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Evaluation of Creep Characteristics of Single-Staple Furniture Joints Made of Different Wood Species

Procjena obilježja puzanja spojeva namještaja s klamericom izrađenih od različitih vrsta drva

ABSTRACT • *In this study, creep characteristics of single stapled furniture joints made of Scotch pine, alder and beech wood under three different load levels were considered. Load levels were determined as 30 %, 40 % and 50 % of the maximum load obtained as a result of static shear test before creep load and applied to wood joints. Laboratory test results showed that the highest creep deformation was observed in the joints made of Scotch pine with the lowest density, while the lowest creep deformation was observed in the joints made of beech with the highest density. In addition, the joints were exposed to lowest creep deformation at the 30 % load level, then the creep deformation of the joints increased at 40 % load level and it reached the highest value at 50 % load level. As a result of creep test, deformation in single stapled joints made of Scotch pine, alder and beech were determined as 2.74 %, 3.71 % and 4.37 % of the deformation that occurred as a result of static shear test performed before creep test, respectively. Ultimately, the overall average creep deformation value of a single staple wood joint under creep loading was determined as 3.61 %.*

Keywords: creep; load level; single staple; wood joint

SAŽETAK • *U radu su istraživana obilježja puzanja spojeva namještaja s klamericom izrađenih od borovine, johovine i bukovine pri različitim stupnjevima opterećenja. Stupnjevi opterećenja definirani su kao 30, 40 i 50 % najvećeg opterećenja dobivenoga kao rezultat statičkoga smičnog ispitivanja prije opterećenja pri puzanju te su primijenjeni na drvne spojeve napravljene klamericom. Rezultati laboratorijskih ispitivanja pokazali su da je najveća deformacija puzanja zabilježena na spojevima izrađenima od borovine, koja ima najmanju gustoću, a najmanja je deformacija puzanja uočena na spojevima od bukovine, koja ima najveću gustoću. Usto, najmanja deformacija puzanja spojeva zabilježena je pri stupnju opterećenja od 30 %, zatim se deformacija puzanja povećala pri stupnju opterećenja od 40 % i dosegnula najveću vrijednost pri stupnju opterećenja od 50 %. Rezultati ispitivanja puzanja pokazali su da je deformacija spojeva s klamericom izrađenih od borovine, johovine i bukovine iznosila 2,74, 3,71 i 4,37 % deformacije koja je rezultat statičkoga smičnog naprezanja provedenoga prije ispitivanja puzanja. U konačnici, ukupna prosječna vrijednost deformacije puzanja drvenog spoja s klamericom iznosila je 3,61 %.*

Ključne riječi: puzanje; stupanj opterećenja; klamerica; drveni spoj

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1 INTRODUCTION
1. UVOD

Staple connected gusset-plate joints can be defined as joints in which at least two elements in a furniture frame structure are connected by the driving of staples through the gusset-plate into the elements. The gusset-plate can be metal, wood or wood-based composites such as wood or plywood. Plywood is generally used as gusset-plate because of its excellent tensile strength (APA, 1997). Since staple connected gusset-plate joints have a higher shear resistance, they connect the places such as the stump and the front rail joints, which were exposed to excessive shear loads in the upholstered furniture frame structure as shown in Figure 1.

Staples as metal fasteners resist horizontal shear forces rather than direct withdrawal forces, particularly during use in furniture frames (Zhang and Maupin, 2005). Therefore, the lateral shear resistance of the staple connected joint depends on the staple holding performance of the wood material used.

Wood material, as a popular product today; is used to achieve many purposes at functional, environmental and aesthetic levels. Wood shows a time-dependent behavior like most materials (Peng *et al.*, 2020). With time, this time-dependent behavior leads to a deformation of the material under load (Kojima and Yamamoto, 2004). This mechanical deformation is called creep (Holzer *et al.*, 1989; Navi and Stanzl-Tschegg, 2009; Du *et al.*, 2013). In creep tests, the material is subjected to a constant loading and the stresses at loading point are followed for a certain period of time.

Creep deformation is quite important in the design of most products. Even though MOR is at an acceptable level, creep deformation is treated as a more disturbing perception for customers. Therefore, creep deformation is an issue to be considered. Moreover, customer satisfaction is considered as an important element in the design of furniture products.

