEM images of MDF before (a) and after exposure to a humid climate ((b) – 1 day and (c) – 30 days)

Slika 8. SEM slike MDF pred (a) in po izpostavitvi vlažnim klimatskim pogojem ((b) – 1 dan in (c) – 30 dni)

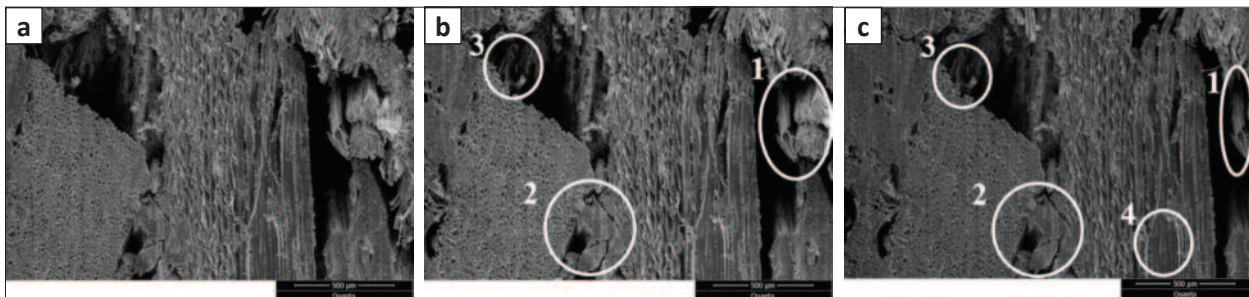


Figure 9. SEM images of particleboard before (a) and after exposure to a humid climate ((b) – 1 day and (c) – 30 days)

Slika 9. SEM slike iverne plošče pred (a) in po izpostavitvi vlažnim klimatskim pogojem ((b) – 1 dan in (c) – 30 dni)

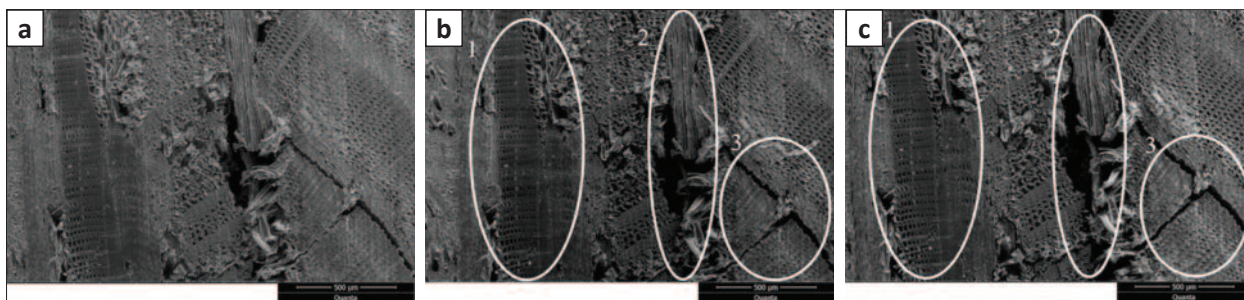


Figure 10. SEM images of OSB before (a) and after exposure to a humid climate ((b) – 1 day and (c) – 30 days)
Slika 10. SEM slike OSB pred (a) in po izpostavitvi vlažnim klimatskim pogojem ((b) – 1 dan in (c) – 30 dni)

per day of exposure, while for particleboard the rate was $0.245 \text{ N} \cdot \text{mm}^{-2}$ per day of exposure.

As noted earlier, the reason for the loss in strength at exposure to water (liquid or gas) is the occurrence of micro and macro cracks/failure in and between constituents, as well as in the adhesive bond between constituents, as shown in figure 8, figure 9 and figure 10.

The marked areas are reference areas where failure (micro and macro cracks) and distance between constituents occurred as a result of exposure to humid conditions. The occurrence of failure is a result of the shape recovery procedure (i.e., the regaining of shape prior to pressing) and relaxation of internal stresses.