In the modern furniture industry, a joint should meet the load over the whole lifetime of furniture. Therefore, it is not enough to evaluate only the short term behavior after assembling (Dias *et al.*, 2018). When a joint is subjected to load, it deforms. If it is subjected to loading over a certain time, creep defor-

mation increases with time. Therefore, creep deformation should be considered in joints.

The performance of a wooden structure is closely related to the joints in the structure or the behavior of joints between the materials (members). Most creep patterns related to the joint are based on studies on lateral shear stiffness. For example, the reduction of lateral shear stiffness of dowel-nailed and nut-screwed joints has been examined (Morlier, 1994; Polensek, 1982).

Smardzewski *et al.* (2013) studied the effect of creeping on changes in the rigidity of selected joints used in constructions of upholstered furniture by changing modulus of elasticity. As a result of the study, it was observed that creeping made a significant change in the mechanical quality of the tested joints by decreasing the modulus of elasticity by 11 % - 16 %.

Xu *et al.* (2015) investigated the effects of pressure load magnitude of the seat cushions commonly used in upholstered furniture and the force-deformation-time behavior of the material used in cushion fabrics. The results showed that the creep behavior of furniture seat cushions consisting of foam, spring and fabric materials can be defined, respectively. The statistical analysis of the experimental data in this study showed that the magnitude of the loads examining the creep behavior had significant effects on the viscoelastic constants in the mathematical expressions to define the force-deformation-time behavior of the cushions evaluated.

Li *et al.* (2019) investigated the creep behavior of balsa wood covered with glass fiber-reinforced polymer from both surfaces. First, static bending test was conducted and ultimate bearing capacities were determined for the specimens. Based on the bearing capacity, four load levels were determined as 20 %, 40 %, 60 % and 80 % for creep loading. Results showed that at small load levels, such as 20 % and 40 %, specimens showed linear viscoelastic behavior; however, they showed creep failure at higher load levels, 60 % and 80 %.

There have been few studies so far that fully explained the creep properties of wood material, both theoretically and practically. Mostly, tests were carried out statically for a short time. However, practical applications and necessary rules for examining the effects of creep of wood material on the service life have not been developed yet. In the furniture area, there is almost no creep study on the joints used for building furniture frames such as sofas. In particular, almost no study has been conducted on creep behavior of the staple connected gusset-plate joints made of beech, alder and Scotch pine, which are mostly used in Turkey and worldwide furniture manufacturing.

The main purpose of this study was to investigate and interpret the creep properties of the joints made of different wood species under different load levels. The specific objectives of this study were to: 1) determine the load levels to be applied for creep testing by applying different percentages of the maximum static load value of the joint as creep load, 2) examine the creep behavior of furniture joints as a result of using different
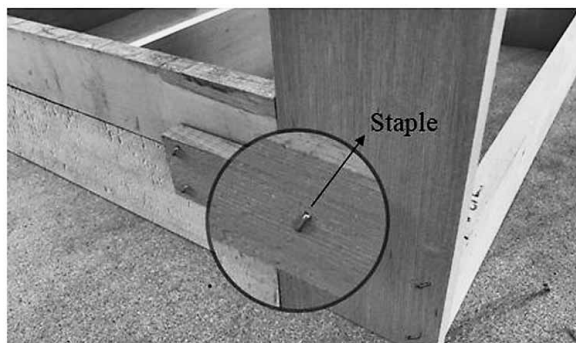

Figure 1 A sofa joint connected with staple exposed to lateral loads
Slika 1. Spoj dvosjeda povezan klamericom izložen bočnim opterećenjima

wood species, 3) quantitatively compare the creep behavior of the joints according to the static behavior of the joints.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Material
2.1. Materijal

In this study, creep behavior of the joints made of Beech (*Fagus orientalis*), Scotch pine (*Pinus sylvestris*) and Alder (*Alnus glutinosa*), which have recently gained a new place in Turkish furniture production, have been investigated. For the static shear test, 30 joint specimens for each wood species, i.e. 90 joints in total, were tested. On the other hand, a total of 27 joint specimens were loaded for creep test for three replications for each wood species. The densities of these wood species are shown in Table 1.

As shown in Table 1, beech wood had the highest density value, followed by alder and Scotch pine. The densities of the materials were determined according to TS 2472 standard (TS 2472, 1976). In this study, wood species were used as the main material and the plywood with 9 layers of Scotch pine veneers was used as side material. Each layer of the plywood was prepared perpendicular to one another, and the surface layers were parallel to each other. Senco staples, coated with a nitro-cellulosic based corrosion inhibiting layer, were

Table 1 Densities of wood species used in joint structure
Tablica 1. Gustoća vrsta drva upotrijebljenih za izradu spojeva

	Wood species / *Vrsta drva*			
	Scotch Pine *Borovina*	Alder *Johovina*	Beech *Bukovina*	Plywood *Furnirska ploča*
Density, g/cm³ *Gustoća,* g/cm³	0.45 (2)	0.51 (1)	0.54 (4)	0.64 (4)

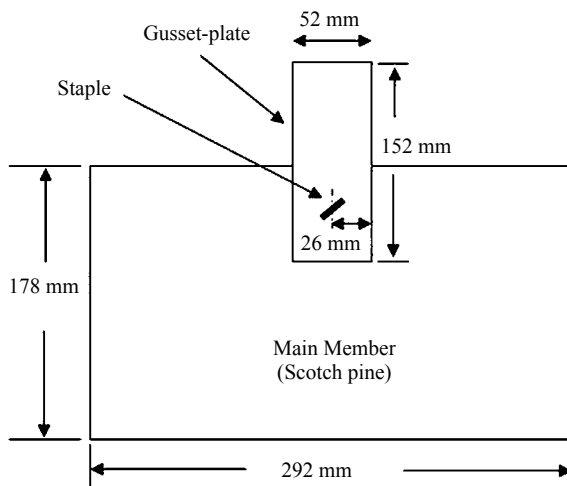The values in parenthesis indicate the coefficient of variation. / *U zagradama je naveden koeficijent varijacije.*

Figure 2 A joint made of Scotch pine
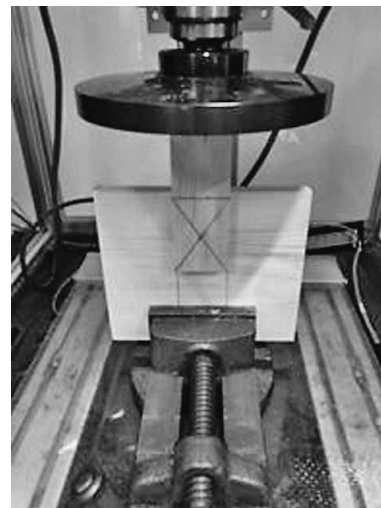**Slika 2.** Spoj izrađen od borovine

Figure 3 Static shear test for single staple Scotch pine joint
Slika 3. Statički test na smicanje spoja s klamericom izrađenoga od borovine

used as metal fasteners in the attaching of the joint members. Staples have a leg length of 38 mm and a crown width of 11 mm. When attaching the joint members, the staple is driven into the assembled members at an angle of 45 º to ensure the best connection between the members. Figure 2 shows a typical wood joint made of Scotch pine.

2.2 Method
2.2. Metoda

2.2.1 Static shear test
2.2.1. Statičko ispitivanje smicanja

In order to determine the load levels to be applied for creep test, 30 single-staple joint specimens were prepared from each wood species and subjected to static shear test at a loading rate of 2.5 mm / min on MTS Criterion Model 45 Universal testing machine, and static shear loads of the joints were determined. This test was conducted based on ASTM D 1761 standard (ASTM 1761, 2010). Figure 3 shows the static shear test for single-staple wood joints.

2.2.2 Creep test
2.2.2. Ispitivanje puzanja

In order to determine the load levels required for the creep test, firstly, static shear loading was applied to the joints, and then the maximum shear load values were obtained and converted from Newton (N) to kg. Creep test was carried out by taking certain percentage values of the maximum shear values in kg and hanging them to the joint specimens in weight. Figure 4 shows a representative of the five test stations prepared for this creep test.

The deflection measurement was carried out with dial gauges with 0.001 mm accuracy and 0-30 mm measuring rod. The measurements were continuously monitored daily and this monitoring ranged from 1 day to 103 days depending on the behavior of the joint specimens under load. Creep deformation at the joints was recorded based on each movement in the dial
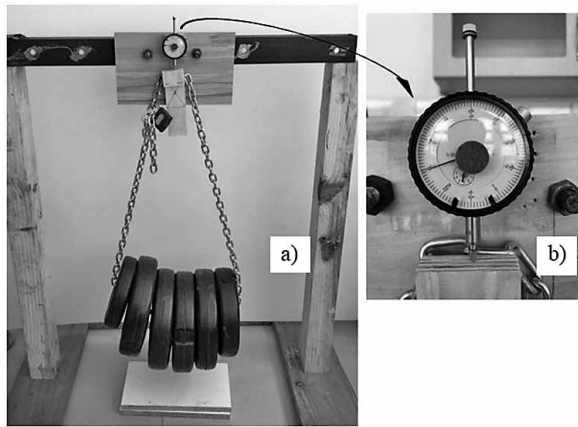
Figure 4 a) Creep test station b) Dial gauge
Slika 4. a) Oprema za ispitivanje puzanja, b) komparator