Differences in the TS, WU, compression shear strength and shear strength of selected panels are, with regard to the constituent morphology, production process conditions and panel density, dependant on the type of adhesive used. For PB-P2 and MDF the UF adhesive was used, hence there was greater TS and more strength loss compared to OSB3 and PW-B, where MUF adhesive was used. MUF adhesive has, according to Ormondroyd (2015), higher resistance against water than UF adhesive.

4 CONCLUSIONS

4 ZAKLJUČKI

In the experiment presented in this paper different wood-based panels were immersed in water and exposed to a humid condition for 90 days. According to the obtained results, the following conclusions can be made:

- The highest decrease in strength with immersion in water was determined for MDF, and the lowest for PW-B.

- The highest decrease in strength with 1-day exposure to humid conditions was determined for PB-PB, and after 90 days for MDF.
- The decrease in strength corresponds to the increase in thickness swelling and water uptake.
- The decrease in strength of the studied wood-based panels was more evident when immersed in water compared to when exposed to a humid climate.

5 SUMMARY

5 POVZETEK

Lepilo ima pomembno vlogo pri zagotavljanju ustreznih lastnosti lesnih ploščnih kompozitov. Njegovo vlogo lahko razdelimo v tri razrede in sicer mora obdržati gradnike v njihovi poziciji v kompozitu, zaščititi mora gradnike pred zunanjimi dejavniki, npr. vodo ter omogočiti prenašanje obremenitev iz gradnika na gradnik. Uporabnost lesnih ploščnih kompozitov, še posebej v primeru konstrukcijske rabe, rabe v zunanjih pogojih ali pogojih povišane vlažnosti je odvisna od kakovosti vezi, kakor tudi odpornosti proti delovanju vode in vlage. Ob prodiranju vode v kompozit namreč pride do razširitve in nabrekanja gradnika ter posledično do "prelokacije" gradnika. Napetosti, do katerih pride zaradi delovanja vode, so lahko tako velike, da pride do porušitve gradnika in vezi med gradniki. Porušitev vezi med gradniki pa pomeni zmanjšanje trdnosti kompozita, kar je ugotovil tudi Suchsland (1973). Spremembo trdnosti in togosti kot posledico izpostavitve visoki vlažnosti so ugotovili tudi Dinwoodie (1978), DeXin & Östman (1983), Gillespie & River (1976), Wu & Suchsland (1997), Wu & Piao (1999), Norita et al. (2008), Mirski et al. (2012) ter Kociszewski (2014). Dinwoodie

(1978) je ugotovil tudi, da je sprememba trdnosti iverne plošče, lepljene s fenol-formaldehidnim lepilom, manjša kot pri iverni plošči, lepljeni z urea-formaldehidnim lepilom. Fenghu & Fangtian (1997) sta zmanjšanje trdnosti pripisala hidrolizi lepila in napetostim, ki nastanejo kot posledica nabrekanja. Napetosti ob nabrekanju so opazili tudi Tarkov & Turner (1958), Niemz & Steinmetzler (1992), Medved et al. (2011).

Namen študije je bil ugotoviti stopnjo spremembe tlačnega striga oz. strižne trdnosti v odvisnosti od časa izpostavitve delovanju vode pri dveh različnih pogojih in sicer pri potopitvi v vodo in izpostavitvi vlažnim klimatskim pogojem.

Za izvedbo študije smo uporabili štiri različne lesne ploščne kompozite, dostopne na slovenskem trgu in sicer bukovo furnirno ploščo, OSB, iverno ploščo in MDF. Bukova furnirna plošča in OSB sta bili zlepljeni z melamin-urea-formaldehidnim lepilom, iverna plošča in MDF pa z urea-formaldehidnim lepilom (preglednica 1).

Iz plošč velikosti $1500 \times 800 \text{ mm}^2$ smo izžagali preskušance velikosti $50 \times 50 \text{ mm}^2$ za določanje debelinskega nabreka (vse plošče), razslojne trdnosti (OSB, iverna plošča in MDF) in tlačnega striga (OSB, iverna plošča in MDF). Strižno trdnost (bukova furnirna plošča) smo določili na preskušancih velikost $150 \times 25 \text{ mm}^2$. Preskušanci so bili nato klimatizirani pri normalnih klimatskih pogojih (temperatura $20 \pm 1 \text{ }^\circ\text{C}$ in relativna zračna vlažnost $65 \pm 5 \%$). Po končani klimatizaciji je bila serija preskušancev potopljena v vodo, ena serija pa izpostavljena vlažnim klimatskim pogojem (temperatura $20 \pm 1 \text{ }^\circ\text{C}$ in relativna zračna vlažnost $85 \pm 5 \%$). Čas potopitve v vodo oz. izpostavitve vlažnim klimatskim pogojem je bil 1 dan, 5 dni, 30 dni in 90 dni, nakar smo določili:

- debelinski nabrek in vpijanje vode po standardu EN 317,
- razslojno trdnost po standardu EN 319 (samo preskušanci, klimatizirani v normalni klimi),
- tlačni strig po standardu DIN 52367 in NT Build 313 in
- strižno trdnost po standard EN 314

Čeprav je običajna metoda določanja kakovosti zlepljenosti pri OSB, iverni plošči in MDF razslojna trdnost, smo se v študiji osredotočili na ugotavljanje razlik z določanjem tlačnega striga. Glavni razlog je povezan s hitrostjo izvedbe preskusa, saj na presku-

šance ni potrebno lepiti prijemal kot pri razslojni trdnosti.

Rezultati določanja debelinskega nabreka in vpijanja vode so pokazali, da se z daljšanjem časa izpostavitve vodi debelinski nabrek in vpijanje vode povečujeta (slika 2 in slika 3). Debelinski nabrek in vpijanje vode sta večja pri preskušancih, ki so bili potopljene v vodo. Pri potopitvi v vodo je bil debelinski nabrek po 90-ih dneh največji pri MDF, pri izpostavitvi vlažni klimi pa pri iverni plošči.

Izpostavitve preskušancev delovanju vode je povzročila zmanjšanje tlačnega striga in strižne trdnosti (slika 4 in slika 5). Pri potopitvi v vodo je že enodnevna potopitev povzročila padec trdnosti za 49 % (bukova furnirna plošča) oz. 96 % (MDF). Daljšanje časa potopitve ni značilno poslabšalo trdnosti spoja. Po 90-ih dneh izpostavitve je bil padec trdnosti med 38 % (pri iverni in furnirni plošči) in 56 % (pri MDF).

Sprememba trdnosti spoja preskušancev, izpostavljenih vlažnim klimatskim pogojem (slika 6 in slika 7) je bila manjša kot pri potopitvi v vodo. Po enodnevni izpostavitvi je bil padec trdnosti manjši od 3.5 %, pri MDF pa je bila trdnost primerljiva z referenčno vrednostjo.

Sprememba trdnosti zaradi delovanja vode je posledica tendence gradnikov po vrnitvi v položaj oz. obliko pred stiskanjem, zgostitve in nesproščenih napetosti kot posledica stiskanja. Absorpcija vode privede do nastanka mikro in makro razpok v gradnikih, kakor tudi do povečanja razdalj med gradniki, kar je bilo ugotovljeno s SEM analizo (slika 8, slika 9 in slika 10).

Razlike v debelinskem nabreku, vpijanju vode, tlačnem strigu in strižni trdnosti so, poleg morfoloških značilnosti gradnikov in pogojev izdelave kompozitov povezane tudi z uporabljenim lepilom. Večji nabrek in večjo spremembo trdnosti spoja smo ugotovili pri iverni plošči in MDF, pri katerih je bilo uporabljeno UF lepilo, medtem ko je bilo pri OSB in furnirni plošči uporabljeno MUF lepilo. MUF lepilo zagotavlja večjo odpornost proti delovanju vode (Ormondroyd, 2015).

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