gauge. Figure 4b shows the dial gauge in which creep deformation is read.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Static shear test and creep test
3.1. Statičko ispitivanje smicanja i ispitivanje puzanja

The average displacement values of each wood joint group evaluated as static shear test results given in this study are presented in Table 2. As shown in the

Table 2 Maximum static displacements
Tablica 2. Najveći statički pomaci

	Wood species / *Vrsta drva*		
	Scotch Pine *Borovina*	Alder *Johovina*	Beech *Bukovina*
Average displacement, mm *Prosječni pomak,* mm	4.96 (19)	4.89 (18)	4.63(18)

The values in parenthesis indicate the coefficient of variation. / *U zagradama je naveden koeficijent varijacije.*

Table 3 Statistical comparison of static shear resistance values (in N and kg) obtained from each wood species
Tablica 3. Statistička usporedba vrijednosti statičkog otpora na smicanje (u N i kg) dobivenih za ispitivane vrste drva

Unit *Jedinica*	**Wood species** / *Vrsta drva*		
	Scotch Pine *Borovina*	Alder *Johovina*	Beech *Bukovina*
	Maximum shear values *Najveće smične vrijednosti*, N		
Average, N *prosjek,* N	809 (C)	1042 (B)	1233(A)
Average, kg *prosjek,* kg	83	106	125

LSD: 53.57 N
The same letters in parentheses indicate homogeneity groups. / *Ista slova u zagradama označuju homogene grupe.*

table, beech joints with the highest density show the least displacement, followed by alder joint with less density and the Scotch pine joint with the least density.

The average maximum lateral shear loads of each joint specimen are shown in Table 3. In order to see the statistical difference among the average maximum lateral shear loads, a SAS statistical analysis model based on one- factor (wood species) at 5 % significance level was run and compared with least significance difference (LSD) of 53.57 N.

As shown in Table 3, as a result of the statistical analysis, the highest shear resistance value was obtained from the single-staple joint made of beech wood. This is followed by alder joint and Scotch pine joint.

Within the scope of this study, first of all, 30 single-staple beech joints with Scotch pine gusset-plate were prepared and their maximum static resistance loads were determined in MTS Universal testing machine in N. These values were averaged and converted to kg in order to obtain creep loading information, because the creep loading values were taken as a percentage of the maximum static load of the same joints. Accordingly, the average maximum static load obtained for the beech joints is 125 kg as shown in Table 4, which shows all percentages determined of these average maximum shear loads. The average maximum static shear resistance loads obtained in Table 3 are presented in Table 4 for beech joint. These loads were converted from N to kg and transformed into loadable values for creep test.

According to Table 4, the load of 112.5 kg, which is 90 % of the average maximum static shear loads, was applied to single-staple beech joint and an immediate separation between the members of joints appeared. Then, 80 %, 70 % and 60 % of the average maximum static shear loads of the joint, 100 kg, 87.5 kg, and 75.5 kg, respectively, were applied to the beech joints and again single-staple beech joints were separated between joint members in a short time. However, the joints were able to withstand a period of time under 62.5 kg, which is 50 % of the average maximum static load. Also, the joints were able to withstand 50 kg and 37.5 kg, which is 40 % and 30 % of the average maximum static load, respectively. Therefore, in this study, creep test load levels were determined as 50 %, 40 % and 30 % of the average maximum static loads of the single-staple joints for beech and other wood species. Similarly, certain percentages of the average maximum resistance values of the material were used as different load levels in previous studies for the creep test. Likewise, Hayman (1981) studied the creep properties of three connected arch structures. These joints were subjected to 85 %, 65 %, and 35 % of the main buckling loads. Nilsson and Johansson (2019) studied the creep

Table 4 Percentages of average maximum static load values for beech joints to be used in creep testing
Tablica 4. Postotci prosječnih maksimalnih vrijednosti statičkog opterećenja za spojeve od bukovine koji su korišteni u ispitivanju puzanja

Mean static load, kg *Srednje statičko opterećenje,* kg	**Percentage values, %** / *Postotne vrijednosti, %*						
	90	80	70	60	50	40	30
125	112.5	100	87.5	75.5	62.5	50	37.5

Table 5 Creep test loading values determined for each joint made of different wood species
Tablica 5. Vrijednosti opterećenja pri ispitivanju puzanja utvrđene za spojeve izrađene od različitih vrsta drva

Wood species *Vrsta drva*	Maximum static load level, % *Najveći statički stupanj opterećenja, %*		
	30	40	50
Scotch Pine *borovina*	25	33	41
Alder / *johovina*	32	42.5	53
Beech / *bukovina*	37.5	50	62.5

properties of wood-based boards and applied bending test as static test on the specimens. For creep testing, 30 % of the maximum static bending resistance value was determined and applied as creep load level. The creep test loads (kg) for the joints made of each wood species are presented in Table 5 for this study.

As shown in Table 6, the specimens loaded at 30 % and 40 % load levels completed the creep tests in different number of days. The number of days of creep test is determined as a result of the stopping of the deformation under the creep load.

3.2 Creep-deformation curve
3.2. Krivulja puzanja/deformacije

The joints made of different wood species under creep load showed creep deformation-time curves at different number of stages. Creep deformation-time curves with different number of stages are as follows: (1) two stages of creep deformation, first accelerating, then decelerating; (2) three stages of creep deformation curve with accelerating, then decelerating and breaking movement; (3) also three stages of creep deformation curve with accelerating, then decelerating and stabilizing creep movement; (4) four stages creep deformation-time curve with first accelerating then
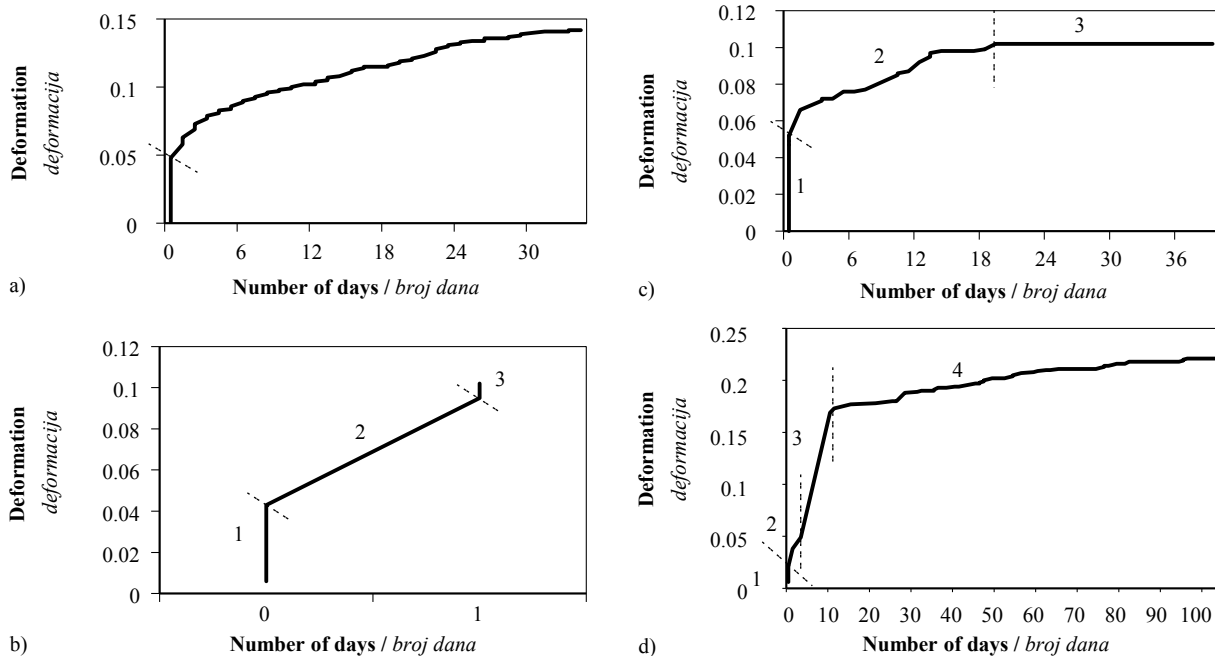

Figure 5 Creep deformation-time curves with a) two stages, mostly for alder joints, b) three stages with separation, mostly for beech joints under 50 % creep load, c) three stages with stabilization, mostly for beech and Scotch pine joint under 30 % and 40 % creep loads d) four stages
Slika 5. Krivulje puzanja/deformacije tijekom vremena: a) dvije faze, uglavnom za spojeve od johovine, b) tri faze s odvajanjem, uglavnom za spojeve od bukovine, uz opterećenje manje od 50 % pri puzanju, c) tri faze sa stabilizacijom, uglavnom za spojeve od bukovine i borovine, uz opterećenje manje od 30 % pri puzanju, d) četiri faze

Table 6 Number of days of testing joints made of different wood species under creep loading
Tablica 6. Broj dana trajanja ispitivanja puzanja pri tri različita opterećenja za spojeve izrađene od različitih vrsta drva

Load level, % *Stupanj opterećenja, %*	Specimen *Uzorak*	Wood species / *Vrsta drva*		
		Scotch Pine / *Borovina*	Alder / *Johovina*	Beech / *Bukovina*
		The number of days / *Broj dana*		
30	I	62	52	16
	II	66	34	80
	III	34	33	39
40	I	65	32	77
	II	47	32	103
	III	56	50	30
50	I	34	75	2
	II	3	33	2
	III	22	42	1

decelerating, accelerating again and gradually stabilizing creep deformation. Figure 5 shows the curves with different stages under creep loads.

In Figure 5, each stage was separated with a dashed-line and numbered. Accordingly, a beech joint only showed a 4-stage creep deformation curve, while two beech joints showed a 2-stage curve. Most beech joints showed a three-stage creep deformation-time curve. On the other hand, at 30 %, 40 %, 50 % loading levels, all of the alder joints showed a two-stage creep deformation-time curve. In the Scotch pine joint, 4 specimens showed two-stage and 5 specimens showed three-stage creep deformation-time curve. Results showed that the deformation-time curves obtained as a result of creep tests on wood joint had at least two stages and generally three stages. The stress-strain curve obtained by Costa and Barros (2015) had two stages as a result of creep study on epoxy adhesive protective materials. The general trend in the deformation-time curves obtained as a result of the current creep study on wood joints is similar to that established in the study by Costa and Barros (2015).

3.3 Failure modes
3.3. Priroda loma

At the end of the creep test, only two types of failure modes were observed as shown in Figure 6. While most of the joints showed staple release mode, only 6 joints, 5 beech wood joints and 1 Scotch pine joint under 50 % load level, showed complete separation of the staple from the main member.

Figure 7 shows different failure characteristics and their corresponding deformation-time curves according to each stage of a single-staple beech joint. In stage a), an increasing deformation was observed, while in stage b), decreasing creep deformation was observed. Finally in stage c), a stabilizing creep deformation was monitored. This three-stage creep deformation failure characteristic is the most observed one in this study. Figure 8 illustrates the average maximum
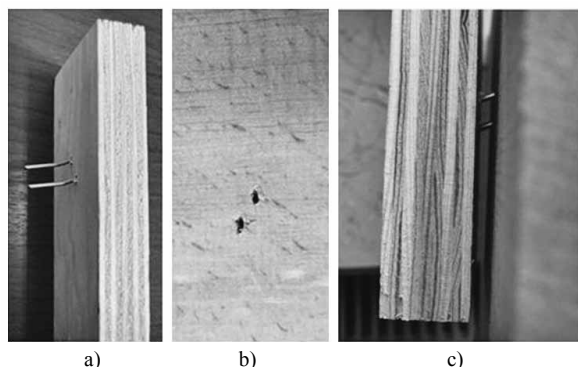

Figure 7 Cross cut view of single-stapled joints under creep load in different stages
Slika 7. Poprečni presjek spoja s klamericom pod opterećenjem pri puzanju u različitim fazama

Figure 8 Creep deformation relationship between load levels and wood species as a result of one-day creep data
Slika 8. Deformacija pri puzanju u ovisnosti o stupnju opterećenja i vrsti drva kao rezultat jednodnevnih podataka o puzanju

creep deformation relationship between wood species at 30 %, 40 % and 50 % load levels according to first day data.

As indicated in Figure 8, the Scotch pine joints with the lowest density showed the highest amount of creep deformation under 30 % load levels at the end of the first day and this was followed by the alder joints with higher density and beech joints with the highest density. The relation among different wood species on creep deformation is similar to the deformation under static lateral shear loading. Similar creep relations were observed at the load levels of 40 % and 50 %. Accordingly, the Scotch pine joints showed the highest average creep deformation and the beech joints showed the lowest average creep deformation. It is inferred from the results that the deformation under the creep load decreases as the density of the material increases. Likewise, in his study, Niemz (1993) observed that increasing the density of the wood material decreased creep deformation values. Nilsson and Johnson (2019) examined the creep properties of wood-based panels under a long time load and stated that these panels exhibit the same creep properties as solid wood materials. These scientists stated that there is an inverse relationship between the density of wood material and creep deformation. In this respect, it is obvious that the re-

Figure 6 Complete separation mode of the joint: a) staple separated from main wood member, b) damage caused by staple when withdrawing from wood material, c) other joint failure mode with staple release
Slika 6. Potpuno odvajanje spoja: a) klamerica odvojena od glavnoga drvnog dijela, b) oštećenje uzrokovano klamericom pri njezinu izvlačenju iz drvnog materijala, c) druge vrste loma s otpuštanjem klamerice
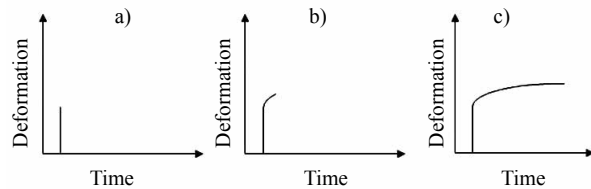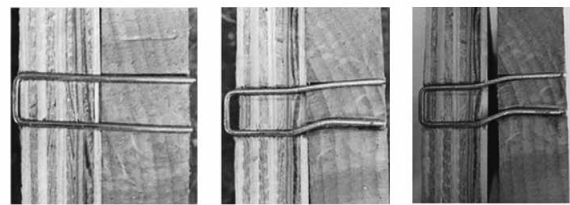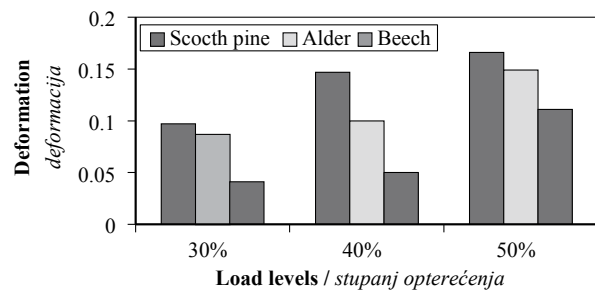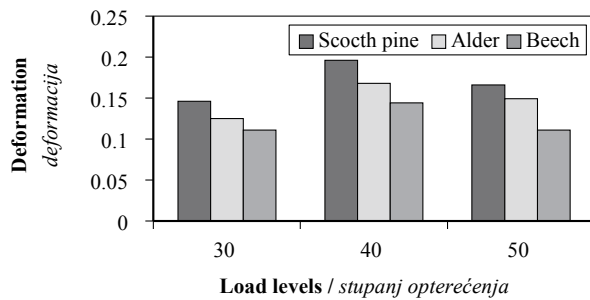
Figure 9 Creep deformation relationships between load levels and wood species as a result of common day creep data
Slika 9. Deformacije pri puzanju u ovisnosti o stupnju opterećenja i vrsti drva kao rezultat uobičajenih podataka o puzanju

sults of the current study are consistent with the previous studies. Additionally, the creep deformation on wood material joints increased as load level increased from 30 % to 40 % and 50 %. Xu *et al.* (2015) tested the specimens under load levels of 250, 600 and 1000 N and reported that creep deformation increased with increasing load levels. Figure 9 shows the average creep values obtained based on the number of common (30) days determined for each load level.

As shown in Figure 9, the lowest average maximum creep deformation at each load level (30 %, 40 %, and 50 %) was observed in the beech joints with the highest density. This was followed by the alder joints

Table 7 Comparison of joints made of different wood species according to their creep deformation
Tablica 7. Usporedba spojeva izrađenih od različitih vrsta drva prema njihovoj deformaciji puzanja

Number of days *Broj dana*	Wood species / *Vrsta drva* Creep deformation / *Deformacija puzanja*, mm		
	Scotch Pine *Borovina*	Alder *Johovina*	Beech *Bukovina*
1st day	0.136(A)	0.112(AB)	0.072(B)
30th day	0.171(A)	0.145(AB)	0.123(B)

The same letters in parentheses indicate homogeneity groups. / *Ista slova u zagradama označuju homogene grupe.*

with lower density and the Scotch pine joints with the lowest density.

A statistical analysis was conducted to see the effect of wood species and load level on creep deformation of all joints by using the 1st day and 30th day creep deformation data at % 5 significance level in SAS statistics program. As a result of the statistical analysis, the relationship between wood species and loading level was found insignificant.

Accordingly, in Table 7, the significance of creep deformation among joints was compared with LSD values of 0.040 and 0.044, respectively, using the creep deformation data on the 1st day and 30th day.

As indicated in Table 7, based on creep deformation data on the first day, single-staple joints made of the lowest density Scotch pine showed significantly the greatest creep deformation. This was insignificantly but marginally followed by alder joints because the alder joint showed insignificantly less creep deformation. The beech joints, on the other hand, showed significantly lower creep deformation than the Scotch pine joints and insignificantly lower creep deformation than the alder joints. In other words, the beech joint showed the lowest creep behavior with its highest density. In general, the joints made of lower density wood were more deformed under creep load, while the lowest creep deformation was observed in joints made of wood with the highest density. An exactly similar relationship is also valid for creep deformations of the joints obtained at the end of the 30th day.

Table 8 shows the values of creep deformation of each sample in the percentage of deformation resulting from the initial static maximum load value, the average values according to the load levels and the overall average value. As shown in Table 8, deformation increases as load level increases from 30 % to 50 %. The overall creep deformation value of the wood joints is 3.61 % of their static deformation obtained initially. Therefore, under long time loading, a furniture joint made of these wood species is subjected to an average creep deformation of 3.61 %. Costa and Barros (2015) found that creep deformation observed on test specimens was 3 % compared to the initial static shear test deforma-

Table 8 List of deformation values of joints made of different wood species in three different load levels under creep load, as a percentage of deformation of the same joints under static shear load
Tablica 8. Vrijednosti deformacija puzanja spojeva izrađenih od različitih vrsta drva pri tri različita stupnja opterećenja kao postotak deformacije istih spojeva pri statičkome smičnom opterećenju

Load level, % *Stupanj opterećenja, %*	Creep deformation amount / *Iznos deformacije pri puzanju, %*				
	Specimen *Uzorak*	Scotch Pine *Borovina*	Alder *Johovina*	Beech *Bukovina*	Average *Prosjek*
30	I.	2.25	2.43	2.5	
	II.	5.1	2.82	2.1	
	III.	3	2.68	1.81	2.74
40	I.	4.17	3.48	2.16	
	II.	4.92	3.37	4.13	
	III.	4.47	4.27	2.4	3.71
50	I.	3.13	4.01	2.34	
	II.	4.34	4.76	4.44	
	III.	6.29	7.03	3	4.37
Overall average / *Ukupan prosjek*					3.61

tion of the specimens. In this respect, the results of the current study are very close to the results in the study by Costa and Barros (2015).

4 CONCLUSIONS
4. ZAKLJUČAK

Creep properties of single stapled furniture joints, made of wood species widely used in furniture industry such as Scotch pine, alder and beech, were investigated. For creep test, 30 %, 40 %, and 50 % were determined as load levels based on the maximum static lateral shear loads of the same joints.

Results indicated that most of the joints under creep load showed deformation curve with three stages - first accelerating then decelerating and finally stabilizing creep movement.

Based on the first day creep data, the joints made of Scotch pine with the lowest density showed significantly higher creep deformation than the joints made of beech with the highest density. This was insignificantly followed by alder joints with a medium density as compared to other wood species. This also means that the alder joints showed insignificant but mathematically observable higher creep deformation than the beech joints. As a result, increasing wood density decreased creep deformation. Additionally, results showed that increasing load levels from 30 % to 50 % increased the creep deformation of the wood joints.

After creep loading, the deformation of the Scotch pine, alder and beech joints was determined as 2.74 %, 3.71 % and 4.37 %, respectively, of their deformation after static shear loading performed before the creep test. Ultimately, this value was obtained as 3.61 % for single-staple wood joints as the average of three wood species. In other words, the average creep deformation value of a single-staple wood joint under load levels of 30 %, 40 % and 50 % was determined as 3.61 %.

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